AquaCats ROV
University of New Hampshire Underwater ROV Team

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Advisors:
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ABSTRACT

The UNH Underwater Remotely Operated Vehicle (ROV) is an interdisciplinary engineering team dedicated towards the design and fabrication of an underwater remotely operated vehicle. This year’s iteration of the ROV, known as Siren, was designed with constraints provided by the International MATE ROV Competition and research specifications, such as size, weight, power consumption, and system capabilities. Design models of Siren were conceived through computer-aided modeling and numerical simulations, and verified through prototyping and testing processes. Several innovations to legacy ROV designs include an overhauled propulsion system, further operator interactivity through virtual reality (VR) technology, faster onboard computer, and an optimized control platform. Ongoing tasks include implementation of feedback control and communication with an Autonomous Surface Vehicle (ASV). Through innovative ideas, analytical tools, and robust engineering design, Siren presents an advanced underwater ROV platform capable of many aspects of research, competition, and industrial application.

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COMPLETED ROV

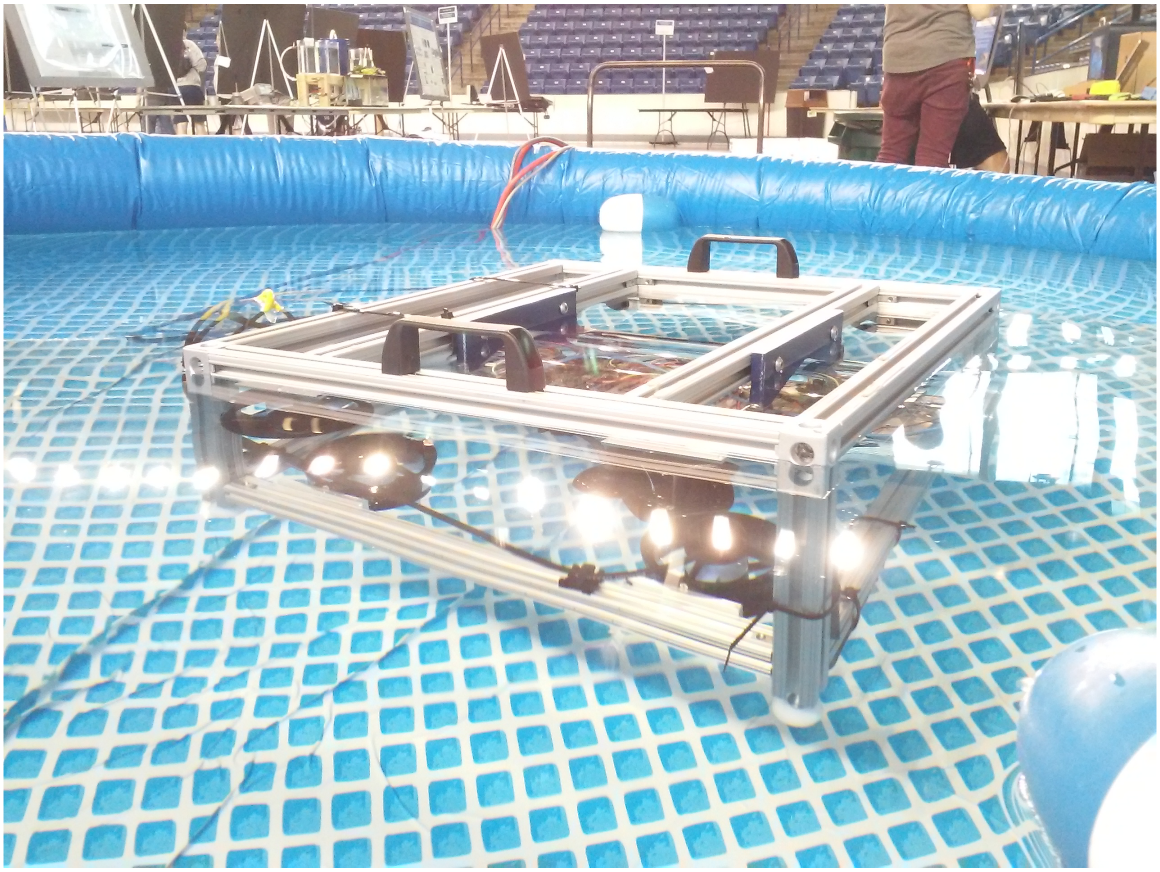


Fig. 1: Completed ROV-005 "Siren"

PURPOSE AND GOALS

The purpose of the ROV team for this academic year was to design and fabricate ROV-005 *Siren* in order to not only compete in the annual International Marine Advanced Technology Education (MATE) Competition, but also as a research support platform. With the primary goal of creating a unit capable of the MATE competition, the ROV was not only designed with the constraints given by the MATE competition requirements, but a so with l research implementations in mind. Previous legacy ROVs are also maintained throughout the year as the ultimate goal of the ROV project is to achieve a swarm of autonomous underwater vehicles (AUVs), thus keeping legacy projects in operational state is of importance.

The MATE Competition for the academic year 2015/2016 is taking place at the NASA Johnson Space Center's Neutral Buoyancy Lab in Houston, TX. The competition requires that all competing ROVs follow certain constructions, such as vehicle dimension, power consumption, and many other. Along with given build restrictions, each ROV must be outfitted in a manner that is capable of performing competition tasks, such as manipulation of items, sensory capabilities, precision maneuvering through obstacles and other varying tasks at the bottom of the pool. In order to make a robust unit capable of all tasks, significant amount of design, prototyping, and fabrication is required.

The primary research platform utilizing the ROV is light based leader-follower control algorithms. These algorithms will be implemented through a light-sensing array consisting of photodiodes, attached to the front of an ROV or any desired vehicle capable of utilizing the array. Currently, *Siren* is planned to be outfitted as a leader ROV, due to it's modular framing and large power well, making it capable of powering high output light sources. Legacy ROVs are planned to be used as follower ROVs.

Therefore, the primary goal of the ROV team for this academic year is to produce a fully functional, competition ready, ROV that is technologically and computationally superior to previous iterations while improving on the advancements made by the previous year's team in terms of user interface and interaction.

DESIGN CRITERIA AND CONSIDERATIONS

MATE Design Constraints

Previous iterations of the UNH ROV team has competed in the Marine Advanced Technology Education (MATE) ROV Competition. Every year MATE hosts an international competition at various locations around the globe that challenges various companies, or school teams, to design and build an ROV capable of finishing a series of underwater challenges. The challenges are new every year and relate to the interests of the host of the competition. For this year's edition the NASA Johnson Space Center is hosting the international competition at its Neutral Buoyancy Lab. The JSC is in Houston, Texas and the competition will take place from June 23-25, 2016.

This year MATE has created five challenges that represent design criteria NASA would like to see in underwater vehicles. The frozen moon Europa of Jupiter is believed to have liquid water under an ice sheet, a primary target for NASA. Several of the challenges relate to NASA goals of driving an ROV on the Europa and bonus points will be given for small, lightweight vehicles.

The main competition goals that relate with travel to Europa are measuring the thickness of an ice sheet, the temperature of a thermal plume, and connecting a power cable to an Environmental Sample Processor.

Other tasks represent the recovery of small cube satellites from the bottom of the pool, manipulating an oil well-head, and returning samples to the surface. These smaller tasks represent current ROV assisted tasks that are done in industry and scientific research goals. Taking samples of different coral species can help determine if the reef is growing or shrinking and returning oil samples can help pinpoint where a leak may be.

All of the MATE challenges require various sensors and manipulators for success. Designing for these challenges was part of this ROV team's design constraints and helped shape the overall design of the vehicle.

Design Considerations

Many design considerations were taken into account prior to the design phase of *Siren*. Due to modularity and transportability of ROVs being an issue in the past, *Siren* was to be designed as a lightweight, compact underwater unit without sacrificing high computational capabilities. To further facilitate the transportation of *Siren*, a modular chassis was required, preferable one that could be assembled and reassembled, thereby decreasing the overall volume taken by the unit. Additional degrees of freedom (DOF) to motion, optimal thrust vectors, and precision maneuverability were also desired, and an angled thruster orientation was considered to achieve this. By utilizing more thrusters, *Siren* could be given more (DOF) albeit at a slightly higher power draw. Also, a valve system was considered in order to ensure ease of attachment and removal of the electronics tray endcap. The valve could be opened prior to attachment or removal, allowing the pressure inside the tube to equalize with the outside ambient, making the detachment and attachment process require less force. Also, as a failsafe in case of catastrophic failure, *Siren* was to be made slightly positively buoyant, so that the unit would surface without the need of a vertical thrust vector.

To improve upon the user interaction implemented by ROV-003 *Viper*'s Leap Motion Controller, an Oculus Rift was considered in order to bring further interactivity with the unit. By attaching a camera to the bow of the unit and streaming the video feed directly into the Oculus headset, the user could get a POV experience of *Siren*. Another innovation in comparison to legacy ROVs is the implementation of a feedback control loop to control the depth of *Siren*. By locking the depth of *Siren* to a desired depth, the unit would be capable of maneuvering in that plane only until the feedback loop was terminated.

DESIGN AND MODELING

Chassis Design

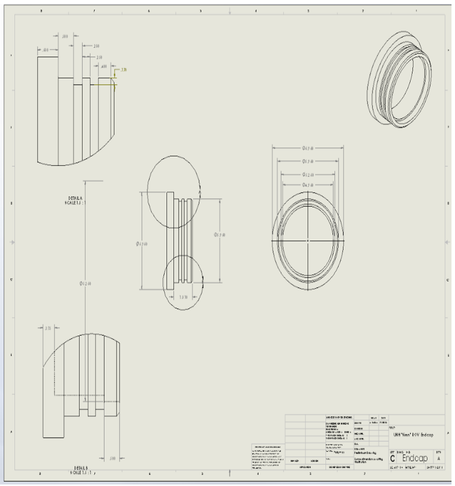
The 5th generation UNH ROV *Siren* was designed as mix of previous proven components and new approaches to old problems.

Fig. 2: ROV-005 Electronics Tube

Similar to previous UNH ROV vehicles, the Siren would utilize a central watertight 6" diameter acrylic electronics tube. Obtained commercially, its strength easily rates beyond the 30 feet water depth in which the Siren operates and clear nature allows for instant confirmation of the power state of electronic components which feature led lights.

This 6" main tube would require custom machined front and rear endcaps to fit within a very narrow window of tolerance for leak prevention purposes. The front cap was designed and fabricated in house at the UNH Kingsbury Machine Shop. Made of ½" sheet acrylic and produced on a CNC vertical mill, it was carefully fitted and epoxied to the main tube. Both water tight and clear, it would serve as the barrier between the front facing camera and the water outside.

The endcap also was custom fabricated as no commercial options existed to fit the needs of the Siren communications tether package. The raw stock material was generously donated by UNH Alumni and owner of Form3D Solutions & Manufacturing of Dover, NH. A 6.5"dia x 6" round of HDPE (High Density Polyethylene) was machined via lathe to include a double O-Ring design with centralized clearance for the installation of tether components.



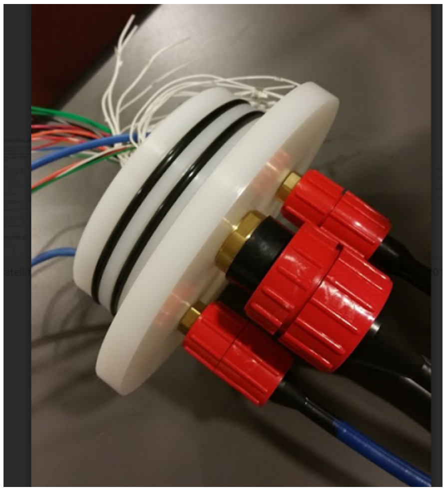


Fig. 3.1 (right): Solidworks drawing of ROV-005 endcap
Fig. 3.2 (left): Completed endcap with connectors

To complement the double O-Ringed back cap, the Siren had SubConn Electrical/Data connectors installed (pictured above in red) to handle surface to ROV communication and power needs. These were an upgrade from previous ROV designs as they provided more reliable water tight connection than earlier generations.

The combination of precision machined front cap, endcap, and SubConn connectors has survived all testing and ensured a zero leak environment for the Siren's onboard electronic components. As leak fixing has consumed a large portion of previous team's energies, this development freed the AquaCats team of a time draining diversion from other build activities.

For the matter of the frame itself, all previous UNH ROVs had utilized a custom cut dual acrylic side wall construction with acrylic or aluminum rod cross beams. This design approach meant that all aspects of the ROV construction was required to be preplanned early in the 6-8 month build to competition process. This created a high barrier to design improvements or dealing with unexpected challenges. Essentially, teams were locked into their initial component arrangements and as each year featured a new group of student builders, expecting perfect foresight early in in their learning process was unrealistic.

The 2015/16 AquaCats team adopted a far more modular approach to framing on the Siren. The chassis would be based on a commercially available product with wide industrial adoption that goes by the name of 80/20.

80/20 is a 1" square aluminum tubing that includes an identical T-Slot on each side. This standardized slotting design allows for access to a wide variety of specialized connectors and fasteners to which all Siren components can be mounted, positioned, and repositioned with a simple hex wrench and just a few moments of time.

No permanent decisions on quantity, type, or position of components needed to be finalized as this flexible system did not require such, and the 80/20 decision choice meant that the *Siren*'s final design could be withheld until very late in the process. This also allows for continual reduction in frame size and weight as the final *Siren* design nears completion. This is a forgiving design that allows for a framing member to simply be replaced with a newer longer piece of 80/20 if frame reduction occurs in error or a design decision is rescinded later in the process.

Propulsion Design

For the past two iterations of UNH ROV, the team has used the Blue Robotics T100 thruster. The T100 is a good design for ROV teams as it is compact, reliable, and can operate at high performance. The 2014-15 team did an analysis on the T100 and another commercially available thruster and decided that the T100 was the best option considering cost, thrust provided, mounting capability, and overall performance. With this work as a guide the T100 was once again selected as the thruster for *Siren*.

Fig. 4: BlueRobotics T100 thruster

Using the same thruster allowed the team to quickly move to the mounting design and arrangement of the thrusters. In the past UNH ROV teams have all used a similar thruster layout. This consisted of six thrusters (the first two generation ROVs used different thrusters, some commercially available and some homemade) with two thrusters pointing in each of the axis. This worked well however there were losses in efficiency due to the placements of the thrusters relative to the main electronics tube. The vertical thrusters, for one, were positioned directly over the tube which made it difficult for the vehicle to surface. Amongst other difficulties a new layout was proposed for Siren.

The new layout consists of eight thrusters with four thrusters providing horizontal movement and four thrusters providing vertical movement. The proposed method has angled thrusters in the four corners of the frame to provide thrust in all planar motions.

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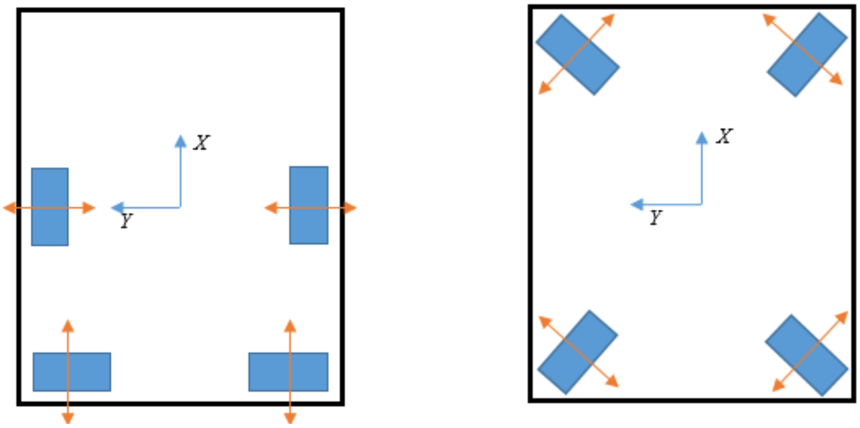

Fig. 5: Thruster orientation of ROV-003 (left) and ROV-005 (left)

A numerical analysis code was written and used to determine which orientation will provide more force. Experimentation was also used to verify the numerical results. Both the numerical analysis and the experimentation showed that the angled thrusters would provide more thrust force in all directions. The only downside of the angled thruster design was the slightly more complicated drive code as all thrusters must work together for effective maneuvers.

Systems Design

The most important section of *Siren* is the electronics contained inside of the main tube. These components include the onboard computer, the speed controllers, the camera, and all the wiring required. This makes the inside of the tube a complex array of wires and components that are vital to the performance of the vehicle. In order to keep track of critical components, a systems diagram was created to show how each piece connects to each other. The tether consists of two Ethernet cables and two power cables. The tether, which is over 75 feet long, connects the driver station to the vehicle. The Ethernet cables provide the communication and the video from the vehicle while the power cables bring 48V to the electronics tray. The first component on the ROV electronics tray is a 48-12V converter which converts the incoming electricity to the desired voltage for most critical components, such as the thrusters. There are also 12-5V converters which power the sensors and the computing components, such as the Raspberry Pi.

The System Interconnection Diagram (SID) can be found on the next page.
All of the wiring of the electronics tray and tether components was a long, but completely necessary, process. The tether side was also made waterproof to ensure no electrical shorts would happen. As some of the wiring and tether making could only happen once, the team worked slowly to ensure proper connections were made and the wires would be safe for use.

A detailed electrical circuit diagram can be found in the appendix.

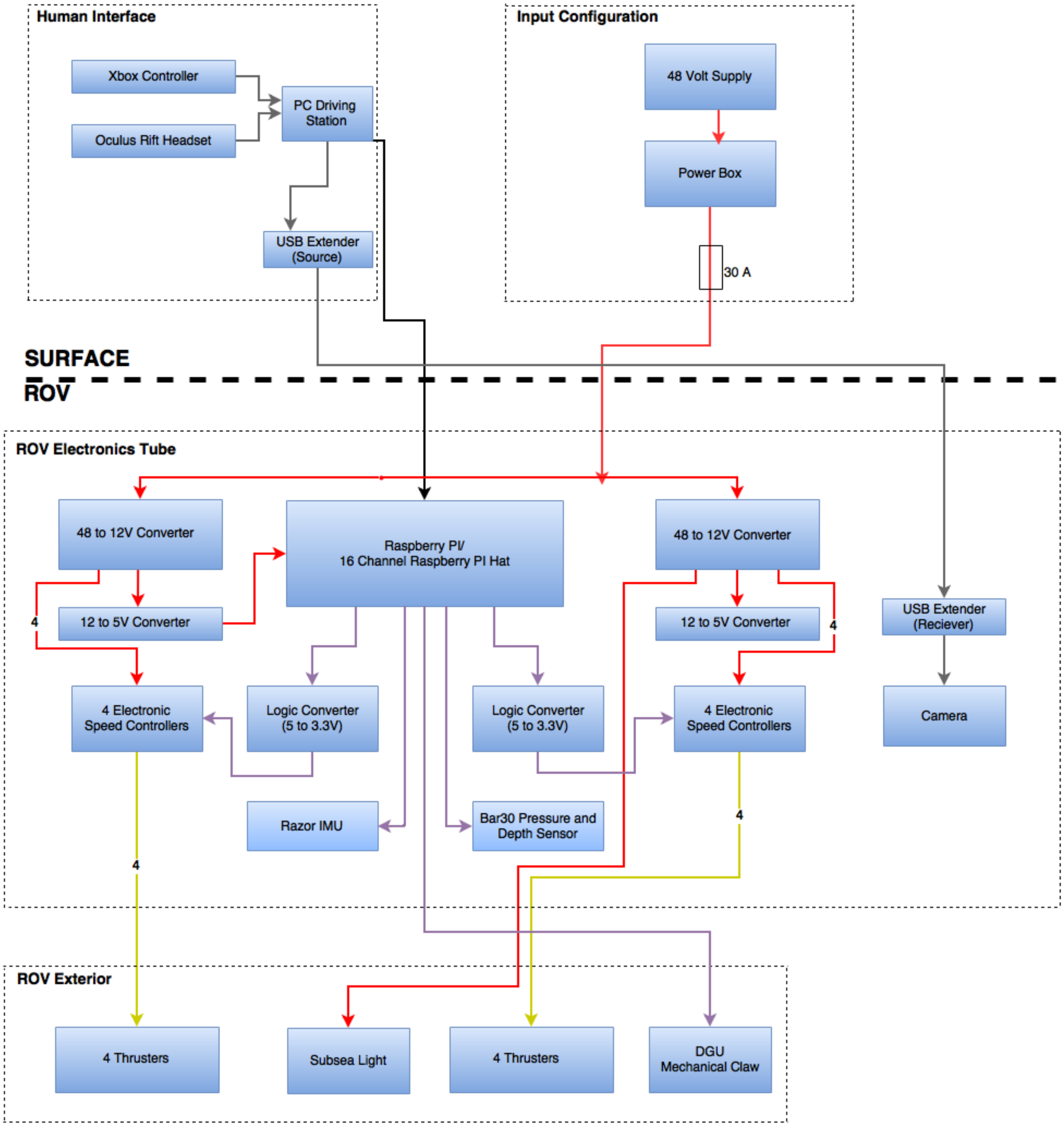

Fig. 6: System interconnection diagram

CONTROLS

Drive control

For the 5th generation ROV a new control scheme was implemented. Previous editions of UNH ROVs have used an Arduino Mega to power and control the vehicle. The Arduino Mega was a good choice for early ROV teams as it is simple to use and works easily with the chosen thrusters. However when trying to do more complicated maneuvers and increasing the autonomy of the system, the Arduino Mega starts to become less responsive and has to work hard. For these reasons a Raspberry Pi 2 Model B was used as the On-Board-Computer (OBC) for ROV-005 Siren. The Raspberry Pi allows for much more computing to be done on board the ROV as opposed to the surface computer/drive station. Relying on less on communication the ROV will be able to act autonomously more easily.

As the Raspberry Pi does not have a way to output the PWM signals the thrusters desired, a Raspberry Pi “hat” was required. The chosen hat was an Adafruit 16-channel PWM/Servo-motor hat that attached easily to the Raspberry Pi itself. The hat has 16 channels for PWM output which were used to control all eight thrusters. Unfortunately the hat’s output signals were at 3.3 V instead of the desired 5 V for the ESC so a bidirectional logic level converter was used to increase the signal. The combination of the Raspberry Pi, PWM hat, and the logic level converters gave complete control of all thrusters.

In order to control the thrusters when desired, currently from human input, a drive code was needed to determine which thrusters are to fire and how powerful. This drive code, written in Python, determines the desired orientation and movement based on controller input and fires either the translational thrusters or the vertical thrusters or, in a rare case, all thrusters. This year’s thruster orientation requires a more complex control code and careful calibration to ensure each thruster fired at the correct speed for optimal control. Due to this a numerical analysis program was written to test all combinations of thruster power for all maneuvers. In the end Siren is capable of movement in 5 degrees of freedom with options for a sixth with easy modification to the control code. Siren can move forward and backwards, left and right, up and down, yaw (spin about its vertical axis), and pitch (change angle relative to the horizontal). Currently Siren cannot roll however this is a constraint put on the vehicle, not a limitation by thruster capacity.

Surface PC to Raspberry Pi Communication and Secure Shell

A difficult hurdle to overcome since the change in microcontroller hardware required establishing a communication line between the surface control station to the Raspberry Pi onboard the ROV. Initial attempts to establish communication resulted in various difficulties, stemming from not only lack of proper hardware/software, but also the lack of knowledge of computer networking. After multiple trial and error attempts, User Datagram Protocol (UDP) was used to establish communication. A core internet protocol suite, UDP uses minimal, unreliable, best-effort transport messages between a server and client. UDP communication is unprotected, and does not provide any security. However, since *Siren* cannot utilize wireless communication, the medium of communication is a CAT5 Ethernet cable. Since the medium is a wired connection, there can be no security compromises due to secure access to the specific IP address used by the communication ports.

After acquiring appropriate communication code and setting up IP and protocols, effective communication was established between the two computers. Initial communication packets included basic text based messages, however with further improvements, the finalized UDP communication packet was capable of sending sensor data, user inputs, and other desired information.

To further improve system robustness, Secure Shell (SSH) network protocol was implemented in order to access files and programs within the Raspberry Pi from the surface station. A simple telnet client, known as PuTTY, was used to create the secure shell in the surface station by submitting the Raspberry Pi IP address to the PuTTY interface. This allows for remote interaction, system restart, and compilation of software implemented on the ROV from the surface station.

Onboard Sensor and Pressure Feedback for Depth Control

As per the MATE competition requirements, *Siren* needed to be outfitted with an accurate pressure and temperature sensor. The Bar30 sensor was deemed to be the most effective solution to *Siren*'s sensory necessities, and the waterproof characteristics of the Bar30 makes the waterproofing challenge much simpler. An accurate sensor, the Bar30 is capable of measuring pressure within a ±0.2 mbar and ±1□C, and is mounted on the bow of *Siren*, in order to ensure no physical interference to the sensor. The operator of *Siren* can obtain the data gathered by the Bar30 on the surface station through UDP packets.

A design improvement made to *Siren* compared to previous iterations of the ROVs was the implementation of a feedback control loop to control various aspects of a ROV. *Siren* utilizes the Bar30 that outputs pressure and temperature to the Raspberry Pi. Within the Pi, a control algorithm is implemented for *Siren* to attain a specific depth set by the user without user input to the controllers, and to maintain that specified depth. The control loop for the logic of the algorithm is shown below.

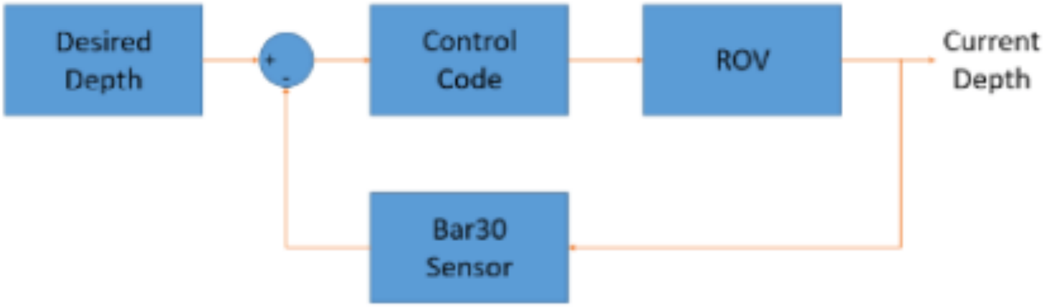

Fig. 7: Depth control feedback loop

User Interface, Oculus Rift, and Virtual Reality Environment

A primary goal of *Siren* was to improve user interactivity with the unit. Improving upon the implementation of the Leap Motion Controller to dictate the movement of the armature onboard ROV-003 *Viper*, *Siren* further improves user interaction through an Oculus Rift virtual reality headset. By directing the video feed obtained from an onboard camera with a 180° view, mounted at the front of *Siren*'s electronics tube, the Oculus Rift along with a software package known as Unity can generate a virtual reality environment where the user can directly see the video feed through the Oculus Rift headset. This allows the user to have a point of view (POV) from *Siren*, allowing for more depth perception and an increased immersion while operating the vehicle.

TEAM FINANCES

Funding

The UNH ROV team for this academic year was funded through New Hampshire Sea Grant, UNH Parents Association Grant, TECH 797, and the UNH Mechanical Engineering Department.

Predicted vs. Actual Costs

Product	Size	Quantity	Price	Shipping	Total Price	Subtotals
Aluminum U-Channel	1.5x1.5x48" -- 1/8"	1	$26.70	---	$26.70	
Aluminum L-Bracket	1.5x1.5x48" -- 1/4"	2	$36.05	---	$72.10	
Aluminum L-Bracket	1.5x1.5x24" -- 1/4"	1	$20.51	---	$20.51	
Super-corrosion-resistant 316 stainless steel	1.5"x1' -- 1/2"	1	$41.31	---	$41.31	
Tube Assemble	4" ID	1	$156.00		$156.00	
Hose Clamp (5 pack)	Size 152	1	$9.27	$5.66	$9.27	
Polycarbonate Sheet (3/8)	36"x36" -- 3/8"	1	$155.31		$155.31	
Polycarbonate Sheet (1/2)	12"x24" -- 1/2"	1	$56.93		$56.93	

Robotic Arm		1	$100.00		$100.00	
Hardware (screws, brackets, bolts, nuts, washers, etc.)		1	$150.00		$150.00	
Bouyancey Foam		1	$50.00		$50.00	
Subtotal - Hardware				$5.66	$838.13	$843.79
Gefen USB 2.0 Extender		2	$284.98	$12.40	$569.96	
Arduino Mega		2	$39.93	$0.00	$79.86	
Arduino Wires and Cables		1	$9.99	$0.00	$9.99	
Raspberry Pi		2	$35.00		$70.00	
48V to 12 V converter		1	$45.00		$45.00	
12 to 5 V converter		1	$35.00		$35.00	
Camera		2	$42.59		$85.18	
Mini Breadboard		1	$4.54	$0.00	$4.54	
IMU	Razor 9 dof	1	$74.95	$0.00	$74.95	
Sensors (light, sound)		2	$50.00		$100.00	
Servos		4	$13.95		$55.80	
Subtotal - Electronics				$12.40	$1,130.28	$1142.68
BlueRobotics T100 Thrusters (with Basic ESC)		8	$134.00	$12.00	$1,072.00	
Tether Supplies		1	$100.0		$100.00	

			0			
Cable Penetrators		10	$8.00		$80.00	
Subtotal - Propulsion & Tether				$12.00	$1,264.00	$1276.00
Machining Costs		1	$500.00		$500.00	
Oculus Rift		1	$350.00		$350.00	
Contingency/Shipping		1	$600.00		$600.00	
Subtotal - Misc				$0.00	$1,450.00	$1450.00
TOTAL PARTS COST						$4712.47
Tickets to Houston		9	$240.00	$2,160.00		
Hotel	3 Room	6 Nights	$100.00	$1,800.00		
Car Rental	Days	7	$200.00	$1,400.00		
TOTAL TRAVEL COST						$5360.00

Total Projected Expenses: $10072.47

The current recorded expenditure so far for the build is as follows:

Date		Description	Income	Expenses	Year to Date
7/1/2015		Balance Forward: 1gd163			$1,376.17
		ME Department Contribution	$ 1,000.00		$2,376.17

10/12/2015		Dean's Office contribution (1gd212)	$ 1,500.00		$3,876.17
7/1/2015		Donation - MATE 15 travel stipend Monterey Peninsula College	$ 500.00		$4,376.17
9/25/2015		Oculus Rift - development kit ($322 & $50)		$ 372.00	$4,004.17
11/12/2015		McMaster Carr - framing/connectors/fasteners		$ 268.93	$3,735.24
12/3/2015		Adafruit - power converters		$ 36.86	$3,698.38
12/3/2015		Powerstream - power converters		$ 187.15	$3,511.23
12/11/2015		Donation - Parents Assoc	$ 3,232.00		$6,743.23
7/9/2015		Donation - Monterey Peninsula College	$ 500.00		$7,243.23
1/4/2016		Blue Robotics - enclosure materials		$ 268.80	$6,974.43
1/15/2016		Adafruit - project supplies		$ 42.81	$6,931.62
1/12/2016		Adafruit - project supplies		$ 26.26	$6,905.36
1/21/2016		Waytek - amp breaker		$ 34.45	$6,870.91
1/25/2016		Adafruit - stacking header		$ 12.36	$6,858.55
2/1/2016		McMaster Carr - framing/sheet metal/fasteners		$ 101.75	$6,756.80

The following records show that the UNH ROV team had $6,756.80 at 2/1/2016. This does not account for other expenditures such as construction of a surface computer ($786.75), SubConn connectors ($1262.51) and other miscellaneous expenses. With the projected travel cost to be approximately $4200, the team for this academic year is projected to spend approximately $7000 on the project, significantly less than the projected amount with a fair buffer.

SAFTEY

Several redundant safety measures were put in place for *Siren*. The top safety concerns were due to high voltage and water leakage. The 48-12 V power converters used had several safety features of their own that were used. This included a sense pin, which would tell the converter if there was a large enough voltage difference to turn on, and a remote on/off pin that measured current output of the converter. These measures allowed for the proper amount of current to pass to the vehicle. On the surface side a power box was created. The power box has analog volt and current meters installed so the pilot knows how much power is being sent to the ROV. The power box also contains an on/off switch with an embedded 30A fuse. This sixe fuse was chosen due to the ROVs current draw of 25A if all thrusters are on at full power. As the drive code does not allow for this, we expect a maximum of only 20A.

The electronics tray is also of concern due to many wires connecting the main components. The connections between the endcap and the tray feature bullet connectors for easy removal. To ensure there is no short circuit anywhere in the tube, heat shrink tubing was used to cover all exposed wire. All components and wires have also been labeled for easy understanding of how the vehicle operates.

Finally the endcap design was critical. As mentioned the double O-ring design allowed for ensured safety. In case of a failure in the first O-ring the second is ready to prevent water from reaching the electronics.

In the case of an extreme failure and we no longer have communication with the vehicle we have designed *Siren* to be positively buoyant. This will allow the vehicle to surface under no power and allows for easy retrieval.

FUTURE IMPROVEMENTS

Future improvements plans consist of adding more feedback control implementations, specifically for 3-axial orientation control using an IMU. Utilization of a printed circuit board (PCB) would reduce wire clutter so often encountered with ROV builds. In terms of user interactivity, the VR environment could be vastly improved in terms of aesthetics. This includes the implementation of a heads-up display (HUD) on the Oculus headset and integration of the Leap Motion Controller and the Oculus Rift to give the user a seamless operation experience.

In terms of chassis design, a smaller tube would be desirable due to the large buoyancy provided by the current tube. An attempt was made this year to reduce the size of the tube from 6” to 4”, but due to the parts used, this goal was not accomplished. Future designs could consist of better parts selection and management, leading to the usage of a smaller sized tube.

CHALLENGES FACED AND LESSONS LEARNED

During the building of *Siren* several issues were faced. Most notably the team effectiveness and efficiency was challenged. Several members did not get their work accomplished on deadlines, which had other members doing more work and struggling to meet their own deadlines.

Waterproofing concerns are always present when designing submersible vehicles. Thankfully *Siren* had not problems when being tested for leaks. This was due to a solid design with tight tolerances, careful inserting of the rear endcap, and following guidelines about O-ring care and replacement.

On the controls side the team members did not have much experience with sending packets of data between two systems. This was accomplished with consultation of computer science majors and several days of basic testing. In the end a successful UPD client and server script were written, unique for *Siren* but also adaptable for use with previous generations of ROVs.

Throughout the school year, members of the UNH AquaCats have learned about design. Members were also involved with all aspects of machining and creating the chassis. This had several members working in a machine shop for hours, using a mill or lathe to ensure the piece fits our tolerance.

REFLECTIONS

“Through this project I have become more confident in my ability to bring a conception to a real world product. I have been involved in design, machining, coding, and piloting the vehicle, all of which have shown me how important each aspect is. I have also realized how much communication is necessary and good team members are important. My favorite memory from this project was the first time I got to put the vehicle in the water, of course the ballasting was off and the code needed tweaks but I got to see a vehicle I made running underwater on a code I wrote.” – Shawn Swist, Junior Mechanical Engineer

“Being the team captain of this team, a lot of responsibility came my way, whether it was build or management related. Despite my specialty being in control systems application, I assisted with machining and assembly of the unit as well. Throughout the course of the year, the team ran into some troubles regarding efficiency and communication, so I had to step up and ensure that the ROV was still on schedule for completion. My favorite memory was when I, as the pilot, managed to qualify our team for the MATE competition. This project has not only given me a chance to apply my knowledge towards a practical purpose, but also use my leadership skills to ensure that the ROV was completed.” – Sital Khatiwada, Senior Mechanical Engineer

“As the lead chassis designer and fabricator I was fortunate enough to go from figment of my imagination, to fleshed out concept, to 3D modeled drawing, and then into the machine shop to make it a reality. Along the way, we took some unusual approaches to problems (thruster layout, frame, etc) and made them work, giving us more confidence in our ability to overcome real world engineering problems during our future employment. This project has taught my cohorts and myself the value of teamwork and the flexibility to try new solutions when your first and best solution isn’t working.”-Matt Falbe, Senior Mechanical Engineer

ACKNOWLEDGEMENTS
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The UNH ROV team would like to thank Joseph Gabriel of Form3D Solutions for his help in designing the endcap.

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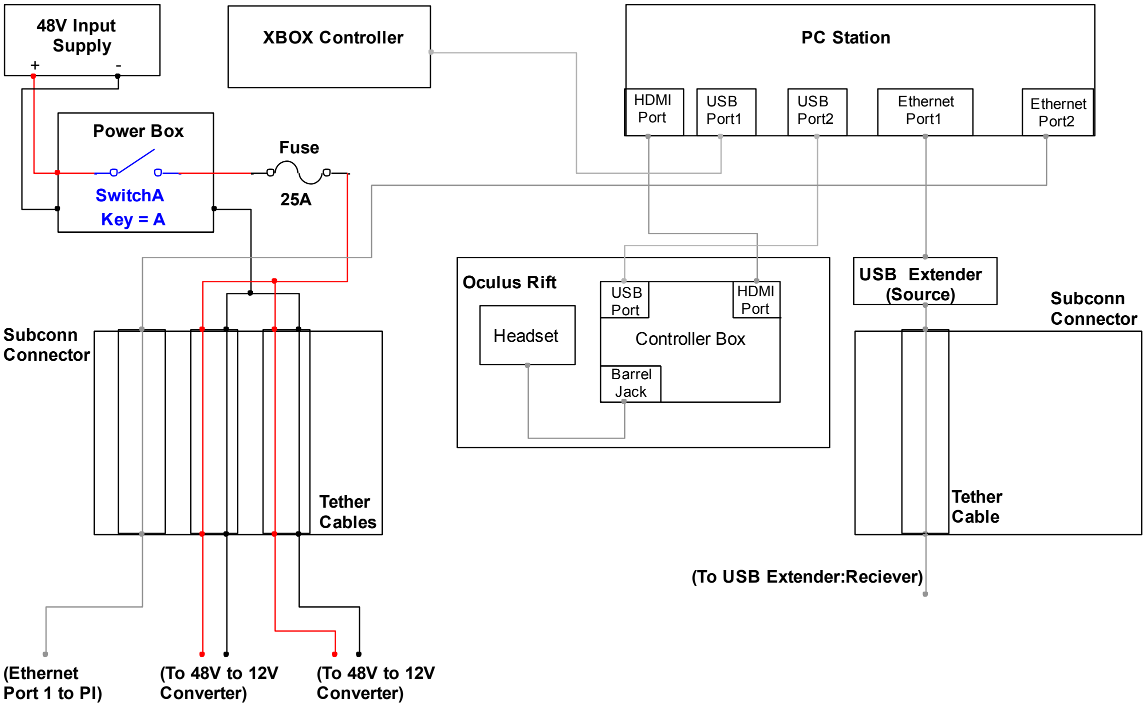
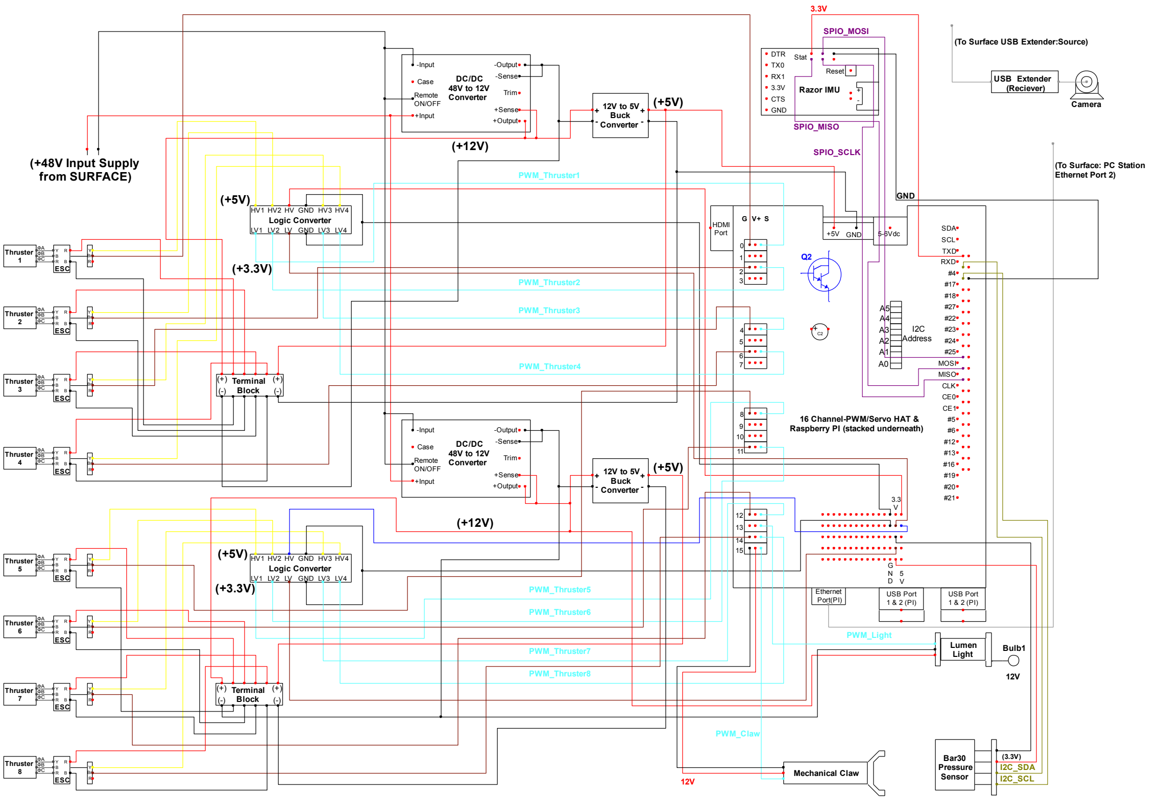
Thank you to Blue Robotics for providing a low cost, high end thruster that is allowed in the MATE ROV competition.

APPENDIX A: Wiring Diagram

Surface



ROV



APPENDIX B: Code Samples

Code written in Python. All codes can be found at:
https://github.com/sswisty/ROV-SIREN

```
"""
UNH ROV 2015/16
Control Code - SIREN

Drive Code V1.0 by Shawn Swist
"""

#==============================================================
#     ----------     Necessary libraries   ------------
from Adafruit_PWM_Servo_Driver import PWM
from ControlFunctions import MotorControl, WriteMotor, Correction
import socket
import sys
from SendReceive import SendReceive
import time     # may not be necessary for final build

#==============================================================
#    ----------------- Inatilization commands ----------------

# Define the hat over the I2C connection pins
hat = PWM(0x40)

# Set the desired frequency for the servos (50 Hz)
f = 48
hat.setPWMFreq(f)

# Define the thruster pins on the ServoHat

thruster1 = 0;
thruster2 = 2;
thruster3 = 4;
thruster4 = 6;
thruster5 = 8;
thruster6 = 10;
thruster7 = 12;
thruster8 = 14;

center = 307;    # Use this to initilize the thrusters
```

```
# Initilize
print "Initilizing ..."
hat.setPWM(thruster1, 0, center)
hat.setPWM(thruster2, 0, center)
hat.setPWM(thruster3, 0, center)
hat.setPWM(thruster4, 0, center)
hat.setPWM(thruster5, 0, center)
hat.setPWM(thruster6, 0, center)
hat.setPWM(thruster7, 0, center)
hat.setPWM(thruster8, 0, center)
# Initilize thrusters for 3 seconds
time.sleep(3)



# ============================================================
#    ------------------ Main Loop -----------------------

while True:

   # Read pressure and sensor, UDP code works by sending message first
   pressure,temp = ReadSensor() # temp too ...


   # Communication with PC
   # Read in game controller values
   LX,LY,RX,RY,LT,RT = SendReceive(pressure, temp)

   # Use controller values to control thrusters
   MotorControl(RX,RY,LX,LY,RT,LT)

   print LX, LY, RX, RY, LT, RT
```