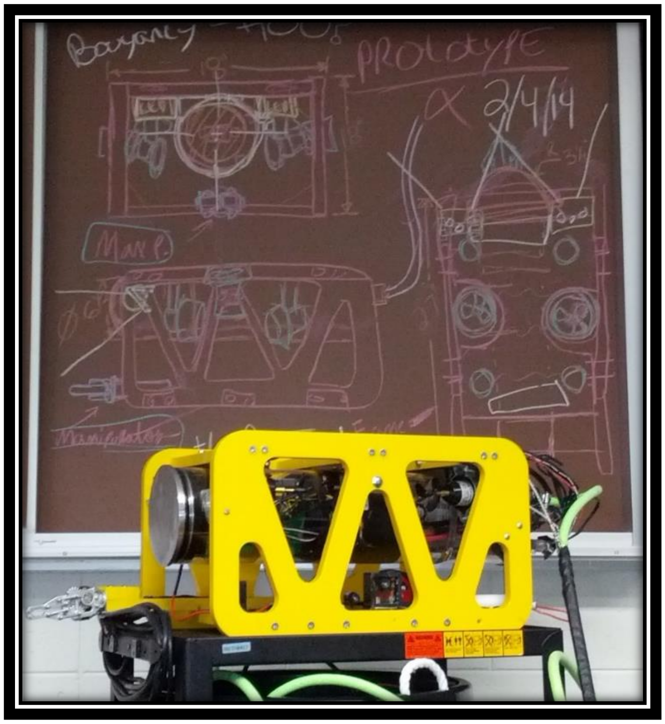
ACC UNDERWATER ROBOTICS

ALPENA COMMUNITY COLLEGE, ALPENA, MI

2014 MATE ROV Competition, Explorer Class



TEAM MEMBERS

Andrew Augustyn- CEO, Engineer, Technical Writer

Branden Deroque- CTO, Programmer, Technical Writer

Mike Dunham- CFO, Engineer, Fabricator

MENTORS

David Cummins-Faculty Advisor

Michael Marin- Electronics and Programming Mentor

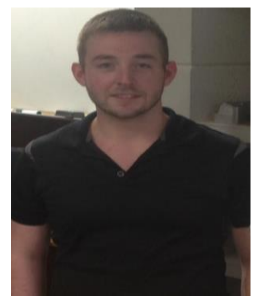
Abstract

The 2014 MATE International ROV competition marks the first year of competition for the Alpena Community College Underwater Robotics team. A small team, consisting of three members, the build was a very difficult but rewarding experience from beginning to end.

This technical report describes the building and design rationale of the ROV *Mariner*, completed by the Alpena Community College Underwater Robotics Team. It has been designed specifically for the 2014 Marine Advanced Technology Education (MATE) International ROV competition and built with the intent of completing tasks in relation to observing and researching shipwrecks, data collection, sampling, and debris removal. A robust HDPE frame houses the large acrylic pressure canister containing the ROV's electronics. Onboard programming was completed in C and processed by an Arduino Mega 2560. The tether, an Outland 3400 series cable, supplies power to the ROV and transmits data between the ROV and surface. Six Johnson bilge pump thrusters propel the ROV and navigation is made possible by four low cost and efficient cameras. Task such as lifting and manipulating objects are completed with the use of a MKII Robotic Claw. Through the process of the build, team members learned essential technical and communication skills that contributed to a quality end product.

The Team

Figure 1: Left to Right: Mike Dunham, Branden Deroque, Andrew Augustyn



Member: *Andrew Augustyn*

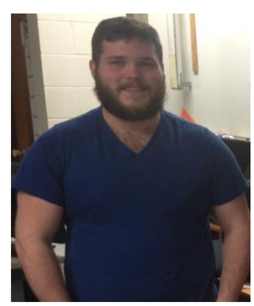
Experience: 1st Year Competitor

Education Level: Graduating Sophomore

Member: *Mike Dunham*

Experience: 1st Year Competitor

Education Level: Graduating Sophomore



Member: *Branden Deroque*

Experience: 1st Year Competitor

Education Level: Graduating Sophomore

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Expenses

The building of the *Mariner* ROV would not have been possible without the generosity and donations from many individuals and businesses, both local and non-local. In total, about 85 percent of the *Mariner* is comprised of donated materials, labor, or monetary support. The chart below is a compressed breakdown of expenses to the team for various subsystems. The more detailed budget sheet may be found in Appendix B.

Subsystem	Subsystem Cost	Donations	Cost To Team
Frame	$427.52	$427.52	$0.00
Tether	$250.00	$250.00	$0.00
Cameras	$40.91	$0.00	$40.91
Electronics/Control	$2,129.58	$1,947.94	$181.64
Mission Specific	$63.63	$20.00	$43.63
Misc.	$208.00	$0.00	$208.00
Totals	**$3,119.64**	**$2,645.46**	**$474.18**

Figure 2: Expense Sheet

Design Rationale

The *Mariner* was designed with the intent of being a low cost, expandable ROV to be used toward observation and research. All tasks of the 2014 MATE International ROV competition were taken into consideration and used to tailor the *Mariner* to be as mission specific as possible.

Frame

When brainstorming the frame design as a team, the initial considerations were for an ROV that would be modular, easy to transport, and expandable. Drawing inspiration from existing observation class and work class ROVs, a frame was chosen that is open and compact yet elegantly simple. The open frame design takes the placement of thrusters into consideration, allowing for greater movement of water while limiting obstructions to thrust. Less material equates to less bulk, less drag, and allows for easier access to components. The frame's material is .75" HPDE. High density polyethylene has excellent tensile strength, rated at 4700 psi and can be easily machined for any necessary design changes and/or additions. HDPE also has a specific gravity of .94 g/cc, making it nearly neutrally buoyant.

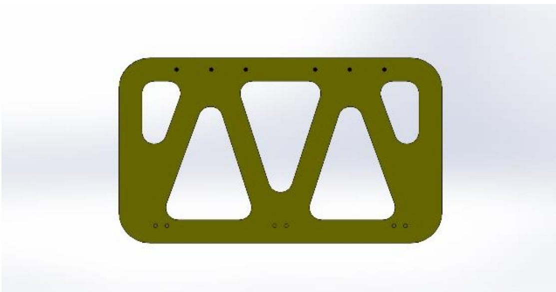


Figure 3: Early Frame Design

Electronics Canister

The electronics canister is one of the single most important components to the functioning of the ROV. It houses all of the circuit boards, power supplies, and essential electronic components that allow for movement and navigation.

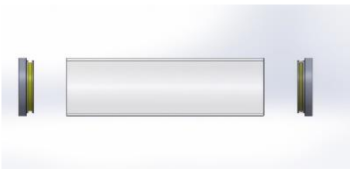


Figure 4: Solidworks Rendering of Canister

The waterproofing is absolutely critical and was the most difficult aspect to take into the consideration.

The actual canister is composed of 6" OD X 5.75" ID extruded acrylic tube and machined aluminum end caps. The end caps were designed in SolidWorks and machined by Kalitta Air LLC, who donated the labor and materials. The 6" end caps are .75" thick and sealed by AS568A-431 O-rings.

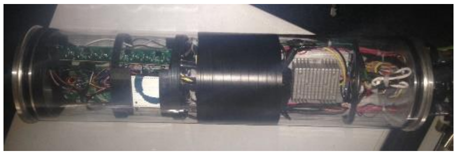


Figure 5: Assembled Electronics Canister

Additionally, a check valve was installed to pull a vacuum of 2.5 pounds inside the canister to provide a watertight seal. The rear end cap was drilled and tapped to accommodate four 1/4" NPT bulkhead cable connectors. These are the points of attachment for the tether and outgoing connections to components outside the canister. The connections are waterproofed using hot glue, tube, and a hose clamp as an inexpensive conductor pass through. It is mounted to the frame with custom 3D printed brackets.

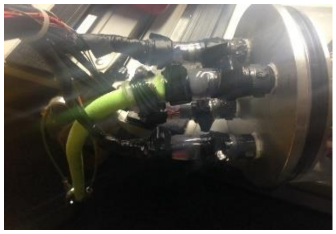


Figure 6: Endcap with Connectors

The internal components of the ROV are mounted on brackets that were designed in SolidWorks and printed on a Solidoodle 3D printer. These brackets fit perfectly in the canister and prevent the movement of internal components caused by vibration.

Tether

The tether is the point of transmission between the surface and the *Mariner*. Power needs to be sent down to the ROV and communication signals are constantly incoming/outgoing to the cameras, Arduino Mega (used for control), and additional sensors. The tether is a C-3400 cable assembly designed for the Outland 1000 ROV. It is a neutrally buoyant (in salt water), multi conductor cable with a braided Kevlar strength member. The cable diameter is .55” and has a weight of 50 pounds per 500 feet. There are 12 #22 AWG conductors, rated for 300 volts, to transmit the DC voltage to the ROV along with one Cat5e Lan Cable (4 TP #24 AWG) for communications.

Figure 7: Outland C-3400 Tether

Thrusters

In choosing thrusters for the *Mariner* and taking all possibilities with thorough research into all aspects of these choices. We came to the conclusion that with our available assets and resources that we should use Johnson 1250 bilge pumps. They are a very reliable motor with stock water proofing, ample torque. They also met our price point for expenditures on thrusters. In testing we discovered, with the propellers we chose, the thrusters output 3lbs (~13 Newtons) per motor at 12V and a Peak Voltage of 5A. They exceeded our expectations as well as fit within our power budget.

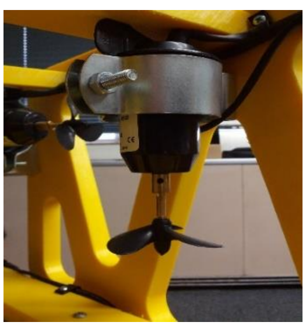


Figure 8: Mounted Thruster

A big consideration in choosing the appropriate thruster was our mounting configuration. After team discussion, we chose to configure the thrusters in a vectored format(see Appendix D). This configuration offers better more maneuverability than other options and mimics its industrial cousins.

Cameras

The *Mariner* is equipped with two main cameras and two auxiliary cameras. The main cameras are the two Mini Digital Pickup Cameras. They are 12 volt cameras that have a visual angle of 93 degrees and 420 TV lines of resolution. The auxiliary cameras consist of one USB camera connected to the hub inside the electronics canister and one backup camera with its own dedicated monitor. The USB camera will serve as a dedicated camera for the photomosaic and the backup camera will monitor sensors/mission tools. The cameras were deconstructed from their out-of-the box condition and reconstructed in a modified state to ensure waterproofing. All cameras except the backup camera are mounted in custom designed housings that were 3D printed and epoxied for waterproofing.

Figure 9: Initial Camera

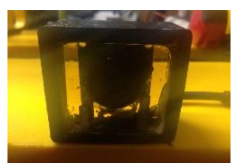


Figure 10: finished Camera

Control

Hardware

Arduino Mega2560

The Arduino Mega2560, is the computational brain of the ROV, *Mariner*. We chose the Mega over the

Uno for the sole purpose of ease. The Mega has more than enough PWM (15), and Digital I/O (39) pins, which allows us to hook everything we need to the Mega, and allowing for future expansion. Using the Mega over the Uno allowed us to have communication to just one board rather than using RS232 communication through two Uno's.

SeaMATE ROV Thruster Control Board

The thrusters of the ROV *Mariner* are powered and controlled by two SeaMATE ROV thruster control boards. Each control board offers the use of up to 4 thrusters at 10 amps a piece. Independent bidirectional PWM allows the thrusters to change direction and vary speed based on the input from the Arduino Mega2560.

Figure 11: H-Bridge Board

Software Scheme

The Control Scheme to operate the *Mariner* uses a PS3 controller connected to a laptop via USB cable (see Appendix C for controls). A secondary program running on the laptop reads all of the inputs from the PS3 controller and converts the raw data to a usable format for the program uploaded to the Arduino Mega 2560. After this conversion the Secondary program then wraps the data into a packet and sends it through a USB port acting as a COM port. It uses a simple Serial Communication protocol to transfer the packets down the tether to the USB hub. The USB hub acts as a networking switch which puts the information on the right track to the Arduino Mage 2560. After the packet reaches the Arduino Mega 2560, the program on the Mega then rips apart the packets to bits of data that correlate to values of states/positions of the PS3 Controller inputs. The Arduino then calculates the data and fires the outputs which go to the H-Bridges to control the thrusters' speed and direction.

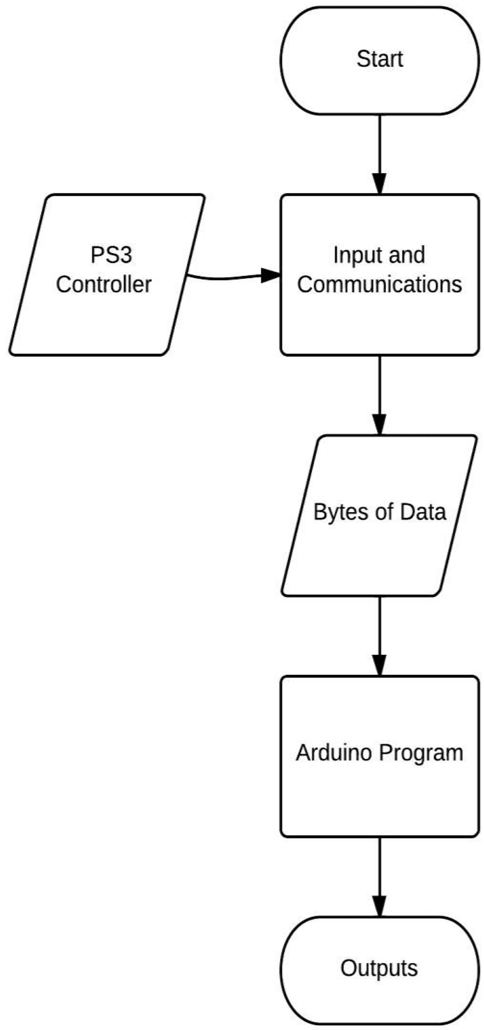


Figure 12: Basic Software Flowchart

Power

Power is supplied to the *Mariner* by an Outland Technology C-3400 cable. Five #22 AWG conductors run in parallel down the tether and supply the approved 48 volts to the connection at the canister. Connections to the power source are made possible with the use of ¼" ring terminals. A single 40 amp fuse has been installed in line with the positive conductor, within the first 20 centimeters.

Power onboard the *Mariner* is regulated from 48 volts to the respective voltages used by components and subsystems. This is done using two 48 volt to 12 volt DC to DC converters. One converter is rated for 30 amps and is the dedicated 12 volt power source for the brushed bilge pump thrusters. The other converter is rated for 10 amps and provides power to the rest of the onboard systems that require 12 volts. An additional step down converter is used to drop the 12 volts to 5 volts to power the USB hub, which then provides power to the Arduino Mega.

Figure 13: 10 Amp Converter

Lights

The aluminum light housing were designed in solidworks and milled by Kalitta Air LLC. Installed in the housings are two 1000 lumen Bridgelux led lights. The lights operate on 12 volts and are potted using Panecea crystal clear flower pot epoxy. This potting provides for an almost perfectly clear, completely waterproof housing. The lights will be mounted to the frame with 10-24 stainless steel bolts. Additionally, the housings have a post designed on one side that will dig into the frame to ensure the housing will not rotate.

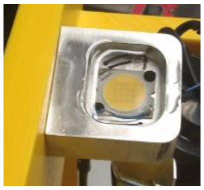


Figure 14: Light Housing

Mission Specific Tools

The mission specific tools consist of a variety of devices that were purchased and modified or custom built. These consist of the robotic arm used as a grabber, measurement device, sampling instrument, and conductivity sensor.

Grabber

The grabber is a purchased MKII Robotic Claw that is powered by a waterproofed micro servo. This will be used for lifting and carrying props and the most important tool for almost every task to be completed. Overall, it has proven to be a simple, low-cost option that gets the job done.

Figure 15: Robotic Arm

Shipwreck Measuring Device (SMD)

The Shipwreck Measurement Device is a simplistic tool comprised of a tape measure located in the viewing angle of a dedicated camera. A section of tape is run through 3/4" pvc and a hook will be connected to the end of the tape. When placed over the screws on the shipwreck, the tape will extend and retract with the

Figure 16: Shipwreck Measuring Device

movement of the *Mariner*, allowing for accurate measurement.

Push Core

The bacterial mat sampling device was inspired by push-cores actively used in marine operations. Two 3/4" pvc female adapters were used with a marble and an o-ring to create a check valve that is connected to a section of pipe. When pushed into material to be sampled, the check valve allows water to escape from the top. When being pulled out of the material, a vacuum is created, allowing the sample to be returned to the surface.

Figure 17: Push Core

Conductivity Sensor

The conductivity sensor began as fish tank conductivity meter. It was then modified to be operated off the Arduino Mega2560 3.3 Volt output and waterproofed by epoxying it in a 3D printed housing. The meter does, however, contain a five minute shutoff that is circumvented by using the Arduino to turn the meter on and off with one of the outputs. It can either be mounted to the *Mariner* or held in the grabber to obtain water conductivity measurements.

Figure 18: Conductivity Sensor

Lift Bag

A 10 Liter dry bag will be used to remove the Danforth anchor from the bottom. The dry bag will have a section of rope connected to its handle and a karabiner attached to the opposite end. The open end of the dry bag will then be filled with air through the use of a hose connected to a regulated dive tank.

Figure 19: 10L Dry Bag

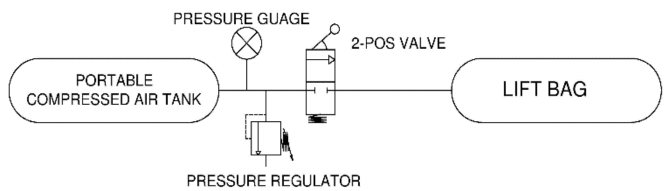


Figure 20: Lift Bag Pneumatic Diagram

Safety

Throughout the process of the ROV build the practice of safety management has been essential to maintaining a safe, hazard free workplace. The three main areas of concern are maintaining safety during the building/maintenance of the ROV, transportation, and operation.

The use of Personal Protective Equipment (PPE) is always stressed and absolutely necessary when there is a possibility of injury. Safety glasses or goggles and close toed shoes are required when working on or operating the ROV, as well as appropriate clothing. When working with machinery, ear plugs are also required. PPE only works if you wear it and wear it properly.

During transportation and operation, the area should always be checked for tripping hazards. Maintaining awareness and not taking shortcuts can go a long way in keeping up a safe environment. If all team members actively practice safety management, the workplace becomes safer for all.

In addition to safe practices by team members, the *Mariner* has multiple safety features in place. Prior to any operation, the safety checklist (Appendix E) must be completed by an approved member of the team. The ROV is fused with a single 40 amp fuse within 20 cm of the power source as well as fuses on individual components. The thrusters are all confined with the frame to remove the potential of injury from contact with propellers. A future addition might include kort nozzles to completely remove the hazard. In emergency shutdown of the ROV is necessitated, the operations could be ceased with the press of a button.

Figure 21: Best Safety Practices

Through the use of best safety practice the team was able to complete the build accident free and without incident.

Troubleshooting

One of the challenges we came across dealt with faulty h-bridge chips on the SeaMATE thruster control boards. When performing a test on the thrusters, we found both h-bridge boards had faults. On one board, only two of the respective thrusters operated correctly. One thruster was completely inoperable and the last only operated in one direction. On the second board, three of the thrusters worked perfectly and the last was also completely inoperable. Neither board had any visible defect, so we consulted with the schematics and used an oscilloscope and multimeter to diagnose the problem. We found the TLE6284G chips were the culprit and they were replaced. After replacement, they worked perfectly.

Challenges

Technical

Probably the toughest part of building the ROV was creating a watertight electronics canister. This is the most important component of the vehicle, as this is where the power is converted to a useful voltage and all of the data processing occurs. Basically, it’s where the magic happens. Throughout the design process, this was the longest and most troubling issue we faced. First off, we had to find a tube that was sizeable enough to contain all the needed components. After purchasing an extruded acrylic cylinder, the issue became the end caps. These are most important to the waterproofing aspect, considering they are at the ends where the water will enter. After putting a flyer out on Facebook, we were lucky enough to have a local business machine the end caps, including the materials and labor. The finished product were end caps with an o-ring that provided more than enough seal to remain watertight.

Non-Technical

One of the more difficult things outside of working on the ROV was dealing with our work environment. We work well as a team but in the lab where most the work on the ROV was done there is a lot of distraction and different personalities to work around. On top of that, our workspace is little more than a closet. This did not hinder our efforts though, as we were able to get the task completed anyway.

Lessons Learned

Technical

Throughout the process of building the *Mariner*, our team came to realize the immensity of the task. We felt underprepared but confident and learned early on that the schedule we did have had to be thrown out completely. Through our education, personal interests, and sheer determination, we were able to break down the build to tackle one task at a time.

One of our biggest challenges dealt with electronics. The SeaMATE thruster control boards we used proved to be unreliable. We spent hours poring over the schematics, spec sheets, and the internet, trying to find answers. We replaced the H-bridges a plurality of times. Consequently our surface mount soldering skills have improved.

Another big issue was programming. Out of the three team members, none of us had ever written a single line of code. Luckily, we had an introductory course through the college that opened the door to C. However, that was only enough to help understand how the language operates. Through intense personal research and lots of gummy worms, we were able to write the program that operates the *Mariner*. Additionally, interference has been more of an issue than anticipated. We had thought our tether would have kept it to a near minimum but this was erroneous thinking. We had debilitating noise on both our video and communications lines. Capacitors did not help, as they solved the problem by pretty much cancelling out the communication or video feed. The best alternative was to use ferrites on our video and communications lines, which helped a lot. There is still a small amount of interference on the video lines but we surmise that it is more due to their shared ground than transmission interference.

Interpersonal

One of the best things about the team as a whole has been our ability to work together. Our experiences throughout the 2 years working together in classes and scuba diving together, we have developed a high level of trust and communication. If we did not have the cohesion that we do this undertaking would have been impossible. Another key aspect of working as team was having access to a mentor who was able to answer most of our concerns, and if he couldn't would lead us to the resources to uncover the answers.

In essence, we have become three amigos. Wherever there is injustice, you will find us. Wherever there is suffering, we'll be there. Wherever liberty is threatened, you will find...The Three Amigos!

Figure 22: Left to Right: Andrew Augustyn, Mike Dunham, Branden Deroque

Future Improvements

Future improvements on the *Mariner* or like ROV, that we would like to see done and implore the next group to try and achieve. We had overcome the challenges of using a Vectored thruster configuration in this iteration of the *Mariner*. To build upon this success, we would like to see the incorporation of brushless motors with electronic speed controllers instead of the brushed motors. After that, possibly building upon the brushless motors and using magnetic coupling to assist with water proofing. We would also like to design our own 3-Function manipulator to assist with operations and missions.

Reflections

The process of building the ROV Mariner, has been one of the biggest achievements, struggles, and opportunities during my scholarly career thus far. It tested everything I thought I knew and learned from school in a way that only a practical application of skills could do. The experience has been rewarding, in that I had a chance to use everything I've learned in class on a real project. Though the *Mariner* has been difficult to work with, constantly fighting back with a new problem or a reoccurrence of an existing problem, has allowed me to hone my troubleshooting skills. . I am grateful for the experience, and having had shared it with two of my peers and more importantly friends. I hope that in future endeavors we find time to come back to the *Mariner* with new ideas, and more importantly experience and upgrade the ROV to achieve more robust duties. I hope the *Mariner*, can become a tool for education and exploration, with ACC's Marine Technology program.

-***Branden Deroque***

The process of designing and building the components of the ROV has been very challenging. The hardest part of the entire project was getting everyone to agree on a single approach to take. Once that was decided it was a case of designing the parts. Solidworks became a huge asset for us as we were able to design and test parts before making them. The pressure can became a big challenge as we had trouble deciding on a material and what to make the ends caps out of. Once we decided on acrylic we had to design end caps that would waterproof it. We were able to design aluminum end caps complete with the correct o-ring grooves and have them made by a local company.

The project took longer than expected but came out nicely. I feel very good about the outcome and am looking forward to seeing it compete in the competition. I am confident that as a team we have done our best and the programming will in fact work. The design is solid and we have worked to our strengths. As a result I believe the *Mariner* is going to do well.

*-**Mike Dunham***

The building of the ROV *Mariner* was a very rich and rewarding experience, from start to finish. However, to say there were bumps in the road would be a massive understatement. The bumps more closely resembled mountains but we managed to keep our heads held high and keep trekking. This has been my most challenging project to date and I feel so much more accomplished viewing the finished product than a few months prior. Laughs were had and tears were shed but we survived. We laughed, we cried, we came, we saw, we conquered.

*-**Andrew Augustyn***

References

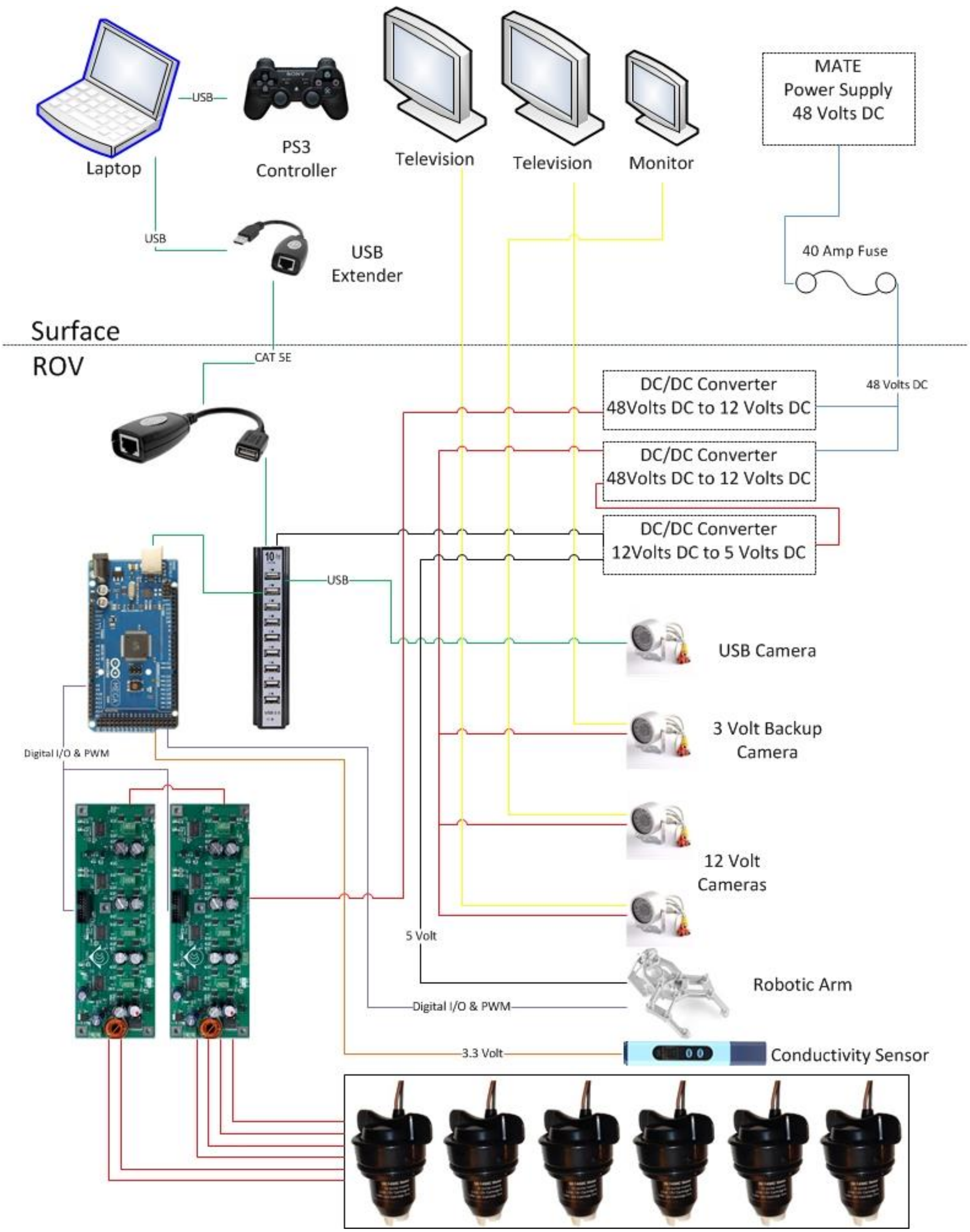
http://www.marinetech.org/. n.d.

http://thunderbay.noaa.gov/. n.d.

Acknowledgements

We Would Like To Thank Our Donors, Mentors, and Sponsors. Without Your Continued Help and Support, This Would Not Have Been Possible!

Appendix A: System Integration Diagram (SID)

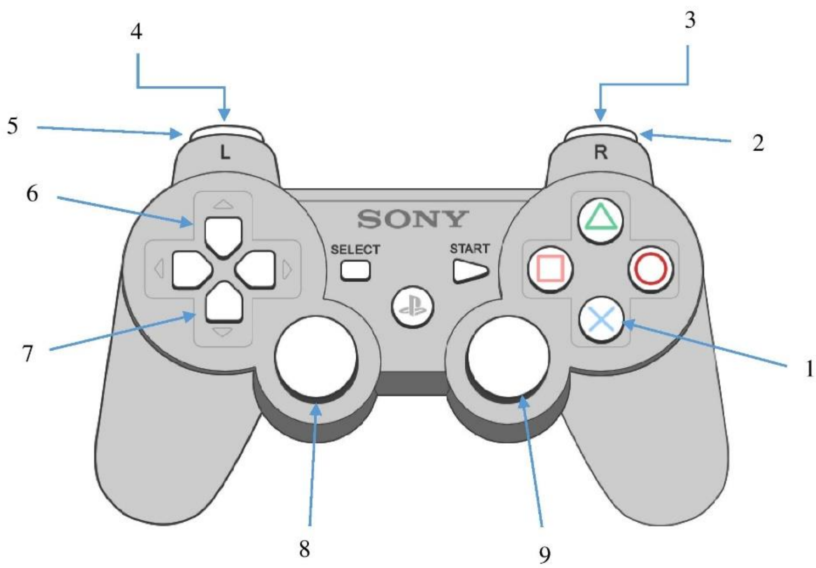


Appendix B: Detailed Budget

Item	Quantity	Code	Vendor	Cost	Extended Cost
Tether	1	D	Outland	250.00	250.00
Arduino Mega	1	P	Amazon	59.99	59.99
Seamate H-Bridge	2	A	ACC MRT	200.00	400.00
USB Hub	1	P	Amazon	7.01	7.01
HDPE	1	D	Alro Plastics	427.52	427.52
Johnson Bilge Pump	6	A	ACC MRT	36.99	221.94
LED	2	P	Digi Key	10.82	21.64
Endcaps	2	D	Kalitta Air	50.00	100.00
Light Housings	2	D	Kalitta Air	25.00	50.00
Labor	1	D	Kalitta Air	100.00	100.00
Acrylic Tube	1	P	Estreetplastics	37.99	37.99
Robotic Arm	1	P	Karlsson Robotics	17.95	17.95
USB Camera	1	P	Amazon	4.99	4.99
Mini Digital Pickup Camera	2	P	Amazon	12.95	25.90
Backup Camera	1	P	Ebay	10.02	10.02
Controller	1	D	Team Member	30.00	30.00
Laptop	1	D	Team Member	600.00	600.00
Monitor	2	D	Team Member	150.00	300.00
Misc. Wire	1	D	Omega Electric	30.00	30.00
Props	6	D	Open Rov	6.00	36.00
Prop Aadpter	6	P	Octura	5.00	30.00
DC/DC Converter 10A	1	P	Amazon	26.95	26.95
DC/DC Converter 30A	1	A	ACC MRT	80.00	80.00
Epoxy	1	P	Jo Ann Fabrics	20.00	20.00
Fuse Holder	1	P	Premium Sound	4.23	4.23
Fuses(5)	1	P	Carquest	3.45	3.45
1/4" Ring Terminals(3)	2	P	Carquest	2.58	5.16
Connectors	2	P	Tractor Supply	4.99	9.98
Hot Glue	1	P	Walmart	3.00	3.00
Heat Shrink	2	P	Home Depot	15.00	30.00
Conductivity Sensor	1	P	Amazon	12.69	12.69
USB to Ethernet Converter	1	P	Amazon	5.24	5.24
Servo	1	P	Sparkfun	12.99	12.99
3D Printer ABS Plastic	1	A	ACC MRT	20.00	20.00
Tubing	1	P	Home Depot	25.00	25.00
Misc	1	P		100.00	100.00

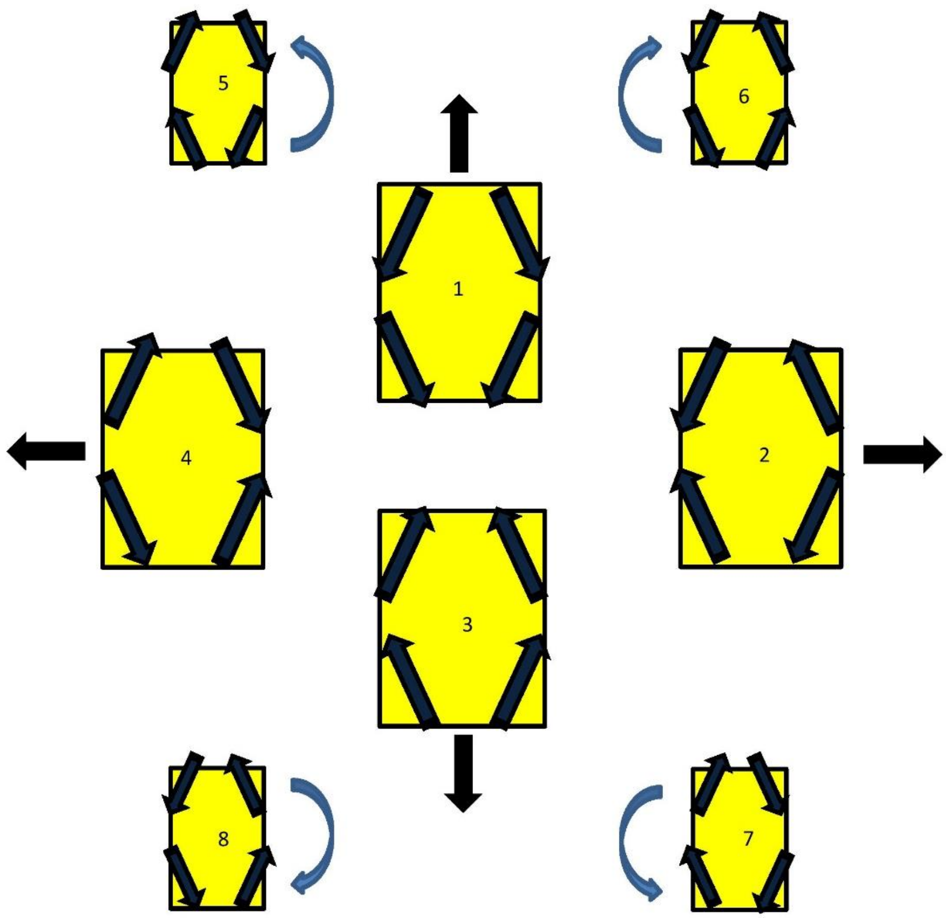
Purchased	474.18
Donated	1923.52
Borrowed from ACC MRT	721.94
Total	3119.64

Appendix C: Controller Diagram



Number	Button	Function
1	X	Activates Continuity Sensor
2	R1	Opens Manipulator
3	R2	Crab Right
4	L1	Close Manipulator
5	L2	Crab Left
6	UP	Vertical Up
7	DOWN	Vertical Down
8	Left Stick	Port Control
9	Right Stick	Starboard Control

Appendix D: Vectored Thruster Diagram



Number	Direction
1	Forward
2	Crab Right
3	Reverse
4	Crab Left
5	Rotate/Turn Left – forward
6	Rotate/Turn Right – forward
7	Rotate/Turn Right – reverse
8	Rotate/Turn Left – reverse

Appendix E: Safety Checklist

Safety Inspection Checklist

Inspector: ______________________________ Position : ________________________

Item	Reviewed
Wearing Safety Glasses And Close Toed Shoes	☐
Area Free Of Tripping Hazards And Equipment Is Secured	☐
ROV Disconnected From Power Source For Inspection	☐
Fuses In Place And Working Properly	☐
Electronics Canister Secure And O-Rings Sealed Properly	☐
No Loose Hardware	☐
Components Secure	☐
No Bare Wires Exposed	☐
Electronics Checked For Shorts	☐
No Sharp Edges	☐
Thrusters Clear Of Obstructions	☐
Correct Polarity When Connected To Power Source	☐
Body Parts Clear From Thrusters When ROV Is Powered	☐
All Components Working Properly	☐
ROV Cleared For Launch	☐

I acknowledge that the items checked have been inspected.

____________________________________ SIGNATURE

____________________________________ DATE