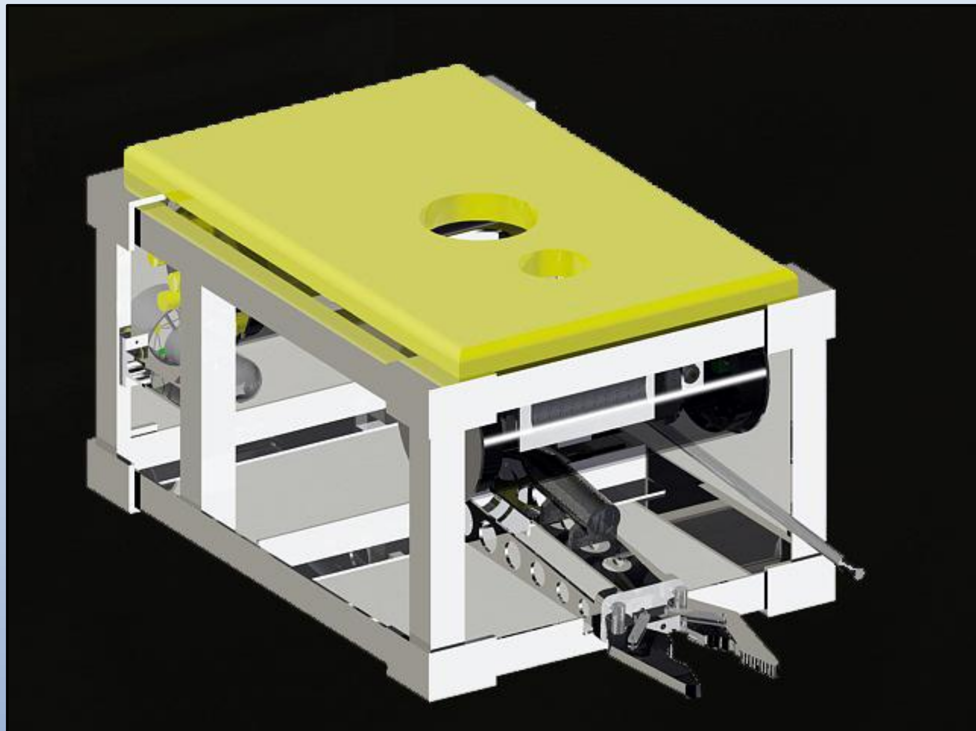
S.U.R.E.

Seawolf Underwater Robotics Engineering

Copiah-Lincoln Community College - Wesson, MS

Seawolf 1



S.U.R.E. Team Members

CEO: Aaron Barr, Drafting
CFO: Zach Fetcko, Business
Design Engineer/Pilot: Chris Herring, Drafting
Electrical Engineer: Chris Olander, Electronics
Safety Officer/Technical Writer: Charles Furr, Electronics
Public Relations: Christy Wright, English

Justin Alexander, Electronics
Steven Schepers, Physics/Engineering
Levi Weeks, Physics/Engineering
Reginald King, Physics/Engineering
Kyle Chrestman, Machining
Keith Smith, Electronic

Instructors/Mentors: Kevin McKone - Physics, Carey Williamson - Electronics, Wes Burkett, Bruce Thomas - Drafting and Design, Bo Johnson - Precision Machining, Richard Baker - Business, Nicole Donald - English

Abstract

The Seawolf 1 is a light duty inspection/observational class ROV constructed specifically for the purpose of taking part in the MATE International ROV competition. Its design, refinement, and construction are the result of the collective imagination, innovation, and effort of the Seawolf Underwater Robotics Engineering (S.U.R.E.) team members.

Drawn in AutoCAD 2012, the Seawolf 1 is designed with an eye toward versatility and adaptability. Its open, box frame, aluminum angle iron design is an intentionally universal one. With this multipurpose base to build on, the ROV can be more easily tailored to perform specific missions. Adding to this flexibility are several custom designed features.

Clear, cast acrylic electronics and camera/lighting housings were created to ensure maximum visibility coupled with minimum reflectivity. The sturdy, specially machined aluminum manipulator arm, a custom design based on fundamental concepts, can be utilized for a variety of tasks requiring physical contact with a specific target. Adjustable thruster mounts allow for fine tuning of the craft's propulsion system, consisting of four Seabotix thrusters, to suit changing conditions. Lastly, the Seawolf 1's power supply, electronics, and control devices were specifically conceptualized and engineered for safety, reliability, and ease of use.

The S.U.R.E Seawolves, under the auspices of Co-Lin Community College, are proud to present this machine as their first ever entry into the MATE competition. With its adaptive basic designs, and rugged, solid construction, the Seawolf 1 is an ROV that comes ready to get the job done, whatever that job may be.

Copiah-Lincoln Community College's S.U.R.E. Seawolves

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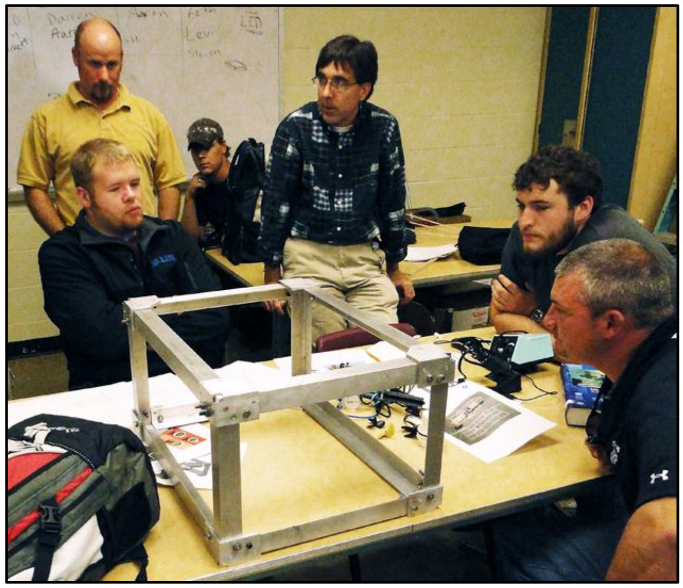
Design Rationale

Overview

From the very start of the project a great deal of thought and planning was applied to both the overall design of the Seawolf 1, and to each separate component that would need to be created or purchased. This process was a long and careful one, consisting of many sessions of brainstorming, rough drafts, research, and trial and error experimentation. Whenever possible, components were constructed from the ground up by S.U.R.E. team members.



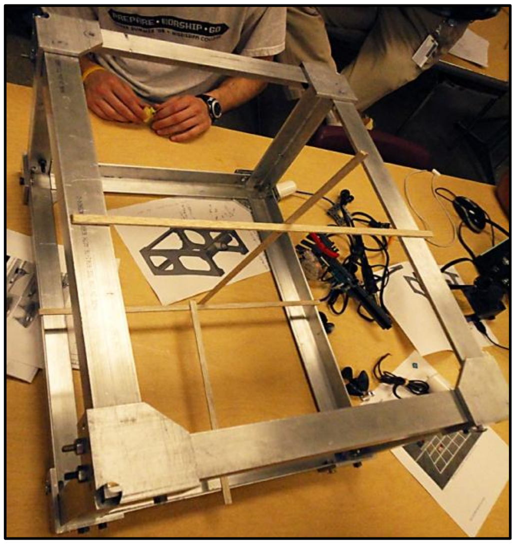
Team members and mentors inspecting the basic framework for the Seawolf 1 at an early design meeting.

Consideration was given not only to each individual operation and task that the ROV would be required to complete, but also to how to best bring these disparate parts together into a working whole.

In brief, each proposed component of the Seawolf 1 was designed to mesh into a functional, efficient, and economically feasible whole.

Frame

The basic framework that will hold all of the systems and tools is undoubtedly one of the most important design elements of any ROV. The Seawolf 1's frame design was laid out originally in AutoCAD 2012. It was decided early on to keep the ROV's basic foundation as simple and uncluttered as possible, to allow room for possible future add-ons and upgrades. Towards this end an open, box-frame design was selected. Aluminum angle stock was chosen as the base construction material for its lightness, durability, and cost effectiveness. Choosing this material



The Seawolf 1's basic frame, with balsa wood sticks being used to simulate possible thruster mount placement.

A before and after view of the aluminum blocks used in fashioning corner pieces for the ROV frame.

would also allow the lion's share of the milling and cutting necessary to be done on site by S.U.R.E. team members.

Beginning with a single, 7.62 m length of the metal, team machinists cut twelve separate pieces for use as the horizontal and vertical struts making up the outer frame, four of 46 cm, four of 30 cm, and four of 60 cm. Solid blocks of aluminum were then milled down into corner pieces into which the struts were fitted and bolted.

Later, as the design was refined and experimented with, three additional 30 cm vertical and two 46 cm horizontal cross-braces were machined and inserted for use as thruster mounting supports. The thruster mounting supports and the accompanying 2.54 x 18.11 cm mounting blocks themselves are designed and drilled out to allow for adjustment in the horizontal and vertical axes, so that the propulsion may be fined tuned.

As the final touch for the frame, four aluminum clips were constructed and fastened to the upper, length-wise, struts, to ensure an easily adjustable method for securing the ROV's syntactic foam.

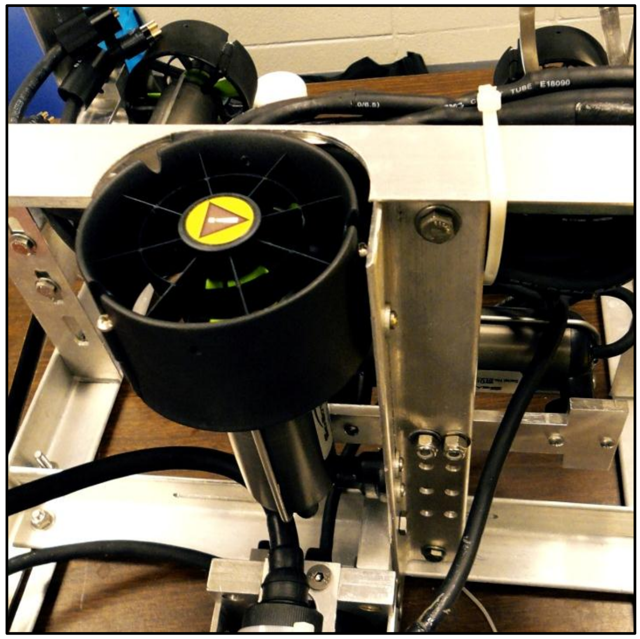
Thrusters

Since one of the most useful aspects of an ROV is its mobility, the number and optimal positioning of the thrusters to be used was one the foremost issues discussed in the team's early meetings, after the basic frame design was decided on.

One of the most popular of the original ideas was a six thruster set-up. This design would have included not only two up and down thrusters, but also matching sets of front and rear vectored thrusters. Upon due consideration, however, it was decided that with a little experimentation a way could be found to achieve approximately the same level of functionality and control using only four thrusters.

After several weeks of research into the specifications of the thrusters compatible with the teams needs, it was decided that four Seabotix, 19.1 V DC, 110 W, BTD150 standard thrusters, would serve.

These thrusters were arranged in pairs. The forward/reverse set were mounted to the frame at the rear lower quadrant, using the adjustable thruster mounts crafted by the team's precision machinists.



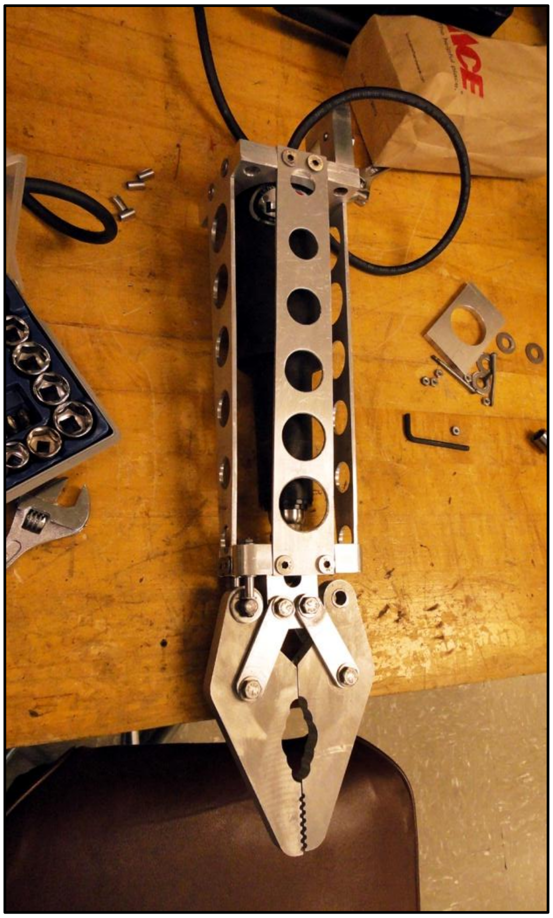
The vertically placed up/down thruster firmly secured to its adjustable thruster mounts and cross-braces.

The second pair were placed approximately two-thirds of the way forward, bolted onto specially drilled cross-braces in order to take full advantage of the adjustable mounts. One of this pair was placed in a vertical position, so that it could serve to propel the craft up or down, and a notch was machined into the cross-brace above it so that the propulsion would be unhindered. The second of the pair was mounted horizontally, facing at a 90 degree angle to the rear forward/reverse units, and is used as a "crabbing" thruster.

Thanks to the custom designed thruster mounts, all of these units can be adjusted horizontally and vertically as required.

Manipulator Arm

One very necessary item that must be included in the design of any ROV that is intended to do more than simply observe, is some means of interacting with its surroundings. For the Seawolf 1 the primary method of such interaction is its manipulator arm.



The Seawolf 1's Manipulator Arm in its finished, but unattached, form.

From the outset of the design phase for the manipulator arm, the team focused a great deal of consideration on the specific tasks that this particular appendage would be required to accomplish in the MATE competition. Grasping strength and speed of opening and closing, a necessity for several of the individual chores, had to be balanced out with a level of control fine enough to allow the operator to pick up and transplant the faux coral without crushing the base or dropping the piece.

Different concepts were talked through, and in some cases even drawn up, in an attempt to determine not only the best structural design, but also to find the most effective operational methods.

For the structural components of the arm, it was decided that a mostly aluminum construction made the most sense from the point of view of continuity with the base frame design materials already used. The body of the arm was machined from flat strips of aluminum, which enclosed the inner workings and driver. The claw's jaws were milled from heavier stock, approximately 20 mm thick by 130 mm long, and then given the gripping grooves and cut-outs appropriate to its intended uses.

Hydraulics as a means of operating the claw was touched upon, and seriously considered for a time. However, there were certain limitations to this approach that persuaded the team to turn instead to an electrical means of activating the device. A small electric bilge pump motor, approximately three amps, was selected at first to power a threaded rod arrangement developed by the team. This set-up allowed the pilot to cycle the claw through its open and closed positions using only the power already available through the tether. Later, as the machine was tested, it was found that a slightly more robust motor would be preferable, to allow the design to reach its full potential.

In order to accomplish this goal a search was done for a unit which would provide the required power. The final choice was a Lenco Marine, 15 amp, 101 Standard Actuator. Although the substitution of this larger motor occasioned a reworking of the manipulator arm control circuits, and some minor programming alterations, the approximately 3,336 N of force it brings to the equation made it worth the extra effort.

In its finished form the arm is affixed to the lower front center portion of the frame by bolts in the interior and steadied by means of a notch in its lower casing which fits securely over the vertical angle of the lower, outer aluminum strut. Aside from its intended uses its dorsal surface also serves as a mounting place for Seawolf 1's main camera.

Cameras

Since a large part of an ROV's usefulness lies in its ability to let its pilot see what is going on in places where a person can't go, cameras are a necessity. The Seawolf 1 is no exception to this, and its cameras are an integral part of its overall design.

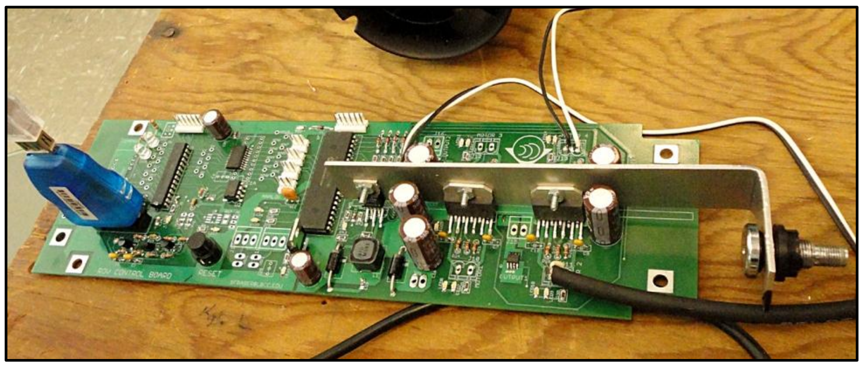
The Seawolf 1 is equipped with two Outland Technology color cameras.

The main camera is a UWC-325/p. 125 mm long by 40 mm in diameter, this 0.2 kg model is depth rated to 600 m. One of its intended functions was as a manipulator arm camera, so only very minimal adaptation was needed. For the team's purposes it was mounted on the dorsal surface of the manipulator arm, so that it could provide the ROV's pilot with the best possible view of the arms target.

The secondary camera being utilized on board the ROV is a 32x32 mm, CCTV Vision Hi-Tech VM38CSHR-B36 open frame color camera. Its color video is based on the matrix 1/3" Sony, it has a resolution of 480, a sensitivity of 0.8 Lux, and a Lens f of 3.6mm/ F of 2.0. Since it was originally designed to serve surveillance systems, an enclosure was needed to allow it to be usable on the ROV. For convenience this camera was placed in same clear acrylic container which houses the Seawolf 1's lights. It is also attached to the same tilt mechanism the lights are attached to, giving it the ability to tilt downward 90 degrees from the horizontal.

The S.U.R.E. team also has hopes of adding an additional camera, perhaps one capable of panning side to side, on a future model.

Electronics



The main circuit board of the Seawolf 1, donated by MATE, in the early stages of its adaptation for use in the ROV.

Designing and implementing the electronics systems onboard the Seawolf 1 has undoubtedly been one of the more challenging aspects of the project. The arrangement and complexity of the electronics and programming involved in running all aspects of the ROV must, of necessity, adapt to keep pace with the evolution of the machine's design from basic idea to full functionality. A great deal of thought and planning was called for, in order to craft a nerve center for the vessel that was capable of performing safely and reliably under submarine conditions.

The nerve center of the Seawolf 1 resides in its main electronics housing. In accordance with the need to distribute both weight and displacement as evenly across the frame as possible, this housing was placed in the upper rear quadrant of the ROV, directly above the two forward/reverse thrusters. It contains the main circuit board, subsidiary circuitry, and the video encoder hardware.

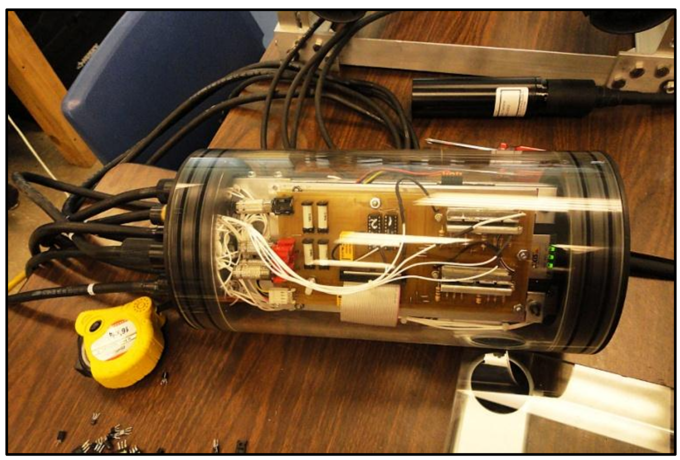
The control systems for the ROV are centered on a parallax microcontroller. Thruster drives are pulse width modulated by a PIC microcontroller. Communications with the surface is achieved via IP, through an AXIS Q7401 Video Encoder, utilizing RS485 communications protocol.

Our electronics technicians have, over the course of the ROV's development, made various additions to the original basic circuit board, which was generously donated to the team by MATE. Among these are an H-bridge circuit for use in controlling the tilt function on the 3.6 mm secondary camera, and the subsidiary circuitry which allows the pilot to operate the manipulator arm. It is also interesting to note that the AXIS Video Encoder installed in the ROV's electronics center was originally intended for use in an IP-based video surveillance system. Parts of its functions have been adapted by the team to serve as the basis for controlling the Seawolf 1's movements and operations.

Last but not least, the Outland tether, donated by SeaTreipid, containing a CAT 5 network line and power conductors, carries data and power to and from the machine, doing its part to ensure the smooth and efficient remote operation of the ROV by the team's pilots.

Electronics, Camera, and Lighting Containment

Working in a marine environment means that any electronics or electrically powered devices must be as proof against moisture leakage as it is possible to make them. When you have many different small electronic components needing protection, the simplest solution can be to group them all into one or two water-tight containers. This is the route the S.U.R.E. team chose to take with most of those parts of the ROV's systems that needed to be kept absolutely dry.



A shot of the main electronics housing detached from its normal position while adjustments are being made.

Two separate containers were constructed out of clear acrylic tubing. The matching tubes, measuring approximately 30 cm by 15 cm, and with a thickness of 0.64 cm, were fashioned to provide the bodies the compartments. The ends of the cylinders were milled out at either end to accept a black acrylic cap fitted with dual o-rings. These caps were then outfitted with water-tight sockets into which connectors and cables could be fed.

The forward container was fitted with a rotating mounting structure which utilizes a geared down 5V motor to operate the tilt mechanism for the secondary camera and lighting array. This array may be tilted from the horizontal downward by as much as 90 degrees.

The rear container holds the brain of the vehicle. It is home to the main circuit board, the secondary circuitry, and the video encoder.

The clear acrylic from which the main part of both housings was created was chosen not only to enhance the field of view of the secondary camera and the visibility of the lighting fixture, but also because it allowed for an unobstructed view of the circuits and hardware installed inside.

Multi-Purpose Sensor

The multi-purpose sensor, mounted to the front end of the craft, is designed to aid in the process of fuel detection and recovery. Its combined functions include: a metal detecting sensor for use in differentiating between metallic and non-metallic debris, an ultrasonic thickness gauge for use in measuring hull thickness, and a neutron backscatter device which will be used to test for the presence of fuel within the hull of the wreck.

Fuel Extraction System

Once the presence of oil has been confirmed by the multi-purpose sensor, the Seawolf 1's Fuel Extraction System comes into play. The driving force used by the team's extraction apparatus is a Wegner belt-driven vacuum pump equipped with a one third horse power Westinghouse electric motor. This pump, which will operate from dry land, will create a pressure differential that will simultaneously push the fuel up to a glass container on the surface, and force the seawater carried by the ROV into the emptying fuel tank.

This system proved to be one of the more difficult components to perfect, since it required the design and construction of an extraction system, a method of attaching the system to the fuel tank, and the building of a suitably realistic fuel tank on which to run practice trials.

One Challenge Faced

As previously stated, the fuel extraction system proved to be one of the most challenging parts of the project. One particularly knotty problem that the team engineers faced when attempting to perfect this process, was the limitations of the team's venturi vacuum. Using the vacuum pump that the team started out with, the vacuum necessary to bring the liquid upward the required distance simply could not be achieved. Despite many re-workings and adjustments, no way could be found to accomplish this task with the venturi vacuum pump originally selected.

In this instance, the solution to the problem turned out to be a substitution in equipment, rather than a system re-design. A Co-Lin laboratory vacuum pump, no longer in use by the school, was found to fill in for the venturi. The Wegner belt-driven pump proved to be just what the doctor ordered. It provided more than enough vacuum to do the job, and allowed the team to move on to other aspects of the system.

Skill Gained

The process of achieving neutral buoyancy is one skill that almost every single person involved with this project has gained an increased knowledge of during the course of the past few months. The need to discover how much buoyancy was necessary to offset the weight of the ROV and its equipment was central to many of the team's calculations and field tests. Aside from the basic figures drawn from the original measurements, one must take into account the buoyant properties of each component as it is added to the machine. The electronics containers and thrusters, for example, add some degree of buoyancy.

The main tool used in reaching a neutrally buoyant state, however, was the block of syntactic foam which the team attached to the top of the ROV. This rigid polyurethane foam, donated to S.U.R.E. by Seatrepid, has a buoyant force of approximately 9 N per 690 cm^3. By a process of repeated testing and multiple calculations, along with using the addition and removal of small weights, a final thickness of 4 cm was decided on. Once the block of foam was given its permanent shape a coat fiberglass resin was applied to seal it, since it was discovered that the milled foam was slightly more absorbent than in its original factory state. It was then attached to the Seawolf 1 using a set of aluminum clips to allow for easy adjustment.

Future Improvements

As proud as the team is of the Seawolf 1, almost everyone who took part in its construction is already pondering what improvements could made on possible future models.

One of the first things to come to mind for many is the desire for more versatile camera mounts. More versatile mounts would mean cameras with increased fields of view, which would in turn lead to improvements in piloting and greater observational functionality.

The addition of multiple degrees of freedom for future manipulator arms is also a desire held by many team members. Such freedom would translate into a greatly increased range of movement for the arm, ultimately making it capable of more complex tasks.

The most prominent item on the wish list, however, is for a more powerful microcontroller. This would address the important issue of memory based limitations, and open up countless possibilities that were simply beyond the means of our equipment this time around.

Troubleshooting

The concept of troubleshooting can be a tricky one to define accurately. That is especially true of a project involving at least a few concepts which the majority of the project members are learning about pretty much for the first time. Which parts of the process should be considered "troubleshooting", and which may be thought of as simple hands-on learning?

In the case of the S.U.R.E team and the Seawolf 1, although research was gone over, and advice sought from various sources, the most valuable tool we have so far found in the areas of both troubleshooting and learning is good old fashioned trial and error.

No matter how many plans are discussed and drawn up, or how many references are consulted, there will always be a long stretch of uncertainty between drawing board and working machine. As anyone who has ever built anything from scratch can testify, designs that work well on paper, or under laboratory conditions, can meet any number of unforeseen variables in actual use that require a creative readjustment in thinking.

The team has without a doubt encountered several such bumps in the road to building this ROV. From figuring out water proofing techniques to streamlining control and communication issues, each new phase of the design process has inevitably brought to light its own unique set of difficulties and complications. For our team the answers to these dilemmas have been as varied the problems themselves.

However, there have been at least a few common threads in our troubleshooting process. In almost all of these cases the best solutions have been found by a combination of persistent experimentation, copious real-world testing, and frequent repetition of the mental mantra " We WILL make this work!".

While this method of problem solving is admittedly not a new one, it has the virtue of being time tested and reliable, and thus far seems to be serving us well.

Reflections

The creation of the Seawolf 1, and its journey over the past months from drawing board to fully realized ROV, has been one long learning process for our team. In the beginning very few of the students involved with the team, or even the instructors serving as team mentors, were more than vaguely familiar with the whole range of concepts involved in the construction and successful operation of a ROV.

The seed of the project was brought back from a workshop on ROV building in California which was attended by two of the team's mentors in the summer of 2011. Armed with their newly acquired knowledge these instructors fired the imagination of a small group of student volunteers, who were enlisted to attempt the construction of a very small scale, very simple, working ROV. Over the course of the next few weeks that first rough version slowly took shape, progressing from the planning stages to eventual working model in fairly quick order.

Though strictly educational and experimental in nature, this original foray into ROV design proved to all involved that with perseverance our little team should be more than capable of creating a functional, competition sized model for entry into the upcoming 2012 MATE contest.

Once it was decided among the group that we would compete, one the very first orders of business was to think about were our funding and materials were to come from.

Fundraising projects, such as video game contests and raffles, were planned and executed. Copiah-Lincoln Community College has been very generous in allowing the use of any school facilities, such as the Precision Machine Shop, that could be used by our members. Both team members and instructors/mentors have eagerly donated whatever usable materials, tools, or components that they personally possessed. The most important resource discovered by the S.U.R.E. team in this endeavor, however, has been the local community. The entire group has been surprised, and touched, by the level of support received from a number of businesses and interested individuals all around the area.

Once at least some of the necessary funds and materials were gathered, the next task was to kick off the planning and design of the actual ROV. A loose, generalized set of goals was originally laid out to give the team at least some framework to refer back to when needed. As beginners in this field, however, it was felt that each member should feel free to do their own research and experimentation. Each person was encouraged to bring any promising ideas before the group, even if said ideas were about an area in which they had no particular personal specialization. In this way several of the craft's major features were given their first form.

Throughout the majority of the spring months the team as a whole would gather at least twice a week for general planning sessions and progress updates. The actual work of creating the ROV's structure, individual components, programming, and circuitry, was carried out at any and all available hours, at some points. This proved to be especially true in the areas of precision machining and electronics, since even a minor change in a peripheral part of the design could add up to a major amount work for the team members handling those tasks. In fact, with that thought in mind, the S.U.R.E. team as a whole would like to take this opportunity to make special mention of the work done by its specialists in these two disciplines. Although this has been a group effort, there can be little question these individuals have gone the extra mile in order to make the Seawolf 1 a reality.

Finally, in April, the time came at last that the team had been long anticipating, putting the working ROV in the pool and running it through its paces. The sense of accomplishment that the Seawolves experienced upon seeing their robot complete its first test tasks is a feeling that anyone who has built something with their own hands can identify with.

All in all, this project has come to mean a great deal to all of those associated with it. The teamwork required, the problem solving skills developed, and the creative mindset fostered by this endeavor all have come together to make an unforgettable learning experience. It is not too much of a stretch to say that, however the results of the competition turn out, our members have been bettered both personally and educationally by being involved.

Special thanks to

Drew Michel and Underwater Intervention for allowing the S.U.R.E. team to attend this year free of charge.

Bob Christ of Seatrepid for technical advice and contribution of materials.

Copiah-Lincoln Community College for monetary contribution and use of school facilities.

Henry at Spectrum Control, for his support.

Brookhill on Natchez, for use of their pool.

Dr. Bret Shufelt, for the use of his pool.

Acknowledgements

Dr. Ronald E. Nettles II, President, Copiah-Lincoln Community College, Wesson Campus.

Dr. Jane Hulon, Vice President of Instructional Services, Copiah-Lincoln Community College, Wesson Campus.

Dr. Gail Baldwin, Dean of Career-Technical Education, Copiah-Lincoln Community College, Wesson Campus.

Budget/Expense Report

Donations			
Name	**Monetary**	**Material**	**Material Value**
Karl Long	$100		
Central Mississippi Engineering	$100		
Outland Technology Underwater Imaging Systems		Cameras, Electrical Cord	$695
Smith Machine & Welding		C&C milling time, aluminum	$684.25
Spectrum Control		C&C milling time	
Flofast		Stainless steel bolts, locknuts, washers	$75
Seatrepid	$250	Syntactic Foam, 100 ft. tether	$200
MATE Marine Advanced Technology Education		Main Circuit Board	$250

Gatlin Corp.		8 ft. O-ring material	$50
B&O welding		Aluminum angle stock	
Kenneth Hartley		19 lbs. lead weights	
Copiah-Lincoln Community College	$2300 (Hotel)		
Co-Lin Foundation	$1000		

Budget/Expense Report

Bought	
Item	**Cost**
Aluminum angle stock	$50
Seabotix thrusters - 4	$2,000
Acrylic tubing	$130
Connectors	$300
Camera circuit board	$50
LENCO Actuator	$125
Power supply	$1,000

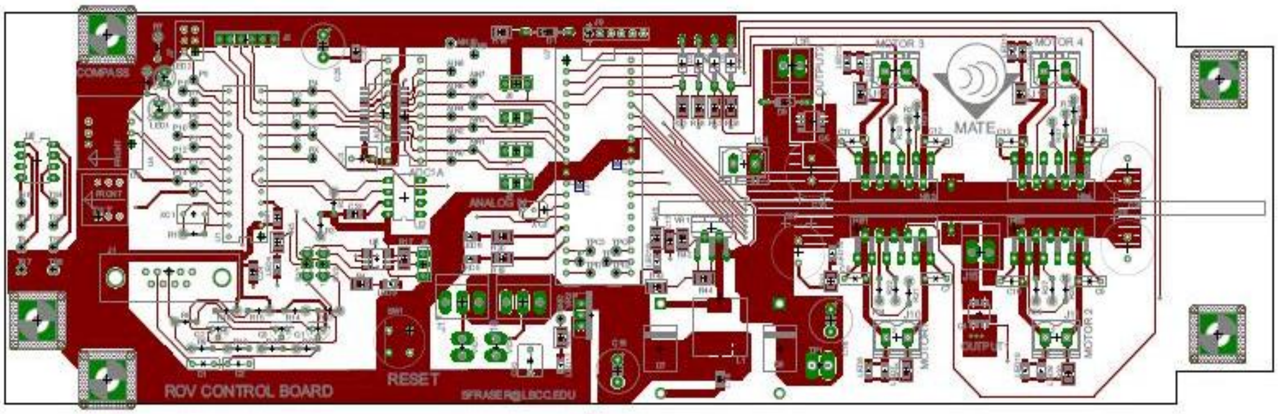
References

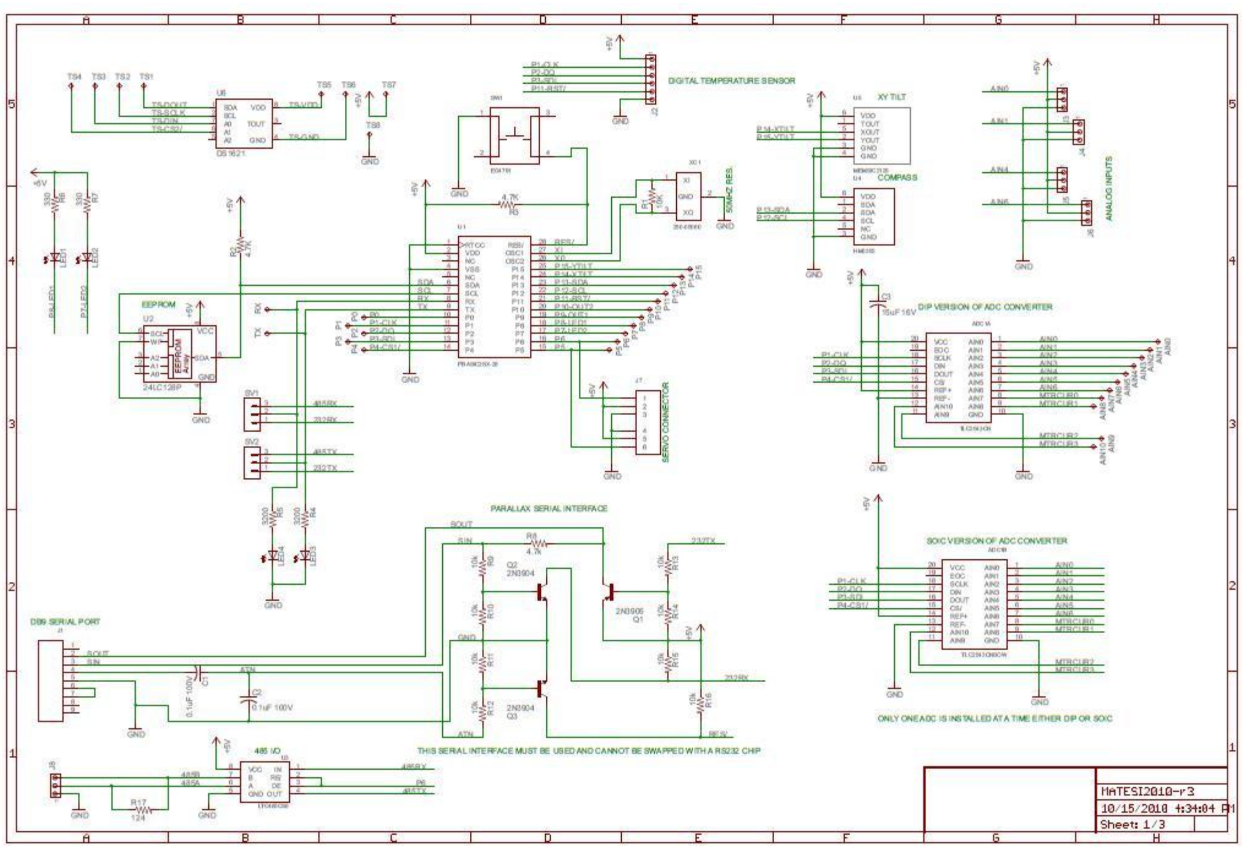
Moore, Steven W. Bohm, Harry. Jensen, Vickie. (2010) "Underwater Robotics: Science, Design & Fabrication", Marine Advanced Technology Education (MATE) Center, Monterey, CA.

Bohm, Harry. Jensen, Vickie. (1997) (2010) "Build your own underwater robot, and other wet projects", Westcoast Words, Vancouver, B.C., Canada.

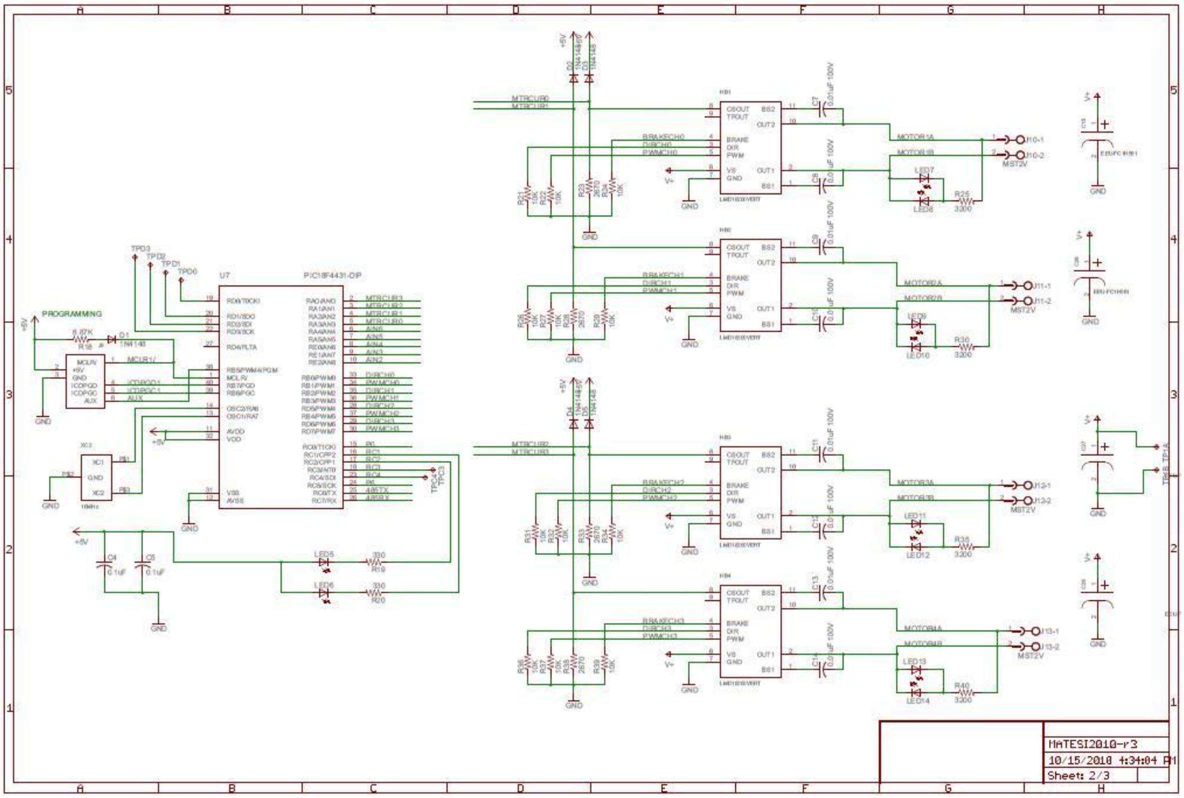
Appendix A: Electronics Schematics

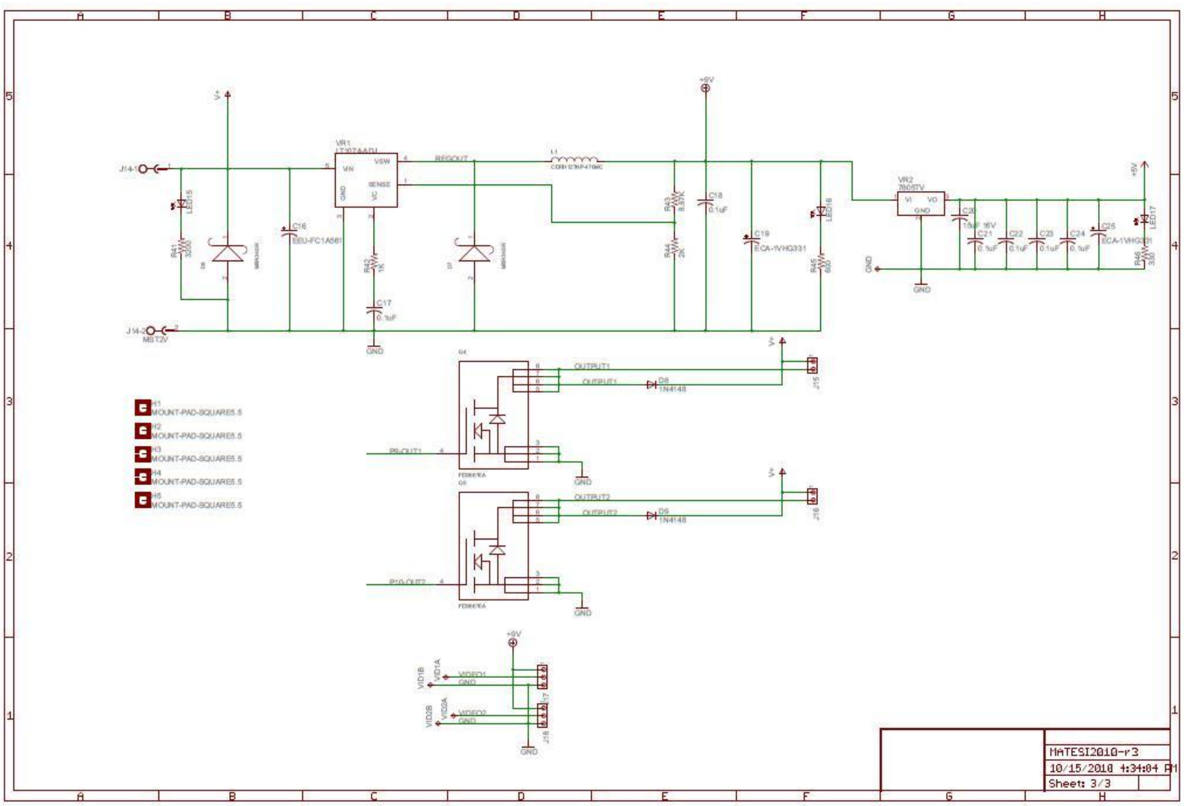
Pictured on the following two pages are schematic drawings for the Seawolf 1's Main Circuit Board.





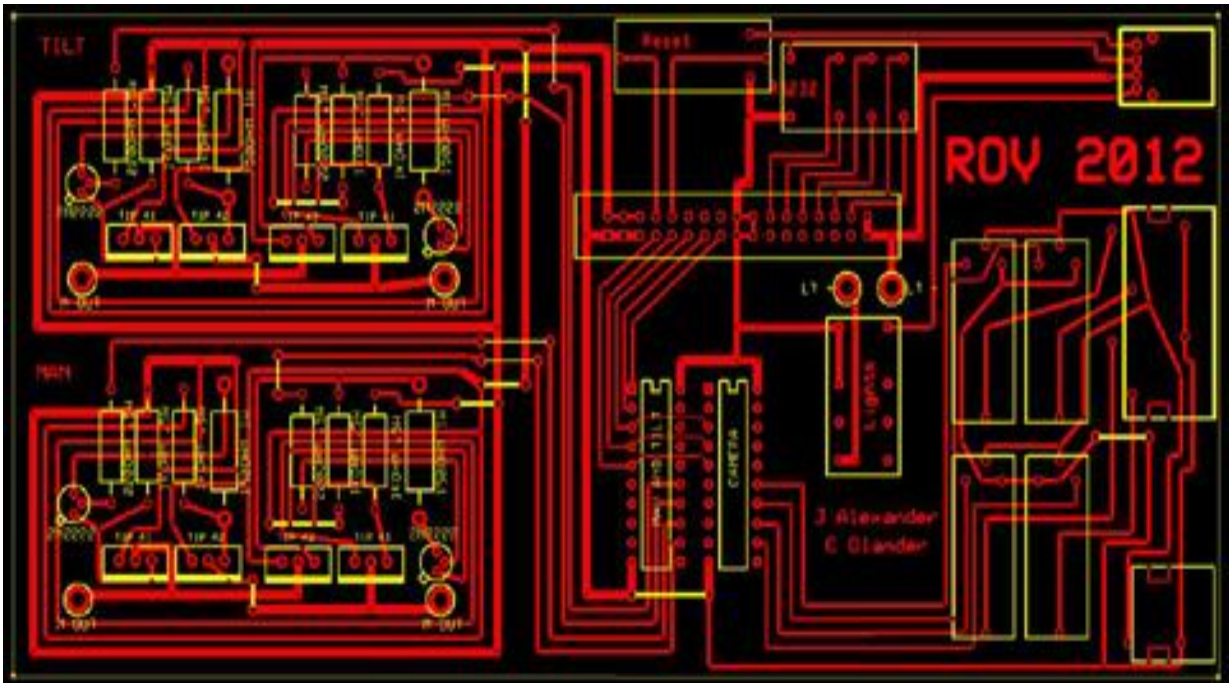
Appendix A:Electronics Schematics





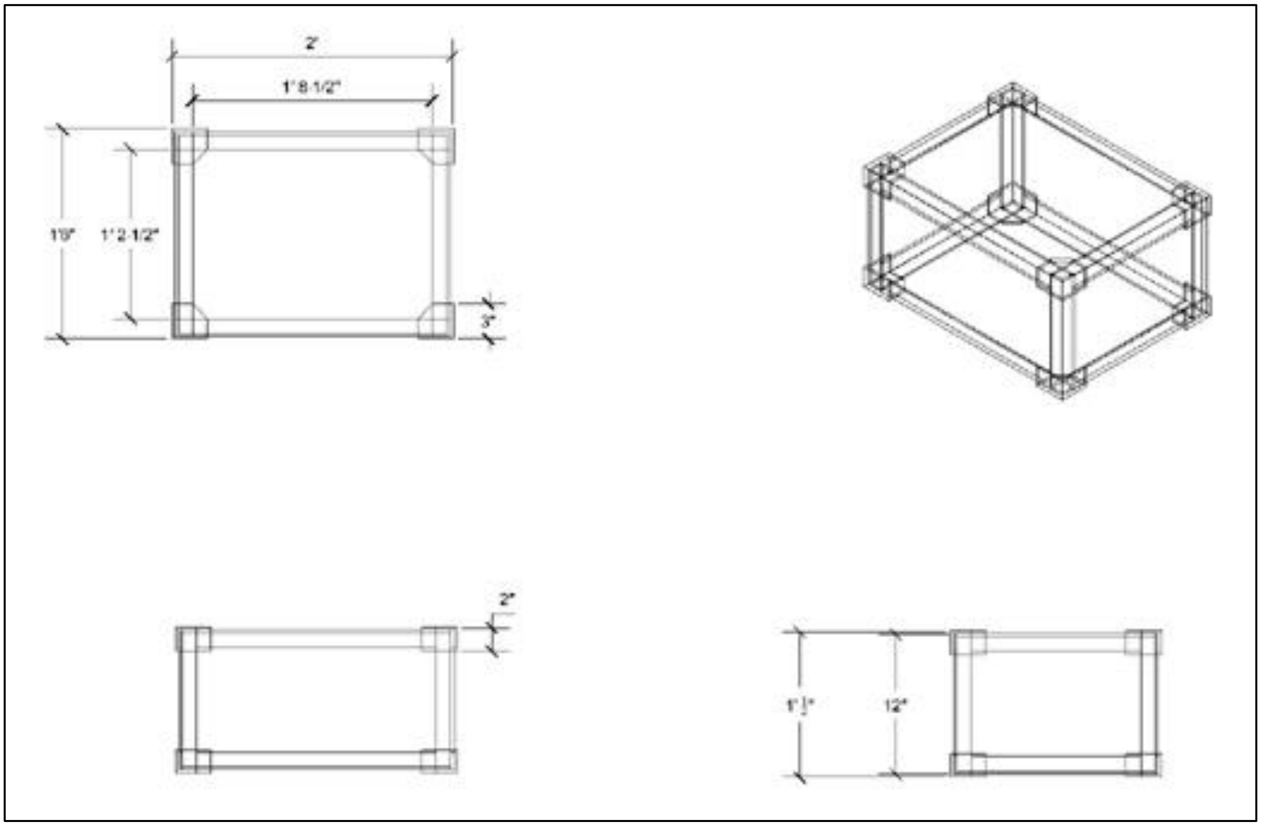
Appendix A: Electronics Schematics

Pictured below is the schematic for the support board layout.*



**Modified for final version.*

Appendix B: Frame Schematics



Appendix C: Statement of Receipts and Expenses

Seawolf Underwater Robotics Engineering
Statement of Receipts and Expenses
For the Period August 1, 2011 to June 21, 2012

Receipts			
Cash Donations		$ 6,270	
Non-Cash Donations		4,258	
Airsoft Raffle		834	
X-Box Tournament Fundraisers		362	
Copper Sale Fundraisers		104	
Total Receipts			$ 11,828
Expenses			
ROV Expenses			
Thrusters	$ 2,000		
Power Supply	1,000		
Cameras	695		
CNC Milling Time	684		
Connectors	300		
Main Circuit Board	250		
Syntactic Foam	200		
Acrylic Tubing	130		
LENCO Actuator	125		
Tether	100		
Weights	50		
Aluminum Angle Stock	50		
Camera Circuit Board	50		
O Rings	50		
Total ROV Expenses		5,684	
Travel Expenses			
Transportation	2,650		
Hotel	2,100		
Total Travel Expenses		4,750	
Advertising Expenses			
Shirts / Uniforms	975		
Office Supplies	50		
Total Advertising Expenses		1,025	
Fund Raising Expenses			
Airsoft Gun to Raffle	189		
X Box Tournament Prizes	180		
Total Fund Raising Expenses		369	
Total Expenses			11,828
Net Receipts in Excess of Expenses			$ 0

Appendix D: Request for Proposals

MATE Center
Monterey Peninsula College
980 Fremont Street
Monterey, CA 93940

Dear Sirs,

Please review our bid for services in response to your Request for Proposals:

An observation class ROV to survey and map underwater wreck site:

Contract Rate (Greater than 6 months)	$ 750 per day
Call-Out Rate (Less than 6 months)	900 per day

A working class ROV to remove hazardous material (fuel oil)

Contract Rate (Greater than 6 months)	$ 5,000 per day
Call-Out Rate (Less than 6 months)	6,000 per day

Invoices will be delivered bi weekly and payments are due within 10 days.

We will provide a demonstration of our capacity to meet your needs at our meeting in Orlando in June 2012. We will have customized an ROV to simulate the missions and if awarded the bid, we can have the actual ROV's functioning and ready to begin work 90 days after the contract is awarded.

Please note that any additional assignments or hazardous materials encountered will be billed at a rate to be determined based upon the assignment.

Thank you for the opportunity to present our proposal and we look forward to seeing you in June.

Sincerely,

Zach Fetcko, CFO