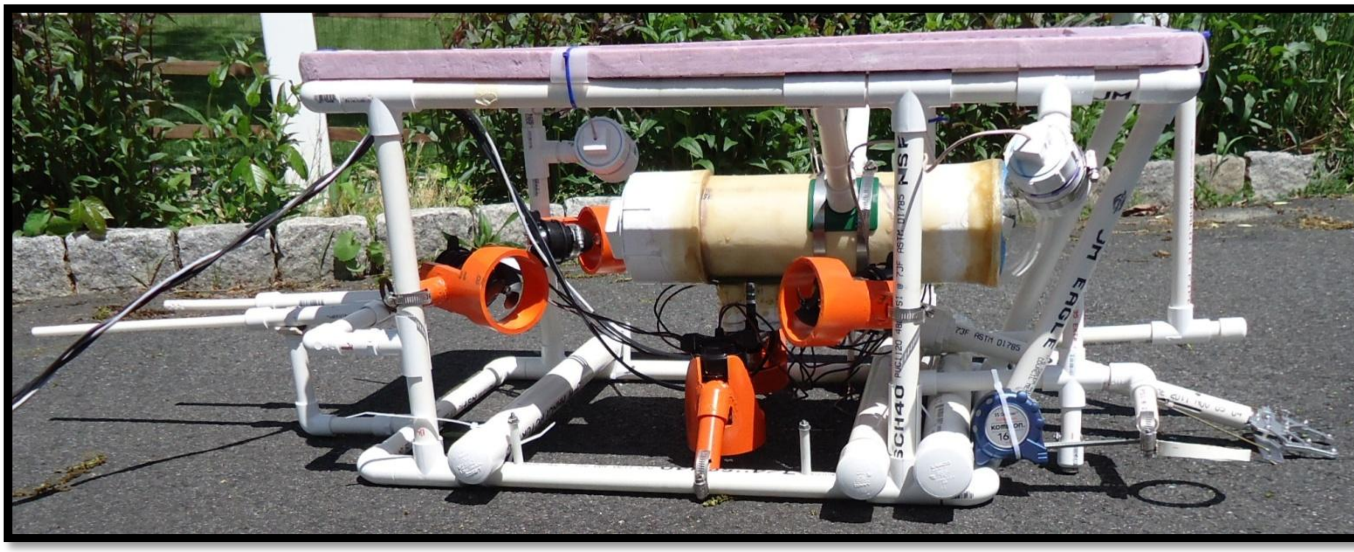
PROVE

Pennsylvania ROV Engineers

▪ Excelsior Homeschool Cooperative ▪ Allentown, PA ▪



MATE International Competition

Technical Report 2012

Team Members

▪**David Sampsell**
Chief Executive Officer, Grade 10
▪**Matthew Buonanno**
Programmer, Grade 11
▪**Stephen Gahman**
Electronics Engineer, Grade 10
▪**Micah Smith**
Design Engineer, Pilot, Grade 11
▪**Natalie Sampsell**
Graphic Designer, Editor, Grade 8
▪**Hannah Smith**
Graphic Designer, Photographer, Grade 9
▪**Thomas Buonanno**
Lead Researcher, Marketing, Grade 8
▪**Tim Gahman**
Tool Researcher, Safety Officer, Grade 8

Mentors

▪Dave Sampsell

▪Leonard Smith

Coaches

▪Robin Sampsell

▪Heidi Smith

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Abstract

Pennsylvania ROV Engineers, or pROVe, was incorporated this year to design and build a remotely operated vehicle capable of inspecting and testing World War II shipwrecks for the possibility of ocean contamination. This capability is important because of the vast number of shipwrecks, including the USS Arizona, which have been on the sea bottom for more than 50 years, and are now starting to show signs of releasing large amounts of oil into the water. Our ROV (Remotely Operated Vehicle), Poseidon, relies on a fully proportional lateral control system, which includes six vectored thrusters, to give it the maneuverability it needs to complete these tasks. The vehicle interfaces with the pilot via an intuitive Xbox 360 controller, and a custom graphical user interface designed specifically for the vehicle. The pilot receives visual information from the ROV via three cameras mounted on the vehicle to provide the optimum view of the toolset. The main camera is mounted inside a dome and is positioned on the front of the vehicle's main pressure housing. It has the ability to rotate 125 degrees, from looking straight down, to looking up at a 35 degree angle.

U.S.S. Arizona

The Team

Our homeschool-educated team includes the following members for our first year of competition:

David Sampsell is a sixteen-year-old tenth grader who lives in Macungie, Pennsylvania. He has been interested in mechanical things his whole life, but first became interested in ROVs after reading the book *Ship of Gold in the Deep Blue Sea*. He has previously built one ROV by himself. In his free time, David enjoys playing guitar, reading, and various sports. David is the chief executive officer of the team.

Natalie Sampsell is fourteen years old and in eighth grade. She likes to listen to music, play piano and violin, read, and draw. She is the technical report editor and a graphic designer for the team.

Micah Smith is seventeen years old and a junior in high school. In his spare time he enjoys playing sports and playing guitar. Micah was interested in joining the ROV team to be able to see engineering in practice as he is considering pursuing some sort of engineering degree in college. He is a design engineer and the ROV pilot for the team.

Hannah Smith is fourteen years old and in ninth grade. In her free time, she likes to hang out with friends, watch movies, read books, play sports, play the piano, listen to music, and take pictures. Hannah is a graphic designer and the photographer for the team.

Matthew Buonanno is a sixteen-year-old junior. He has always loved examining and understanding the intricacies of complex machines, and anything related to the computer will engross him. He especially enjoys programming, and has benefited greatly from his participation in the MATE competition as he programmed the control system. Matthew is hoping to major in some field of engineering in college, possibly with a minor in computer science.

Thomas Buonanno is thirteen years old and is finishing up eighth grade. Right now, he wants to be an engineer, though he is not yet sure exactly what type. He is interested in technology or possibly something in the medical field.

Stephen Gahman is a fifteen-year-old sophomore who loves sports, chemistry, and now ROVs. He is the electronics specialist on the team (along with David Sampsell), and learned most of what he knows through this experience. Although he is not certain of his future pursuits, he is leaning toward engineering and will most likely choose a field in that category.

Timothy Gahman is thirteen years old and in eighth grade. His interests include golf, hunting, and robotics.

Micah at Pool Test

Braiding the Tether

Matthew Programming

Budget/Expense Summary

The proposed budget as we began the project was $1,000. As the project has progressed, we have done well with sticking to the budget, with the final ROV cost being slightly less than originally expected. Our team was able to keep costs down by using creative ways to complete the assigned tasks, by using lower-priced items, and by using our own designs rather than purchasing large pre-designed, pre-constructed devices. Since everyone was involved with the work as a whole and actively contributing, this allowed for more opportunities for ingenuity, which led to being more efficient with our available funds. The estimate for our international competition participation is $1,500. Following are the income summary and the budget and expense summary. Refer to Appendix 1 for expense details.

INCOME SUMMARY		
Sponsors	**Donations**	**Value**
Home Depot	Gift Card	$53.37
Borton-Lawson	Monetary Gift	$200.00
Excelsior Homeschool Cooperative	Monetary Gift	$250.00
Allen Supply	Tape w/ FMV ~ 10	$0.00
DSS SolidWorks	Free Software w/ FMV ~ $99	$0.00
Air Products and Chemicals	Baseball Ticket Raffle	$80.00
Individuals	Monetary Gifts	$587.13
Total		$1,170.50

BUDGET AND EXPENSE SUMMARY				
Category	**Subcategory**	**Expenses**	**Expense Summary**	**Budget**
Electrical & Cameras	Cameras	$71.55	$291.92	$260.00
	Electrical Components	$150.01		
	Tether	$70.36		
Frame	PVC	$67.37	$161.91	$175.00
	Floatation	$45.38		
	Ballast, Camera Mount	$49.16		
Pressure Housing	Dome	$35.44	$134.85	$150.00
	Internal Structure	$21.18		
	PVC	$57.86		
	Clamps	$5.91		
	Epoxy, tape, dope	$14.46		
Propulsion	Bilge Pumps	$205.12	$234.61	$210.00
	Propellers	$21.47		
	Propeller Adaptors	$8.02		
Tools	Manipulator	$33.21	$109.20	$200.00
	Task Tool Supplies	$75.99		
ROV Subtotal		$932.49	**$932.49**	**$995.00**
Administrative	Entry Fee, Poster, T-shirts	$238.01	$238.01	
Total		$1,170.50	**$1,170.50**	

Design Rationale: ROV Components

Frame

The frame on ROV Poseidon is composed of ¾ inch PVC piping, in the basic shape of a box. We chose this shape because it had superior stability, tool mounting options, and also a better ability to support our vectored thruster arrangement. Two angled support braces were installed on the front of the ROV. The reasoning behind this was that, when working underwater, the vehicle will either be working on something in front of it, or slightly below it. This angled arrangement allows focus on both areas. Aluminum was considered as a possible frame material, but was dismissed, as it is more expensive and harder to work with than PVC.

Electrical

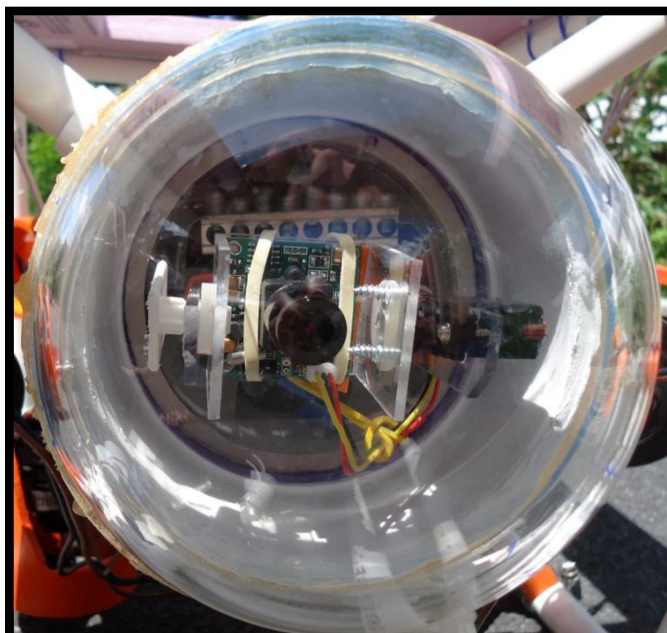
Because of the way our thrusters are set up, our lateral thrusters are only required to turn in one direction. To achieve this, we wired a circuit using N-channel MOSFETs. Because we wanted proportional control, we also used an Arduino microcontroller. Basically, the power flows from the power source through the thruster to the MOSFET. It flows through the MOSFET to ground. However, the vertical thrusters are required to spin both ways, so we wired an h-bridge, using two double pole double throw relays. All of this is constructed upon a solderable breadboard which is mounted on a cylinder which slides in and out of the pressure housing. Also mounted in this cylinder is the Arduino, terminal strips for the thruster wires, and a separate strip to connect all of the ground wires.

Ballast

For ballast, our team opted to build a neutrally buoyant vehicle. The main reason for this decision was simplicity – as a first year team, we didn't want to have to deal with the complexities of a variable buoyancy ballast system for our first competition. For floatation, we decided upon a closed-cell foam panel, with the center cut out for better vertical hydrodynamics. Our team debated between foam and possibly building PVC buoyancy pods. The foam was decided upon because of its easy adjustability—it's easy to cut some off/add more—and also because we wouldn't have to worry about leakage.

Video Systems

Poseidon utilizes three board cameras in waterproof housings for visual control of the ROV. The first of these cameras is color, and is mounted inside our main pressure housing. Keeping the camera dry is a Plexiglas dome. Because of the dome's hemi-spherical shape, the camera has a vertical range of 125 degrees; it can look almost straight up or straight down, and anywhere in between. The pressure housing, and thus the camera, is mounted in the center of the ROV, towards the top, and a little back from the front. This gives the camera a good view for navigation, and also for general use of the tools mounted on the front.



First Camera inside Pressure Housing

The second camera is a black and white camera, and is also mounted on the front. It is stationary, and waterproofed by means of a PVC and Lexan housing. Its placement is such that it provides a secondary view of the tools while in operation, and it especially helps with reading measurements off of the tape measure. The third camera, identical in construction to the first, is mounted on the back of our ROV. There are several tools mounted on the back of the vehicle, and this camera is there to provide the pilot with enough location information to perform the tasks.

Pressure Housing

The pressure housing and enclosed electronics are the focal point of our vehicle. The computer-based control system needs a decent amount of support paraphernalia on the ROV, such as microcontrollers and motor controllers, which all take up space. Thus our pressure housing had to be rather large. We also wanted modularity, specifically with the tools, and the ability to remove the tether if necessary for ease of transportation. In the end, we came up with a cylindrical design, as it is the best shape for resisting water pressure. Constructed out of four inch PVC, on one end a Plexiglas dome is mounted, and on the other, a large screw-in plug for removing the electronics. Wires for the thrusters, tether, and tools, run out of five smaller screw-in plugs that come out the bottom of the housing.

Pressure Housing

To aid in the design and fabrication of one of the more complicated parts of the vehicle, a CAD drawing of the entire assembly was first created in SolidWorks. Inside the pressure housing resides our electronic control system, referred to as the internal structure. The internal structure is precisely the same size as the inside diameter of the pipe, and slides tightly inside through the removable plug at the rear of the housing. We were also able to design this structure in SolidWorks. The main camera, mounted on the front of the internal structure, looks out through the dome. Reference Appendix 3 for internal structure and pressure housing drawings.

Tether

Poseidon was designed with a thin, flexible, and maneuverable tether in mind. Its control scheme is such that it only requires one category 5 cable for control of the whole ROV, as well as video capabilities for up to four cameras. Also in the tether are two 12 American Wire Gauge power wires that provide power to everything on the vehicle, apart from the cameras, which are powered through the category 5 cable. The three wires, one communication and two power, are braided together in a standard three rope braid. This keeps the tether flexible and compact at the same time. Twelve gauge wires were chosen because they were not too expensive, flexible, but still maintained adequate voltage levels onboard the ROV.

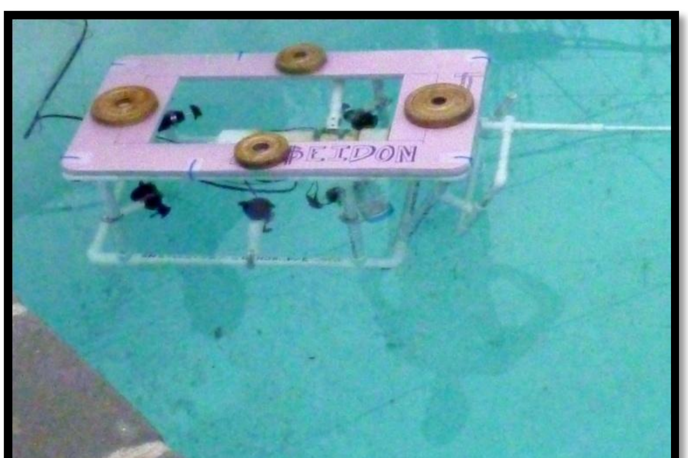
Propulsion

For propulsion, it was decided at an early stage that bilge pumps would be used. As a first year team, we wanted to focus on the basics, and not have to worry about complicated seals for motors, etc. We chose to go with the 750 gph pumps because they were a good tradeoff between price and the thrust that they would provide, and they did not draw as many amps as the 1000 gph bilge pumps. For the vertical thrusters, though, we did chose to go with the 1000 gph pumps, because they would be holding up the weight of any objects our ROV would pick up.

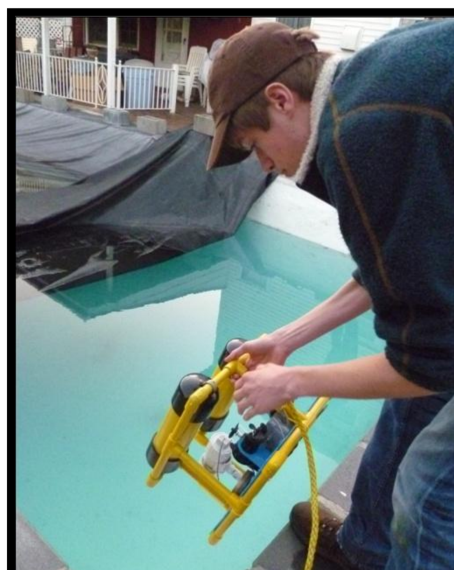
Thruster

Programming

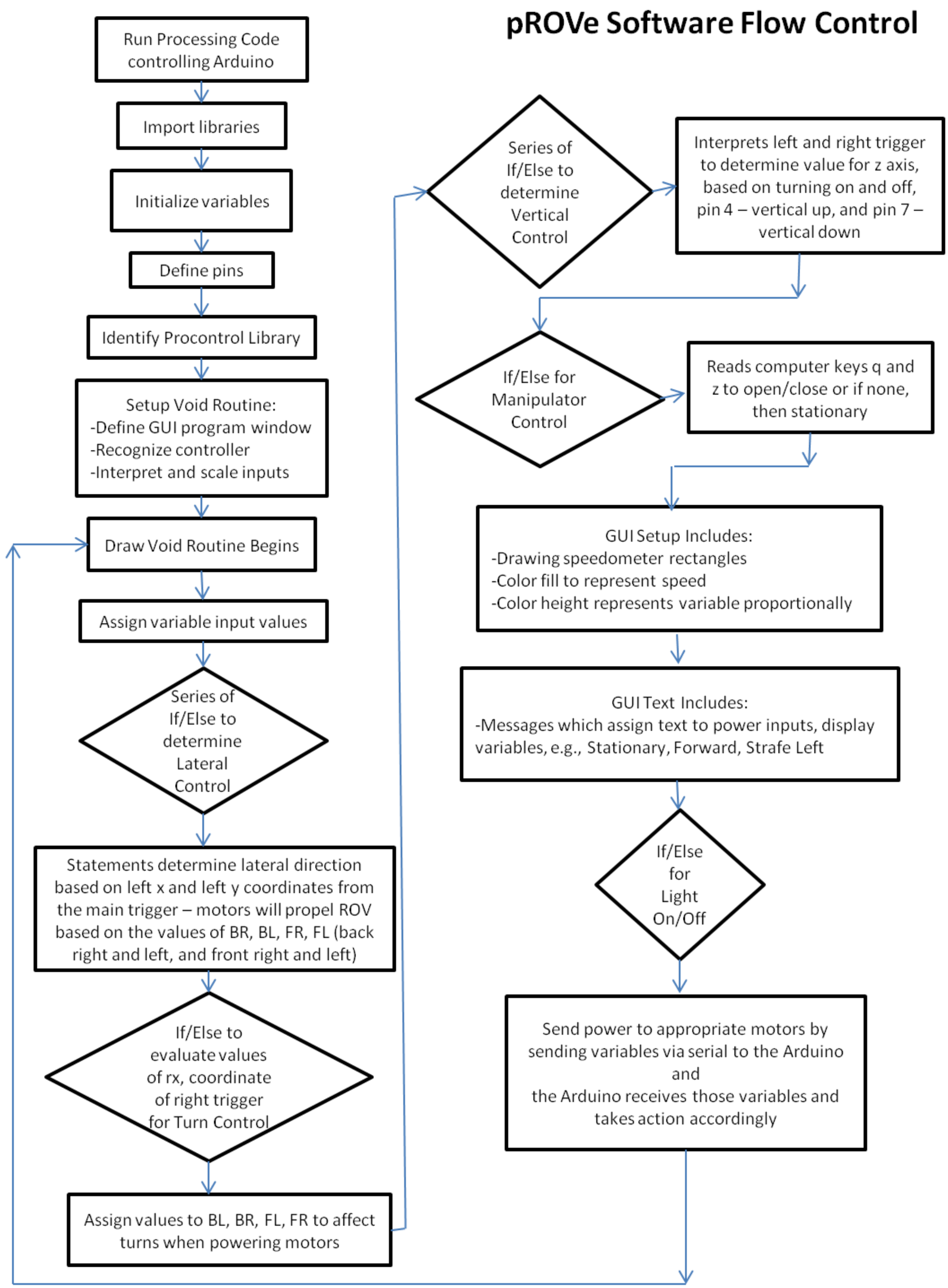
We always approached our ROV with the idea of controlling it digitally, as previous ventures using toggle joysticks were deemed too imprecise to serve the delicate procedures we would need to complete in the missions. David researched microcontrollers, and ultimately decided that Arduino Uno was the best balance between cost and efficacy. Matthew, having a self-taught programming background, began introducing himself to the Arduino and its programming environment. The team unanimously agreed from the start that a wired Xbox 360 controller would be the best control device; designed with intuitive and ergonomic handling, it was the controller with which Micah, our ROV pilot, felt most comfortable. Matthew wrote code to interpret Xbox input signals through a library and assign those input signals to electrical output as was appropriate. Both joysticks on the Xbox controller were used. The left joystick dealt with main thruster directional control; different positions of the stick in the Cartesian coordinate plane resulted in different motion of the ROV by way of the thruster power. All control was real-time and proportional. The right joystick handled on-the-spot turning, which could be used while the ROV moved directionally also. Toggle buttons were assigned to simple tasks, such as light control. Once Matthew completed the motion controls, he moved on to designing a graphical user interface (GUI). The GUI was designed with simplicity and clarity in mind. After assigning power to the thrusters, a speedometer for each thruster is adjusted, resulting in real-time and proportional feedback for each thruster.



Ballast Test



Viewing Poseidon with David's ROV


pROVe Software Flow Control
Run Processing Code controlling Arduino
Import libraries
Initialize variables
Define pins
Identify Procontrol Library
Setup Void Routine:
-Define GUI program window
-Recognize controller
-Interpret and scale inputs
Draw Void Routine Begins
Assign variable input values
Series of If/Else to determine Lateral Control
Statements determine lateral direction based on left x and left y coordinates from the main trigger – motors will propel ROV based on the values of BR, BL, FR, FL (back right and left, and front right and left)
If/Else to evaluate values of rx, coordinate of right trigger for Turn Control
Assign values to BL, BR, FL, FR to affect turns when powering motors
Series of If/Else to determine Vertical Control
Interprets left and right trigger to determine value for z axis, based on turning on and off, pin 4 – vertical up, and pin 7 – vertical down
If/Else for Manipulator Control
Reads computer keys q and z to open/close or if none, then stationary
GUI Setup Includes:
-Drawing speedometer rectangles
-Color fill to represent speed
-Color height represents variable proportionally
GUI Text Includes:
-Messages which assign text to power inputs, display variables, e.g., Stationary, Forward, Strafe Left
If/Else for Light On/Off
Send power to appropriate motors by sending variables via serial to the Arduino and the Arduino receives those variables and takes action accordingly

Challenges

Non-Technical: Scheduling

Since we are all homeschooled, it proved very difficult at times to make our schedules work together in order to meet. For example, Stephen and Tim lived the furthest from our meeting place, so it was most difficult for them to attend the meetings. And since neither of them can drive (yet) and both of their parents work, a lot of collaboration and communication was required by the parents in order for them to attend the meetings.

Another challenge we ran into was keeping up with our development schedule. The reason for this was that in order to continue the building process, each completed component needed to be in working order. For example, to test the electronics in the water, we needed to put them in the pressure housing. However, we ran into problems with keeping the pressure housing water-tight. Then to test the electronics, the code needed to be working, and so on. We tried to have people working concurrently on individual tasks when possible to help us meet our overall schedule goals. We realized that our development schedule was very dependent upon everything working correctly quickly. Refer to Appendix 4 for the project schedule.

Technical: Waterproofing

While the pressure housing setup worked well in theory, we ran into several problems when we started pressure testing. The first problem occurred when we did our first test. The five plugs along the bottom were letting in water at an atrocious rate. Apparently, the solvent used had not totally bonded the plugs with the housing. To solve this problem, we coated the housing with fiber glass. On our second pressure test, the water leaked at a significantly slower rate, but was still getting in. Then, at the end of the test, the dome fell off. It had been mounted with a single bead of silicone caulk, which was evidentially not sufficient to hold it on. After remounting the dome with epoxy, and covering the joint with fiberglass, another pool test was conducted. Unfortunately, water was still getting in. It was very discouraging; after all we had been through, to still have water in the housing. After much discussion, it was finally decided that another coat of fiberglass resin should be applied to the five plugs mounted to the bottom of the housing. Finally, after much work, the housing was water tight. There had evidentially been several tiny holes, the size of pinpricks, in the fiberglass, which were slowly letting in water.

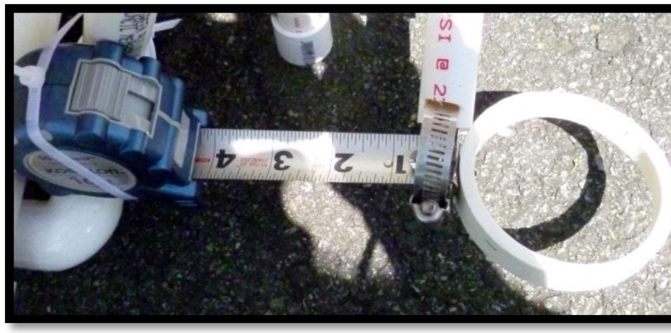
Troubleshooting Techniques

Because of the complicated software and electrical aspects to our ROV, we did a lot of troubleshooting. If something didn't work, we approached the problem logically. We broke the problem down into steps, and tested each one, until we found where the problem was. This method was especially effective in things such as a loose wire, or a mistyped character in some software code, where the problem wasn't readily apparent if we didn't analyze each step. A good example of how we used this method is in our problems with the code on the Arduino. For some reason, after a short time in the water, the ROV would stop responding. By power cycling the vehicle, it could be remedied easily, but the problem would come back within a few moments. At first, the computer was suspected. We thought that there might be a problem with the code. Eventually, though, the computer code running on the laptop topside was vindicated, as the variables being sent down to the Arduino proved to be consistent with the pilot inputs. The motor control circuits were also suspected; we had had problems with the motors turning on by themselves and not stopping before. This was ruled out, however, after a test was conducted in which we immediately tested the electronics manually after the problem developed. Eventually, it was narrowed down to the communication between the Arduino and the laptop located topside. We had been using a free open source software called Firmata to establish communication between the Arduino and the laptop. For some reason, it wasn't working correctly. We ended up writing our own code for the interface. This also cleared up another problem – with Firmata, we were not able to control the servo that tilts our main camera. We were able to write this ability into our new code.

Payload Description

Mission Task 1: Survey the Ship Wreck

Measure the length of the wreck
A self-retracting, rust resistant tape measure with large numbers that could easily be viewed by the ROV camera was installed A large PVC ring was affixed (1.25 cm length of piece of 3-inch PVC pipe) to the end of the tape measure that could be used to simply "hook" onto the mast extending from the bow of the ship. The tape measure was attached to the right side of the ROV so that it could function freely without interfering with other tools to be used later in the mission. The PVC ring and tape portion of the tool was extended from the main body of the ROV approximately 15 cm using a segment of PVC tubing and a hose clamp. This was done so that the mast extending from the bow of the ship could be easily viewed by the ROV's cameras while hooking it with the PVC ring. After hooking the PVC ring to the extended mast at the bow of the ship, the ROV would move in reverse to the other mast at the stern of the ship, extending the tape measure as it moved. After reaching the ship's mast at the stern of the ship, the ROV cameras would be used to read the measure to determine the ship's length. We realized this may not be accurate and therefore several tests were completed to calibrate the reading of the tape measure to obtain the actual length of the ship. After measurement, the ROV would move forward and upward to free the PVC ring from the mast at the ship's bow and the tape measure would retract, relying on the spring system in the tape measure to retract it. The ROV would rise and simultaneously the loop would lift off of the mast at the ship's bow.



Tape Measure

Determine ship orientation on the seafloor
A waterproof compass was affixed to the front of the ROV in view of the main ROV camera. Initial investigation of the compass identified a design problem: the magnetic field created by the motors interfered with the orientation of the compass needle, thereby giving an inaccurate reading of the ship's orientation. Experimentation determined that the compass needed to be affixed to a rod on the front of the ROV at least 30 cm. away from the ROV's motors. We planned to use the compass simultaneously while measuring the ship, using the extended tape measure to carefully align the ROV with the sunken ship and obtain an accurate orientation with the compass. Once a reading was obtained, it could be calibrated to true north, if necessary, by comparing the ROV's compass reading with the true compass reading provided by officials at the test site.

Create a map of the wreck site
To obtain an accurate mapping of the wreck site, the pROVe team relied on its three cameras. The main ROV camera was mounted behind a clear Acrylic dome inside the front of the pressure housing, which was located approximately midway vertically inside the ROV frame. The utility of the camera was maximized by affixing a servomotor to the camera housing that enabled the adjustment of the camera view vertically by the ROV controller. This enabled a full range of viewing angles in the z-plane from almost 0° (straight down) to about 125° (elevated 35°

above horizontal). One fixed black and white camera was mounted on the outside right of the ROV, above the tools to obtain an aerial view of the site. A comparable fixed camera was mounted to the rear of the ROV to provide similar elevated views from the rear of the ship. The three cameras allow for viewing of the wreck site from multiple angles and locations.

Determine metal or non-metal debris piles

A testing tool which relies primarily on a magnet was created to discern if material in the sunken ship's debris field was ferrous or not. It was recognized early in the tool development that the most essential component of this task was to ensure a good contact of the magnet with the simulated debris. Although the ROV controls and cameras could assist us, we determined the best method to ensure a good contact with the debris would be to affix a magnet to a mast or probe of some type. This presented a complication in the fact that while the mast/probe could be used to ensure a good contact with the debris, it would also make it difficult to decipher, even with the fully functioning ROV cameras, if the magnet was actually attaching to an object. A modified mast/probe was developed using a system of PVC tubing, modified pipe fittings, and a spring that would function in a plunger type of action. The magnets were attached to the bottom of the plunger. It was theorized that the magnet affixed to the bottom of the mast, and the mast connected to a plunger, would facilitate bringing the magnet into contact with the debris. If the debris was not metallic when the ROV moved upward and away from it, nothing unusual would occur. However, once the magnet affixed to the bottom of the plunger came into contact with metallic debris, as the ROV moved upward and away from the debris the plunger would be pulled down and the deflection could be observed by the ROV's main or auxiliary cameras. The spring located inside of the plunger would then reset the plunger to its original position at rest, and allow the tool to be used for multiple uses. Several different sized magnets were tested in an underwater environment to empirically identify the optimum magnet size or number of magnets to best observe the deflection and complete the test.

Metal Detector

Scan the shipwreck with sonar

To accomplish this task, we relied heavily on two key components that were an important part of the ROV design. The first key element was the ROV's motorized dexterity and stability achieved by its multidirectional vector controls using four horizontal thrusters and two vertical thrusters. The second key element necessary to complete this task was the ROV's adjustable camera located in the pressure housing. We relied on the stable positioning of the ROV, using the controls and thrusters while allowing for small adjustments to the view of the motorized camera, to allow the ROV to remain transfixed.

Mission Task 2: Remove the Fuel Oil from the Shipwreck

Mechanism to raise fallen mast to the surface

A mast comprised of PVC tubing was added to the front left side of the ROV outside of the main frame of the ROV. The mast was positioned such that the lift bag would sit vertically on the mast extending upward inside the 3-inch diameter capped ABS pipe acting as the lift bag. The lift bag assembly was positioned on the front left of the ROV so that the ROV frame would not interfere with the raising of the lift bag while at the same time allow for a clear view of the lift bag hook located on the bottom of the lift bag. An air line brought down from the surface via the ROV tether and positioned such that its terminal opening was inside the ABS lift bag, was used to deliver air into the lift bag. Using the ROV motor controls and cameras would allow us to position the lift bag hook located on the bottom of the lift bag, to hook onto the metal ring located on the fallen mast, and lift it to the surface.

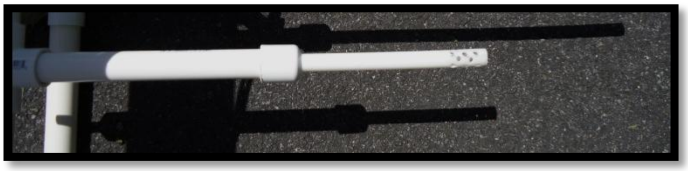
Sensor to determine if a fuel oil sample is inside the fuel tank

We designed and built a sensor rod to be placed against a surface for 5 seconds to determine if fuel oil remained inside the tank. Although a fixed sensor could have been used to achieve this task using the motor controls and the ROV cameras, we agreed that maintaining contact may be difficult if there were any underwater currents. Therefore a modified sensor was developed using a spring and PVC tubing. The sensor consisted of a tube-within-a-tube and a compressible spring (located inside the outer tube) to allow deflection of the sensor. Once the sensor is partially compressed when it comes into contact with a specified location, this design allows the sensor to maintain a constant contact while allowing for small movements of the ROV caused by underwater currents. Because of possible interference among the tools, the sensor was designed with a magnetic catch to keep it in place during the use of the sensor. An external spring, looped around the end of the sensor closest to the ROV body, was used to eliminate a potential tool conflict after the sensor task was completed. With the external spring in place, the sensor could be automatically adjusted out of the way by pivoting the sensor by “tapping” the end of the probe upward. To improve the utility of the ROV and create a design where the tools did not conflict with one another, the sensor was affixed to the rear of the ROV and the rear-fixed camera was used to provide visuals to complete the task.

Probe

Method to siphon oil and transport to surface

In order to obtain a fuel oil sample and return it to the surface, a sealed plastic jar was used to act as a vacuum tank to siphon water from the fuel oil tank using plastic tubing. To create the vacuum tank, a hole was drilled in the bottom of a plastic jar and in the screw-on cap. Clear plastic tubing (1/4 inch) was inserted into a rubber bushing placed in the hole in the bottom of the jar. This created an air tight seal between the bottom of jar and the tubing. The cap was removed from the bottom of the jar and a balloon was placed across the opening in the top of the jar. The cap was replaced on the jar such that the deflated balloon lies on the inside of the cap of the jar when the balloon is deflated. A vacuum was created using a pump, by sucking air out of the clear tubing penetrating the bottom of the plastic jar. A vacuum could be observed in the jar because the balloon in the vacuum tank was now “inflated” although it was not really inflated, it was just enlarged because a vacuum was acting in the tank between the bottom of the jar and the balloon. The clear tubing was extended along the ROV frame and inserted into a 3/8-inch PVC tube at the rear of the ROV. This PVC tubing created the actual probe that was to be used to puncture the petroleum jelly seal on the fuel tank. The end of the probe was plugged so the petroleum jelly would not fill the end of the plug and interfere with sampling. Multiple holes were drilled in the end of the probe to allow more than one avenue for the fuel sample to enter the probe and the internal sampling tubing connected to the vacuum tank. An electrically activated valve, connected to the ROV controller was placed between the two segments of the one-quarter-inch tubing connected to the vacuum tank and the probe. The valve would be initially closed to hold the vacuum in the vacuum tank. Once the probe broke the seal on the oil tank, the valve could be opened using the ROV controller, releasing the balloon and the vacuum thus siphoning the sample into the tube. The motor controls of the ROV and the ROV cameras would be used to align the probe in the fuel port and determine when to release the vacuum in the vacuum tank. The sample jar would remain sealed until the ROV returns to the surface where the sample could be removed for analysis.



Liquid Sampling Device

Mechanism to remove, pick up, and transport coral and reseal the hole

It was decided early on that a manipulator would be needed for completion of some of the tasks, specifically removing the endangered corals, and affixing the patch to the hull of the ship. We considered building our own manipulator from scratch, and made several designs in SolidWorks, but in the end, there was not enough time to actually fabricate either of the designs. Instead, we purchased a manipulator from Sparkfun. This manipulator, however, required extensive modification for it to actually work in our application. The main modification we made was to change out the servo based control system for one run by a bilge pump. The manipulator is mounted on the front of the ROV, beneath the main camera and angled slightly down. The bilge pump turns a threaded shaft which runs inside the ¾ inch piece of PVC. As this shaft turns, a threaded fitting runs up and down the shaft, with protrusions sticking out through slots on either side of the PVC. Attached to these protrusions are two control rods, which attach to each “finger” of the manipulator, and move them forward and backward as the threaded fitting moves up and down the shaft.

Manipulator

Future Improvements

The main thing that Poseidon lacks is power. Overall, it’s just a little too slow and sluggish in the water. Maneuverability is good, but it’s slow. The reason is pretty simple; the ROV is fairly massive, and the thrusters don’t produce enormous amounts of thrust. Putting larger motors on the ROV is not really an option, as we are limited to 25 amps, and the vehicle uses most of that power now. We could either find a more efficient propeller design, or find motors that are more powerful than the bilge pump motors, while still drawing a comparable number of amps. Another thing that could be improved is the camera quality. The cameras have slight interference with one another, with a very faint ghost image appearing on the screen. This could probably be reduced with additional filtering.

Lessons Learned

One skill we gained was in our testing methodology. When we had problems with components such as the electronics or software during our pool tests, we soon learned that we should test these components separately before moving to the pool to test the whole vehicle. Then we could make the changes we needed beforehand. This was especially helpful as we went along and wanted to make the best use of our pool time. It saved a lot of time because our construction location was a distance from our test pool.

All of our team members worked together very well; we were a natural group and never really had any serious issues with interaction. This isn't, however, to say that all was smooth sailing. Often, our meetings seemed a little inefficient, and our schedules didn't always match up – resulting in half the team showing up and sometimes even leaving before the rest of the team arrived. This meant we were often a bit disconnected. In the future, we would improve this with an increased focus on organized communication. If we maintain communication, our efficiency would be increased and we can devote ourselves to an even better ROV.

Reflections

"David approached me in August with the potential task of designing the control scheme for our ROV, knowing I enjoyed programming. I barely hesitated; the whole deal sounded like it was right up my alley and like a refreshing challenge. I wouldn't say I was ever overly-confident, but as time went on, what confidence I had began to drain. It seemed like I kept hitting walls, struggling to get started on my task. I was afraid of failing, of letting my team and myself down. One night, however, I just sat down and drew up a simple sketch: a cross. I drew values of *n* in at different positions, and in an epiphanic brainstorm, began writing a series of logic statements. This was where I really started rolling on my programming. It's not like after that, every line of code was immediately successful or enjoyable, but I think at that moment I had this feeling of, "We might actually be able to do this whole thing." I'm also really glad to say that, over the course of this school year, I've become much better friends with all of my team members, down to my younger brother. I was already on good terms with all of them, but I would not hesitate to say that this experience has brought us together as friends, and that is something invaluable for which I am truly grateful." **Matthew Buonanno**

"I joined the team because I thought it would be a practical way to get involved with engineering and to learn about the unique field of underwater ROV work. I have enjoyed the camaraderie of the team and getting to work on a project that is both challenging and rewarding."

Micah Smith

"I enjoyed being on the Pennsylvania ROV Engineers MATE team because it was a great way to learn about engineering and techniques in that field. It was also a great way to be involved in a project that involved teamwork. I have enjoyed documenting the work of the team through pictures. It has helped to keep a dated visual record of our work so that we can remember when the various objectives have been met and how the ROV changed in appearance as we progressed. "

Hannah Smith

"Although I am the 'electronics specialist', most of what I know I learned through this experience. I'll admit that at the beginning of the season I had my doubts about how quickly I could learn all of the technicalities. But thanks to Mr. President's (David Sampsell) patience, I was able to contribute to the team. I also had a great time building relationships with my teammates, working through the challenges we faced."

Stephen Gahman

"The MATE competition has taught me that teamwork is important and that it takes many minds to come up with the best idea or solution. It has also taught me that truly engineering is really trial and error when it comes down to it. Even when you think everything will be perfect, there is almost always something wrong, but you find the problem and keep working on it until the problem is fixed. Finally MATE has taught me that a time schedule is very important and you need to make sure that you do not overestimate what you can do in one meeting."

Thomas Buonanno

"I learned how complicated electronics and computer programming are."

Timothy Gahman

"I have really gained a better understanding of how much work goes into the smaller items of a project like this, including things like t-shirts, updates, and keeping track of work through technical report writing and photography. I also enjoyed learning about the more complicated processes involved in this project, including the electronics, the computer programming, the tools, and other things.

Natalie Sampsell

"Probably the hardest part for me was not so much working on the ROV, but leading the team. I haven't had a whole lot of experience in leadership roles before, so it was a new experience for me. Balancing my workload of tasks for the ROV, schoolwork, and having things for the team to work on at meetings wasn't easy. If I ever participate in this competition again, this will be a big area for me to work on."

David Sampsell

Teamwork

Since this was our first year in MATE, most of us were rather new to the idea of ROVs. However, when our team came together, it was amazing to see all of our different talents unify to form our company. For example, Hannah and Natalie enjoy art, so they worked together to make our spec sheet, sponsor updates, and tech report look presentable. They were also a big factor in finding sponsors and designing the mission plans. Micah is very creative and mechanically minded, so he designed most of the tools and their mounts. Matthew is the programmer, a job which most of us were glad we didn't have to fill. Tim and Thomas are the young guns on the team, and they really enjoyed researching for parts on the internet. They found several parts which are now on the ROV, including the propellers, the prop adaptors, the manipulator claw, and several other items. Stephen was very fascinated with the electronics, so he took that position on the team. And David oversaw the entire project.

In our first meetings, we came up with a schedule for ROV development. Early on we had setbacks due to the time it took for ordered parts to arrive. Further setbacks included the pressure housing leaking, electronics difficulties, and code troubleshooting. Although we tried to get as much done as possible at the meetings, it just wasn't enough. So we assigned homework. Micah worked on the tools at home, Matthew worked on the code at his place, and Stephen researched electronic development at his home. We also scheduled extra meetings for just Matt and David, so they could work on the code without any distractions, or just Stephen and David to work on the electronics. These assignments and extra meetings enabled us to progress much quicker, and helped us grow as a team since we were relying on each other to accomplish their part.

Safety

As our Safety Officer, Timothy Gahman was a general enforcer/reminder of what the team should and shouldn't do in order to prevent any injuries. This included wearing safety glasses whenever a member used an electrical tool, wearing rubber gloves when a member dealt with high voltage batteries and wires, and taking general precautions during any testing periods. For the physical characteristics of our ROV, we incorporated a main power switch that will immediately turn off the ROV wherever it is. Outside of the electrical box, there is a small 25-amp fuse in case of a short circuit. If there is no fuse, the circuit will break at the weakest point, possibly being exposed to water. The fuse acts as the weakest point, and can be easily replaced. We have attached a kort nozzle on each propeller, protecting body parts, wires, or anything in the water from getting caught from the spinning blades. The ROV as a whole was designed so that any possible dangerous items are as close to the center as possible and not close to the outside where they can cause harm or be broken.

References

- *Underwater Robotics: Science, Design, and Fabrication* by Steven Moore, Harry Bohm, and Vickie Jensen
- *Getting Started with Arduino* by Massimo Banzi
- *Beginner's Guide to SolidWorks 2011 Level 1* by Alejandro Reyes
- http://www.arduino.cc/playground/Interfacing/Processing
- http://www.solidworks.com
- http://www.youtube.com/watch?v=Te5YYVZiOKs
- http://www.homebuiltrovs.com

Acknowledgements

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We also thank:

We would first like to thank God for blessing us with an awesome team that was able to do their best, create lasting friendships, and put everything they had into this project.

Mr. Sampsell, for sacrificing his time to provide an often-needed shot of organization and reality, and for his motivational speeches,

Mrs. Sampsell for hosting the meetings, coordinating, asking code questions, and supplying snacks and moral support,

The Smith family for pool use, artistic guidance, tools inspiration, and for believing in this effort,

Our parents for supporting and believing in us and allowing us to embark on this adventure,

Physical Graffi Tee's for amazing t-shirts,

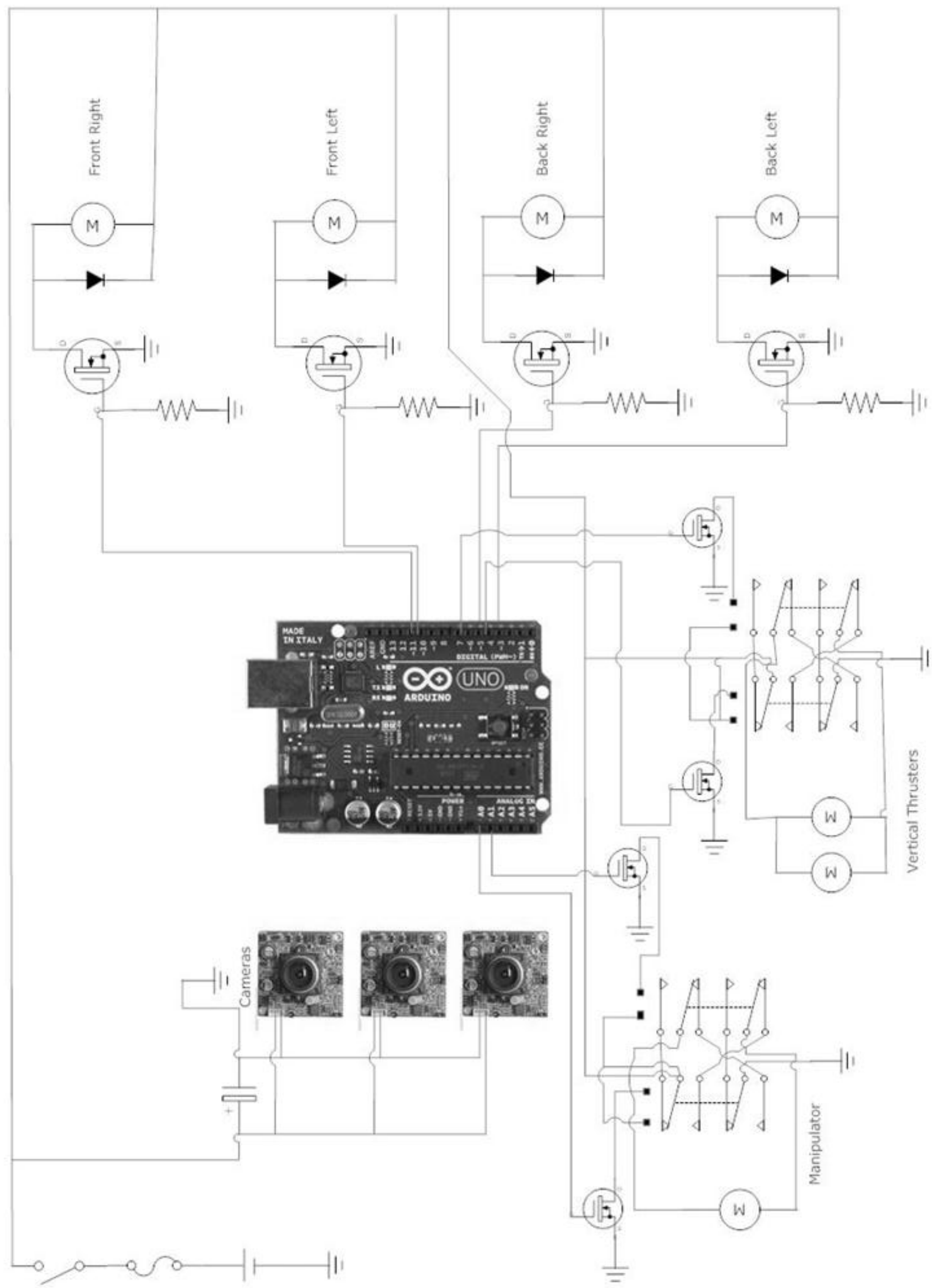
and

David Sampsell, for introducing us to the world of ROVs, having a vision to create a team, and helping in every piece of this project.

Appendix 1: Expense Detail

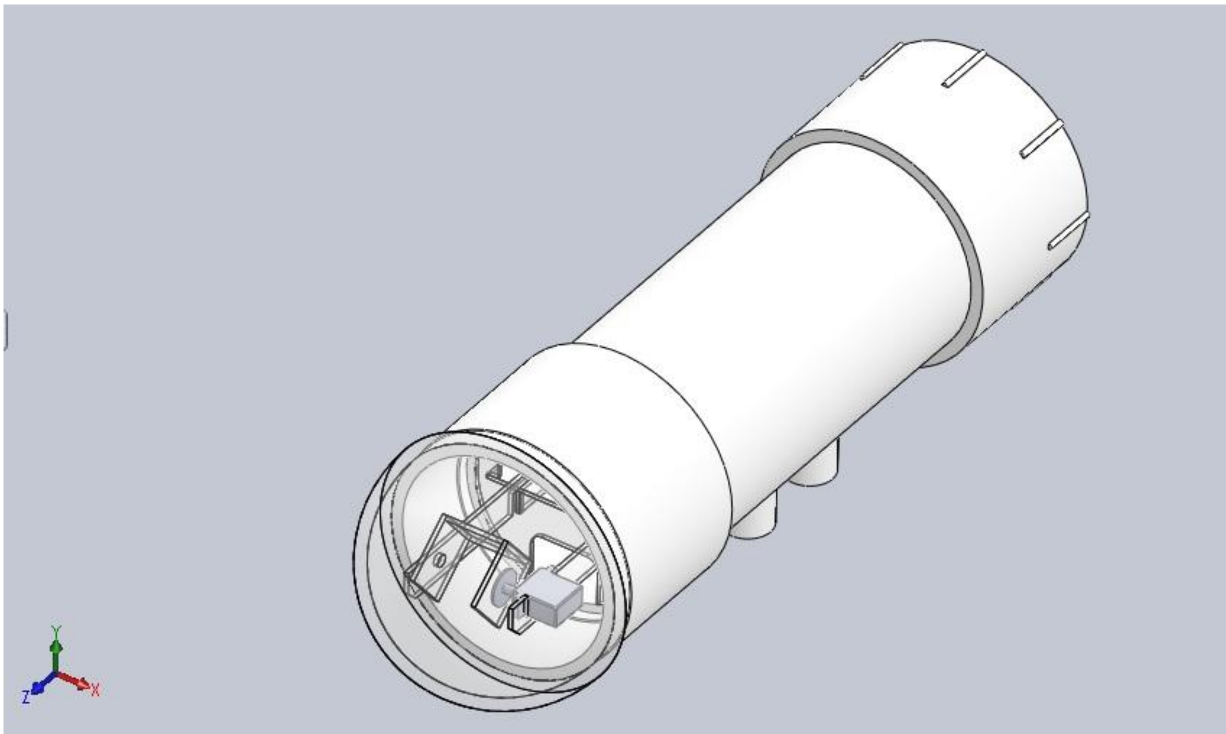
Date	Supplier	Items	Category	Subcategory	Total Cost
12-Jan-12	Home Depot	PVC pipe, fitting, clamp, silicone	Frame	PVC	$26.84
12-Jan-12	Home Depot	PVC pipe, fittings, cement	Frame	PVC	$26.53
13-Jan-12	Leaders Hobby	Prop adapters, Analog servo	Propulsion, Electrical	Propellers, Electrical	$30.18
13-Jan-12	Supercircuits	Color and B/W cameras	Electrical	Camera	$71.55
13-Jan-12	Surplus Shed	Acrylic dome	Pressure Housing	Dome	$17.72
15-Jan-12	Revolution Shop	Propellers	Propulsion	Propellers	$21.47
17-Jan-12	West Marine	Bilge pumps	Propulsion	Bilge Pumps	$205.12
6-Feb-12	Surplus Shed	Replacement-acrylic dome	Pressure Housing	Dome	$17.72
13-Feb-12	Home Depot	Polycarbonate sheet	Pressure Housing	Electrical	$21.18
14-Feb-12	Home Depot	PVC fittings	Pressure Housing	PVC	$6.32
14-Feb-12	All Electronics	Electrical components	Electrical	Electrical	$32.42
20-Feb-12	Plumbing Supply	Saddle T's	Pressure Housing	PVC	$15.11
22-Feb-12	MATE	Competition Entry Fee	Administrative	Entry Fee	$50.00
28-Feb-12	Home Depot	PVC pipe fittings	Frame	PVC	$11.45
5-Mar-12	Home Depot	PVC pipe, electrical wiring	Press House, Electrical	PVC, Tether	$96.48
8-Mar-12	Bell Hardware	Coupling	Frame	PVC	$0.83
29-Mar-12	Sears	PVC plug	Pressure Housing	PVC	$2.10
31-Mar-12	Sears	PVC plug and Teflon tape	Pressure Housing	PVC, Tape	$2.10
31-Mar-12	Bell Hardware	Marine epoxy paste, clamp, PVC	Pressure Housing	PVC, Epoxy, Clamps	$12.88
2-Apr-12	All Electronics	Electrical components	Electrical	Electrical	$20.20
3-Apr-12	Allen Supply	Pipe repair kit	Pressure Housing	Pipe dope, tape	$8.33
4-Apr-12	Staples	Poster board	Admin	Poster	$18.01
4-Apr-12	Home Depot	PVC, clamps, plastic sheet & foam	Frame	Floatation	$45.38
4-Apr-12	Ferguson	PVC fittings	Manipulator	PVC	$2.00
12-Apr-12	Sears	Spring and cable ties	Tools	Contact Probe	$2.64
12-Apr-12	Tractor Supply	Clear PVC, Disposable Syringe, Rubber grommets	Tools	Sample Probe	$6.01
12-Apr-12	Sparkfun Electronics	Robotic claw, magnet ring, voltage regulator, servo	Manipulator	Manipulator	$28.68
13-Apr-12	Walmart	Balloons	Tools	Sample Probe	$1.03
14-Apr-12	Sears	PVC Pipe, Pipe Fittings	Tools	Sample Probe	$3.49
14-Apr-12	A.C. Moore	Styrofoam balls	Tools	Lift Bag	$4.76
14-Apr-12	Lowe's	PVC pipe and fittings, tubing	Tools	Contact Probe	$6.92
14-Apr-12	Home Depot	PVC pipe and fittings, magnets	Tools	Magnetic Tool	$4.36
17-Apr-12	McMaster-Carr	Compass, tape measure	Tools	Tools-Meas/Comp	$35.93
18-Apr-12	Monoprice	USB cab conv, adaptor, binding post	Electrical	Electrical	$17.34
22-Apr-12	Sears	Threaded rod, Fasteners	Manipulator	Manipulator	$4.53
23-Apr-12	Physical Graffi Tees	Team T-shirt order	Admin	Team T-shirts	$170.00
23-Apr-12	Ferguson	PVC pipe and fittings	Manipulator	Manipulator	$1.72
24-Apr-12	Lowe's	PVC pipe and fittings	Tools	Magnetic Tool	$5.97
25-Apr-12	All Electronics	Heat shrink tubing, solenoid, relay	Electrical	Electrical	$20.80
26-Apr-12	Home Depot	Heat shrink tubing	Electrical	Tether	$5.27
29-Apr-12	Lowe's	PVC pipe and fittings	Frame	Ballast, Cam Mount	$49.16
30-Apr-12	Home Depot	Hinge and bolt	Tools	Sample Probe	$2.88
8-May-12	Radio Shack	Arduino	Electrical	Electrical	$37.09
				TOTAL =	**$1,170.50**

Appendix 2: Electrical Schematic

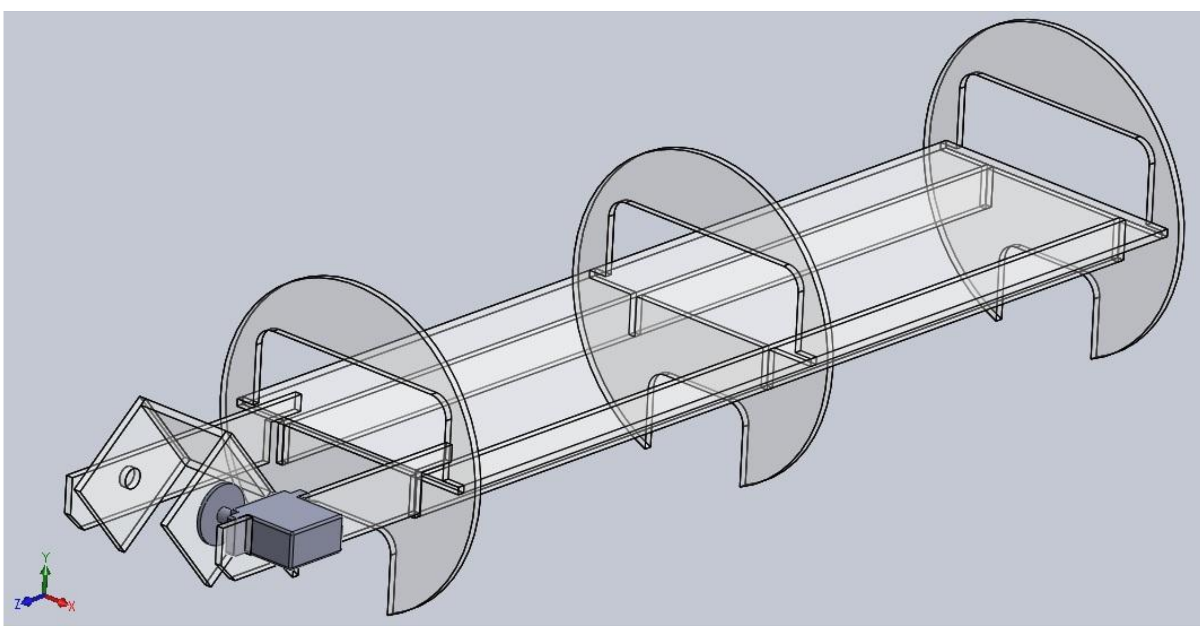


Appendix 3: Pressure Housing and Internal Structure

Pressure Housing



Internal Structure



Appendix 4: Schedule