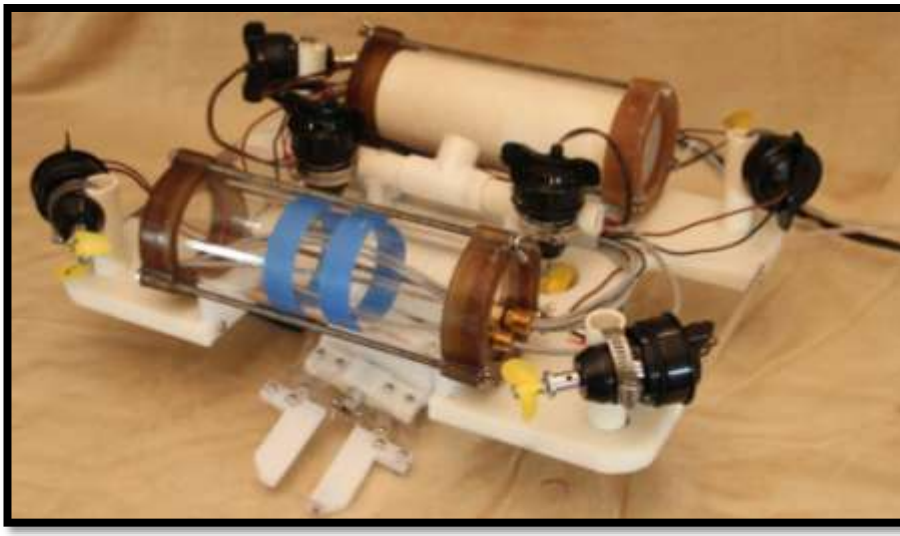
Pennsylvania ROV Engineers

▪ Excelsior Homeschool Cooperative ▪ Allentown, PA ▪



Team Members

- **David Sampsell**
  Chief Executive Officer, Grade 11
- **Ben Green**
  Lead Programmer, Grade 10
- **Stephen Gahman**
  Design Engineer, Grade 11
- **Micah Smith**
  Design Engineer, Grade 12
- **Natalie Sampsell**
  Tool Designer, Graphic Designer, Editor, Grade 9
- **Hannah Smith**
  Graphic Designer, Photographer, Grade 10
- **Matthew Buonanno**
  Mentor Programmer, Grade 12

Mentors

- Dave Sampsell
- Leonard Smith

Coaches

- Robin Sampsell
- Heidi Smith

MATE

International Competition

Technical Report 2013

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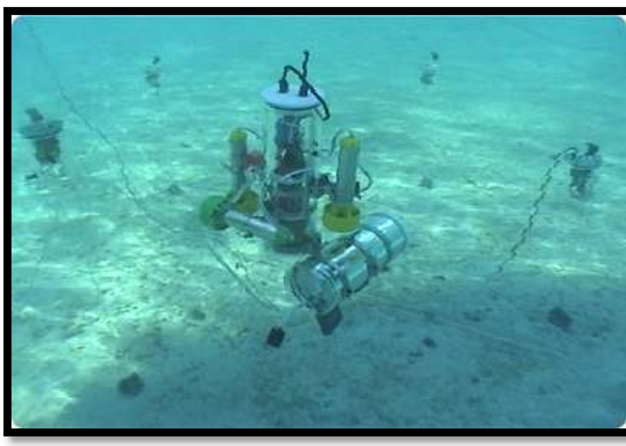
Abstract

A relatively young company currently in its second year of operation, Pennsylvania ROV Engineers, or pROVe, was originally incorporated to build a remotely operated vehicle capable of inspecting shipwrecks for environmental hazards. This year, the team focused on designing a completely new vehicle for the purpose of maintaining underwater sensor networks. These sensor networks play an important role in long term scientific observation and study on the sea floor, and at times require maintenance to continue functioning at full capacity. Our ROV (Remotely Operated Vehicle), Poseidon Mk II, incorporates a custom fully proportional lateral and vertical control system that allows for bidirectional control of all six vectored thrusters. This thruster arrangement, coupled along with a custom software application and Xbox 360 controller integration, provides a seamless connection between the pilot and the vehicle. A tilting color camera mounted inside the main acrylic pressure housing allows for a 180 degree vertical viewing area, and an optional second camera increases visibility.



Underwater Sensor

The Team

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

David Sampsell is a seventeen-year-old homeschooler currently in eleventh grade. He has been interested in ROVs for several years now, even more so after competing in last year's competition. When he is not building ROVs, he enjoys playing guitar with his friends, skiing, various team sports, and eating the world's best pancakes. He is the chief executive officer of the team.

Natalie Sampsell is fifteen years old and in ninth grade. She likes to listen to music, play various instruments, act, play basketball and soccer, read, and draw. She is the technical report editor, tool designer, photographer, and a graphic designer for the team.

Micah Smith is eighteen years old and a senior in high school. In his spare time he enjoys playing sports and playing guitar. Micah learned a lot last year that he has put into practice this year as a key design engineer. He plans to pursue engineering at Liberty University in the fall.

Hannah Smith is a 15 year-old sophomore who has been homeschooled all her life. When not doing work, she enjoys playing sports, such as soccer, watching movies with her family and friends, playing the piano and guitar, listening to music, and taking pictures. Hannah helped with graphic design, created the spec sheet, and was also a team photographer.

Matthew Buonanno is a seventeen-year-old senior. 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 intends to major in biomedical engineering, and possibly minor in computer science, at Drexel University.

Stephen Gahman is a sixteen-year-old junior. A one-year veteran of the MATE competition, he is part of the design team, and is again involved in the electronics aspect of the ROV. His future plans include a mechanical engineering degree of some sort, and he may also have the opportunity to play baseball in college.

Benjamin Green is a sophomore in high school and the newest member of our team. Several years ago, at summer camp, he received the nickname Kreg, which has been used prominently ever since. He enjoys programming, non-competitive soccer, video games, and chocolate milk. He is the youngest of five boys, and has been homeschooled since kindergarten. Being a Rita's Italian Ice employee, he likes to promote the specials with his family and friends in hopes of getting them to visit. He is considering studying computer programming, civil engineering – or both – in college. He's honored to be a part of pROVe, and is ready to win the gold!

Natalie Working

Stephen, Ben, David, and Micah

Getting Ready to Test

Budget/Expense Summary

The initial budget was $1,100 for total project spending, with actual expenses being very close to this target. We were able to reuse our tether, bilge pumps, and propellers from our first year ROV, Poseidon, but we envisioned a much more sophisticated control scheme which necessitated much research and development and the associated material costs. We were able to save a lot on the frame, tools, and pressure housing by designing them ourselves and making them from basic building materials. Since everyone was involved with the work as a whole and actively contributing, this allowed for many opportunities for ingenuity, which led to being more efficient with our available funds. Following are the income summary and the budget and expense summary. The estimated cost for participating in the International Competition is $4500. Refer to Appendix 1 for expense details and Appendix 2 for a summary schedule.

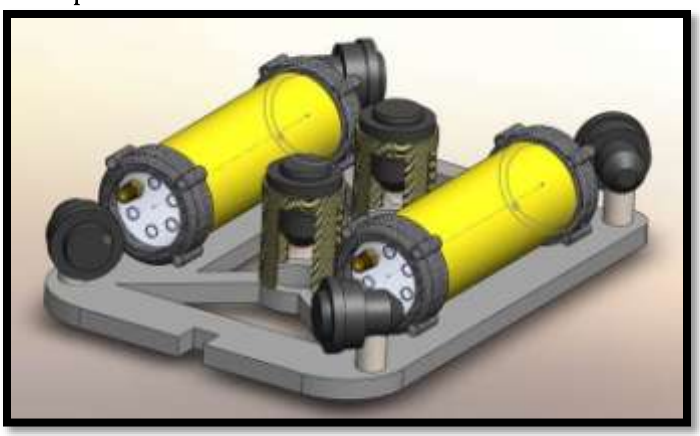
INCOME SUMMARY		
Sponsors	**Donations**	**Value**
Home Depot	Gift Card	$50.00
DSS - Solidworks	Free Software w/ FMV ~ $99	$0.00
Individuals	Monetary Gifts	$1,058.55
Total		$1,108.55

BUDGET AND EXPENSE SUMMARY			
Category	**Poseidon Re-use Value**	**Expenses**	**Budget**
Electronics & Cameras	$70.00	$562.50	$370.00
Frame	N/A	$44.51	$100.00
Pressure Housing	N/A	$184.42	$250.00
Propulsion	$212.00		
Tools	N/A	$19.11	$80.00
ROV Subtotal	**$282.00**	**$810.54**	**$800.00**
Administrative	N/A	$298.01	$300.00
Project Total		**$1,108.55**	**$1,100.00**
Value of Poseidon Mk. II		**$1,092.54**	

Design Rationale: ROV Components

Frame

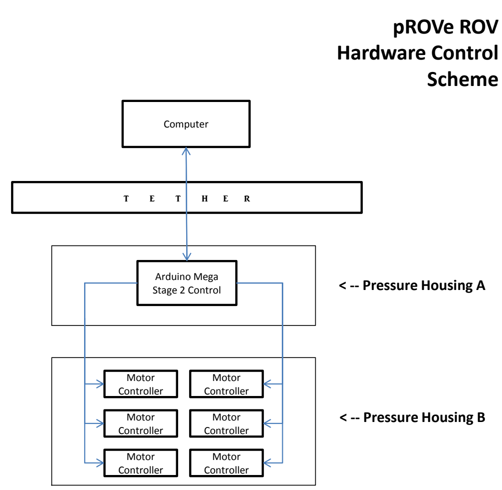
The frame for the ROV is composed around a base cutting board made of 3/4 inch thick USA poly. This base is 28 inches wide by 15 inches long. The design was chosen to keep a more compact and hydrodynamic ROV while also providing great stability and control. The USA poly provides a very strong base while also being quite easy to work with, allowing us to match our designs. The cutting board was also very cost effective for our budget as was the PVC to make the motor mounts for the thrusters. We also purchased ½ inch cutting board of the same USA poly that was used for creating the mounts for the pair of pressure housings and for the manipulator.

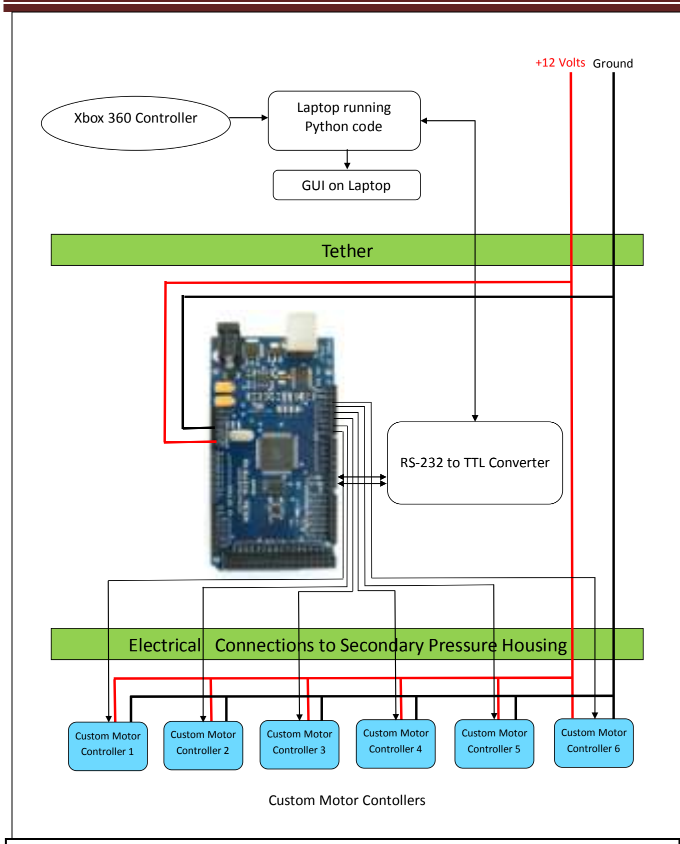


Poseidon Mk. II

Electrical

The control system on Poseidon Mk II has three basic components: the laptop and Xbox 360 controller running software on the surface, an Arduino Mega onboard the ROV and our custom built motor controllers, also located onboard the ROV, though in a different pressure housing. The system starts with the Xbox 360 controller receiving human input, and sending that data on to the computer, where it is processed, and speeds and directions for the motors are calculated. From there, a RS-232 serial connection relays these values to the Arduino Mega onboard the vehicle. The computer program also receives information on things like voltage levels from the Arduino. Since all the number crunching takes place on the computer topside, all the Arduino has to do is receive the values for the thrusters and the camera servo and then send them out to the appropriate devices. Last year, we achieved proportional unidirectional control of our horizontal thrusters using a single N-channel MOSFET for each motor. For the vertical thrusters, we used relays wired in an h-bridge configuration. This year, however, we wanted proportional control of all our motors in both directions, which would allow us to access the full potential of a four thruster vectored setup. It would also allow us to drive our vertical motors proportionally, which was not possible with the relays we used last year. We considered purchasing commercially available motor drivers, but those available that suited our technical specifications were pricey, so we decided to build our own. A MOSFET h-bridge configuration was soon decided upon, mainly because of the low on state resistance of MOSFET transistors. We put a lot of time into making this work, and experienced a lot of setbacks, but in the end we had a very versatile motor controller built completely from scratch. Though not as cost effective as we thought it would be due to research and development costs, the knowledge and experience gained far outweighed the cost.





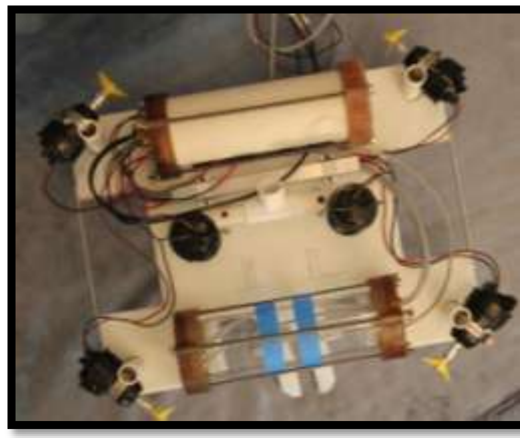
Poseidon Mk. II Motor Control Electrical Schematic

Ballast

For ballast, the ROV pressure housing design provides natural buoyancy. Our plan is to securely attach weight to the bottom of the ROV and to add flotation to the top as necessary. Last year's similar buoyancy system worked well and we didn't need the complexities of a variable buoyancy ballast system, as there was no apparent benefit of choosing a different system.

Video Systems

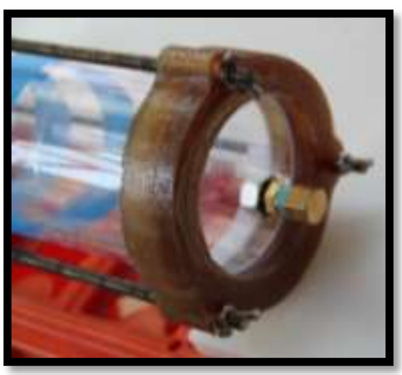
While we planned on having three cameras in total last year, we were only able to compete with one camera, because of difficulties with interference and failed waterproof housings. However, since our main camera was able to tilt 180 degrees, we still had quite adequate visibility. In light of this, it was important that our main camera again be able to tilt up and down, allowing us to see more with one camera than with several stationary cameras, and without the added complexity of having multiple video feeds. To do this, we housed our main camera in our primary pressure housing, which was machined out of optically clear acrylic. Since the camera was pointed out the side of the housing, all we had to do was fabricate a mechanism that allowed it to tilt up and down. A servomotor with a bracket for the camera fit the bill nicely, and allowed a good view of what was above the vehicle all the way down to looking at the manipulator. At the surface, the video feed could be displayed on either a laptop computer, or the MATE provided monitor.



Top View of ROV with Clear Pressure Housing for Camera and Controls

Pressure Housing

We have always felt that having control electronics onboard the ROV is critical to a successful design for several reasons. Firstly, it allows for a thinner tether – only two large wires for power and one small communication line are necessary with this arrangement. Secondly, since the motors are controlled from the vehicle itself, we can supply the vehicle with power via two large wires, versus supplying each motor individually. This causes less voltage drop overall, and thus more power actually gets to the thrusters. In addition to allowing for a more powerful and maneuverable vehicle, onboard electronics allow for future upgrades or modifications without modifying or adding wires to the tether. Additional components can simply hook up to the power and control systems already in place on the vehicle. Because of these advantages, sturdy, reliable watertight enclosures are needed to house the electronics required by a system such as this. Last year, our team elected to build a single pressure canister out of 4" PVC pipe, with an acrylic dome mounted on the front to allow for a tilting camera. While it did eventually work, initially waterproofing this canister was quite difficult. In addition, removing components on the vehicle wired into this housing was difficult, as was removing the electronics for maintenance or modifications. Because of these drawbacks, it was decided that a reliable, modular pressure housing design was necessary. To accomplish this goal, we decided two smaller pressure housings would work best. One housing would house our microcontroller and camera, while the other would contain our motor controllers. To seal the housings, we used o-rings sandwiched between the ends of the housings and a Lexan disc, through which wires could pass. For sealing the actual wires, we potted them in custom made waterproof connectors, which also used o-rings, allowing us to easily remove any individual motor on the vehicle. To hold the Lexan disks tight against the ends of the housing, we casted fiberglass end caps for either side, connected to each other by three stainless steel threaded rods. Overall, the system worked quite well. The o-rings provide a reliable and easily removable seal for each component, and since both pressure housings use the same parts, they are largely interchangeable in case of breakage or upgrades. Refer to Appendix 3 for CADD representation of pressure housing.



Custom Pressure Housing End Cap

Tether

Our tether was designed to be thin, flexible, and maneuverable. Our 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.

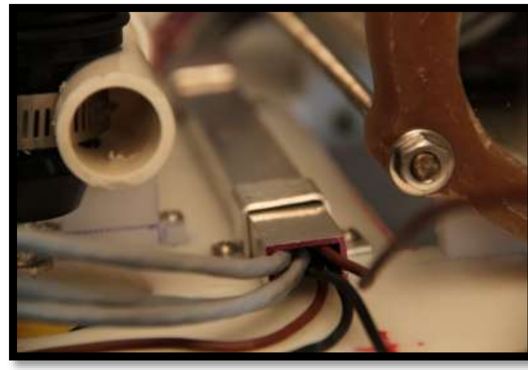
Propulsion

For propulsion, it was decided to reuse the bilge pumps from our first year ROV. We used 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 we used 1000 gph pumps, because they would be holding up the weight of any objects our ROV would pick up.

Protected Vertical Propellers

Programming

The team decided that the Xbox controller was the obvious choice for a good remote controller. David and Matthew, the Senior Programmer, made an executive decision to switch from the Processing language, which was used last year, to Python. This was a major decision, which proved to be a smart switch. Python is a more flexible language, and Ben had experience with Python, which made it easier for him to write the code. Figuring out how to determine the correct horizontal motor directions and speeds, taken from the x-y coordinate of the left joystick, proved slightly difficult at first. David, Matthew, and Ben overcame that obstacle just to reach another hurdle: the Xbox controller outputs an x-y coordinate inside a square, not a circle, as expected. After intense deliberation, that hurdle was also jumped. Next was the left joystick, controlling on-the-spot turning, the d-pad, controlling the main camera servo and the manipulator motor, and the triggers, controlling vertical movement. Shortly, we had a finished program. Next was the Graphical User Interface (GUI). Due to an excess of time and talent, Ben decided to figure out how to make a GUI with a visual representation of the ROV moving around on the screen. After a few hours of failed attempts and Google searches, he found a good example code that drew a rectangle, moved the rectangle, redrew the rectangle, and repeated. This was a simple, easy-to-use GUI. He adjusted the example code for use with the main code. This GUI also displayed the speeds and directions of the motors in the corners of the screen. The entire GUI was set to refresh 20 times every second, 20 frames per second. Refer to Appendix 4 for software flow charts of stage 2 control and custom motor control.



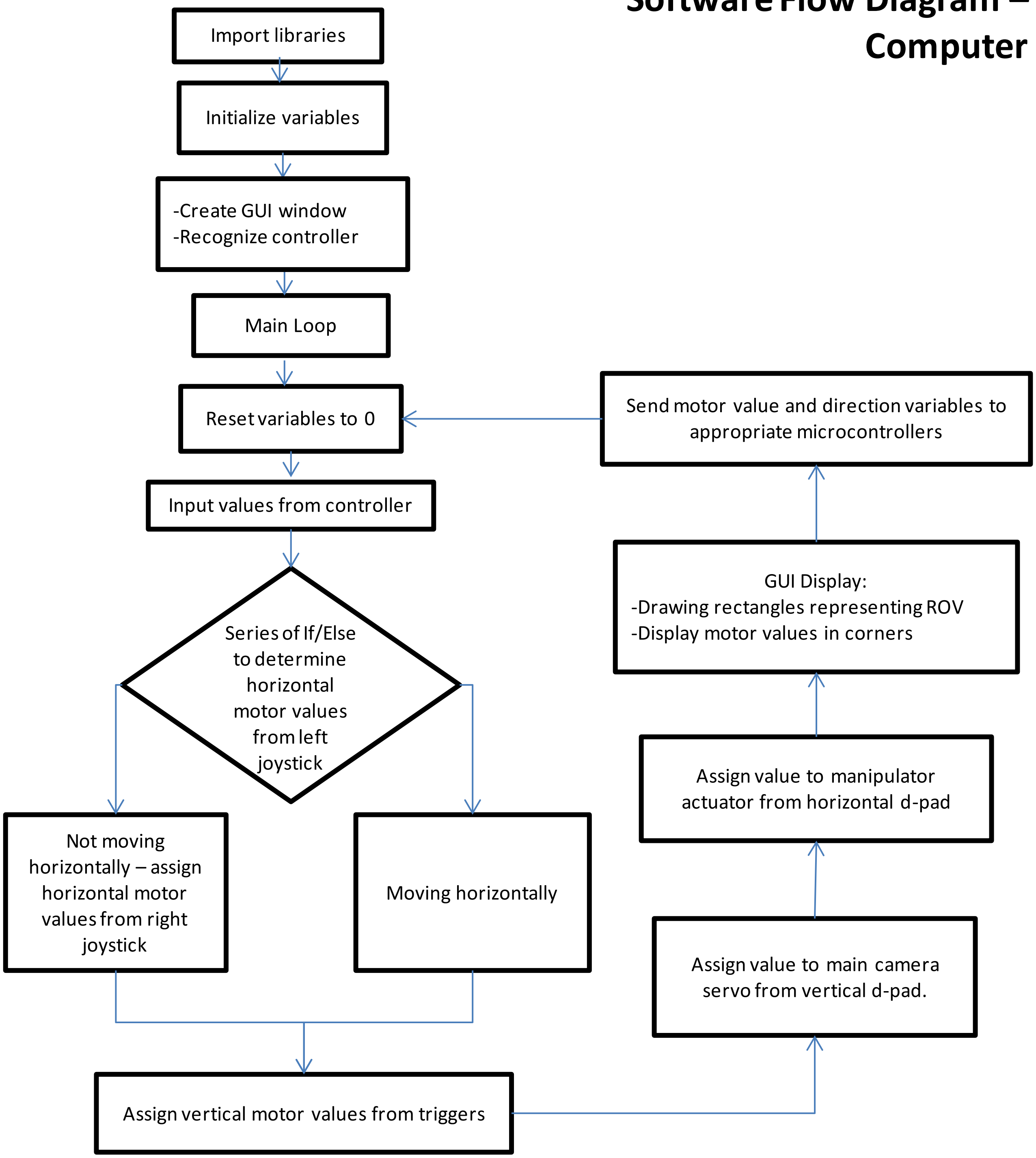
Integrated Cable Containment System

Troubleshooting Techniques

As this was our second year of competition, our team already had considerable troubleshooting experience. Mainly, troubleshooting was necessary in the design of the electronics and computer programs. When we ran into a problem, we broke it down logically. Each step of the process was then tested and analyzed, until the offending portion of code, electronic circuitry, or other problem was identified. At this point, we decided whether we could fix the problem, or whether or not a different overall approach was necessary. For example, we ran into a problem programming our motor controllers. At a certain position in the program, several variables were being reset. By breaking down the problem and eliminating extraneous information, we were able to determine exactly where in the program this was happening and fix the problem. Another excellent example in which we ran into trouble was in the design of the motor controllers. Because of the custom design of the motor controllers, we designed, fabricated, tested… repeatedly.

Following is a summary of the computer's control scheme.

pROVe ROV
Software Flow Diagram – Computer



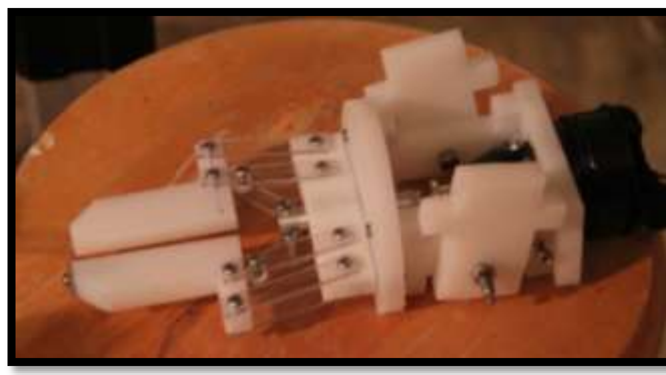
Challenges

Many challenges arose while designing and constructing this vehicle, mostly because of the complex nature of the waterproof housings electronics that went into Poseidon Mk II. On an initial test of the waterproof housing, water leaked inside. After breaking down the housing, sanding the o-ring seal surfaces, and putting it all back together the housing withstood pressures over twice as high as it would experience during the actual competition. Because we had decided to design and build our own motor controllers, we ended up having a lot of problems. Eventually, the main problem was narrowed down to a MOSFET driver chip that we had incorporated into our design. For some reason, it just was not working at all, and would fail in mysterious ways. When the chip was replaced with another alternative, the motor driver finally worked.

Payload Description

Mission Task 1: Complete a Primary Node and Install a Scientific Instrument on the Seafloor

After studying the missions, the design team decided that a well-functioning manipulator would be critical to maximize our score. Last year, we found that ordering a pre-made claw and attempting to modify it to fit our needs proved rather difficult, so we decided to construct this year's manipulator completely from scratch. After constructing a few different designs on Solid Works, we selected what we believe to be the best one. A bilge pump turns a threaded shaft that runs inside a ½ inch aluminum pipe, which has a nut secured at one end; as the shaft spins, the pipe moves back and forth. This pipe is connected to two arms, which are in turn connected to the main structure of the manipulator. The back and forth motion of the pipe causes the manipulator to open and close accordingly, producing the grabbing force necessary to pick up and carry the objects in the missions. The main structure of the manipulator is constructed from a ½ inch thick cutting board (USA Poly), and the moving arms are fabricated from a Lexan sheet. Stainless Steel screws hold the frame together, promising a long lifetime. The entire device is mounted on the bottom of the ROV so that it protrudes out the front end, directly underneath the camera. There is also a functional utility hook (FUH) protruding from the left arm of the manipulator to use to pick up or move objects. Mission task one includes a lot of picking things up and moving them around. We thought that the best way to complete these tasks would be to have the FUH for basic moving and a manipulator for adjusting the items to fit in their proper spots. Refer to Appendix 3 for a CADD representation of the manipulator.



Manipulator

Mission Task 2: Design, Construct, and Install a Temperature Sensor over a Hydrothermal vent opening and Measure Temperature over Time

To make our temperature sensor we used TMP36 as our thermistor. This is an analog device that has a very wide range and that uses a solid state technique to determine temperature. The design concept is that as the temperature increases, the voltage across a diode increases as a known rate. In our sensor we measured the voltage change with a volt meter and correlated this to the temperature change. In order to calibrate our sensor, we used a known temperature device to measure room temperature, refrigerator temperature, ice water, and freezer temperature. For each of these conditions we also measured the voltage across the TMP36 and established a voltage versus temperature correlation. Our sensor is waterproofed with shrink wrap wire tube with epoxy potting material on top of that and a flexible drinking straw covering it all. The design is powered by a 9 volt battery reduced to 5 volts using a linear voltage regulator. This system is also protected with a three amp fuse. We added a 10k resistor to the voltage output to stabilize the signal. For maximum accuracy and stability over time, we decided to insert our sensor through a hole drilled in 1 and ¼-inch PVC tube. We would then use our manipulator to position the tube over the thermal hydrothermal vent opening. Our sensor is attached to a 35 foot category 5 cable separate from the ROV that uses three twisted pairs of wire. The cable is attached to a volt meter at the surface where we will record the change in voltage and determine the temperature using the correlation chart that we created at the needed increments of time.

Temperature Sensor

Mission Task 3: Replace an Acoustic Doppler Current Profiler on a Mid-Water Column Mooring Platform

Similar to the items under mission task one, mission task three involves different activities that use the FUH and the manipulator, or some combination of the two. More of the items include using the manipulator and the ROV simultaneously, for example, the opening of the door. With the camera located in such a way that we will be able to see what we are doing with the manipulator at all times, this should not be a hard task.

Mission Task 4: Remove Bio-fouling from Structures and Instruments within the Observatory

The removal of the bio-fouling will require the use of the manipulator and/or the FUH to lift/hook and move them. The speed of the smaller design of our ROV will be helpful in moving these efficiently.

Future Improvements

One thing that we hope changes in the future is the fact that we researched and designed a completely new ROV two years in a row. This left us with minimal time for actually testing the ROV and practicing missions each year. We hope that this year's design will work well enough that we could use it as a starting point for next year, so that we don't have to start from scratch again.

We have many ideas for technical improvements, but one critical one comes from our concern about protecting our complex electrical circuits. We hope to test the polarity of the power wires to the ROV and have a green light that indicates that the ROV is ready to operate, with a red light or no light to indicate that it is not ready to operate.

Lessons Learned

As a team we learned to be flexible this year and not just work on whatever our role was. We had to learn to be willing to help wherever, do whatever job was put in front of us, and not just our specialty. We should have given ourselves more time at the beginning of the year to allow more time for testing in a pool. Another lesson was learning to question design decisions before fabrication to predict problems and how to eliminate them before actually facing them. This practice led to more effective initial designs. Our flexibility, desire to work hard, and thinking about future challenges helped us overcome our lack of time and busy schedules.

Reflections

"When I learned that we were getting the team back together for a go at MATE 2013, I was really excited. MATE 2012 was an incredible experience for me, and I was glad to have another chance to work with an ROV. My role this year was very different from my role in 2012; instead of taking on the whole control design and programming of the ROV myself (with help from David), I acted more as a mentor for Ben. I first coded a prototype fallback control scheme in case we were unable to create a more robust one in time for the competition. Although we ultimately didn't use it, I discovered something both valuable and unexpected: I saw how much I really had learned. Last year, I wrote a similar program in Processing; this year, I wrote using Python, and what took weeks - even months - in 2012 took only a few days in 2013. If there's anything I wanted to gain from MATE, it's experience - and I clearly did, and continue to do so. I helped Ben get started, and assisted him with some debugging and code analysis. It was a new experience to work both as a guide to and a peer with him, and I'm glad for it: experience is a valuable tool."

Matthew Buonanno

"I enjoyed this experience a lot more as a second year team because I had a better understanding of the amount of work that goes into a project like this. The workload was similar to last year however we learned to work more efficiently as a team. I believe our team was able to succeed last year and will do well this year because of our team's joint desire to be successful and to overcome the challenges placed in front of us. I really enjoyed participating on this year's team and really appreciate the opportunity to be a part of pROVe."

Micah Smith

"This experience has been amazing. Being a graphic designer on the team has built my knowledge in this specific field and may open opportunities later in my life. I have thoroughly enjoyed working with this team through success and failure, and I am excited to see the results of our hard work."

Hannah Smith

"Last year, we had an idea of what we wanted the final product of the ROV to be like, but most of the design occurred during the construction. This year, we decided to change that by making a complete design, then beginning construction. Predictably, we spent too much time designing, not leaving as much as we would have liked to build. Should we participate in this competition next year, I would like to find the happy medium, leaving enough time for both design and construction."

Stephen Gahman

"This year, I wanted a job that was a little more technical in addition to my work on the technical report and in graphic design with the poster and t-shirts. I was finally given the task of designing and building the temperature sensor. I really have enjoyed my work on the team and am glad to have had a part in this valuable experience."

Natalie Sampsell

"Nothing ever works the first time, and though this is frustrating I have come to realize that is to be expected and is a part of creating something new."

David Sampsell

"Early this year, David asked me if I wanted to participate as the Junior Programmer. I remembered hearing bits and pieces about the pROVe team the year before, but wasn't really sure what it was all about. After David explained a little about the whole competition, I gladly agreed. I already had some programming experience, as I am in a class learning the Python language. Conveniently, David and Matthew, the Senior Programmer, made decided to switch from the Processing language to Python. This was nice, because it meant I wouldn't have to learn the Processing language. Looking back, I'm glad I joined the team, and I think it has been a valuable experience."

Ben Green

Teamwork

Our team chemistry really began last year when nothing seemed to go right, but through perseverance we stuck together and obtained success. However, last year's meetings proved to be quite unproductive, as we would all come to the meetings but would work on things which only required two or three of us. This year, after establishing each member's individual role on the team, we set up meetings for smaller groups such as the design team, the building team, or the programming team. By meeting in this way, our time together became much more efficient. Also, it caused us to trust and depend upon each other; since we were responsible for separate aspects of the ROV, we did not wish to let down the rest of the team by not fulfilling our responsibilities. Furthermore, as the separate aspects of the ROV were completed, we trusted that those responsible accomplished the final product to the best of their ability, in order to make the ROV as quality a vehicle as possible. Finally, this team wouldn't exist if we couldn't work around our schedules. We are all high-school students, and most of us have jobs or play sports or both. Only by working together were we able to set aside time to meet, enabling us to participate in this competition

Micah and Stephen with Safety Glasses

Safety

Basic safety practices were regularly followed during all stages of ROV fabrication and use. This included wearing safety glasses and closed-toes shoes, using power tools properly, and taking precautions when using tools or doing any testing. 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 attached kort nozzles on the horizontal propellers and we designed the frame to protect the vertical propellers, which in turn protects body parts, wires, or anything in the water from getting caught from the spinning blades. The vehicle was designed with grab handles on both sides and the back to help maneuver the vehicle in and out of the water efficiently and safely. The vehicle is also equipped with a central safety bracket which holds the vertical thrusters and allows a person to get a sturdy hold on the vehicle. Our whole ROV was designed to maximize safe operating features.

Grab Handles – ROV Top and Three Sides

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- http://www.homebuiltrovs.com

Acknowledgements

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We also 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,
and our families who supported our work:
Buonanno, Gahman, Green, Sampsell, and Smith.
And as always, we would like to thank David Sampsell, our CEO, who spent countless days and hours working with our team and inspiring us when things didn't go right, as they often did.

Pressure Housing

Propeller

Ecclesiastes 4:9-10: "Two are better than one; because they have a good reward for their labour. For if they fall, the one will lift up his fellow: but woe to him that is alone when he falleth; for he hath not another to help him up."

Appendix 1: Expense Detail

Date	Supplier	Items	Category	Total Cost
13-Jan-13	Chef Depot	Poly boards - 2	Frame, Manipulator	$47.25
24-Jan-13	Home Depot	Fittings	Pressure Housing	$4.21
21-Feb-13	McMaster-Carr	Acrylic, Clear PVC	Pressure Housing	$93.38
7-Mar-13	Home Depot	Fittings	Pressure Housing	$4.48
8-Mar-13	NewEgg	Xbox controller, USB serial converter	Control System	$55.55
8-Mar-13	Digi Key	Electronics	Control System	$96.75
27-Mar-13	Digi Key	Electronics	Control System	$220.23
3-Apr-13	Radio Shack	Arduino	Control Stystem	$62.00
7-Apr-13	Sears	Fittings	Pressure Housing	$5.27
8-Apr-13	MATE	Competition Entry Fee	Administrative	$75.00
10-Apr-13	Radio Shack	Compass	Tools	$6.86
18-Apr-13	Lowe's	Aluminum Angle	Frame	$9.51
21-Apr-13	Autozone	Fuses	Control System	$15.88
24-Apr-13	Home Depot	Fittings, Fiberglass	Pressure Housing	$77.08
25-Apr-13	Digi Key	Electronics	Control System	$104.69
25-Apr-13	Physical Graffi Tees	Team T-shirt order	Administrative	$145.00
27-Apr-13	Staples	Poster board	Administrative	$18.01
6-May-13	Radio Shack	Electronics	Control Stystem	$7.40
10-May-13	Staples	Poster printing	Administrative	$60.00
			TOTAL =	**$1,108.55**

Items re-used from Poseidon

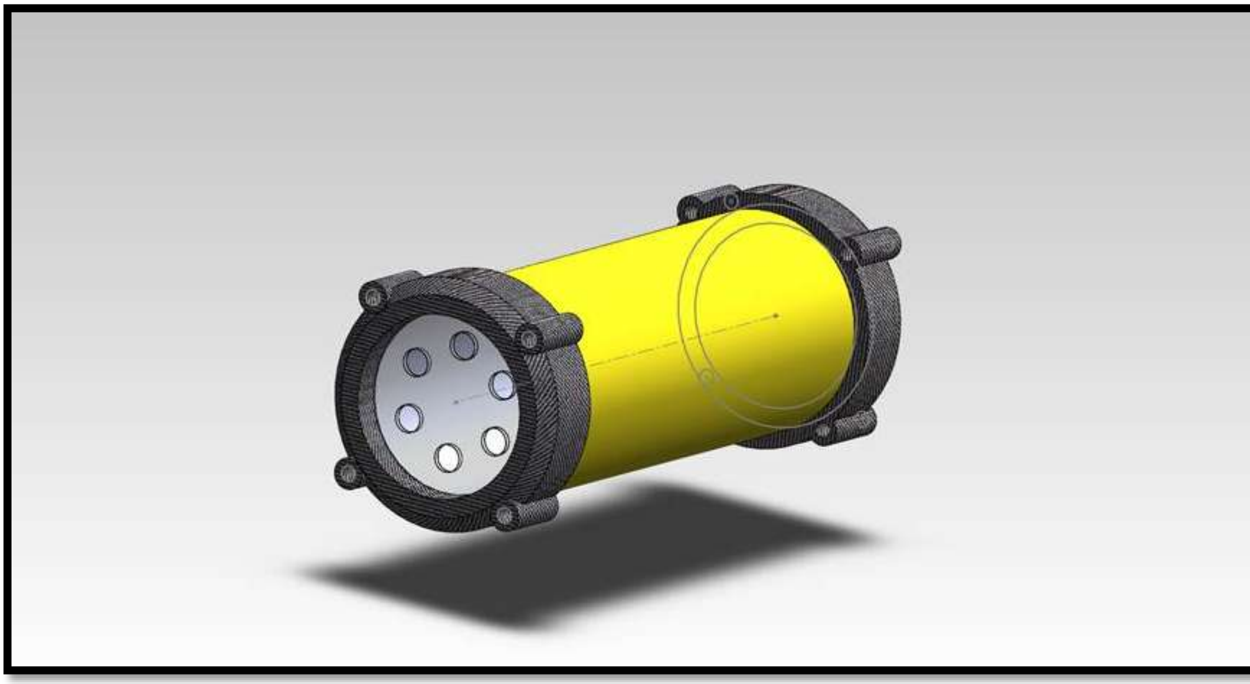
Items	Category	Total Cost
Bilge Pumps	Propulsion	$180.00
Tether	Tether	$70.00
Propellers	Propulsion	$32.00
	TOTAL =	**$282.00**

Appendix 2: Schedule

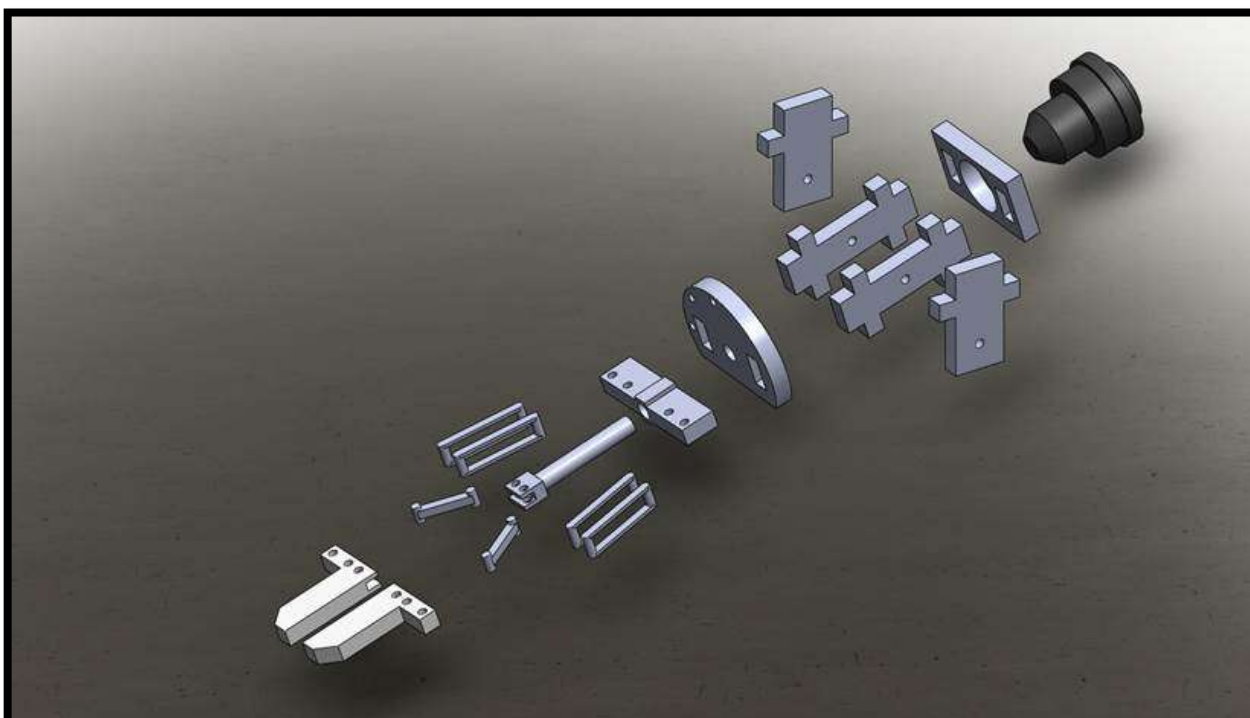
pROVe MATE Project Schedule 2013																			
		Duration																	
			Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 36
No	Description	Wks	23-Jan	30-Jan	6-Feb	13-Feb	20-Feb	27-Feb	5-Mar	12-Mar	19-Mar	26-Mar	2-Apr	9-Apr	16-Apr	23-Apr	30-Apr	7-May	14-May
1	MATE 2013 Missions Review	1																	
2	Overview of Competition and Goals	1																	
3	MATE Rules/changes	1																	
4	Marketing package to develop sponsors	1																	
5	Budget	1																	
6	Initiate design concepts & research	3																	
7	Presentations to potential sponsors	3																	
8	Frame, presure housing, controls R&D	6																	
9	Electronics R&D	11																	
10	Build ROV	5																	
11	T-Shirt design	2																	
12	Finalize ROV	2																	
13	ROV Testing and Practice	3																	
14	PA Regional Competition	0																	

Appendix 3: Pressure Housing and Manipulator

Pressure Housing

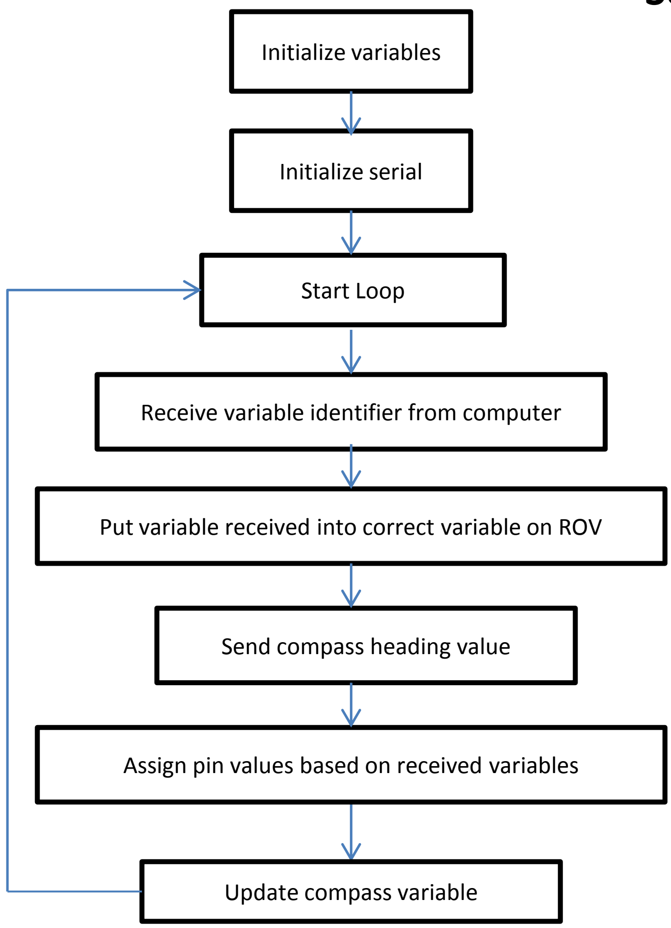


Manipulator



Appendix 4: Flow Chart

pROVe ROV Software Flow Diagram – Stage 2 Control



Custom Motor Control