# HYDROBOTICS INC.

## Company Staff:

CEO: Robert Piispanen
CTO: Ian McElroy
CFO: Yelena Randall
COO: Everett Collins
R&D: Joe Grenier, Chris Haramut
Machinist: JP Sullivan
Electrical Engineers: Tom Hamilton, Jackson Sugar
Software: Tommy Muth, Jeffrey Martinez,
Alexander Syhabouth
Mentor: Scott Hara
Engineers: Arnav, George, Joel, Joshua, Maximillian, Mingxing, Reed, Rihui, Sean, Shane, Tony


MU-ROV

## Company History:

- Founded Sept. 2015
- Inaugural meeting Sept. 23rd, 2015
- First major design review Dec. 16th, 2015 (5th design iteration)
- Major Redesign Jan. 15th, 2016
- Construction began Feb. 1st, 2016 (9th design iteration)
- Rhode Island Robot Block Party Apr. 9th, 2016
- Presentation at ASME awards ceremony at Raytheon Apr. 15th, 2016
- Construction completed Apr. 27th, 2016

## Specifications & Features:

- Lightweight: 19.8 lbs, 9kg (w/ tether)
- Affordable: $7,000
- 2-Degree Vector Thrust
- SubConn Connectors
- Adaptable for alternative missions
- Software designed for parity with research vehicles

# Contents

# 1 Abstract

As a first-year team, the University of Rhode Island (URI) Hydrobotics ROV Team has built a team, a business, and most importantly, a fully operational ROV called MU-ROV and will be competing in the 2016 MATE ROV Competition this summer. The team has a faculty advisor, Dr. Stephen Licht, three graduate mentors and 22 undergraduate students ranging from freshmen to seniors that are mostly Ocean Engineering majors but include other engineering focuses as well as physics and computer science. These students are committed to creating and piloting an ROV that is functional in a variety of conditions and can complete "Mission to Europa" themed tasks as per the MATE Competition requirements.

The MU-ROV is the product of over 12 iterations of designs and many months of careful construction and now weighs in at 9 kg with a diameter of about 52 centimeters. Equipped with 4 Crust-Crawler thrusters, the MU-ROV is capable of motion in up-down and left-right directions as well as strafe and tilt. Two cameras positioned on the front and bottom of the ROV feed live streaming video to topside for navigational purposes. The pilot on topside is able to precisely control the ROV with an Xbox controller. For the completion of the MATE assigned tasks, the MU-ROV is also equipped with a jig designed for manipulation and a manipulation arm as well as a pressure and temperature sensor.

The URI Hydrobotics Team is proud to present MU-ROV that was not possible without the support of the College of Engineering at URI as well as the Department of Ocean Engineering.

# 2 Introduction

HydRobotics is a brand new company that was established in the Fall of 2015. We started off with only 2 students, one graduate mentor, and one faculty advisor, and built this company from the bottom up. We began with the motivation to make a name for ourselves and our university by creating a company that can efficiently produce safe, cost effective, and reliable ROVs. This motivation quickly spread as our company grew to 25 active students, and 3 graduate mentors.We had around $4,500 worth of assets, including 4 Crustcrawler motors worth $600 each, 5 Aquastar ESCs $80 each, existing lab electronics, and money left over from a previous robotics team at the university.

In order to achieve our goal we needed to structure the company in such a way as to run as smoothly, and effectively as possible. We elected our CEO, Robert Piispanen, our CFO, Yelena Randall, and our CTO, Ian McElroy. We then decided to split the company up into different sectors including Business, Research & Development, Software, Structure, and Coding. Each sector worked on different aspects of the ROV, which allowed the company to effectively spread its man power. We created the following Gantt chart in order to accomplish our goal.

| Task: | October: | | | | November: | | | | December | | Color Key | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week Of: | 10/5/2015 | 10/12/2015 | 10/19/2015 | 10/26/2015 | 11/2/2015 | 11/9/2015 | 11/16/2015 | 11/23/2015 | 11/30/2015 | 12/7/2015 | Critically Important | |
| **Preseason Refresher** | | | | | | | | | | | Very Important | |
| Required Physics | | Complete? | | Ok | | | | | | | Important | |
| Terminology | | | | Ok | | | | | | | | |
| Construction Practices | | | | Ok | | | | | | | | |
| Data Management | | | | Ok | | | | | | | | |
| Program Overview | | 50% | | Ok | | | | | | | | |
| Time Managment | | 25% | | Ok | | | | | | | | |
| Meeting Times | | Complete | | Ok | | | | | | | | |
| Tutorials | | | | Ok? | | | | | | | | |
| Team T-Shirts | | | | | | | | | | | | |
| **Pre Design** | | | | | | | | | | | | |
| Existing System Brainstorming | | | | | | | | | | | | |
| Design Spiral Round One | | | | | | | | | | | | |
| Payload | | | X | X | X | X | X | X | | | | |
| Ballast | | | X | X | X | X | X | X | | | | |
| Propulsion | | | X | X | X | X | X | X | | | | |
| Navigation | | | | | | | X | X | | | | |
| Power | | | | X | X | X | X | X | | | | |
| Tether | | | | | | | | X | | | | |
| Control | | | | | | | X | X | | | | |
| Structure | | | | | X | X | X | X | | | | |
| Manipulator Arm | | | | | | | X | X | | | | |

Figure 1: Fall Proposed Timeline

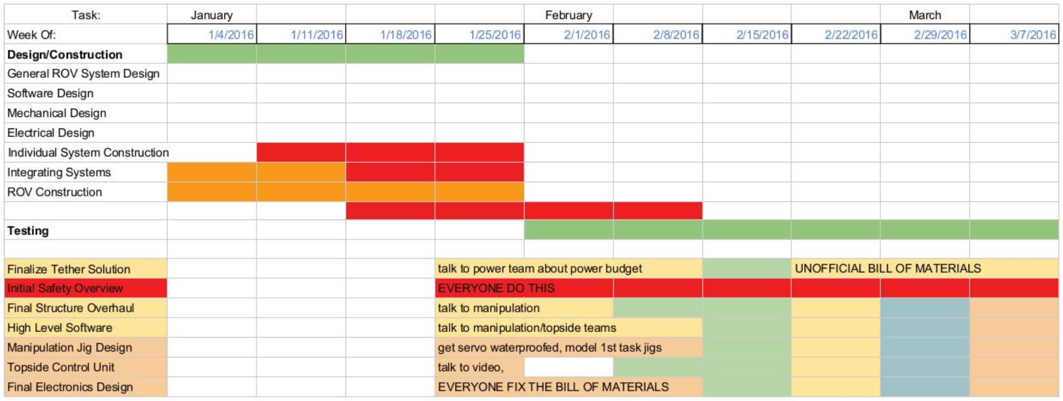



Figure 2: Spring Proposed Timeline

Unfortunately, we started to fall behind schedule in the Fall with the Pre Design, and Design/Construction phase as seen in red on the gantt chart. This led to scheduling challenges, nearly missed deadlines, and last minute decisions. We view the challenges we faced as experiences to learn from. These challenges are typical of up-and-coming companies, and we see these as opportunities and areas we can improve ourselves as a company. Despite our difficulties, our company has accomplished its goal by designing and creating its Mini Underwater Remotely Operated Vehicle, MU-ROV. MU-ROV is a multi-purpose underwater vehicle that utilizes many off the shelf parts, features and practices that are widely used by professionals. This makes the vehicle dependable and easy to use, while keeping the cost low for the customer.

# 3 Design Rational

## 3.1 Design History

This year has been a blur of ideas. At the inception, the ROV was woefully complex with multiple housings and very elaborate mechanical features. Over the course of many late nights and several design meeting with professors, the ROV was slowly but surely simplified into a simple, easy-to-build system. Figure 3 shows the slow transformation of our ROV over the months.


Figure 3: ROV Design Progression

## 3.2 Structure Fabrication

The structure of the MU-ROV was based around stability and efficiency, thus creating an ROV that is stable enough to effectively complete the tasks required, yet small and light for ease of transportation. To ensure a small yet stable ROV, stability calculations were created via Excel for the center of buoyancy and center of gravity of the ROV. By calculating the hydrostatics of the ROV, the pitch, roll, and yaw was determined ensuring a stable vehicle allowing for precise maneuverability.

By using professional grade material such as Ultra-High Molecular Weight Polyethylene (UHMWPE), the framework of the ROV can be stable and extremely durable. After talking with professional underwater roboticists in the field, a functional jig and manipulator were created to operate within the ROV's field of view, yet still maintaining a compact form.

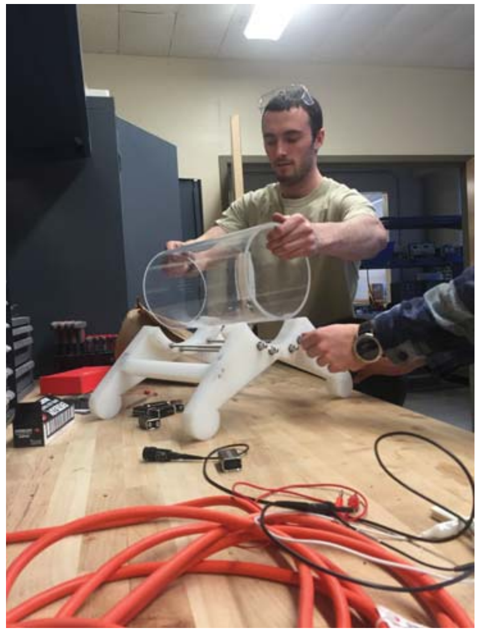


Figure 4: Test fitting the housing on the freshly machined structure

Our main housing was designed for simplicity. By using a single acrylic housing, we created a hydrostatically stable mechanically simple system. The entire housing was constructed out of acrylic with a PVC endcap. The clear acrylic made troubleshooting easy, as any indicator lights were clearly visible. Furthermore, cameras were placed easily in the tube, thus giving us the ability to look easily in most directions.

The acrylic front-end was constructed out of standard parts purchased from McMaster. These were chosen for simplicity and timeliness in case we needed to rebuild. A 7" OD Acrylic tube with 0.25" wall thickness was used as the main housing. This was then chemically welded to a 7" acrylic circle (also available from McMaster). A methylene chloride based cement was used to chemically weld the pieces together. This chemical welding process not only prevented leaks, but also assured the strength to handle 40ft of water pressure. Best of all, absolutely zero machining was required.

Unfortunately the other end of our housing did require extensive machining. A PVC endcap enabled us to take our payload in and out, and connect the tether. The machine drawing used to create this endcap can be seen in Figure 5. Again, all stock was ordered from McMaster and machined in house.

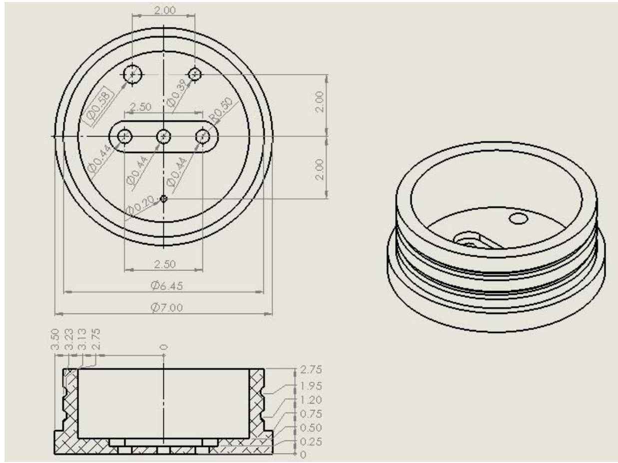



Figure 5: Machine drawings used during fabrication

The lower drawing in Figure 5 represents the features created on the lathe. A large metal lathe was used in order to chuck the 7" PVC stock. This end cap used two 1/4" thick o-rings to form shaft seals against the acrylic. A desired o-ring compression was used to calculate the dimensions on the endcap. The 1/4" o-rings were the thickest commonly available, which resulted in a reliable seal against the acrylic tube, which was not machined. Furthermore, with the acrylic housing design we are able to see if any water leaks in past the first or second o-rings.

The upper drawing in Figure 5 represents the features created on a Bridgeport mill. Some holes were simple through holes, while others were power threaded using the Bridgeport. This ensured a secure o-ring seal for our connectors. All this design was first prototypes using Solidworks.

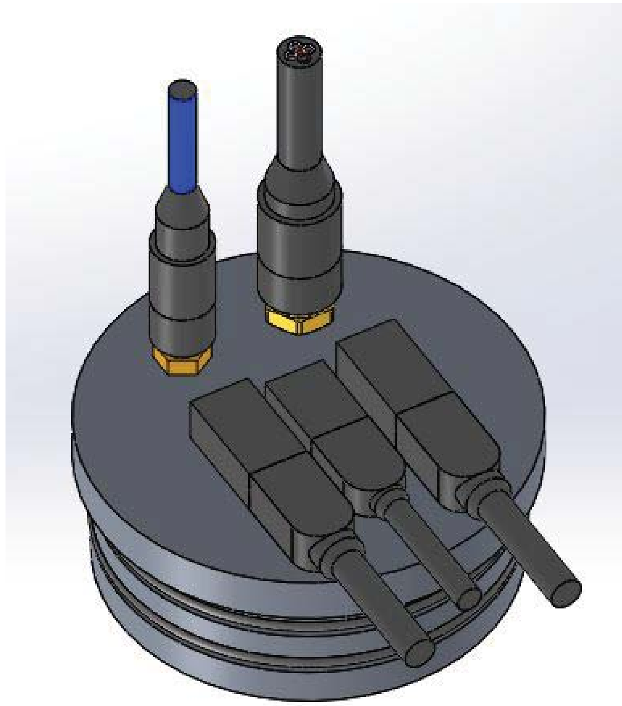


Figure 6: Finalized endcap with connectors and o-rings in place

The Subconn Connectors are by far the most critical portion of our end-cap. By using the Low Profile series we were able to streamline the product and reduce the overall footprint. Furthermore, by using the Ethernet Series connector we were able to avoid any problems with spotty connections, which had previously been experienced with home-made Ethernet connectors (loss of twisted pair). Thus the Subconns finished off the simple and reliable system housing system, which enabled all other departments to implement their systems.

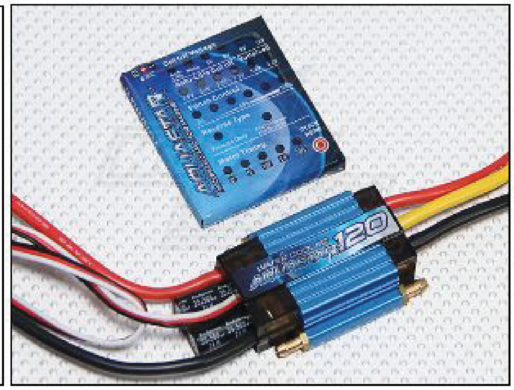
## 3.3 Electrical Engineering

### I ROV Payload

Stated previously, MU-ROV consists of a single watertight housing which holds our entire electrical system. The bottle end cap is consisted of five subconn connectors (power, data, thruster x 2, and misc.) that allow us to ensure a watertight seal between our receptacles on our end cap. Each pin in every connector is assigned a number, which corresponds to an inner component inside the bottle to ensure we are powering or sending and receiving data from the right source. On the inside of the end cap we have two 10A fuses one going to each of our Barracuda DC/DC converters which allow us to step the voltage down from 48V to 12V. From there one of the barracudas is entirely responsible for our four crust crawler thrusters. Each thruster has its own ESC, which communicates to the Pololu. The Barracuda also leads into a smaller DC/DC converter which steps the 12V down to 5V. The 5V then powers our two Raspberry Pi Model 2 systems, our gigabit switch, our sensors and our single servo for the manipulator. Each Pi has a Pi cam which is responsible for our two onboard cameras, one for navigation and the other as for viewing the playing field on our initial descent, and to assist with the alignment of our jigs. The main navigation camera features a fisheye lens that was designed for a cell phone to enhance our field of view. One of the Pi's is responsible for powering our Pololu servo controller, which enables us to communicate and send signals to our thrusters. From here both of the Pi's are connected via Ethernet Cat5e into an onboard gigabit switch which feeds into one cat5e Subconn on the end cap.

Our inner components of the ROV lay on a custom made acrylic tray which was designed to enhance the visibility of connections as well as to keep everything in contact on one removable slide. The tray is composed of 1/8in. acrylic and a circular skeleton that allows an easy way to interchange components inside our bottle.


Crustcrawler Thruster




Aquastar 120a ESC

For thrusters, Hydrobotics Inc. utilizes four Crust Crawler 400HFS-L Hi-Flow Thrusters which operate at 12v and 10A and withstand depths up to 300ft. The Crust Crawlers were existing assets from an old ASV (Autonomous Surface Vehicle) team at URI, along with a few sets of matching AquaStar motor controllers, and a Pololu Mini Maestro servo controller to communicate to each individual thruster. The Aquastars relay the power to each thruster and receive Pulse Width Modulation (PWM) signals from the Polulu. MU-ROV features a vectored thrust system with vertical thrusters positioned at 45 degree angles to help maximize the thrust capacity, and to enable the ability to strafe left and right without turning, making it easier to maneuver around different obstacles that we could face out in the field.

## II Tether

The tether is composed of three cables: One Cat5e cable and two 14 American Wire Gauge (AWG) power cables, one used for power and the other for ground. The Cat5e transfers data between Topside and the ROV. It was chosen over other alternatives such as coaxial cable because it satisfies the system's communication requirements with the added benefits of increased flexibility, and decreased size. The power cables' AWG size 14 was chosen because it is the smallest diameter wire that has an acceptable voltage drop over the 100 feet of tether while being able to handle the corresponding current safely. The two power cables are twisted upon one another in order to decrease their electromagnetic interference on the Ethernet cable.

All three cables were put together within a wire loom, making the tether neat and less likely to kink on itself. It holds all the cables tightly in place which is important to keep the two power cables twisted upon each other at all times. The wire loom also adds buoyancy to the tether, resulting in a neutral net buoyancy for the tether.

Paracord was added to the tether as an emergency feature to be used to pull the ROV to the surface safely. The paracord is setup to receive all the tension in the tether effectively diverting it from the Subconn connectors to ensure the safety of the ROV.

Additionally, pieces of foam were added to keep the tether at the ROV end upright and out of the way. That is to ensure unrestricted camera vision and ROV movement. At topside the tether is kept neat and out of the way of the work areas by utilizing a spool.

## III Topside Command

MU-ROV also features a unique custom made topside unit which is all enclosed inside a durable, weather resistant pelican case. Every hole made for connections for our tether and power lines are securely fastened by water resistant pass throughs. For safety, everything is divided up into AC power, and DC power. On the AC side of things we have our given 120V AC coming in and passing through an 30amp AC circuit breaker and a surge protector power strip before powering up out monitor and intense PC. The intense PC acts as our topside computer which enables us to communicate down the tether as well as to view our camera feeds and to start up the ROV via ethernet. On the DC side we have 48V which leads to a 40 amp breaker before entering our emergency kill switch (big red button) which leads to our power receptacle for the tether pass through. The inside of the box is protected by a clear acrylic Lexan removable cover which will neatly hold the keyboard, Xbox controller and start up and shut down procedure for our pilots.

## 3.4 Software

MU-ROV functions using a system link called Procman between the topside computer and Raspberry Pi. Our key components for control are Python and a Xbox controller. Our code structure in Python allows our co-pilots to flexibly change the button layouts of the controller or movement speed of MU-ROV for the comfort of the pilot. This code uses lightweight communications and marshaling (LCM) for communicating between different pieces of code. Camera streams were setup using a media player called Mplayer providing high resolution, low latency video for the pilots.

MU-ROV functions by mapping controls from the Xbox controller to different motor motions. The major parts that we need our ROV to communicate with are the Xbox controllers, computer, Raspberry Pi, Pololu servo controller, and the motors. Each part of our code communicates independently with one another so that changing one piece of code doesn't break everything else.

Our team decided to use a controller that everyone would be familiar with. The controllers provided a button layout that was easy to configure. If one of our pilots are not comfortable with the control scheme, we are able to change it in a few seconds. The controller driver sends signals from the topside computer to the ROV where they are mapped to different motor signals.

The brain of MU-ROV is the Raspberry Pi. The Raspberry Pi takes all the Xbox commands from the topside computer. Different commands were then mapped to various motor motions. The two thumbsticks on the joystick control the horizontal motors, and the triggers and bumpers control the vertical motors. The Raspberry Pi sends commands to the Polulu which takes those commands and sends pulses to the motors. Those pulses are what make the motors work.

# 4 Safety

Throughout production and testing certain safety precautions were used. In during fabrication safety goggles, close-toed shoes and proper attire were always used especially while using machinery. It was also important that whenever using machinery that there were always at least two team members in the shop in case of emergency.

When testing the ROV, proper communication was used to ensure the ROV could be safely inserted and removed from the tank. On the MU-ROV there are many features to ensure that the ROV itself operates in a safe manner. It is equipped with shroud covers over the props, and caution labeling on all moving parts and electrical wires.

Included below are our safety guidelines for operation of the ROV while it is in the water. We also developed procedures for properly connecting and disconnecting the ROV from its power source.

## 4.1 In Water Safety Procedure

- Clean and grease O-rings
- Clean O-ring grooves
- Connect all inner components to the endcap
- Attach the endcap to the ROV
- Check the bleed screw O-ring
- Screw bleed screw into the bulkhead
- Connect the tether to the ROV
- Connect the power lead of the tether to the ROV
- Run initial motor test
- Connect cameras

# 5 Conclusion

Many challenges were faced by the assembly of MU-ROV and being a first year team we often found ourselves constantly looking at each other for answers we had no idea even existed. Probally one of the main non-technical challenges we faced was actually figuring out where to start in the beginning of the year. Our team is composed of mainly underclassmen with a few upper and a few grad student mentors who had little to no experience and knowledge of how ROVs are actually made. We had this inspiration of creating a new name for our University that would allow the growth of our engineering department and the faculty and students that surrounded it. Another was maintaining and positioning a diverse group of fellow undergrads who all had different interests and skills in a way that they received the same positive impact from the team. In addition to this is encouraging others to look differently at challenges. To view everything from a different perspective that would result in a unique and valuable piece of equipment regardless of the price tag. Unfortunately these skills aren't offered as a class and is what makes up the top group of engineers today, along with their remarkable inventions and solutions. This alone was found to be the biggest challenge faced with designing a professional grade ROV.

## 5.1 Technical Challenges

Throughout our journey we came across a few technical related challenges. The camera selection and way of communication with them probably caused us the most pain. We wanted to form our camera decision around our communication type. We looked at coax lines communicating with HD-SDI, however that required an additional amount of lines in our tether which meant more weight and more money. From this we decided to use Ethernet for all our communication which resulted in a cheap and effective way to receive our data on topside and reduced the number of data cables to one. With this, we found ourselves utilizing the camera port on our on-board Raspberry Pi's which were already being used as a our main communication to the ROV. Regardless of the issues faced with the distortion and camera angle, we were still able to see well enough to complete the qualifier task. Another related issue that was tackled was assembling and organizing the inner components of the ROV. It was difficult to find an easy and reliable solution to finding a place where all of our electronics can be accessible and interchangeable. To solve this we utilized the resources here at the Narragansett Bay Campus at URI and looked at the different solutions that our professionals used on their underwater vehicles. With this in mind, we came up with and acrylic tray that would contain all of the ROVs components on stand-offs. The tray allows easier access and a cleaner approach by giving the client the ability to slide the tray in and out upon discretion to help avoid any safety hazards that are created with the limited space inside the bottle and faster setup time.

With the assembly of an ROV that's capable of handling the harsh environments of Europa, to maneuvering through the depths connection communication lines comes along a pretty price tag. Our funding was restricted to $4000 to assemble our ROV and topside unit. From this we were left with little to no funds for our travel expenses to the national competition and scrambled to receive just enough to get us down to Houston. For future purposes we plan on providing a better budget projection now that we have some experience with the necessities of building an ROV.

# 6 Appendix

| ROV Sub-Group | Components | Acquired | Quantity | Cost | Total | Part Description |
|---|---|---|---|---|---|---|
| **Structure** | UMHW Sheet 1'x1'x1" | McMaster Carr | 3 | $33.35 | $100.05 | Structure Sheet |
| | UMHW Rectangle 1"x3/4"x1' | McMaster Carr | 3 | $5.19 | $15.57 | Structure Bar |
| | Type 316 Threaded Rod 1/4"-20 1-1/2' Long | McMaster Carr | 5 | $3.83 | $19.15 | Hardware |
| | Type 316 Socket Head Cap Screw 1-4"-20 Pack of 10 | McMaster Carr | 2 | $3.80 | $7.60 | Hardware |
| | Type 316 Hex Nut 1/4"-20 Pack of 100 | McMaster Carr | 1 | $8.09 | $8.09 | Hardware |
| | Cap Nut 1/4"-20 Pack of 10 | McMaster Carr | 2 | $6.94 | $13.88 | Hardware |
| | Type 316 Flat Washer 1/4" Pack of 100 | McMaster Carr | 1 | $8.25 | $8.25 | Hardware |
| | Buna-N O-Ring No. 362 Pack of 5 | McMaster Carr | 2 | $4.56 | $9.12 | O-Rings |
| | | | | | $0.00 | |
| | | | | | $0.00 | |
| | | | | | $0.00 | |
| **Housings** | BH6M | MacArtney | 1 | $76.19 | $76.19 | Connectors |
| | IL6F | MacArtney | 1 | $44.44 | $44.44 | Connectors |
| | DBH8M | MacArtney | 1 | $121.80 | $121.80 | Connectors |
| | DIL8F | MacArtney | 1 | $131.20 | $131.20 | Connectors |
| | LPIL7M | MacArtney | 1 | $102.24 | $102.24 | Connectors |
| | LPBH7F | MacArtney | 1 | $178.08 | $178.08 | Connectors |
| | LPBH9F | MacArtney | 1 | $112.82 | $112.82 | Connectors |
| | LPIL9M | MacArtney | 1 | $64.32 | $64.32 | Connectors |
| | DLSB-F | MacArtney | 1 | $7.80 | $7.80 | Connectors |
| | DLSB-M | MacArtney | 1 | $7.80 | $7.80 | Connectors |
| | DLSA-F | MacArtney | 1 | $5.04 | $5.04 | Connectors |
| | DLSA-M | MacArtney | 1 | $5.04 | $5.04 | Connectors |
| | LPB Strap | MacArtney | 3 | $6.56 | $19.68 | Connectors |
| | 1/4" Thick 6" Acryllic Hemisphere | California Quality Plastics | 2 | $21.68 | $43.36 | Dome Lens |
| | Acryllic 7" Diameter 7" Thick 1/4" | McMaster Carr | 2 | $15.12 | $30.24 | Lens |
| | Acryllic Tube 7"OD 6-1/2"ID 1' Long | McMaster Carr | 2 | $52.29 | $104.58 | Housing Tube |
| | White Delrin Rod 7" Diam 3" Long | McMaster Carr | 1 | $117.99 | $117.99 | Endcap |
| | 6061 Aluminum Rod 7" Diam 3" Long | McMaster Carr | 1 | $88.83 | $88.83 | Endcap |
| | Scigrip Plastic Pipe Cement | McMaster Carr | 2 | $5.71 | $11.42 | Acryllic Cement |
| | Brass Hex Nut Pack of 10 | McMaster Carr | 1 | $6.14 | $6.14 | Subconn Nuts |
| | 3/8" Square Drive Socket Bit | McMaster Carr | 1 | $8.56 | $8.56 | Socket for Subconns |
| | 3/8" Square Drive Socket Stnadard Bit | McMaster Carr | 1 | $5.56 | $5.56 | Socket for Subconns |
| | Worm Drive Clamps For Firm Hose and Screw | McMaster Carr | 1 | $9.85 | $9.85 | Vacumn Bolt |
| **Payload Structure** | | | | | $0.00 | |
| | | | | | $0.00 | |
| | | | | | $0.00 | |
| | | | | | $0.00 | |
| | | | | | $0.00 | |
| | | | | | $0.00 | |
| | | | | | $0.00 | |
| | | | | | $0.00 | |
| **Payload Components** | ELP 1080P Megapixel Network Camera | Amazon | 1 | $38.99 | $38.99 | Cams |
| | TP-LINK 5-Port Gigabit Switch | Amazon | 1 | $17.99 | $17.99 | Ethernet Gigabit Switch |
| | PIC16F1705 | Digi-Key | 2 | $1.15 | $2.30 | PIC |
| | DC/DC Converter 15W 5V 3A | Digi-Key | 1 | $30.50 | $30.50 | DCDC Converter |
| | DC/DC Converter 12V 33A | Digi-Key | 1 | $67.40 | $67.40 | DCDC Converter |
| | TEMP Sensor | Digi-Key | 2 | $9.95 | $19.90 | Temp Probe |
| | Honeywell Pressure Sensor | Digi-Key | 1 | $110.28 | $110.28 | Pressure Sensor |
| | FUSE HLDR 500V 10A | Digi-Key | 6 | $1.32 | $7.92 | Fuse |
| | FUSE Glass 10A 250 VAC | Digi-Key | 8 | $0.36 | $2.88 | Fuse |
| | FUSE Glass 5A 250 VAC | Digi-Key | 8 | $0.36 | $2.88 | Fuse |
| | FUSE Glass 1A 250 VAC | Digi-Key | 4 | $0.36 | $1.44 | Fuse |
| | FUSE Glass 100mA 250 VAC | Digi-Key | 4 | $0.24 | $0.96 | Fuse |
| | 1 Ohm Resistor 5W | Digi-Key | 5 | $1.88 | $9.40 | Resistor |
| | Conn Terminal Block 10mm | Digi-Key | 1 | $6.03 | $6.03 | Terminal Block |
| | Pickit 3 Debugger | Digi-Key | 1 | $47.95 | $47.95 | PIC Debugger |
| | DC/DC Converter 12V 33A | Digi-Key | 1 | $67.40 | $67.40 | DCDC Converter |
| | USB to TTL Serial Cable | Adafruit | 1 | $9.95 | $9.95 | Converter |
| | Rasp Pi Camera Flex Cable | Adafruit | 2 | $1.95 | $3.90 | Cable |
| | Adjustable Pi Camera Mount | Adafruit | 2 | $4.95 | $9.90 | Camera Mount |
| | Rasp Pi Camera | Adafruit | 2 | $29.95 | $59.90 | Camera |
| | | | | | $0.00 | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| **Tether** | 14 AWG Stranded Blue Wire 500ft | Home Depot | 1 | $32.37 | $32.37 | Power Wires |
| | 12 AWG Stranded Green Wire 500ft | Home Depot | 1 | $46.37 | $46.37 | Power Wires |
| | Power Connectors Heavy Duty 10-12 AWG | Mouser.com | 2 | $1.10 | $2.20 | Power Connectors |
| | Heavy Duty Blue SBS50 Power Connectors | Anderson Power Products | 1 | $9.09 | $9.09 | Power Connectors |
| | | | | | $0.00 | |
| | | | | | $0.00 | |
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| Subgroup |
|---|
| Structure |
| Housings |
| Payload Structure |
| Payload Components |
| Tether |
| Topside Control |
| Misc. |
| Shipping |
| **Total** |
| |
| **Starting Account Total** |
| **Current Account Total:** |
| |
| **Travel Dontations** |
| URI College of Engineer |
| URI Ocean Engineering |
| Raytheon |
| Total: |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | $0.00 | | |
| | | | | | $0.00 | | |
| **Topside Control** | Conn Cap C90 Plug | Digi-Key | 2 | $11.93 | $23.86 | Topside Plug Connector | |
| | Conn Cap C90 RCPT | Digi-Key | 2 | $12.78 | $25.56 | Topside Plug Connector | |
| | Conn RCPT PNL w/PIN | Digi-Key | 1 | $9.52 | $9.52 | Topside Plug Connector | |
| | Conn RCPT PNL w/SKT | Digi-Key | 1 | $11.25 | $11.25 | Topside Plug Connector | |
| | Conn Plug CBL w/ PIN | Digi-Key | 1 | $16.07 | $16.07 | Topside Plug Connector | |
| | Conn Plug CBL w/SKT | Digi-Key | 1 | $17.72 | $17.72 | Topside Plug Connector | |
| | DIN Rail 3mnnx7.5mmx1m | GALCO | 1 | $2.68 | $2.68 | ???? | |
| | 30A/277VAC Circuit Breaker | GALCO | 1 | $21.35 | $21.35 | Circuit Breaker | |
| | 6' Extension Cord | Amazon | 1 | $8.99 | $8.99 | Extension Cord | |
| | Tripp Outlet and Trasformer Surge Protector | Amazon | 1 | $9.99 | $9.99 | Surge Protector | |
| | | | | | $0.00 | | |
| | | | | | $0.00 | | |
| | | | | | $0.00 | | |
| **Miscellaneous** | | | | | $0.00 | | |
| | | | | | $0.00 | | |
| | | | | | $0.00 | | |
| | | | | | $0.00 | | |
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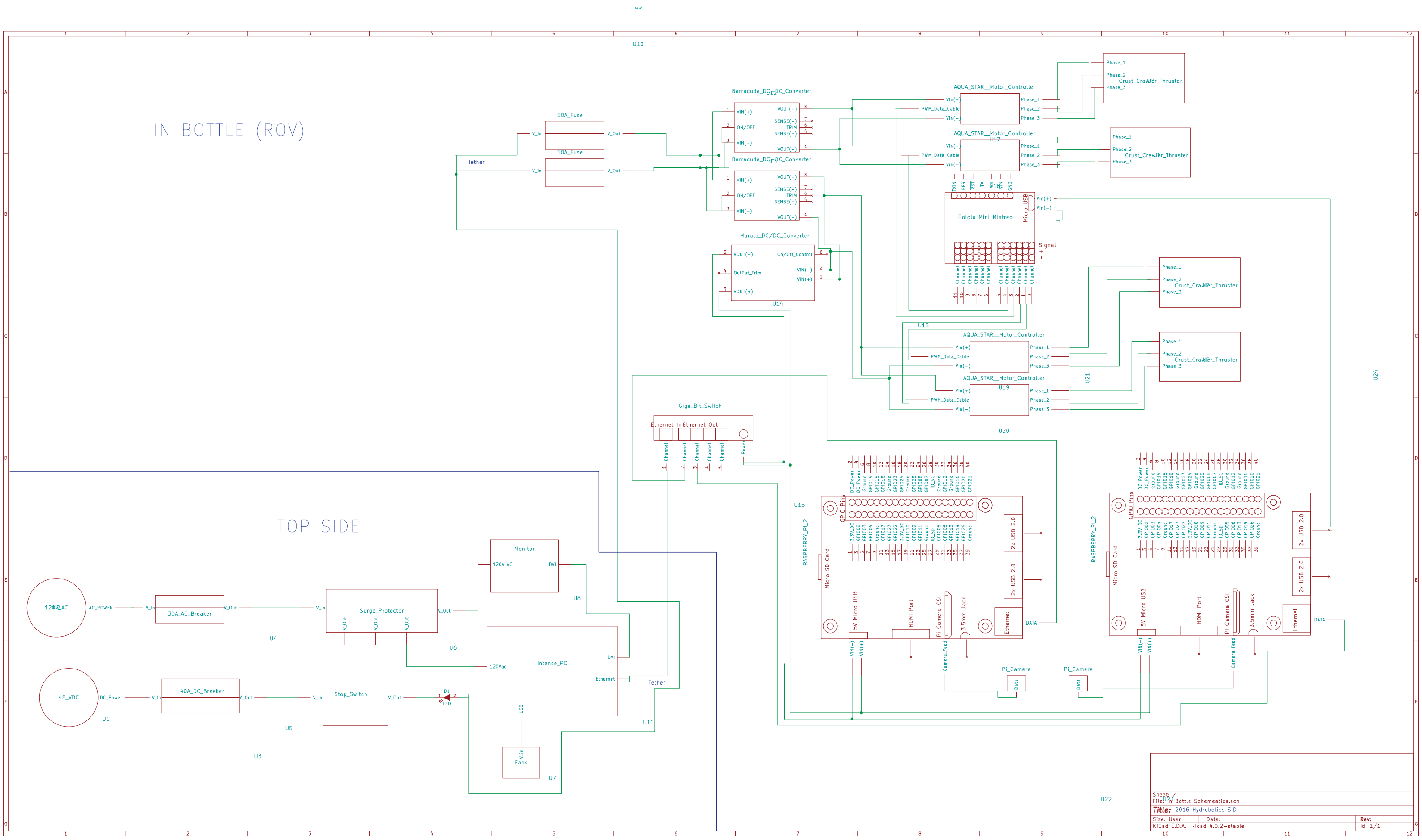
| | | | | | $0.00 | | |
| **Shipping** | Amazon Order | Amazon | 1 | $21.07 | $21.07 | | |
| | McMaster Cement Order | McMaster Carr | 1 | $5.67 | $5.67 | | |
| | Digi-Key Initial Payload Order | Digi-Key Electronics | 1 | $65.80 | $65.80 | | |
| | MacArtney Subconn Order | MacArtney INC | 1 | $69.00 | $69.00 | | |
| | CQP Hemisphere Order | California Quality Plastics | 1 | $29.90 | $29.90 | | |
| | McMaster Lens Order | McMaster Carr | 1 | $6.08 | $6.08 | | |
| | McMaster Structure Order | McMaster Carr | 1 | $13.03 | $13.03 | | |
| | Digi-Key Secondary Payload Order | Digi-Key Electronics | 1 | $109.77 | $109.77 | | |
| | Adafruit Primary Order | Adafruit Industries | 1 | $12.25 | $12.25 | | |
| | Digi-Key Topside Order | Digi-Key Electronics | 1 | $8.66 | $8.66 | | |
| | Mouser Tether Order | Mouser | 1 | $7.99 | $7.99 | | |
| | GALCO Topside Order | GALCO | 1 | $21.78 | $21.78 | | |
| | McMaster-Carr Bulkhead Order | McMaster Carr | 1 | $6.07 | $6.07 | | |
| | Amazon Cord Order | Amazon | 1 | $7.64 | $7.64 | | |
| | Amazon Power Connectors Order | Amazon | 1 | $5.03 | $5.03 | | |


IN BOTTLE (ROV)
TOP SIDE
10A_Fuse
10A_Fuse
Tether
Barracuda_DC/DC_Converter
Barracuda_DC/DC_Converter
Murata_DC/DC_Converter
AQUA_STAR__Motor_Controller
Crust_Crawler_Thruster
Pololu_Mini_Mistreo
Giga_Bit_Switch
RASPBERRY_PI_2
RASPBERRY_PI_2
PI_Camera
PI_Camera
120V_AC
30A_AC_Breaker
Surge_Protector
Monitor
Intense_PC
48_VDC
40A_DC_Breaker
Stop_Switch
LED
Fans
File: In Bottle Schematics.sch
Title: 2016 Hydrobotics SID
Size: User
KiCad E.D.A. kicad 4.0.2-stable
Id: 1/1

# 7 References

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