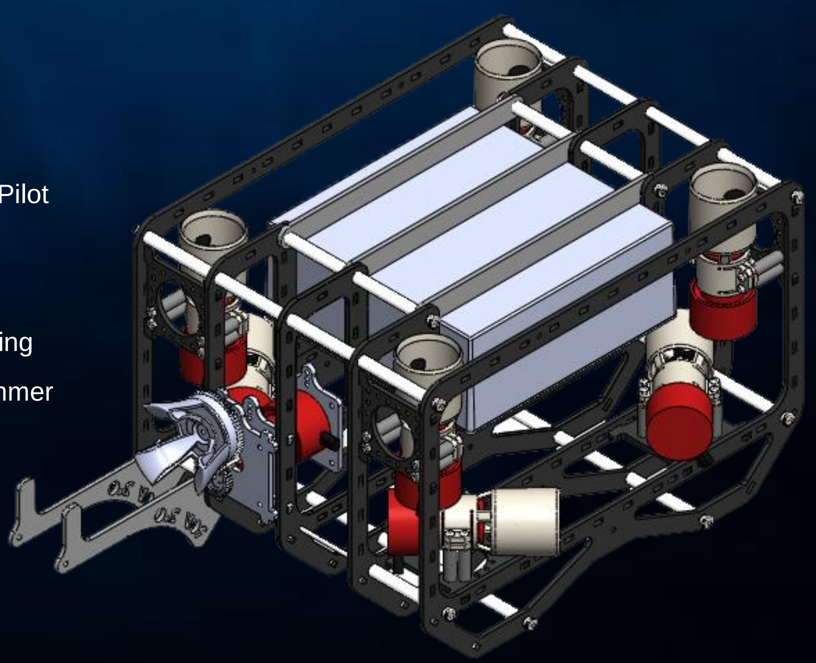
Remotely Operated Vehicle

Northern Illinois University - DeKalb IL, United States
MATE Explorer Class 2017
Technical Report

Staff:

Adam Kraft – CEO, Mechanical Engineer
Andrew Widmar – CFO, Electrical Engineer, Pilot
Austin Parduhn – Mechanical Engineer
Charles Fortner – Mechanical Engineer, Pilot
Dennis Grekousis – Fundraising and Marketing
Joel Rushton – Mechanical Engineer, Programmer
Hannah Higgins – Mechanical Engineer
Mary Reinertson – Electrical Engineer

Advisor: Jacob Klein



Contents

Abstract

The NIU Robotics Club has designed and fabricated a fully custom underwater vehicle to contend in the 16th annual MATE International ROV competition. Modularity and easy configuration were two ideas central to the company's design process. These ideas are reflected in the standardized tab and slot design of the vehicle. In terms of maneuvering, a vectored thrust system was chosen because it allows the company to carefully and precisely move the ROV at a small cost to efficiency and acceleration. Custom electronics power all facets of the machine from a series of specialized PCBs. A waterproof servo is used to control the primary gripper. As an extension of the main gripper, an aluminum hook that extrudes out past the primary gripper to assist with maneuvering different objects through the tasks. A bilge pump motor and gearbox are used to control a separate manipulator that is custom designed to grip and turn the valve. Three USB webcams are plugged into a hub, that is then fed through a USB extender to the surface to a laptop. Readily available webcam viewing software is used to view the camera feeds. This project was a challenge for NIU Robotics, a team with a combination of new and seasoned application engineers and robot builders. Our approach fit our resources and style, culminating in a robust system that we look forward to demonstrating at the Long Beach City College.

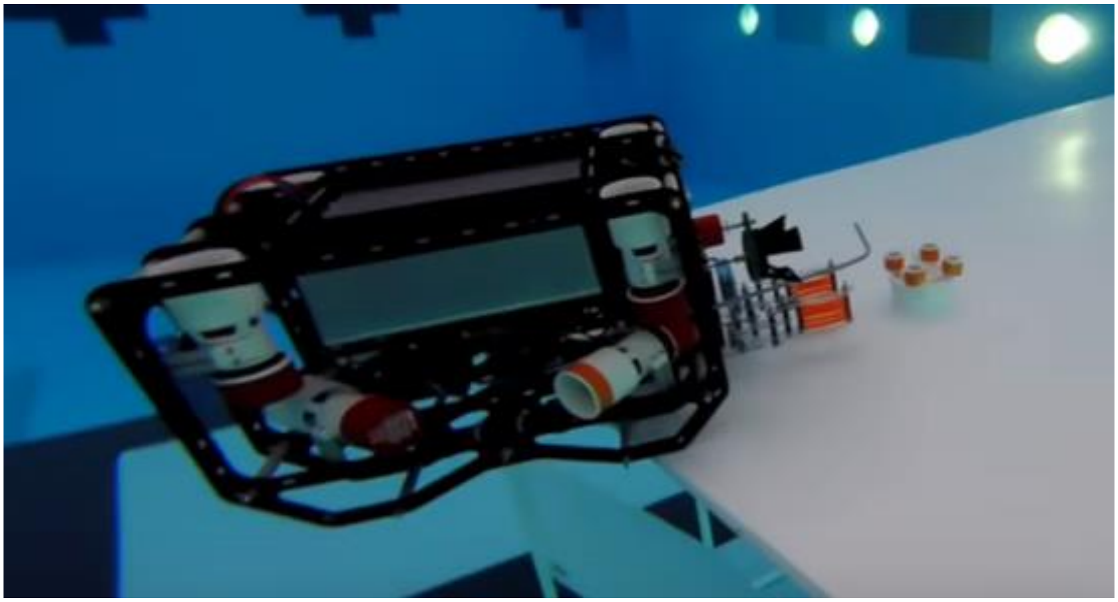


Figure 1: Completed ROV

Design Rationale

Overall Design Rationale

The 2017 NIU Robotics ROV is designed to be both easily assembled and extremely modular. This modularity allows for a more functional product in which the user can choose a system that fits both their budget and specific need, while also allowing for easy replacement of broken or out-of-date components. The ROV is also very versatile, meaning that specialty attachments can easily be added, allowing the ROV to perform a number of new applications without the need for a complete redesign.

Mechanical

Chassis Design

The ROV chassis system is very similar to that used last year. The decision to reuse much of the old chassis design was made due to the fact that the chassis is highly modular, slightly buoyant, and easily re-configurable. The material used, 3/16-inch-high density polyethylene (HDPE), was initially chosen because it is easily machined, positively buoyant, and absorbs impact well. The plates are also modular and can be used for mounting generic hardware as well as straight or angled motor mounts at varying positions, endoscope mounts, and a variety of other attachments.

The main chassis body is made up of five panels, with the three center panels being slightly modified to accommodate the 250 x 250 x 100 mm waterproof enclosure that encapsulates the onboard electronic systems. This box is then held in place with 1 in. slats of HDPE and long #8 threaded rods. The five main chassis panels are each separated by a distance of 81.3 mm (3.2 in.), allowing for modules to be added around the periphery at intervals of 35.6 mm (1.4 in.) along the front, back, and bottom edge. The panels are equipped with holes for the chassis structural fasteners as well as trapezoidal structures along the bottom to serve as landing surfaces. The design of the chassis also leaves plenty of space for structural supports and hardware.

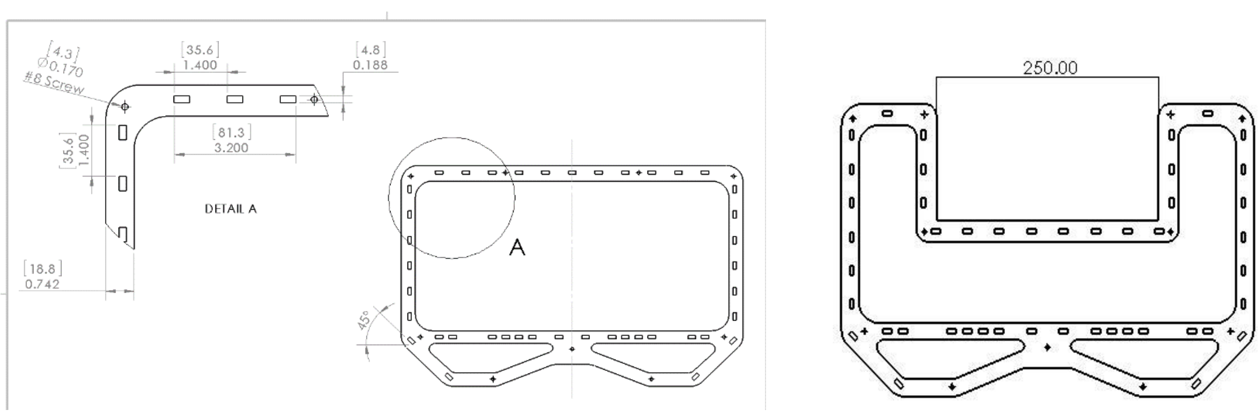


Figure 2: Chassis Drawings with Dimensions

The Straight Thruster Module mounts between two of the main chassis panels. This module mounts parallel to the two panels it sits between and includes spacers to ensure that the propeller shrouds are not in the way of other chassis elements. The spacing and number of mounting holes along this module allow for five different motor mounting positions along the length of the plate.

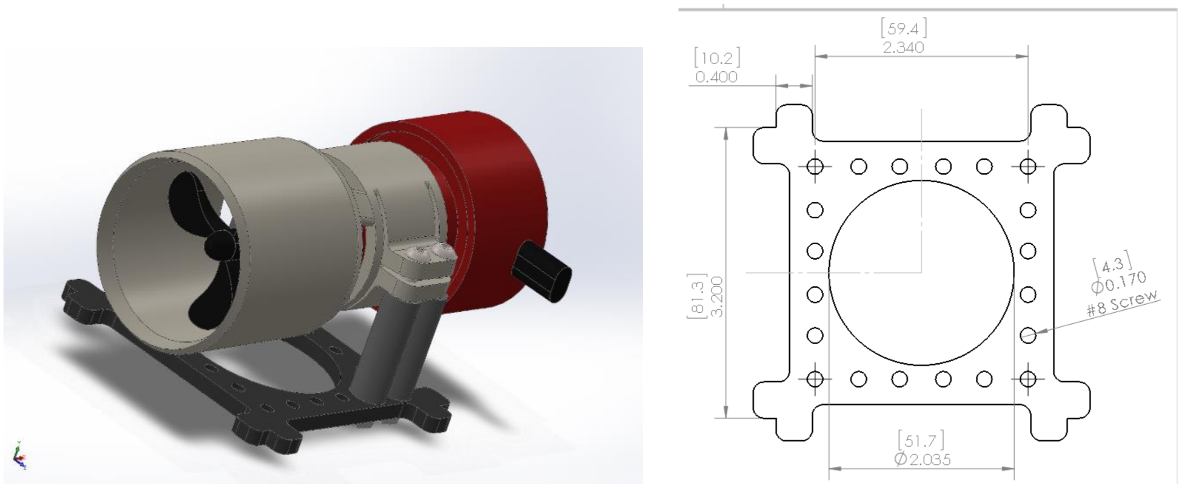


Figure 3: Straight Thruster Module

The Angled Thruster Module mounts to the ROV in exactly the same way as the straight thruster module. However, the two differ in the fact that in this module, the motor's angle can be adjusted. On the NIU Robotics ROV, thrusters have been mounted at an angle of 45°, but the design of the plate allows for motors to be rotated by 22.5° increments.

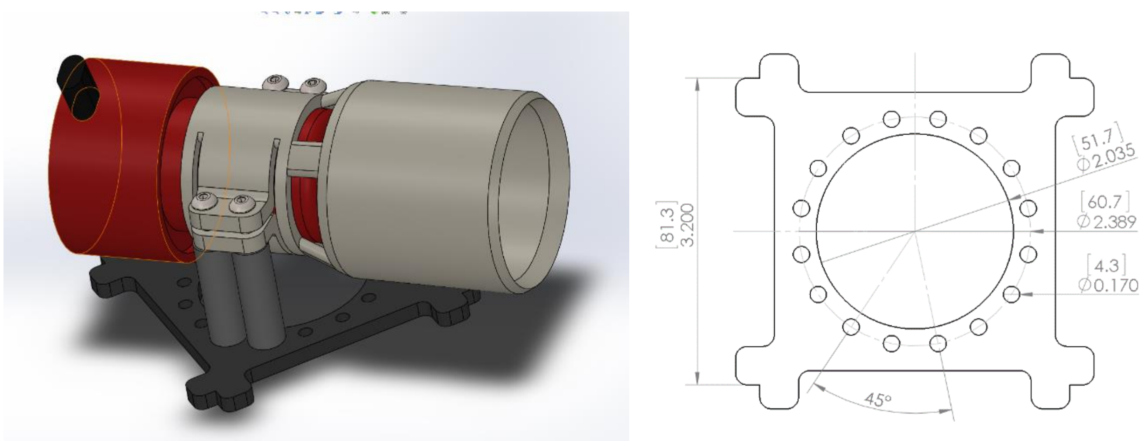


Figure 4: Angled Thruster Module

Propulsion

The propulsion system used for this year's ROV is identical to that used last year. This is because it was easy to use, extremely effective, and fit the needs of our company. Rule 28D Bilge Pump Motors were seen as the optimal means of propulsion for the ROV because they were already waterproofed and so required few modifications. Once the motors had been chosen, Graupner G2308.50 and G2308.50L propellers were added to them. The 3 blade, 50 mm (1.97 in.) propellers thread onto M4 rods and attach to the bilge pump motors via custom brass couplings. These couplings transfer torque from the motor to the propellers while keeping the propellers firmly attached to the motor shaft. More specifically, a pair of set screws holds each coupler onto the motor shaft, a cone tip set screw sits in the lip of the shaft, keeping the coupler from sliding off the shaft, and a flat set screw sits against the flat of the motor shaft to transfer torque from the motor to the propeller.

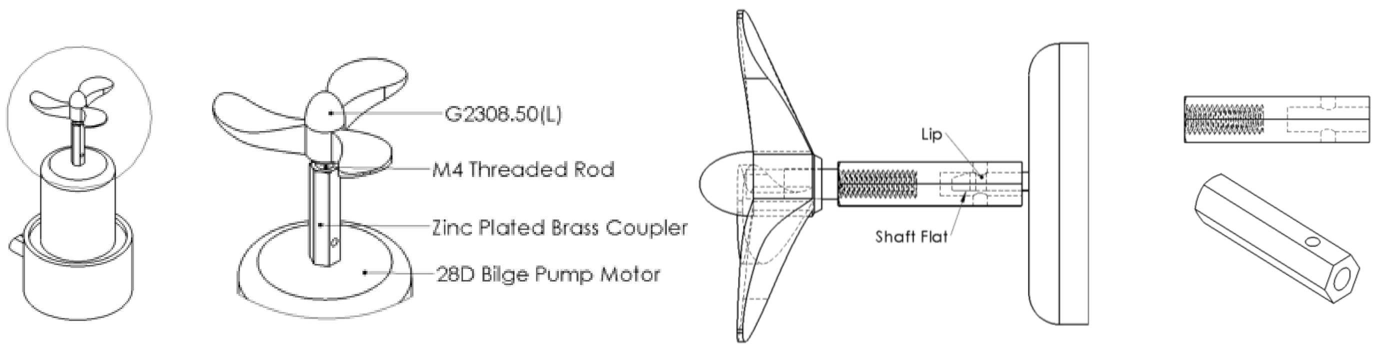


Figure 5: Propellar and Propellar Couplers

The Motor Shrouds project in front of and behind the propellers by at least 2 cm (0.79 in.) to completely encompass each propeller. This protects against user injury and equipment damage. Each shroud holds a motor using a friction system in which the unstrained separation angle of the clamp is 5°, allowing the shroud to securely grip the motor. Also, since the protective shroud that encircles the propeller has a 2° draft, simply moving the motor forward or backward inside the shroud's clamp can account for any variation in the diameter of the propellers. The clamp and shroud are then connected by four small arms which leave ample space for water to easily flow.

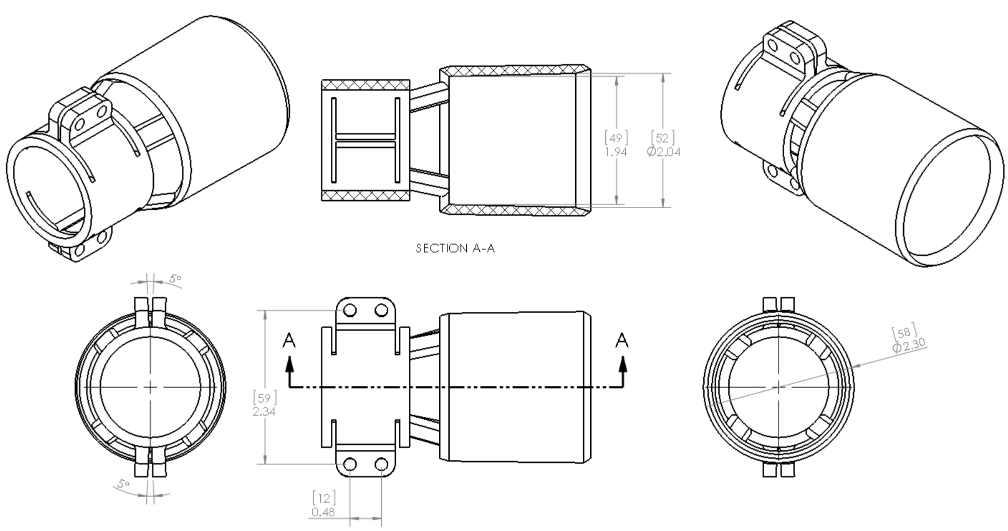


Figure 6: Rapid-Prototyped Propeller Shrouds

The Vectored Thrust System configures four motors in a way that allows for translational as well as rotational motion. This range of movement is achieved by varying the speed coming from each motor so that the net thrust coming from all four motors results in the desired motion. That is to say, maximizing thrust on all motors will move the ROV in a cardinal direction while using a variety of speeds from each motor allows the user to maneuver the ROV in any number of different translational and rotational directions and velocities. Although this is not the most efficient system, it was chosen because it allows for easier and more careful maneuvering, which is vital when completing some of the more precise tasks. Also, because of the modular nature of the chassis and thruster modules, these thrusters can be re-oriented and reconfigured to adapt to the specific needs of the user.

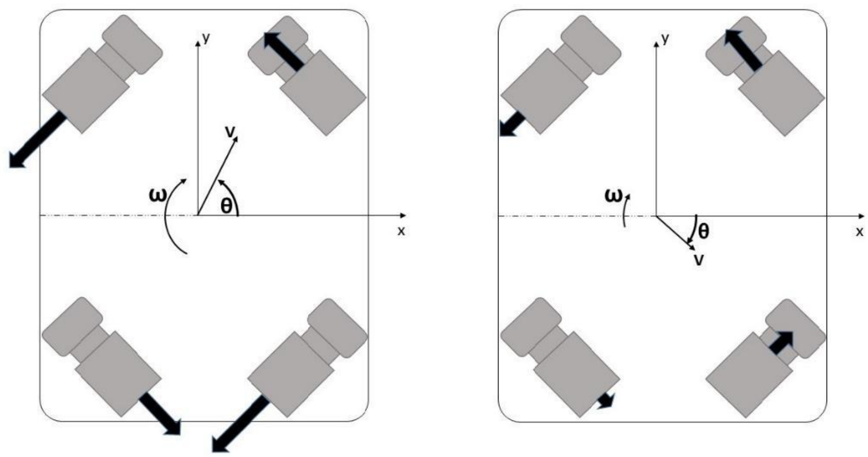


Figure 7: Vectored Thrust Example

Manipulator

This year's manipulator designs are based upon several key principles: simplicity, versatility, machinability, functionality, and cost. The combination and correlation of these principles is what shaped the manipulators into what they are now. The ROV features three separate manipulators to complete the tasks outlined for this year's competition. The first manipulator is a custom-fit solution that conforms to the shape of the gate valve, and spins to open and close it. It consists of three semi-rigid fingers arranged around a circle that is ever-so-slightly smaller than the outer diameter of the gate valve handle. With a camera pointed at the manipulator for visibility, the ROV engages this manipulator with the gate valve handle and the irregular shape of the manipulator and the handle create enough grip to turn the valve. It is actuated with a 24 volt bilge pump motor and a gearbox with a 3 to 1 speed reduction for added torque. An attempt was originally made to try a direct-drive between the motor and the manipulator, and while it had enough torque to turn the valve, it spun too fast for an operator to count the number of turns of the valve.

The manipulator is based upon a common four bar construction, which is a common design amongst manipulators. What is different about this design; however, is that where gears are typically used to translate the motion from one gripper piece to another, we used a simple linkage. This way, the design became more simplistic, and more customizable in terms of the width in which we wanted the manipulator to stretch.

Another way that the manipulator is simple is the removal of last year's the pneumatics, and swapping them out for a waterproof servo. This significantly decreases the weight and complexity of the ROV, as well as increases the amount of available internal space that the ROV has. Through testing, the servo has proven to be more effective than the pneumatics, mainly due to its simplicity.

During the construction of the manipulator, it was unknown exactly which tasks our team was going to attempt at competition, so the manipulator was designed for them all. The circular contour is made for the fountain piece, which was crucial since we had to demonstrate the light and water show task for the demonstration video. The four-bar construction keeps the tips of the manipulator parallel at all times, allowing for any other size object to be easily grasped by the manipulator. Although this manipulator is fairly large, its construction is rigid, so the manipulator possesses the size to pick up large objects, but also the precision to pick up smaller objects.

The manipulator consists of very few materials, these materials include: polycarbonate sheet, Delrin acetyl rod, and hardware. With this said, only two machines in our machine shop needed to be used, which made machining very easy. All the polycarbonate was cut on our water jet machine to make up the body of the manipulator. The Delrin acetyl was then machined on our lathe to make the bushings and spacers. Between these two processes, our machining time was finished, and it was ready to be assembled.

The manipulator functions very well. One of the main ideas behind the construction of the manipulator was rigidity. We did not want any play between the hardware and polycarbonate parts, and this was achieved by using tight tolerancing, and precise machining. By having a rigid manipulator, operation of the manipulator becomes much more consistent and dependable, thus making its functionality very efficient and effective.

As an extension of the primary gripper, a .1-meter aluminum hook was added. This hook extends over the middle top of the primary gripper. It is used to help complete several tasks throughout the competition.

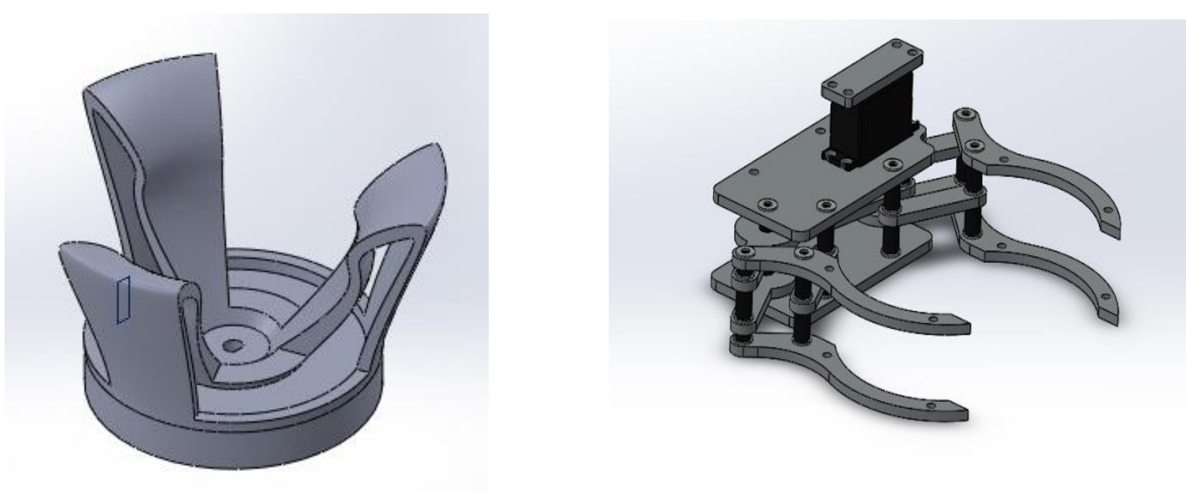


Figure 8: Valve Manipulator and Gripper

Electronics Enclosure

Last year, the company experienced many difficulties with the electronics enclosure used, not only with waterproofing but also with accessing the electronics once the box was sealed. The largest improvements sought after for this year's box was something that was accessible while still being resealable and waterproof.

The electronic enclosure on the 2017 ROV is a 250 x 250 x 100 mm IP68 aluminum box from Deltron enclosures. The company was actually lucky enough to receive this box as a donation from Deltron enclosures. The enclosure is mounted into the ROV so the lid faces downward.

Within this enclosure is a completely custom designed and 3-D printed scaffold system to house the ROV's onboard electronics. The scaffold, which is nylon printed on a Selective Laser Sintering (SLS) printer, consists of 3 layers which are each 234 x 234 x 3.18 mm in size. These dimensions allow the scaffold to fit snuggly in the enclosure. The bottom layer sits on the lid of the box so that the company can easily lift off the bottom of the box to access the electronics on the scaffolding. Within the scaffolding, mounting holes for each of the boards are inset from the surface of the scaffold layer by 1 mm, allowing the boards to set into the surface of the scaffold. This inset is done for all boards on the second and third layer of the electronics scaffold. Each board also has four mounting holes, allowing the company to easily secure the boards to the scaffold.

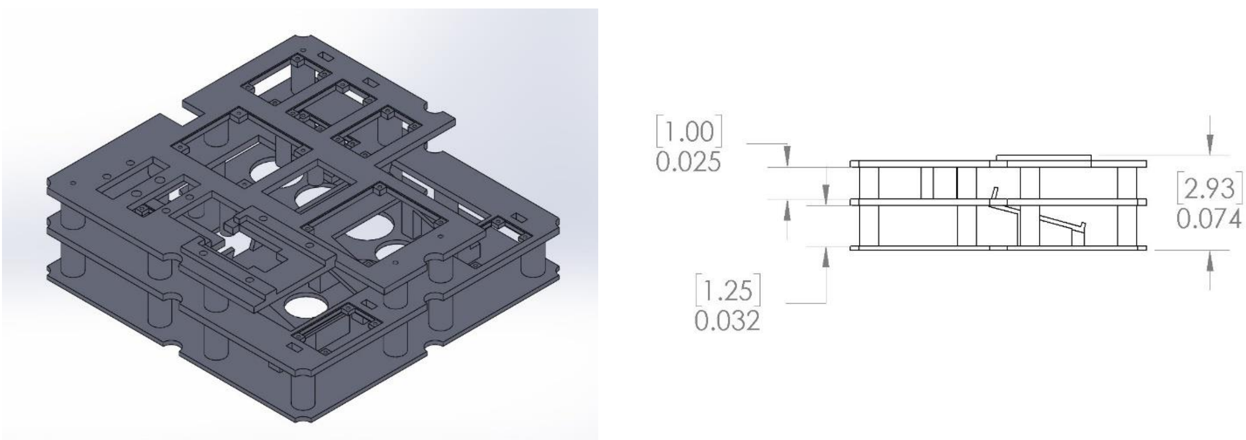


Figure 9: Full Assembly of Electronics Scaffold

All wires on the ROV route to the lid of the electronics box where waterproof connectors pass the wires through to the boards inside. This means that the bottom layer of the scaffold is comprised mostly of holes that surround these waterproof connectors, allowing the wires to pass through and route to the boards housed in the upper layers. There is also a large hole that surrounds a 57.15 x 57.15 mm (2.25 x 2.25 in) copper plate that is thermal pasted to the lid of the electronics box. Resting against this copper plate is the ROV's Vicor board. This copper plate acts as the heat sink for the Vicor board. There is also a mount for this Vicor board that mounts through to the third layer. This mount uses springs to ensure that the Vicor board is firmly pressed against the copper plate at all times. Finally, there is a large platform on the bottom layer on which the USB hub sits. This hub is large enough that it extends through the second scaffold layer.

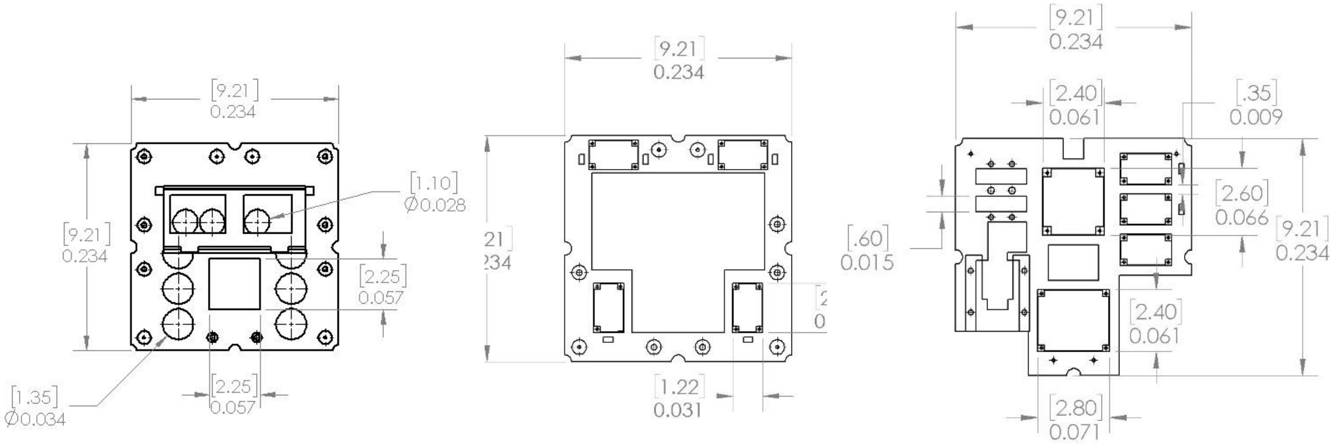


Figure 10: Base Layer, Second Layer, and Third Layer of Electronics Scaffold

The second layer of the electronics scaffold houses six motor controller boards, where four boards mount on the top side of the layer and two mount directly beneath. There is also open space for the Vicor mount, the USB hub, and space to route wires up to the third scaffold layer. The third scaffold layer contains three more motor controller boards, along with two BECs, a USB to ethernet converter, the power distribution board, and the ROV control board.

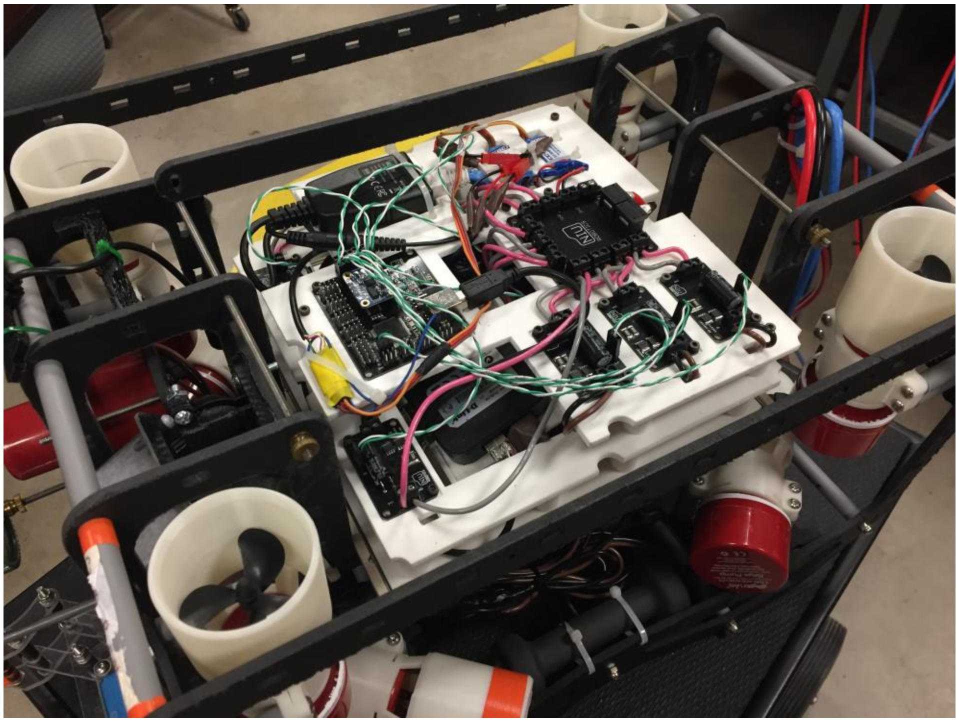


Figure 11: Open Electronics Enclosure

Electrical

Power

The 48V supplied by the MATE power supply is regulated onboard the ROV using a custom voltage regulation board referred to as the "Vicor board." This board utilizes two 48V to 24V Vicor regulators connected in a parallel configuration. This allows the ROV to achieve a total maximum rated current output of 22.86A at 24V. The Vicor regulators operate near 90% efficiency but still require passive heatsinking in order to stay within their thermal operating limits. The Vicor board was chosen as the optimal solution to the 48V regulation problem due to the significantly reduced size that the custom board provides when compared to alternative commercially available solutions. The team received a very generous donation of these regulators from Vicor, which further incentivized their usage.

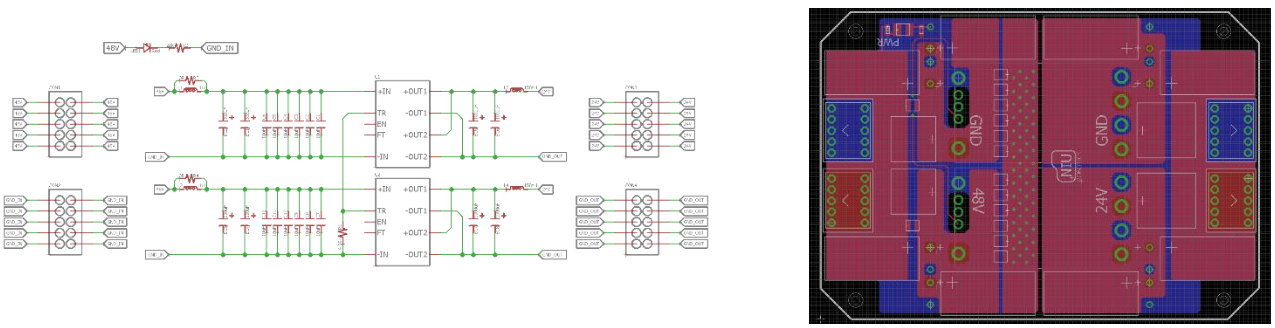


Figure 12: Vicor Board Schematic and Layout

The 24V output by the Vicor board is directly fed into a custom power distribution board that acts as a hub for all other devices that operate off 24V. The power distribution board has a total of 11 terminals that other devices can be connected to. The board is designed to be stackable with other boards identical to it. This allows the number of accessible 24V terminals to be increased without sacrificing large amounts of additional space within the electronics box. This power distribution method was chosen due to its simplicity and reduced size compared to commercially available alternatives as well as the benefits it provides in terms of optimization and flexibility of power connections.

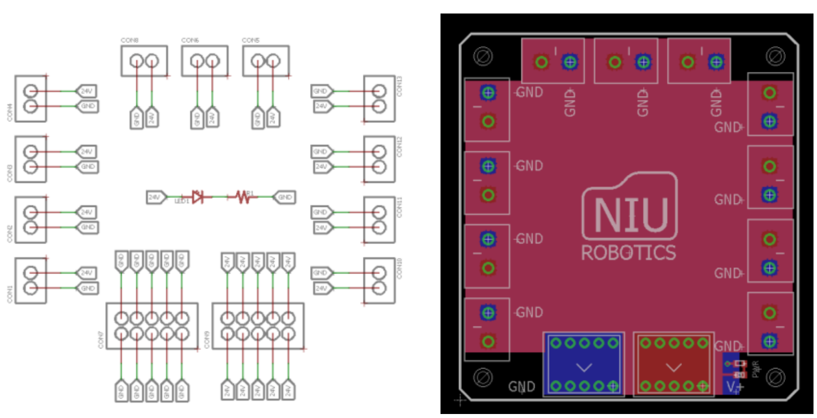


Figure 13: Power Distribution Board Schematic and Layout

In order to regulate the 24V from the power distribution board down to the 5V control voltage level, two CASTLE BEC voltage regulators are used. The first regulator provides power to the communication and control circuitry, while the second regulator provides power directly to the onboard gripper servo. These regulators were chosen because of their simplicity, high output current capability, and low cost. The same regulators had previously been successfully used on other projects which allowed the benefit of a proven solution at no additional cost.

Communication

The exclusive method of communication between the control station and the ROV is a standard USB serial interface. In order for the USB signal to be transmitted over the 70-foot length of the tether, a commercially available USB extender is used to boost the signal. On the control station end, the extender module is plugged into a laptop USB port. The extender module outputs the signal onto a cat 6 ethernet cable which makes up the main portion of the tether. On the ROV end, the ethernet cable is terminated with another extender module which then outputs a standard USB port. The extender is completely transparent, so no additional considerations are needed and the method allows on board access to a USB port as if the ROV were connected directly to the laptop. A cable is then run from this USB port into a 7-port USB hub which extends power and communication to several onboard cameras as well as the control board. Using a standard USB serial interface provides the most optimal communication method as it allows for several features not easily attained through other methods. First, standard Arduino based programs to be uploaded over the tether without the need for any additional connections. Second, basic serial communication can be used which allows for already written code to be repurposed for use on this year's ROV which saves development time. Third, it allows for the use of USB based cameras.

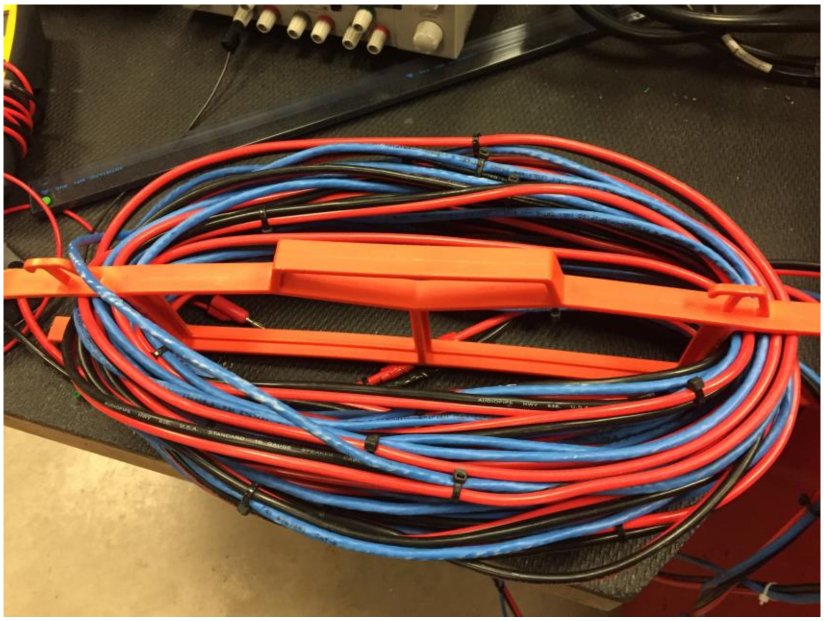


Figure 14: Coiled Tether

Vision

The vision system used on this year's ROV consists exclusively of USB based digital cameras. There are two types of cameras used. The first is a USB endoscope which provides the benefits of a small, already waterproofed enclosure, and an incorporated light. However, this camera comes with the drawbacks of not providing any easy mounting solutions as well as having a very short focal length. The second camera type is a USB webcam which provides the benefits of high resolution, a wide field of few, and a longer focal length. However, this camera comes with the drawback of needing a much larger custom waterproof enclosure. Both cameras are utilized so that their strengths are optimized. The endoscopes are used to monitor manipulators and view tasks which fall within their optimal focal length, while the webcam is used as the main drive camera. The decision to use USB based digital cameras was made due to the general advantages USB cameras have over other analog and digital camera alternatives. They work well with the rest of the already established USB based communication system and provide improved quality with no significantly noticeable latency. Additionally, video feeds from these webcams can be viewed using any number of already available software solutions on a standard laptop. This allows for a significant simplification of the control station by eliminating the need for special analog video converters, external monitors, and most significantly, the use of AC power within the control box.

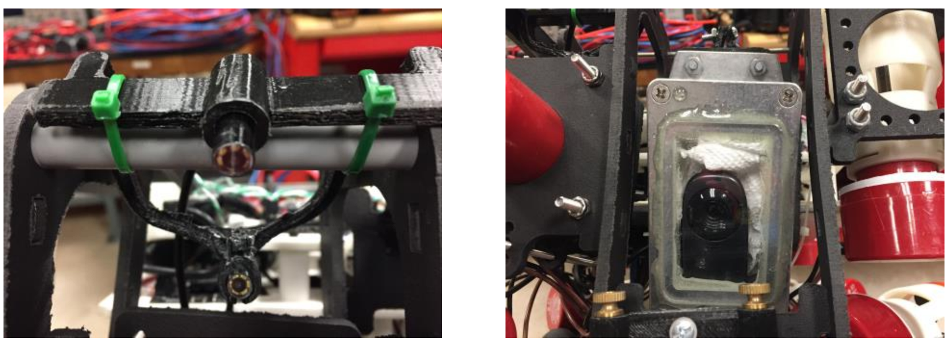


Figure 15: Endoscopes and USB Webcam

Control

The primary means of controlling the ROV is through a custom designed electronic control board. This board contains an ATmega2560 microcontroller, a USB to serial converter, a 5V to 3.3V voltage regulator and level shifter, an onboard 9 degree of freedom IMU, a 16 channel PWM expander, and related supporting circuitry and connectors. The microcontroller performs all necessary logic functions such as decoding control commands from the control station and then sending appropriate control signals to various other devices. The USB to serial converter allows the microcontroller to connect to the USB hub and communicate via the USB serial interface. The voltage regulator and level shifter convert 5V power and signals to 3.3V power and signals for use by devices such as the HC-05 Bluetooth module. The onboard IMU provides a means of obtaining the ROV's orientation information which can be used to improve the stabilization of the ROV while performing certain tasks. The pwm expander provides additional control signals that are routed to and used to communicate with the ROV's motor controller boards. The decision to use a custom board was made due to the advantages such a board provides in terms of customizability, cost reduction, space optimization, and connection integrity over the plethora of commercially available alternatives.

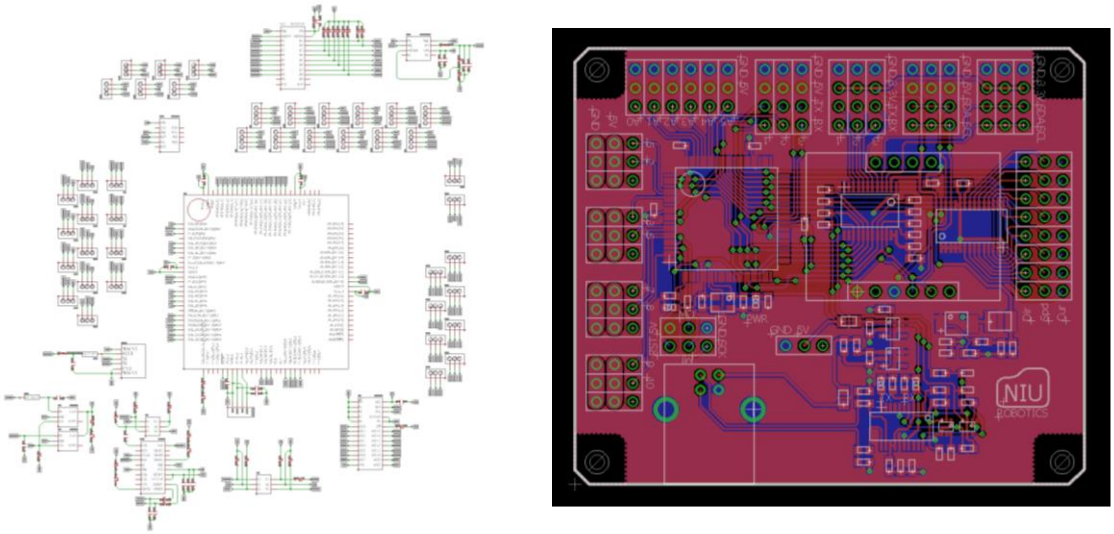


Figure 16: Control Board Schematic and Layout

In order to control the ROV’s thrusters and the valve manipulator, multiple custom designed motor controller boards are used. These boards are based off the A4956 brushed DC motor controller integrated circuit produced by Allegro Microsystems. The boards are capable of supplying power to all ROV thrusters and necessary manipulators while also controlling both their speed and direction. Speed control is determined by the duty cycle of a pwm signal obtained from the control board, while direction control is determined by the state of a simple digital signal from the control board. The boards are designed to be stackable in order to best optimize space inside the electronics enclosure. This custom board was selected as the best solution for motor control due to the significantly reduced cost and increased performance it provides when compared to other alternatives that were looked at.

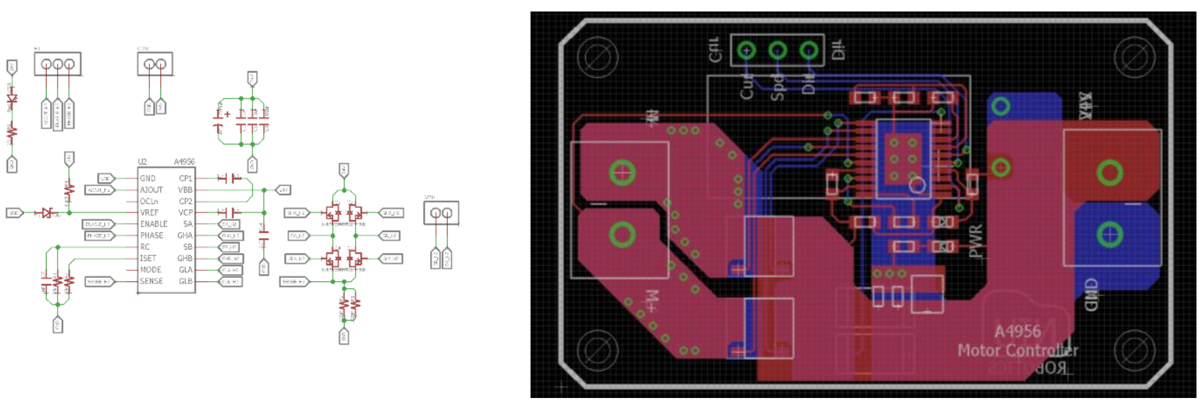


Figure 17: Motor Controller Board Schematic and Layout

Software

Overall

The ROV software is designed in two parts: the Control Station code and the ROV code. The Control Station code is responsible for reading values from the controller, displaying video feeds, and relaying information to and from the ROV. The ROV code handles control of the individual motors and all of the manipulators.

ROV Code

The ROV code takes direct input from the controller, dividing it into the appropriate blocks to control the drive system and the manipulator. The servo for the active gripper is limited to the open and closed states of the gripper to prevent the servo from overheating. The drive system is divided into two sections: horizontal and vertical drive. The horizontal drive uses three joystick axes to control translational motion in the horizontal plane and yaw rotation, the vertical drive uses two joystick axes to control vertical ascent and pitch rotation and two buttons to roll left and right. On the ROV, if commands from the surface are not received for 200ms, all pins that enable motor drivers are turned off, rendering the ROV in a safe, motionless state.

Control Station Code

The control station uses SDL2 to interface with an Xbox One controller. It also takes advantage of a third-party Serial COM manager to send data to the microcontroller on the ROV over USB serial. The program reads all buttons and joystick axes that are used to control the ROV into an array of bytes. Each joystick axis is mapped from its native range to the maximum range of a byte (0-255). Eight of the 12 buttons used are mapped bitwise into a single byte, which is then re-parsed on the ROV's microcontroller. The array is then converted into a string of chars to facilitate sending it over the serial line. The structure of the controller array is as follows: The character "A" as a header, the left-stick horizontal axis, the left-stick vertical axis, the right-stick horizontal axis, the right-stick vertical axis, a byte containing the first 8 button values, the left-trigger axis, the right trigger axis, the remaining 4 buttons in a byte, then the character "Z" as a footer.

Flow Chart

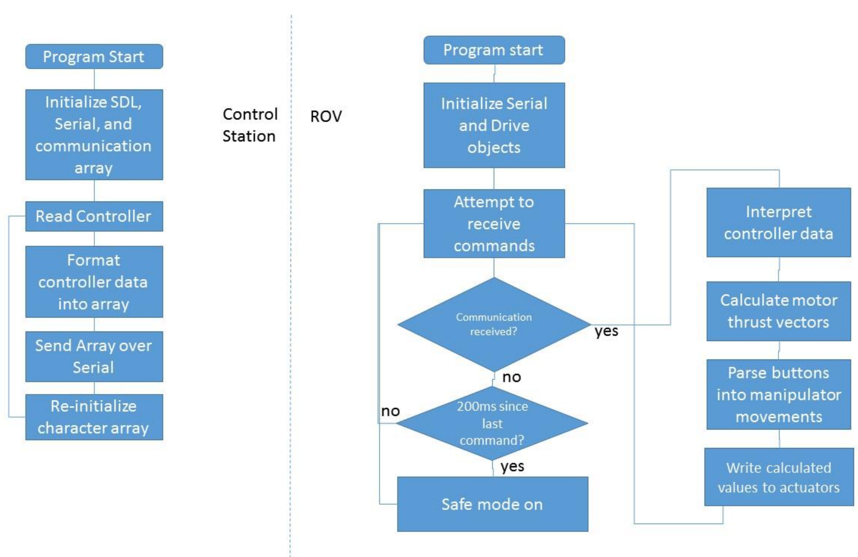


Figure 18: Software Flow Chart

Project Costing

ROV Project Costing			
Date	Item	Type	Total Price
Mechanical Equipment			
10/24/2016	Thrusters	Re-used	$ 625.00
10/24/2016	Chassis Materials	Re-used	$ 235.00
1/20/2017	Prop Materials	Purchased	$ 41.61
1/4/2017	Electronics Box	Parts Donated	$ 30.00
1/30/2017	Control Station Box	Purchased	$ 31.00
3/27/2017	HDPE Chassis Material	Purchased	$ 119.87
3/30/2017	Waterproof Connectors	Purchased	$ 75.38
4/17/2017	3D Printed Scaffold	Parts Donated	$ 500.00
4/26/2017	Prop Materials	Purchased	$ 146.10
		Total:	**$ 1,803.96**
Electrical Equipment			
10/24/2016	Tether/Wire	Re-used	$ 72.00
10/24/2016	Laptop	Re-used	$ 800.00
10/24/2016	Vicor Regulators	Re-used	$ 318.00
12/17/2016	PCB Components	Purchased	$ 19.00
1/24/2017	PCB Components	Purchased	$ 22.86
3/3/2017	Printed Circuit Boards	Purchased	$ 91.23
3/14/2017	Waterproof Servo	Purchased	$ 99.99
3/15/2017	PCB Components	Purchased	$ 260.97
3/21/2017	Printed Circuit Boards	Purchased	$ 53.65
3/27/2017	Endoscopes	Purchased	$ 82.85
3/28/2017	USB Hub/USB Connectors	Purchased	$ 32.81
		Total:	**$ 1,853.36**
Logistics			
2/28/2017	Mate Registration	Purchased	$ 250.00
3/24/2017	Lodging	Purchased	$ 1,373.00
5/23/2017	Travel	Purchased	$ 2,962.00
5/26/2017	Shipping	Purchased	$ 212.00
		Total:	**$ 4,797.00**
Funding			
9/6/2016	Previous Funding	Cash Donated	$ 750.00
12/7/2016	C and J Plumbing	Cash Donated	$ 500.00
12/8/2016	College Funding	Cash Donated	$ 850.00
3/21/2017	Pet King Brands	Cash Donated	$ 500.00
3/31/2017	IDEAL Industries	Cash Donated	$ 3,000.00
		Total:	**$ 5,600.00**
	Total Material Cost:		$ 8,454.32
	Cash Donated - Items Purchased:		$ (274.32)

Project Management

Over the course of building the ROV, the company used a Gantt chart like system to ensure that everything was being completed on time. Every task, including non-technical tasks, were placed into an excel sheet and given a certain week to be done by. Under each task was the name of those who were charged with completing this task. At the beginning of each week, the company would hold a meeting to go over which tasks had been completed, which tasks still needed to be completed, and go over any additional tasks that should be added to the chart. Tasks that were completed were changed to be green. Tasks that were behind schedule were change to be yellow. Some tasks were also changed to be orange when the task was late due to shipments of parts that had not come in on time. This helped ensure that everyone knew what had to be done and when it should be done. This system kept the company accountable while also ensuring that the ROV was done on time and that every part was done to the best of the company's ability.

						Regional Competition 4/29		Video Submisison 5/13		
Week of:	3/20	3/27	4/3	4/10	4/17	4/24	5/1	5/8	5/15	Key
Task	Design Scaffolding	Test Electronics	Manipulator Fab.	Box Completed	Practice in Anderson	Bluetooth Modules	Raw Video Footage	Submit Video!!!		Completed
Person	Charles | Hannah	Andrew | Mary	Adam | Jacob	Everyone	Everyone	Hannah | Mary	Everyone	Everyone		Behind
Task	Contact Anderson Pool	Machine lid	Remount Tether Sw.	Manipulator Functional	Video Requirements	Read Safety Requirements	Continue Tech Doc	right trigger gripper probs		Waiting on Parts
Person	Joel	Joel | Charles	Andrew	Adam	Hannah	Everyone	Everyone	Joel | Charles		
Task	Manipulator Design	Mount Connectors	Test motors with ELE	Full Systems Test	Cut Polycarb for box	Begin Tech Doc		stabilization		
Person	Adam	Joel | Charles	Andrew	Everyone	Jacob	Everyone		Charles		
Task	Chassis Modification	Waterproof No ELE	Assemble Chassis	Scoring Analysis	Gripper Programming	CS Hardware Mounting		gui		
Person	Austin | Jacob	Joel | Charles	Jacob	Hannah | Mary	Joel | Andrew	Joel		Joel		
Task	Comm Programming	Mount ELE to Scaffold	Motor Programming	Test Cameras	Wiring for Box	Diagnose camera issues		look into the other tasks		
Person	Andrew | Joel	Charles | Andrew | Mary	Joel | Andrew	Mary	Andrew | Mary | Hannah	Andrew | Charles		Mary		
Task	Control Station	Waterjet Chassis	Spinner manip hand	Confirm Pool Reserv.	Make Spinny manip mount	Rover team to borrow cam		TECHNICAL DOCUMENT		
Person	Joel	Jacob	Hannah | Charles	Joel	Joel	Jacob				
Task	Order Cameras	CS Hardware Mounting		Finish Coms Prog.	Book Flights	Talk to Gabel				
Person	Joel	Joel | Jacob		Joel | Charles	Joel	Joel				
Task	Servo Waterproof Test	Make Stickers		Check on ideal money	Mounting Gripper to chassis	IMU Stabilation				
Person	Jacob	Dennis		Dennis	Adam | Jacob	Joel				
Task	Spinner Manip Design	Comm Programming		Know if you can go	Modify Scaffold	Fix Translation Code				
Person	Joel	Andrew | Joel		Everyone	Charles	Charles				
Task	Camera Box research	Figure out Shipping		Email Regional people	Clean powder from scaffold	SID and Brochure Due?				
Person	Hannah	Hannah		Joel	Mary	Mary				
Task	Air BNB Contacted	Fit ROV in Battery Box		Anderson Pool Contract	Clean electronics					
Person	Joel	Hannah		Joel	Andrew					
Task		Manipulator Design Cont		Order Camera Box	Charge gopro					
Person		Adam		Mary	Mary					
Task				Camera Programming	Modify Passive gripper					
Person				Joel	Jacob					
Task					Mount for endoscopes					
Person					Hannah					
Task										
Person										

Figure 19: Project Management Spreadsheet

Safety

The ROV contains several features that ensure its safety. All parts that could cause injury, such as motors and rods that extend out past the chassis, are covered and labeled so that no harm is inflicted when working with the bot. Another safety measure, typical of systems that interface hardware and software, is a timeout failsafe. This failsafe will shut off motion and manipulator systems if new data is not received from the surface control station within the timeout period. Furthermore, if the ROV should lose communication with the control station for any reason, the motors automatically shut off and will not restart until communication is restored.

When testing the ROV to simply check that all electrical systems were working, precautions were taken to make sure that the operators and the ROV itself were not damaged or injured. Before connecting the ROV to the 48V power supply, all connections were checked to ensure that no wires were shorting and that everything was connected correctly. Once this stage of testing was completed successfully, the ROV was placed in a small tank filled with water so that the company could confirm that everything on the ROV was waterproof and worked well underwater. During this step, the company carefully inspected any place water could be entering and watched for bubbles, which would have indicated that something was not sealed properly.

Once the bot had been deemed safe underwater, it was taken to the pool so that it could be driven and tested more thoroughly.

All parts of the ROV are easily accessible by the company and all other operators. This helps to ensure that if any part of the bot needs to be removed or repaired, it is inherently safe for any member to do so. All wires run into a single box, and each can be tracked to where it connects. This allows members to safely modify any part of the ROV without the risk of compromising other parts of the bot or those around them.

Designs tested, pitfalls encountered, and lessons learned during the design and building process

Although much of the ROV was reused from last year, the company encountered many new challenges in getting ready for this year's competition. With a new electronics box, the company had to modify the center panels of the chassis to create an inset in which to secure this new box. However, once the parts were machined and the electronics box was inserted, the company found that the box was tapered and so was slightly too large at one end. Because of this, it did not fit in the chassis as planned. By filing the panels where the box was too large, the company slightly widened the inset, allowing the electronics box to fit well.

Another design issue encountered was the original placement and design of the ROV's passive gripper. The original gripper was supposed to help with the removal and reinsertion of the plug in the Entertainment Task. However, this passive gripper did not work as planned, and so was not able to complete the task as hoped. Our eventual solution was to remove that gripper completely. In its place, an aluminum hook was used and was placed as an extension on the primary gripper. This not only improved our ability to perform that particular task, but was found useful in a number of other tasks as well.

One of the major issues that had to be overcome was difficulties with waterproof servos. When the servos were completely submerged, a problem was encountered and connection with the servo was lost, causing the servo to revert back to a fully closed position. Since the servo was integrated into the bot via a custom connection that had been made and waterproofed by the company, it was believed that water was leaking into this connection somewhere, causing the servo to short. After finding alternate methods of waterproofing the electrical connection and applying them, it was found that the connection was not the only source of leakage. Along the wire leading up to the servo, there was a break that had not been noticed and was only found after extensive testing. In order to correct this, liquid electrical tape that was used on the electrical connection was also applied along the rest of the wire. After this was done, the error was corrected and our primary gripper worked while completely submerged. This process took the company about two weeks, a time frame in which we could not move forward with completing the other tasks.

All of these setbacks helped company members develop both technical and soft skills. Our ability to assess issues and effectively fix them has greatly increased, as well as the overall quality of the ROV. Furthermore, since our company does not have very many members, often times one or two of the members would be working on a certain system and would find a problem. They would then attempt to find a solution by themselves or would turn to the rest of the company and ask for help. This has helped us increase our communication and ability to cooperate with others. Since all members had knowledge of each part of the bot, we were able to help each other work through each of the issues we encountered.

Future Improvements

As mentioned above, one of the major setbacks while building our ROV was the waterproofness of the servos. The wire from the servo may have become degraded over time due to the chlorine in the pool's water. Although we were able to remedy this issue with the used of liquid electrical tape, the servo still does not work as well as hoped. Even though we are able to use it, for the future, the company would begin to research alternative methods. Last year, the company used pneumatics to control the active manipulator. Using this method again is a definite option, since it was fairly successful then. However, researching other options that are more effective for underwater use is also the plan for the future, since the last two methods worked, though not as intended.

Furthermore, since our electronics were located within a box, we had to create a scaffolding to hold them all. Because of the size of the box, the scaffolding layers were very close together, and once it was all put together, the components that were within the layers were very hard to reach. Although this year's electronics were much easier to access than last years, there is still some difficulty in reaching all of the different boards once it is all put together. For next year, one of our improvements would be to find a better solution for housing the electronics. One such method that could be tried is using a tube instead of a box. However, a great deal more thought and planning is required to ensure that our electronics are being safely connected as well as giving the company easier access.

Acknowledgements

The NIU Robotics ROV Team would like to thank the following organizations and persons for their donations and support of our project:

Sponsors

IDEAL INDUSTRIES, INC
VICOR
Deltron Enclosures
Solidworks

Northern Illinois University College of Engineering and Engineering Technology
NIU CEET Machine Shop Personnel
Armor Technologies

NIU Staff

Dr. Ji-Chul Ryu
Dr. Sachit Butail
Mike Reynolds
Dave Diaz
Mia Hannon
Cheryl Lubbers
Patricia Maxwell

NIU Robotics Team Members

Jacob Klein
Thomas Corbett

The NIU Robotics Team would also like to thank MATE Center and Marine Technology for sponsoring the competition, as well as the Long Beach City College for hosting the competition this year.

References

1. **Arduino - Reference. Accessed May 26, 2017.** https://www.arduino.cc/en/reference/homePage**.**

2. **(http://www.arkom.co.uk), Arkom Limited. "Industrial Electrical Enclosure Boxes." DEM. Accessed May 26, 2017.** http://www.dem-uk.com/deltron-enclosures/**.**

3. **"A4956: Full-Bridge PWM Gate Driver." Allegro Microsystems. Accessed May 26, 2017.** http://www.allegromicro.com/en/Products/Motor-Driver-And-Interface-ICs/Brush-DC-Motor-Drivers/A4956.aspx**.**

4. **Root. "DCM3414V75H31C2C01." Internal-link-on-image-multi-lan. Accessed May 26, 2017.** http://www.vicorpower.com/products?productType=cfg&productKey=DCM3414V75H31C2C01**.**

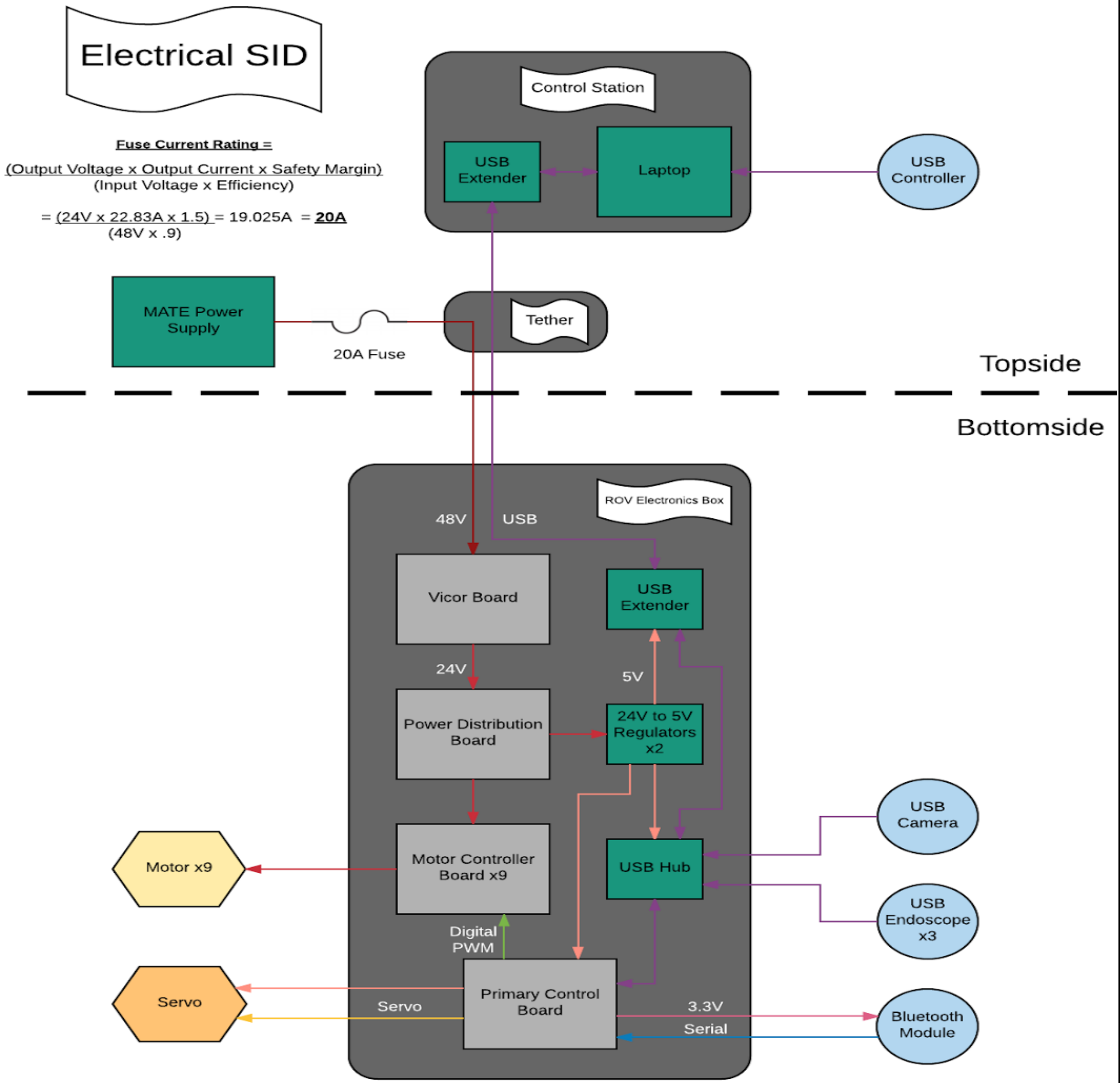
5. **"IP Code." Wikipedia. May 21, 2017. Accessed May 26, 2017.** https://en.wikipedia.org/wiki/IP_Code**.**

6. **"Marine Advanced Technology Education :: EXPLORER_2017." MATE. Accessed May 26, 2017.** https://www.marinetech.org/explorer_2017/**.**

7. **"Resource Center." SolidWorks. Accessed May 26, 2017.** http://www.solidworks.com/sw/resources.htm**.**

Appendix

A. Electrical SID



B. Budget

ROV Budget		
Item		Price
Mechanical Equipment		
Chassis		$ 150.00
Thrusters		$ -
Manipulators		$ 150.00
Electronics Enclosure		$ 50.00
	Total:	**$ 350.00**
Electrical Equipment		
Power Circuitry		$ 150.00
Communication Circuitry		$ 100.00
Vision Circuitry		$ 75.00
Control Circuitry		$ 250.00
Control Station		$ 150.00
Tether and Wiring		$ -
	Total:	**$ 725.00**
Logistics		
Travel		$ 2,500.00
Lodging		$ 1,500.00
Shipping		$ 400.00
Mate Registration		$ 250.00
	Total:	**$ 4,650.00**
	Grand Total:	$ 5,725.00