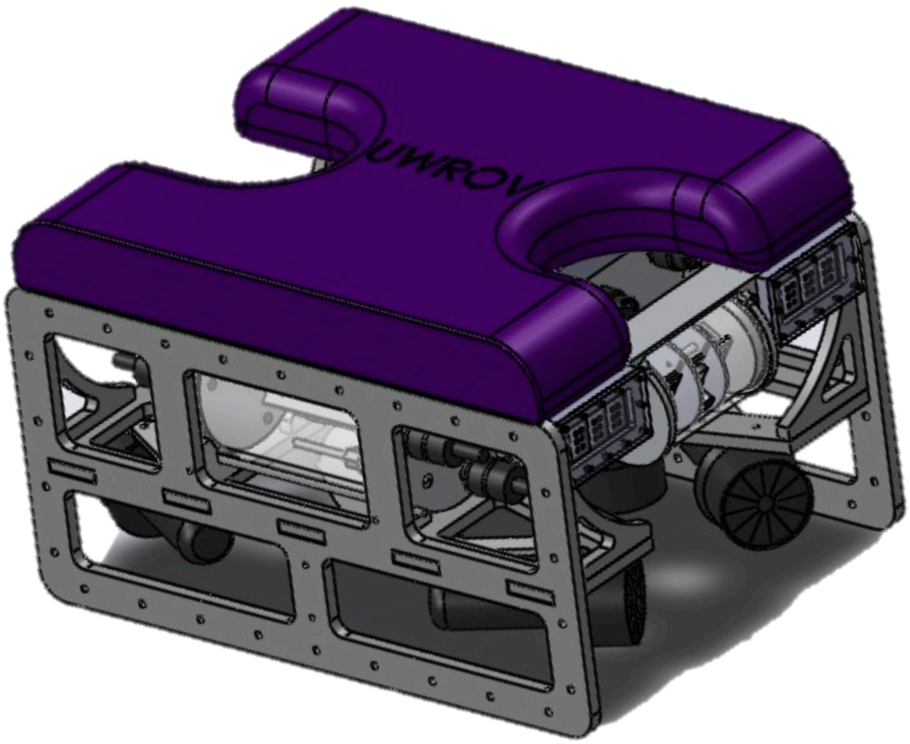
UNDERWATER ROBOTICS AT THE UNIVERSITY OF WASHINGTON

ORCUS

University of Washington
Seattle, WA



Team Members

Name	Position	Major
Ryan Cox	CEO/CFO	Electrical Engineering
Erica Sampaga	V.P.	Oceanography/ E.S.S. Geology
Adrian Junus	Pilot/ Mechanical Technician	Mechanical Engineering
Tyler Yeats	Programmer	Computer Science & Engineering
Juliana Pesavento	Electrical Technician	Oceanography
Joseph Downs	Mechanical Technician	Mechanical Engineering

Advisor
Rick Rupan

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1. Abstract

ORCUS was designed to complete the missions planned for the 2014 Marine Advanced Technology and Education (MATE) International Remotely Operated Vehicle (ROV) Competition. This vehicle is also intended for use in a variety of research opportunities through the University of Washington for students and faculty. As such, ROV ORCUS was designed to be more robust for long missions and greater depths. The vehicle meets MATE safety requirements and is capable of being deployed from a ship. ORCUS was initially built with the 2013 MATE competition in mind; however it has been adapted to the 2014 missions. Some features of ORCUS consist of a (detachable) tether management system, dual system cameras, syntactic foam for buoyancy, graphical user interface to display system stats, and vehicle mobility in every direction.

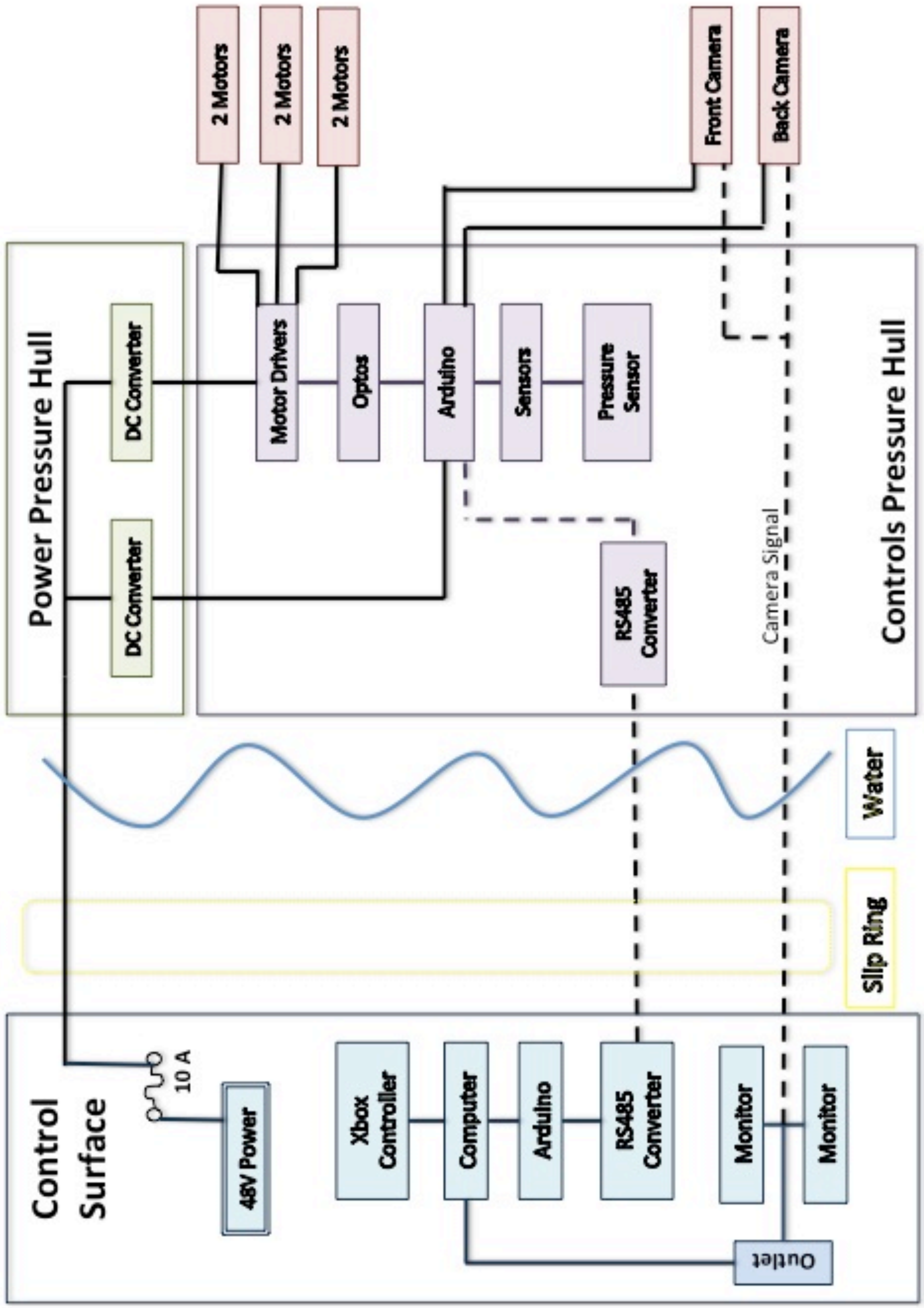
2. Budget

The budget is summarized below in tables 1 and 2. 8,445 dollars were raised from a variety of sources including local companies, university departments, individuals and fundraising. The majority of the plane tickets were bought using sponsors airline miles. This year's total expenditure comes to 7009.90 dollars. This leaves 1435.1 dollars for last minute travel arrangements and the rest for development over the summer and early next year.

Table 1: Income		
Amount	**Source**	**Notes**
$3,500	Regional Scale Node	
$1,500	Boeing	
$500	MTS	
$1,165	Kickstarter	
$150	Karl Kunkle	
$500	Novian and Lina Junus	
$500	Steve Riser	ROV Shipping Costs
$630	Russ McDuff	Juliana's Plane Ticket
~50k miles	Rick Rupan	Ryan's Plane Ticket
~100k miles	John Delaney	Adrian and Tyler's Plane Tickets
~25k miles	Virginia Armburst	Joe's Plane Ticket to Albena
~25k miles	Novian Junus	Joe's Return Plane Ticket
1.5hr	UW Lamborghini Lab	Used water jet to cutout frame
5hr	ClaroWorks	Used CNC mill to make endcaps
Total		
$8,445		Not including miles

Table 2: Expenses		
Amount ($)	**Description**	**Notes**
120.00	Golf Cart DCDC Converter (x2)	Purchased
18.00	Arduino UNO (x2)	Purchased
125.00	Arduino Mega (x2)	Purchased
67.40	Pololu Motor Driver	Purchased
135.08	Misc Electrical	Purchased
4200.00	Seabotix Thruster (x6)	Purchased
799.95	McMaster Hardware	Purchased, 9 orders
63.43	Parker oil compensation nipple	Purchased
58.25	Kickstarter fee	Purchased
55.34	Amazon fee	Purchased
470.88	T-Shirts	Purchased
2.25	PayPal transfer fee	Purchased
85.00	Shipping Supplies	Purchased
75.00	Shipping Costs	Purchased
100.00	Mate Registration	Purchased
104.12	Kickoff Refreshments	Purchased
530.00	CRTC	Purchased
Total		
7009.90		Current total paid expense
300.00	Shipping	Estimated shipping cost
2500.00	Connectors	Donated and reused
210.00	Slip Ring Connector	Donated and reused
360.00	Pololu Motor Drivers (x6)	Reused
220.00	Camera (X2)	Reused
47.80	LED Module (x4)	Reused
132.05	Acrylic tubing	Reused
174.50	Aluminum rounds for endcaps (x6)	Reused
150.00	Syntactic Foam	Donated and reused

3. Systems Integration Diagram



4. Design Rationale

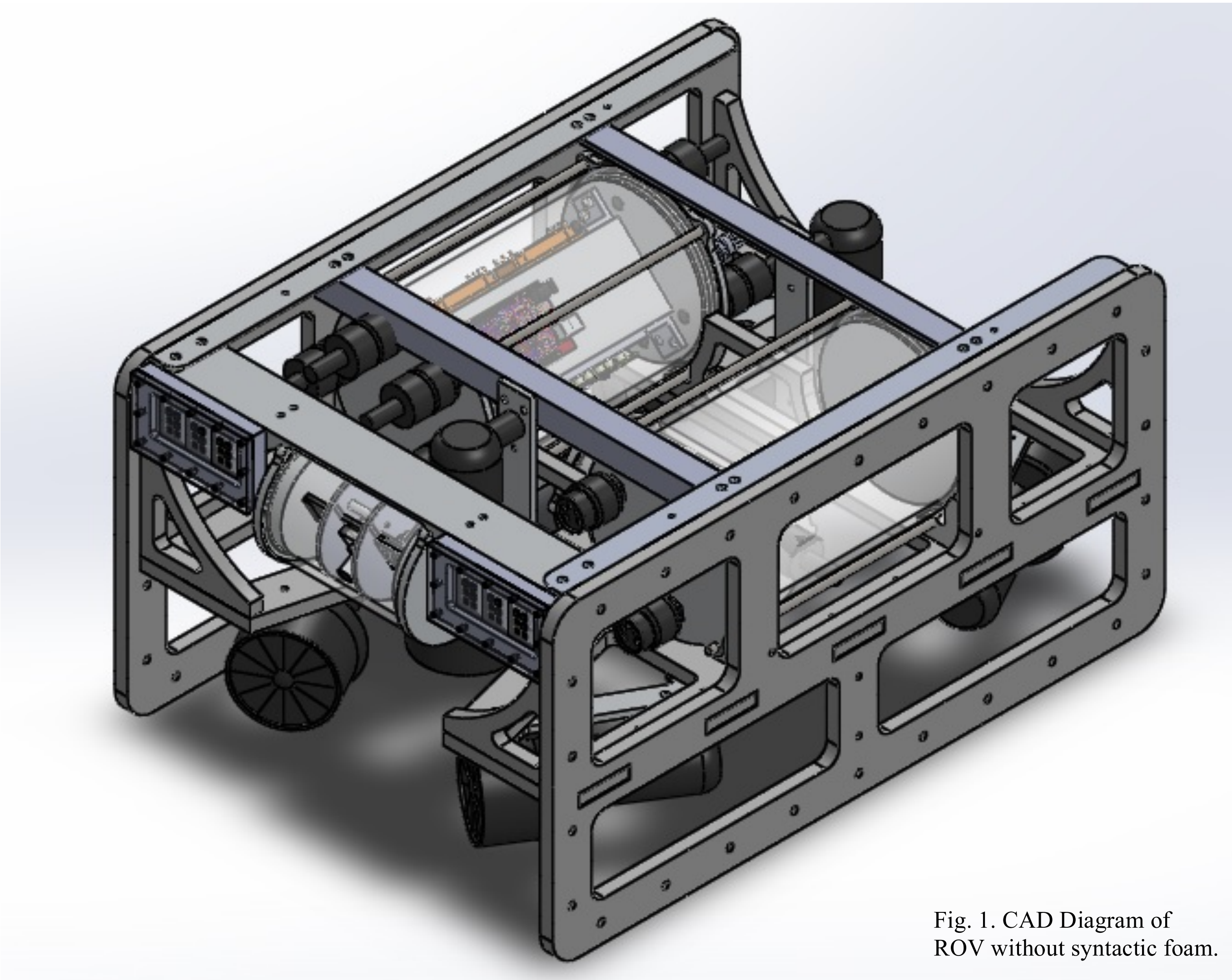


Fig. 1. CAD Diagram of ROV without syntactic foam.

4.1 Frame

Design inspiration for this vehicle was originally taken from several Seabotix ROVs that were a similar size, with similar capabilities, to what was wanted for the ROV ORCUS. With the Seabotix as examples, the translational motors were configured in a holonomic configuration with two electronics pressure vessels straddling a pair of vertical thrusters.

The frame is made out of a marine grade high density polycarbonate commonly referred to as starboard. Starboard was chosen to reduce the risk of corrosion, is close to being neutrally buoyant, and is rather easy to work with. The majority of the machining was done on a water jet in the University of Washington's Lamborghini Composites Lab.

This frame was reused from last year, requiring only minor modifications to add new tooling. Extra aluminum and plastic supports were added for strength and to mount the foam more securely.

4.2 Propulsion

The vehicle is propelled by six Seabotix BTD-150 brushed DC motors. These thrusters were chosen because of their relatively low cost and high reliability. Four of the thrusters are arranged in a translational holonomic configuration, which allows the vehicle to move in every direction. Two motors are mounted vertically for increased power.

The Seabotix thrusters were the largest commercial product used on the vehicle. Last year the company attempted to design and build their own magnetically couple brushless thrusters, however the custom thrusters were never fully functional due to electrical complications. As a result, this year the company decided to buy robust Seabotix thrusters.

Fig. 2. Back view of ROV with motors displayed on the bottom and pressure housings encased above.

4.3 Pressure Housings

The electronics and camera pressure vessels all use a standard cylindrical design. The tubes are made of clear quarter-inch thick acrylic. Acrylic was chosen because it is the most economical material for large diameter tubes. The clear acrylic also allowed provided the cameras with an optimal waterproof housing, as there is nothing to obstruct the view. The end caps were made from aluminum because it is easy to machine, relatively cheap, and easily accessible. The seal is made using solid o-rings. The end caps have a face seal and a backup piston seal, and are held together by external rods. The two large electronics housings have a plug that can be used to pull a vacuum on the vessel creating a pressure differential at the surface to help hold it together.

Three of the four pressure housings are being reused from last year. Most of the electronics inside have been updated but the housing itself has already been tested and could be reused. The fourth housing was manufactured this year and follows the same design as the other three because they have already proved to be effective.

4.4 Power System

The vehicle runs off of 48 volts at the surface. The power is sent to the vehicle through the tether where it is immediately converted to 12 volts by three 48 volt to 12 volt DC-DC converters located on board. Two of the large converters each power three motors and the third powers the electronics and cameras. The majority of the power on the vehicle is drawn by the motors, which is why the load is spilt between two DC-DC converters. The rest of the electronics are on a separate converter with isolated grounds to protect the sensitive electronics from the voltage spikes caused by the motors.

4.5 Cameras

ORCUS boasts two composite video cameras with LED illumination. The camera feeds are sent to the surface through twisted pairs and are plugged directly into monitors. These cameras were chosen because of simplicity this system was already proven in the previous year. The control system hardware does not support video so upgrading the cameras system would require updating the entire control and communication system. Currently there is one camera placed along the top front of the vehicle to see forward and the second camera is positioned within the vehicle, looking downward to see what is beneath the ROV.

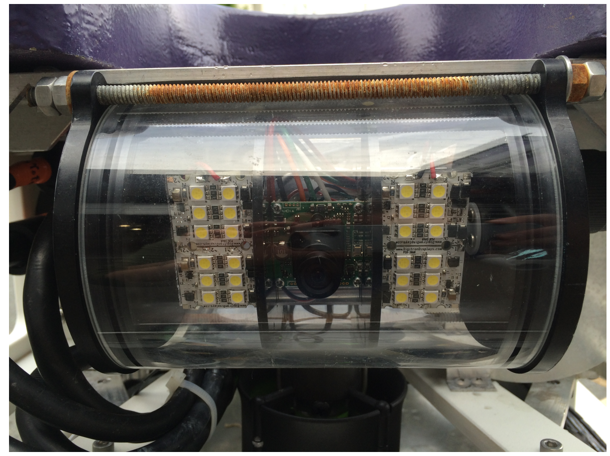
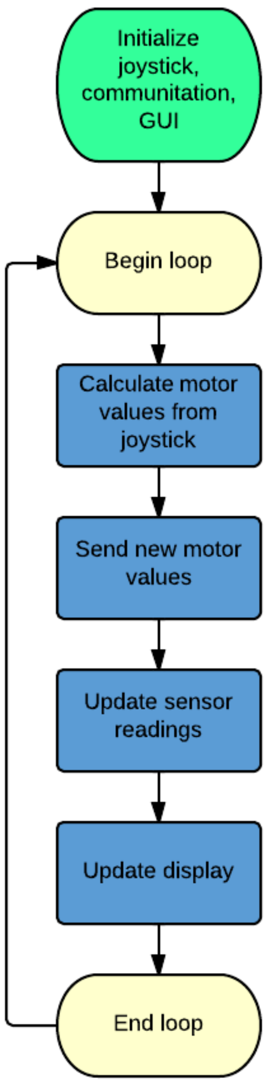


Fig. 3. Front facing camera mounted with LEDs on both sides within a waterproof housing.



Surface GUI Code

4.6 Control System

The vehicle is controlled by an Arduino microcontroller, which receives commands from the surface and relays the appropriate PWM signal to the motor drivers. The Arduino also receives the onboard sensor data and sends it to the surface.

The Arduino microcontroller is the other main commercial component used on this vehicle. The Arduino was chosen for several reasons one of which is it is easy to use. The Arduino programming environment is ideal for students starting to learn how to program as it is very high level and has a huge support community online with tutorials and libraries. Most radioshacks also carry Arduinos so if one breaks it is easy to replace most anywhere in the country as opposed to a custom or less common board.

4.7 Programming

There are three main components that comprise the drive system: a surface side computer in the control box, an Arduino microcontroller that drives the ROV itself, and another Arduino that acts as an intermediary between the surface and the water, also in the control box. The computer controls the GUI, displays sensor values, and sends joystick values and other commands to the ROV while the remote Arduino receives drive values and sets the motor power accordingly, as well as sends sensor data back to the surface. The intermediate Arduino accepts the input from both other systems and relays the information to the appropriate location.

This year, the code is written in Python 2.7 for surface control and C++ for the Arduinos. Python was chosen for its ease of use and portability to various different systems, and version 2.7 is the most widespread and supported stable release. C++ was the best choice for the Arduinos as it is widely supported and is fast enough that programs can run efficiently.

4.8 Surface Control

On the surface, the GUI offers a bridge between the pilots and the ROV. It is designed to be intuitive and practical, and runs off a computer stationed in the control box. The interface is written in Python 2.7 and makes use of the Pygame module for hardware interfaces and graphics, and the pySerial module for communication with the Arduino. The computer connects to an Arduino Uno, which then connects directly to the ROV.

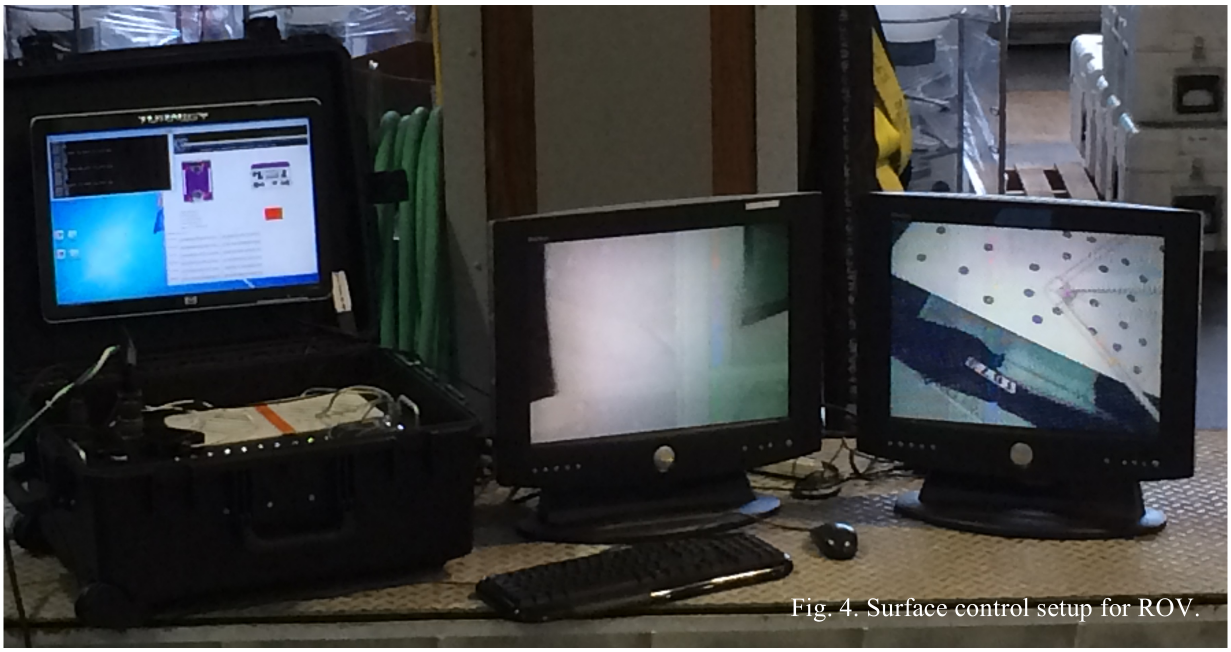


Fig. 4. Surface control setup for ROV.

4.8.1 Hardware

To control the robot’s motion, a wireless Xbox controller was used. A wireless version was chosen so that the driver was not confined to a small radius around the control box, which was especially useful when test driving and learning how the ROV handled. The Xbox controller itself is an easily understood interface that many are familiar with and it includes the axes and buttons that are required. In addition to the controller, some keyboard keys are used as input, such as the space key to trigger the emergency stop.

4.8.2 Motion and Sensor Calculations

The surface computer receives joystick and other input and calculates the appropriate motor outputs. Vertical motion is simple, as there are only two motors that exclusively control it, but horizontal motion is more complex due to the angled motor configuration. Initially, the power was determined using trigonometric means, assuming the motors were angled at 45 degrees instead of 60. However, this failed in edge cases and was not as accurate as desired.

Currently, the joystick position is translated into a point in 2D space, and multiplied by a matrix so that it is represented in a basis that has axes parallel to the motors, at 30 degrees from the original Y-axis. The power for each motor is then the coordinates of this point in the new basis, normalized so that the motors do not run at more than 100%. Turning is considered a separate axis, and the motor rotational value is scaled linearly with the joystick.
To find the overall horizontal motor power, the translational and rotational components are calculated, in the range -255 to 255, and are then summed and capped at the max value. As negative values correspond to running the motor backwards, summing the motor powers is an effective means of combining translational and rotational motion.

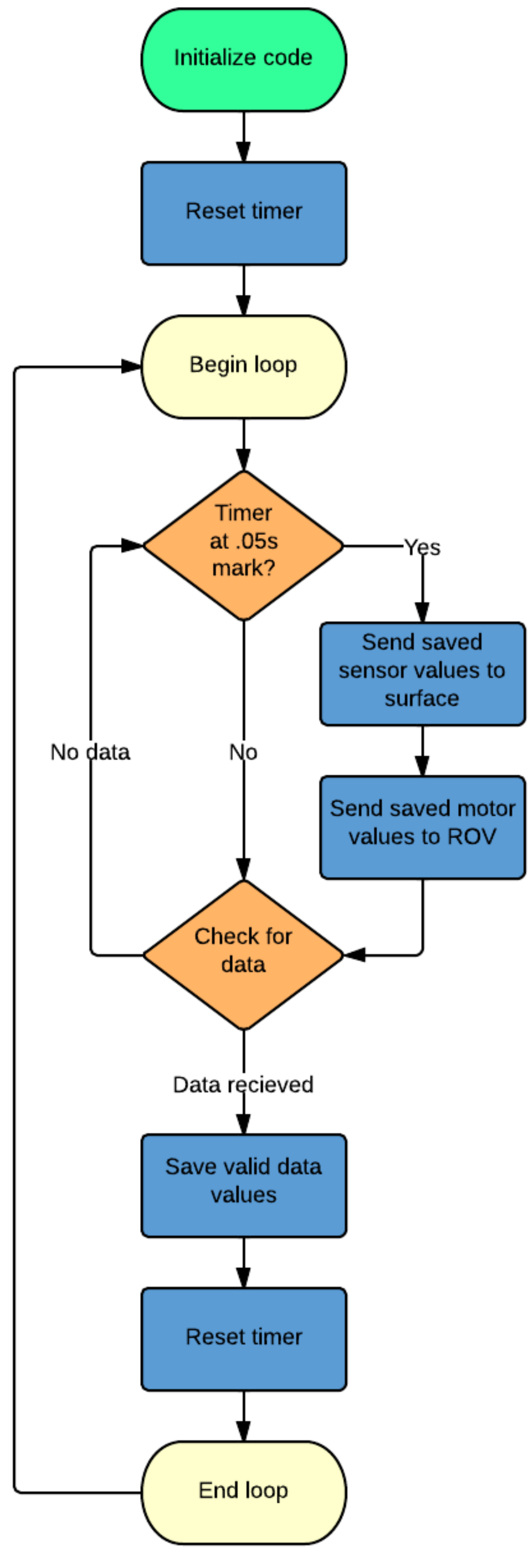
Sensor values are read from the ROV as single bytes, so they appear as numbers from 0 to 255. The GUI can then translate these numbers into something more meaningful, such as degrees in the case of temperature, or even derived depth in the case of pressure.

4.8.3 Environmental Calibration

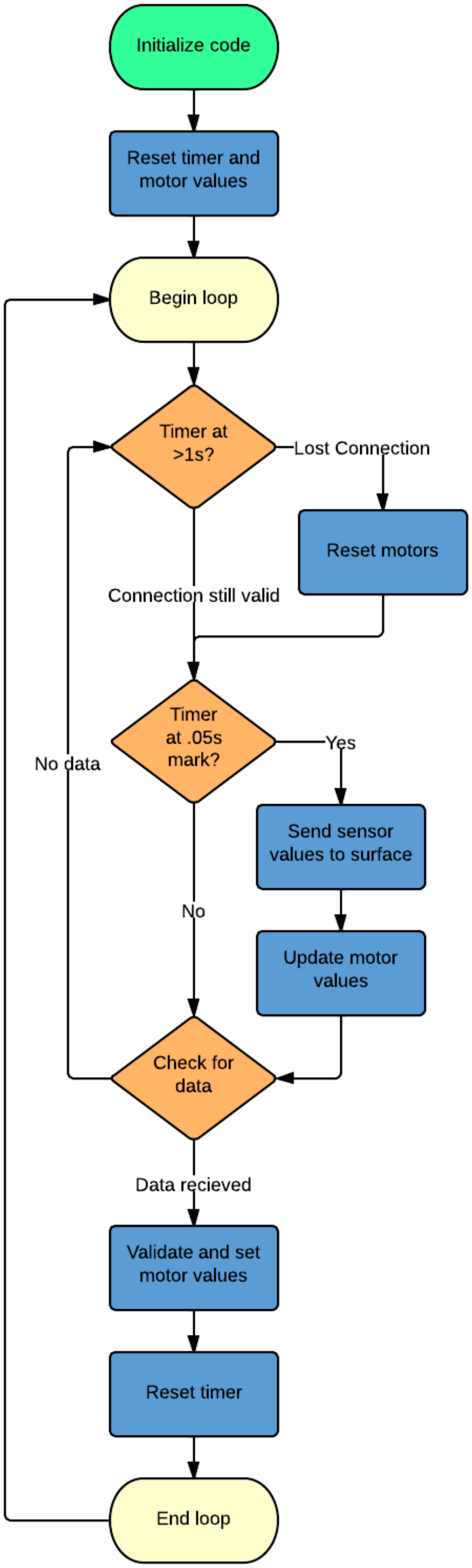
There are also means of stabilizing the robot programmatically. Because water densities and the exact ROV configuration differ from place to place, making the ROV neutrally buoyant everywhere is difficult without the time consuming task of adding or removing increasingly small weights. To circumvent this, there is a feature by which the pilot can set the downward motors to add a constant force, either upward of downward, to their usual motion to simulate weight being added or removed. If the ROV is too light, there will be a constant downward force; if it is too heavy, there will be a constant upward force. This allows the pilot to focus on completing the tasks rather than have to worry about keeping from rising or sinking. Additionally, the Xbox controllers are not always centered properly, so they can be calibrated so that the current reading is read as zero.

4.8.4 Intermediary Arduino

Between the GUI and the ROV there is another Arduino. This Arduino reads motor values from the computer and sends them to the ROV. At the same time, it reads sensor data from the ROV and sends them to the computer. It provides an easy method for communicating with the robot



Intermediate Arduino Code



ROV Code

Arduino without having to use a USB cable, which is limited in functional length.

4.9 ROV Control

The ROV is controlled by an Arduino Mega microcontroller. It also has sensors for internal and external monitoring, including pressure, temperature, humidity, acceleration, and compass direction.

4.9.1 Underwater Control System

The main purpose of the control system on the ROV is to set motor values and send back sensor values. No actual calculation takes place to increase running speed. Whenever the intermediate Arduino sends bytes, they are read by the ROV. If the values are well formed, the motors are set to the appropriate values. As the read values are bytes, and as the motors take values from 0 to 255 as power input, all motor power values are guaranteed to be valid. Ten times a second, the sensor readings are sent back up to the surface. If there are no motor values for more than a second, the ROV assumes that connection has been lost and shuts off the motors for safety.

4.9.2 Motor Control

Changing the power or direction too quickly on the motors can have detrimental effects. To mitigate this, the Arduino on the ROV tracks the current output of the motors and does not let their value change too rapidly. This is done by saving the desired motor power (received from the surface) separately from the actual motor power. Periodically, the actual power is updated in the direction of the desired power by an amount proportional to their difference.

4.10 Communication

The surface Arduino and the onboard Arduino communicate using a serial protocol called RS485. RS485 is a differential version of RS232 giving it a much greater operating range.   The Arduinos use RS232 so it is converted to RS485 using an integrated circuit that is rated to produce a signal that can be propagated to 4000 feet, which is much longer than the current tether.

Communication between the Arduinos and the computer occurs by sending very small, three byte packets very rapidly. Each packet consists of a header followed by a byte repeated. The repetition is a simple and easy way of ensuring integrity of the system: it prevents corrupted bytes from being read and makes sure that headers are not interpreted as data, or vice versa.

One packet corresponds to either one motor command or one sensor value. In the case of motors, the header determines the motor and the data is what value to apply to that motor. Each motor is fully specified by its direction and its power, each of which have different header values for each motor. As there are six motors, it takes only 36 bytes to set the state of the ROV, which at 9600 baud can be done in about 30 milliseconds. Sensor values are sent in much the same way. The header specifies which sensor the data is for, and the data is the reading of the sensor.

When reading values, each system (the computer, intermediate Arduino, and ROV) looks for a valid header. When it finds one, it then reads the next two bytes. If the match, they are taken to be the correct value; if not, they are discarded and the process repeats.

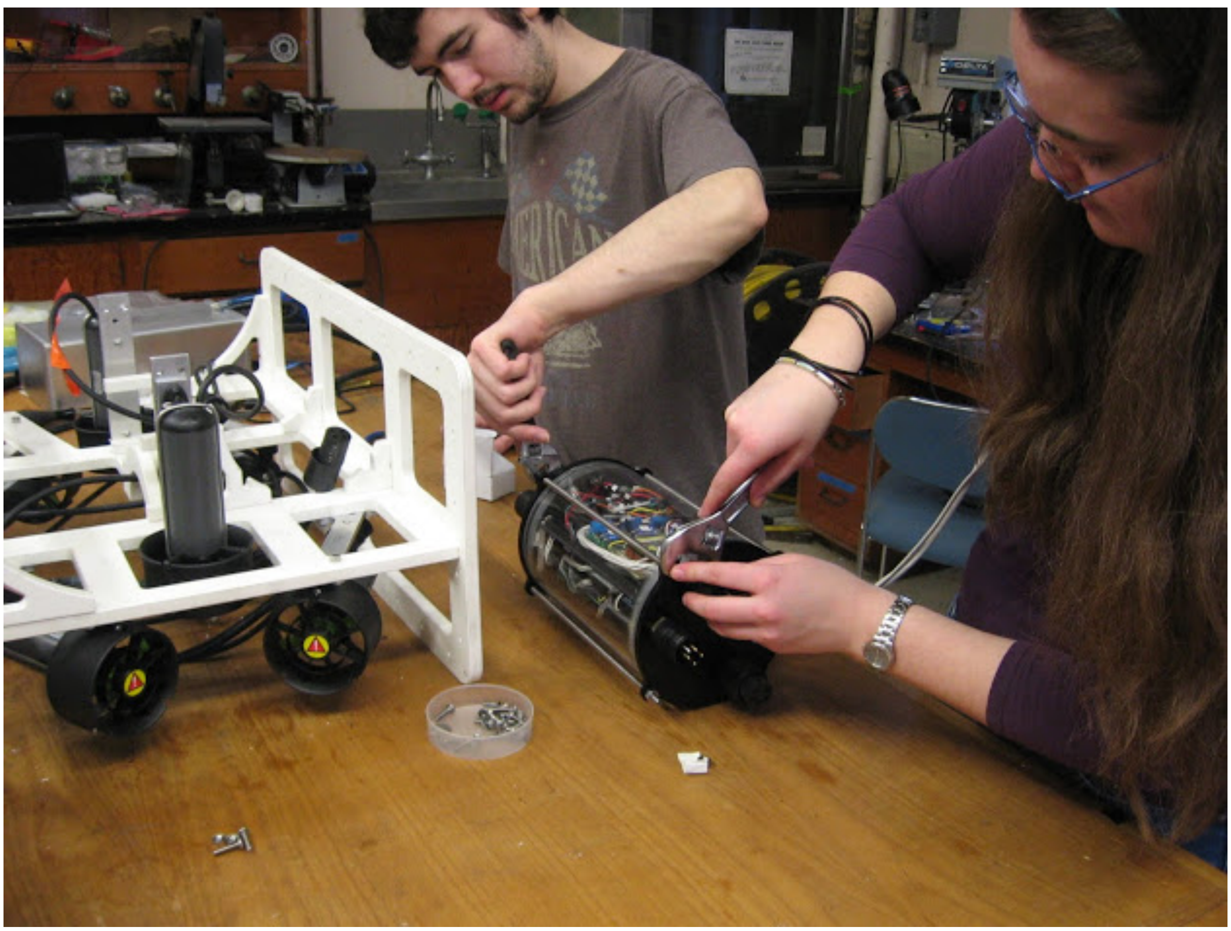


Fig. 5. Juliana and Joe working on one of the electrical pressure housings to be mounted onto the ROV.

5. Troubleshooting Techniques

Fig. 6. Bottle with lead pellets located in the corner and lead strips bolted to the inside bottom edge of the ROV frame.

As expected when building any sort of ROV, some issues may arise that require some troubleshooting. Some of these issues included poor connections, fitting everything required on a compact vehicle, and buoyancy. In the main electronics housing there are several connectors that allow the end caps and waterproof connectors to be taken off and separated from the rest of the electronics. This was nice when working on the wiring but occasionally the cameras would cutout. Once the connectors were tightened and the pressure vessel sealed up, the other camera would cut out with all communication lost. The source of these problems was due to wiggling the connectors, causing the cameras to cut in and out. This issue was fixed by replacing the connectors with more reliable latching Molex connectors.

The ultimate goal is to have as a compact of a vehicle as possible to reduce wasted space, maintain center of gravity, and reduce any problems that may arise in regards to buoyancy. Fitting everything within the frame proved to be a difficult task. There were several phases that required components to be switched in order to fit within the vehicle, with occasional modifications being made to the frame itself in order to better accommodate everything on board. As little material as possible was removed from the frame in order to maintain stability. In the event where something did have to be removed, it was done in a way that allowed the design to still meet its function, but also leave salvageable by-products for use later.

In regards to trouble shooting buoyancy issues that could occur from switching between salt and freshwater bodies of water, bottles with lead pellets were attached to the bottom of the vehicle. Initially, ORCUS was positively buoyant with lead strips attached to help be closer to neutrally buoyant. This modification was not the most desired since it didn't allow for minute changes in buoyancy. Having the bottles with lead pellets allowed for fine adjustments to the buoyancy, allowing for the corners to be ballasted individually, and attaining a centered center of mass.

6. Testing

6.1 Power Converters and Motors

A great effort was made to test the power system early in the year because the company has had trouble with it in the past. Once the new DC-DC converters were sourced and bought they underwent extensive testing. A test platform was created that used the DC converter to drive four large motors. The motors were much larger than the ones used on the actual vehicle, which had not arrived yet. The larger motors were attached to a frame and suspended in a dive tank. Over two days the system was pushed hard and eventually to the point of failure. The failure was due to the terminal strip, which the main power was running through, started melting. The final system uses much smaller, more efficient motors and does not draw anywhere near the amount of power that caused the failure the first time. The terminal strips were also replaced with higher current terminal strips. Some of the test results are shown below.

Test 1:
Testing 2 motors (#s 1,2 both forward direction)
Current draw at battery (48V) = 8.2 amps
Motor Controller 1 – 1,74 V = 26 amps (@12V) - Temp of controller = 190F
Motor Controller 2 – 1.95 V = 29.5 amps (@12V)
PWM setting = 224 (out of 255)

Test 2:
Testing 3 motors (#s 1,2,4 all forward direction)
Current draw at battery (48V) = 8.6 amps
Motor Controller 1 – 2.12 V = 32 amps (@12V) -
PWM setting = 200 (out of 255)

6.2 Pressure Housings

All of the pressure vessels were tested before the installation of the electronics. The vessels were placed at the bottom of a 10-foot tank and left over night. All of the containers were dry. Once the vehicle was fully assembled it was tested thoroughly, again, before putting it the water. For two weeks last minute electrical, mechanical and software adjustments were made to the components within the housings. Some other tests included running the motors and cameras for extended periods of time, which exposed problems that were not immediately apparent.

6.3 Vehicle Testing

For the first wet test the ROV drove around on the surface and was checked frequently for overheating and leaks. After successful surface tests it dove and was still checked frequently. The wet tests started two to three weeks before the first deadline, allowing for several hours of dive time previous to the regional competition.

7. Safety

A great consideration was given to safety when designing and building the ROV. The team followed a safety first philosophy at all times from manufacturing to deployment. Practices include wearing the proper eye protection when machining and having proper instruction and knowledge of the machines before operating.

The ROV was designed to be compact and entirely enclosed to reduce safety risks during deployment. All the motors are enclosed by the frame and are shrouded with grates to stop large objects from striking the blades. There are also warning labels on the motors. In the event of an electrical failure, there is a 10-amp fuse in the control case. In addition, there are also two 25-amp fuses aboard the vehicle connected to the inputs of the main DC-DC converters and a 30-amp fuse connected to the power supply. Should communication to the vehicle be lost, the motors will stop running and the vehicle will float to the surface. In the graphical user interface there is an emergency stop button that will stop all the motors immediately.

When preparing the vehicle for deployment, no one touches the vehicle unless it is powered off. The tether management system allows slack to be spooled up easily so that it does not present a tripping hazard. The tether is also detachable, making transportation of the vehicle easier and reducing the risk of something being damaged upon travel. A rope has also been integrated to relieve the strain from the wires in the event that the tether needs to be pulled on.

7.1 Safety Checklist

1. Plug in the computer and both monitors into the dry 120AC Voltage power supply.
2. Check the 40A fuse on the battery power supply; to make sure that it is not blown.
3. Connect 48V, 40A power supply to the power wire.
4. Check the 10A fuse in the computer dry-box; to make sure that it is not blown.
5. Connect the power wire to the computer.
6. Secure the power wire with a zip-tie to the dry-box for strain relief.
7. Connect the external monitors to the dry-box.
8. Check that the Xbox controller has fresh batteries.
9. Bring up the control system for the ROV and connect the Xbox controller to the system.
10. Check the tether dispenser and make sure that it rotates without any problems.
11. Connect the tether to the ROV.
12. Check all of the ROV wet mate connectors to make sure fully secured – use a wrench.
13. Connect the dry tether to the computer dry-box.
14. Secure the dry tether to the computer dry-box with a zip-tie for strain relief.
15. Checks to make sure the LEDs have turned on for the cameras and that the two monitors are getting live feed from the cameras.
16. Run all six motors separately to make sure that they are responding correctly to commands.
17. Recheck all connections one more time, just to make sure.
18. Ready for launch!

8. Challenges

One challenge the team faced was meeting our intended goals and deadlines. There were several times where we planned to get the vehicle into the water for the first time, but due to various hiccups with hardware components, the program, or the electronics, submersion had to put off for several weeks. Eventually, it was realized that time for potential problems would have to be allotted for each project in order to give a more accurate representation for when tasks would be completed. Another technical challenge had to do with waterproofing. One particular housing on the ROV was unable to maintain a waterproof seal, with its replacement part being difficult to correctly fit in the ROV. In order to accommodate the new housing, some minor modifications had to made to the frame in order to place and secure the component. Fitting all of necessary components within the waterproof housings, in an accessible manner, also caused some delays due to constantly needing to reconfigure their positioning and needing to check all the components to make sure they were functioning.

The team was continuously growing and shrinking every week due to inconsistent team members. This made it a challenge to appropriately assign tasks and get things done on time. Once the team stabilized to what it currently is, task assignment and commitment has been less of an issue. Overall, the team has made great strides to building the ROV, but it was not without its challenges. Our achievement can easily be seen in the fully functioning ROV.

9. Lessons Learned

There are several lessons to be learned on any group project, especially with one that can cause many technical problems. The ROV ORCUS was initially supposed to compete in the 2013 MATE International Competition, but due to unforeseen technical difficulties the night before the qualification, the team was unable to participate. This year, extensive testing was done to ensure that every system was functioning and that the vehicle could perform the necessary tasks.

Speciation of tasks between members was also an issue that was addressed. The team started with approximately 20 people, however that dwindled down to the current six-person team. This led to the difficulty of allocating various tasks to different people, as it was uncertain about who would even be showing up to the next meeting. With the current members the tasks were broken down as such: Juliana and Ryan dealt with all the electrical components, Joe and Adrian dealt with mechanical aspects such as frame mountings, machining housings, and developing tools, Tyler was in charge of programming and making sure the on-deck control system worked, and Erica dealt primarily with more administrative tasks, such as organizing a timeline of events, presentations, and as a second pair of hands for whatever task needed to be completed at the time.

Having a solid timeline of events was something that the team learned that they needed in order to keep track of deadlines and when certain tasks needed to be completed by. Major deadlines such as being prepared for the regional competition demonstration were stuck to, however smaller deadlines, such as when parts needed to be machined by were not always met. Reasons as to why some deadlines were not met included, availability of facilities such as the machine shop or dive tank, student schedule conflicts that included midterms and other activities, or waiting for parts or other components to be shipped to the school.

10. Future Improvements

At the moment to vehicle represents a robust platform, which can be built upon for future research. The most useful change presently would be to upgrade to a digital camera system. Upgrading the cameras would give a better quality picture and more importantly would make it possible to bring the video into the computer. This would make it possible to record the video, take still pictures and use computer vision techniques. This upgrade would require an Ethernet base communication system and more computationally powerful hardware onboard to transfer the data.

Currently the vehicle is also a bit strapped for internal space. While being compact is useful in keeping everything on board and neat, it doesn't allow for much interchanging or storage for various payloads. In the future, allowing for a slightly larger and more spacious frame with more structures would allow for easy mounting of payload tools. Some of these potential tools include a manipulator, hooks, or a container that allows for storage of materials collected.

11. Reflections

Adrian Junus
Working with UW's ROV team has proved to be one of the best teamwork experiences I've had. I'm happy to say that I've never had the pleasure of working with people as motivated and reliable as this year's team. All of us readily gave several hours each week to get ROV Orcus into the water, and it's really exciting to me to see our robot work. Additionally, as one of the team's mechanical technicians, I've learned more about machining and designing parts than I have in any other college class or project. Finally, I get to pilot our vehicle at the competition, which will be really cool.

Erica Sampaga
After participating on a variety of ROV teams that have participated at regional and international MATE ROV competitions I had a general idea of what I would be walking into to. This year was the first year that I've participated as a college student and it presented itself with a different and more diverse set of challenges. With actual engineering majors on the team, the speciation of tasks between members was more defined and created a big step up from what I had been used to working with. ROV has always been a great team effort and I'm glad to have continued that experience into college.

Joseph Downs
Working on the UW's ROV team allowed me to really understand the process of building an underwater vehicle. I learned a lot about the design, building, and troubleshooting processes while I have been a part of the team. Different materials were necessary to use for many specific

purposes, and I learned to become very efficient with making parts out of these materials. It is very fulfilling to see the ROV working in the water after a lot of time building it. Fitting and stabilizing all the parts in the ROV has been extremely enjoyable. Overall, my experience has been very engaging in building the ROV and I will never forget all the things I have learned as a part of the team.

Juliana Pesavento
Being part of the ROV team has been one of the best experiences that I have had. I have learned more about technology than I thought I would ever know, and surprising I found that I loved it! ROV has led me to become more and more involved in ocean technology. I entered college as an oceanography major thinking that I would follow biological or chemical oceanography, but being in ROV has made me question what I want to do, and I have found myself turning more and more to the technology. Since I joined ROV I have gotten into the University's ARGO Lab and am working with a class to start a cabled observatory in Portage Bay. ROV is what introduced me to this path, and I have everyone on the team to thank for inspiring and teaching me!

Ryan Cox
This year the team was focused creating a robust ROV platform that can be used for research and competition. ROV ORCUS satisfied these goals, though it is not finished, it is at a point where it can be used for exploration such as examining objects at the bottom of Lake Washington and Lake Union. Next we plan to outfit the vehicle with sensors or other systems to use it for actual research. Other than creating the ROV itself the team also gained a great deal of experience working on technical challenges in a small engineering team. All the skills we practiced this year including, team communications, project management, taking initiative, are all important in the workplace. In this way the members have practiced many skills that employers are looking for which will hopefully help to get them jobs after college.

Tyler Yeats
While I had been on a robotics team in high school, this was the first time I did a large engineering project in college. It was also my first time working on an underwater vehicle, and although many of the skills are the same, it was a different experience. The most notable difference was the importance placed on navigation, contrasting the land-based robots I had worked on before where it was always possible to see them. This project was also a good chance to learn to work efficiently with a dedicated team. Especially with our plans to use the ROV for research purposes outside of the competition, this team has shown me the possibilities of ocean technology.

12. References

Software: http://pygame.org/docs/, http://pyserial.sourceforge.net, https://docs.python.org/2.7

Mechanical: http://www.seabotix.com/products/auv_thrusters.htm, http://www.synfoam.com/SynFoamHP.html

Electrical: http://arduino.cc/en/Reference/HomePage

13. Acknowledgements

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