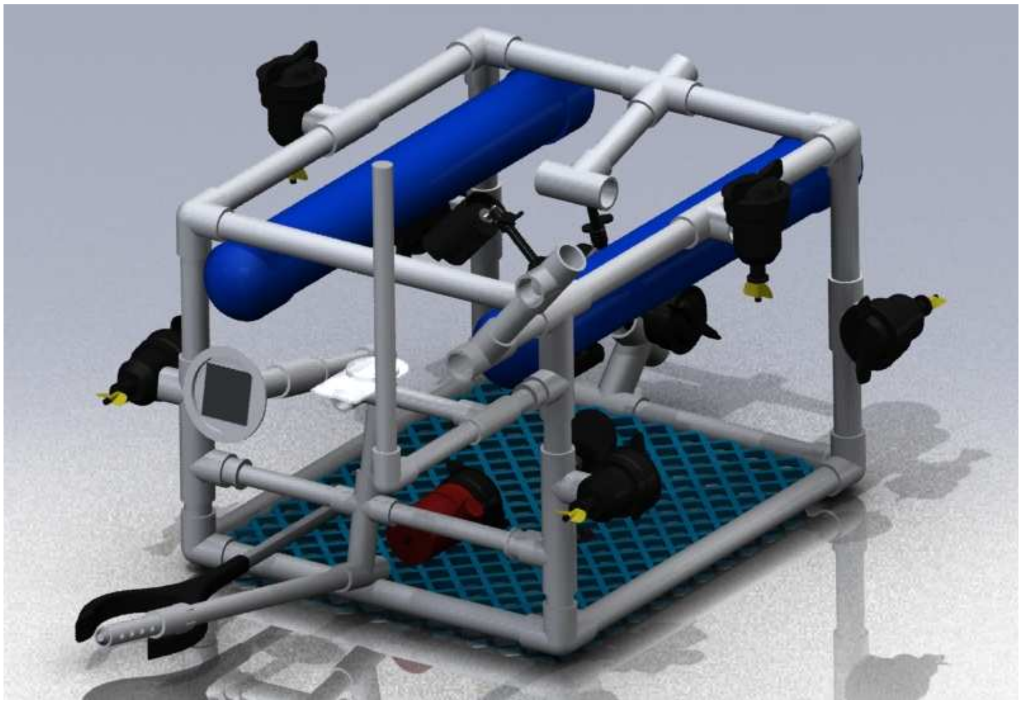
Cape Henlopen High School Robotics Team

Cape Robotics Company

Lewes, DE



CEO: Matt Spicer

Chief Engineer, Co-Pilot: Galen Selph

CAD Design, Pilot: Mitchell Taylor

Computer Systems Analyst: Brooks Emery

Visual Specialist: Trevor Aldred

Safety Managers: Sarah Meding and Nicole Bishoff

Payload Specialist: Bobby Wyatt

CFO: Kevin Yang

Tether Operator: Chris Faircloth

Marketing Specialist: Esther Kung and Maggie McGirk

Propulsion Specialists: Tom Ashcraft, Jacob Kee, and Nick Prestipino

Mentor: Mr. William Geppert

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Abstract

Cape Henlopen High School's team, Cape Robotics Company, proudly presents the *Annabelle Lee* to compete in the 2012 International ROV Competition sponsored by the Marine Advanced Technology Education (MATE) Center. An ROV is a remotely operated vehicle, an underwater robot designed to help scientists explore the depths of the ocean without physically entering potentially hazardous locations or tight areas. The compact cube shape of the *Annabelle Lee* proves to be sturdy and motion efficient. Primarily made from PVC, our underwater vehicle is not only reasonable in cost, but cleverly put together. The three cameras allow us to visualize a vast range underwater which helps with maneuvering and piloting our ROV.

The fifteen member team designed and built the ROV which is made for the theme "ROVs in World War II shipwrecks." The team had to build hand made parts and put their minds together to come up with a cost-efficient working ROV which we believe can accomplish all mission tasks. The Cape Henlopen Robotics Team greatly enjoyed applying real life problem-solving skills while working together to build a machine that could survey the *S.S. Gardner*.

Introduction

Cape Henlopen High School has been competing in the MATE Center's competitions for seven years. The combination of motivated students and a committed teacher/mentor has allowed the team to bring more advanced technologies to the competition each year. This year, the fifteen member team is comprised of bright young students hoping to advance their knowledge in mechanics and engineering. The group brought new ideas and knowledge together to construct an ROV which it is proud of.

Our ROV is built on the principle that complicated solutions are not always best. The team designed systems to complete the mission tasks quickly and efficiently. The *Annabelle Lee* has lived up to the team's expectations and the Cape Henlopen Robotics Team is confident that it will be able to perform its duties meeting great standards. The *Annabelle Lee* is a unique ROV that is, not only cost effective, but superior in the surveying field.

1. World War II Shipwrecks

In their heyday, the tankers and battleships of WWII patrolled the open oceans. They supplied the industrial war machines of the belligerents and sunk countless enemy ships. Though today the naval giants of WWII no longer stride atop the waves, they still constitute a serious threat to the world's ocean environments because of the hazardous materials they contain.

WWII shipwrecks contain immense amounts of oil and other toxic materials that have the potential to do great harm if leaked into the ocean. The *Lukenbach,* for example, contained over 457,000 gallons of fuel oil when it sank in 1953 (MATE, 2012, p. 29). In addition to oil, the toxic materials from WWII munitions can pose a threat to the marine environment in the area surrounding a shipwreck (Parliamentary Assembly, 2012, p 2). To make matters worse, the condition of most wrecks remains a mystery. Are they slowly hemorrhaging oil? How sensitive is marine life in the vicinity of the wreck?

In the past few years, some international organizations have addressed the problem of hazardous shipwrecks. For instance, in 2007 the International Maritime Organization held the Nairobi Convention on shipwrecks and approved a measure that would obligate its member states to clean up wrecks, especially where they interfered with international commerce (2007). This past January, the European Council urged its members to sign the still loosely-enforced Nairobi Convention. In particular, the council's report on shipwrecks stressed the need to "predict rates of corrosion" of the hulls of sunken ships and gain "knowledge of the physical properties of oil, toxic and radioactive substances" that may still remain on board the thousands of submerged wrecks (Parliamentary Assembly, 2012, p. 2).

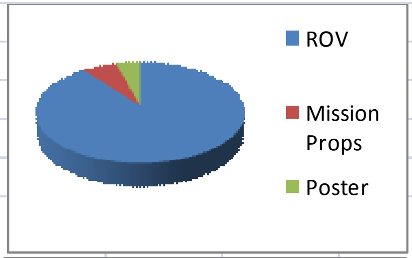
ROVs are part of the solution to the problem of hazardous wrecks. Because they are expendable, ROVs can be sent down to the dangerous depths of the ocean to evaluate and salvage oil and other toxic substances without putting the pilot directly in harm's way. With specialized payload tools, an ROV can also take direct action to reposition endangered marine organisms. Cape Robotics Company looks forward to contributing to the solution of the shipwreck problem by using its ROV to survey the *S.S. Gardener*.

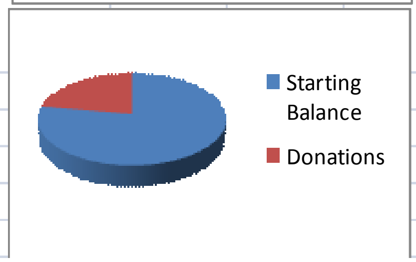
2. The Team

Name	Grade	Position	Goals
Trevor Aldred	11	Video Specialist	Plans to attend college to major in mechanical engineering.
Tom Ashcraft	12	Propulsion Specialist	Plans to attend University of Delaware to major in University Studies.
Nicole Bishoff	12	Safety Officer/Fundraiser	Plans to attend college to major in early childhood education.
Brooks Emery	11	Computer Analyst	Plans to attend college at the University of Delaware to study education to become a high school teacher.
Chris Faircloth	12	Tether Operator	Plans to attend college at the University of Delaware to study mechanical engineering.
Jacob Kee	12	Propulsion Specialist	Plans to attend University of Pittsburgh to major in mechanical engineering.
Esther Kung	11	Marketing and Communications Specialist	Plans to attend college to study pre-med and become a pediatrician.
Maggie McGirk	12	Marketing and Media Outreach Specialist	Plans to attend college at the University of Delaware to study criminal justice.
Sarah Meding	12	Safety Officer/Fundraiser	Plans to attend college at the University of Delaware to study pre-veterinarian animal science.
Nick Prestipino	12	Propulsion Specialist	Plans to attend University of Delaware to major in engineering.
Galen Selph	12	Co-Pilot, Chief Engineer	Plans to attend college at the University of Delaware to study mechanical engineering.
Matthew Spicer	11	CEO/Captain	Plans to study finance or engineering and become an entrepreneur.
Mitchell Taylor	12	CAD Specialist, Pilot	Plans to attend college at the University of Delaware to study mechanical engineering.
Bobby Wyatt	11	Design Integration Specialist	Plans to attend college.
Kevin Yang	11	CFO, Mechanical Engineer	Plans to attend college.

3. Expenditure Summary

Expenses		Income Sources	
ROV	$2,937.26	Starting Balance	$4,318.13
Mission Props	$196.06	Donations	$1,235.00
Poster	$137.98		
Total	$3,271.30	Total	$5,553.13
	Remaining Account Balance	$2,281.83	





Please Refer to Appendix B for detailed records of Expenses and Income.

4. Design Rationale

4.1 Mission Oriented

This year's ROV was designed to survey the *S.S. Gardner*. The PVC framing provides for a lightweight, sturdy, and smooth maneuvering ROV. Because PVC is so easy to put together, take apart, cut, and purchase, modifications were not too difficult to make. Parts could be added as needed or shrunk down to smaller scale. A claw was incorporated also. Other parts that were added specifically for this year's competition include:

- Lift bag device
- Compass
- Modified measuring tape

4.2 Design Process

Using Cape's previous ROV designs as a reference, the team avoided running into the obstacles of past years. Once the ROV was envisioned, prototypes were assembled, tested, and modified. Practice refined the design of the ROV to its present state.

The final CAD design is a combination of portions that were created before and after the physical building of the ROV.

4.3 Mechanical Structure

Cape Robotics Company chose to use a box structure as the frame of its underwater vehicle. The company found that this shape was most conducive to maintaining neutral buoyancy. In addition, the cube shape was also easily outfitted with a variety of payload tools. The frame is built with PVC piping because it is cheap and waterproof. A plastic grate is zip tied to the bottom edges of the frame. Payload tools are fastened to the grate.

4.4 Payload Tools

The *Annabelle Lee* is equipped with four payload items to complete the mission tasks. They are the Fuel Extractor/Tank Capper, Modified Measuring Tape, and Tri-Tool.

<u>Fuel Extractor/Tank Capper</u>

Figure 1. Fuel Extractor/Tank Grabber

Figure 2. Close-up of fuel extractor

As its name suggests, the first payload tool is designed to extract a fuel sample from the tank and cap the tank once sampling is completed. The Fuel Extractor/Tank Capper is attached by a PVC cross to a PVC cross brace that extends across the front face of the ROV, parallel to bottom of the machine. The lower portion of the tool is comprised of two lengths of ½ inch PVC connected by a coupling. It extends 41 centimeters from the machine, a length that the company found to be sufficient to reach the fuel tank without any other payload tools getting in the way. The nine centimeter section of the PVC tank is perforated around its circumference while the end is sealed with a coil of red electrical tape wrapped around a small plastic cap that extends from the middle of the coil of the tape. The smaller surface area of the plastic cap makes it easier to guide the tool into the fuel tank's opening. Once inside, a switch-activated bilge pump motor attached via plastic hose to the other end of the fuel extraction tool is turned on and the fuel is sucked through the holes and into the plastic tube where it is ultimately pumped to the surface for collection. Once a full sample is collected, the pilot simply maneuvers the *Annabelle Lee* backwards and downwards slightly so that the Tank Capper portion of the tool is even with the fuel tank's opening. Because the tank cap is only loosely attached to the ROV, it only needs to touch the fuel tank opening lightly before the ROV pulls away.

The company's love of simple, practical engineering solutions is reflected in the Fuel Extractor/Tank Capper tool. The team considered using a drilling mechanism and break line hoses to complete this part of the mission. However, it was ultimately decided that the pros of the simple design outweighed the cons. For one, PVC attachments are light and easy to affix to the frame. Also, the only moving parts required came ready-made in the form of a commercial bilge-pump motor. All in all, the Fuel Extractor/Tank Capper may look elementary, but it gets the job done.

Modified Measuring Tape

Simplicity is also a defining quality of the *Annabelle Lee*'s measuring tool. The device is essentially a tape measure zip-tied to the front, foreword portion of our payload tool shed. A plastic ring is drilled to the tab at the end of the retractable tape. This ring is placed over the PVC notch on the bow of the shipwreck. Then the front thrusters are activated, propelling the machine backwards as the tape measure unravels. At the other end of the shipwreck, the pilot views the number on the tape measure via the payload camera so that the length of the ship can be recorded. Once this is done, the measuring tape is retracted as the machine travels back along the length of the ship to the bow.

The main flaw of the measuring device was the susceptibility of commercial tape measures to corrosion by water. After a few practice sessions, the internal springs that allowed the tape to retract were rendered useless because of corrosion, and consequently the tape measure could no longer fulfill its purpose. The company attempted to modify the internal workings of the tape measure, but this proved too time-consuming. Ultimately, the problem was solved by purchasing a small supply of team measures. When one was no longer functional, it was simply replaced with another. This solution allowed our pilots to complete the measurement task and freed up the engineers to devote themselves to other aspects of the mission.

Tri-tool

The tri-tool is perhaps the most versatile component of the *Annabelle Lee*'s payload. Its three separate attachments are designed to accomplish three separate mission tasks. The foundation of the tri-tool is a 25 centimeter section of ½ inch PVC attached by PVC tee to one of the front vertical edges of the ROV. From that pipe, the three tools branch off.

First, there is the lift bag apparatus which attaches to the end of the main shaft of the tri-tool. It consists of a 90 degree PVC elbow connected to a 31 cm vertical section of ½ inch PVC that holds the lift bag in place. Three nylon cords are fixed to the bottom of the lift bag. These chords hold a metal hook which is used to affix the lift bag to the mast. This lift bag is located at the end of the tri-

Figure 3. Lift bag apparatus

tool's shaft in order to protect the ROV from damage when air is pumped into the bag.

Figure 4. Newton Spring Scale

A Newton spring-scale is the second component of the tri-tool. Attached by zip-tie to the end of the tri-tool shaft, it hangs downward over the debris field. Two magnets are tied to the spring scale's bottom hook. When the magnets hang over a metal sample, they pull the spring scale indicating the presence of magnetic force and therefore, metal. The company designed this component with simplicity and efficiency in mind. Materials already present in the classroom were used to create a basic, yet reliable payload tool that can indicate the slightest magnetic attraction between a magnet and metal debris sample.

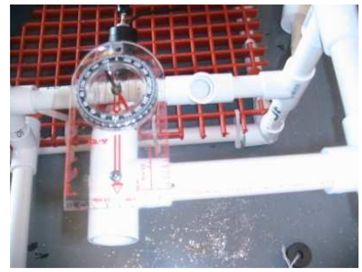


Figure 5. Compass

Finally, the tri-tool includes a compass component to measure the orientation of the shipwreck. The compass is mounted on a PVC extension from the main shaft directly under the payload tool camera so that when the pilot positions the machine directly over the shipwreck as he prepares to measure its length, the orientation can be quickly read from one of the camera monitors.

<u>The Mechanical Claw</u>

Figure 6. Mechanical Claw

During the design phase of constructing the *Annabelle Lee*, the company determined that a simple mechanical claw would be necessary to extract corals from the sides of the shipwreck and to reposition the mast once the lift back was attached. The claw is essentially a modified garbage picker which was originally designed to close when a trigger pulled a string that caused the claw to clamp down. The trigger mechanism is replaced by a bilge pump motor which pulls on the string to close the claw.

Rather than construct our own arm from scratch, the team once again decided to adapt simple commercial systems to suit our needs in the construction of the claw. Using the garbage picker and bilge pump motor was a cheap, yet effective solution to the engineering problems presented by the coral and mast.

Tether

Figure 7. Tether

The Company's Tether was specifically designed to best fit the needs of our ROV. Pool noodles sections were added as flotation devices to keep the tether from dragging. The tether consists of 16 gauge speaker wire, camera wires, and a plastic hose. Although 16 gauge wire is rigid, it provides the least voltage drop from power source to ROV. The camera wires connect to a screen above the surface which allowing the pilot to maneuver the ROV. The small hose was incorporated to pump fuel directly to the surface because keeping fuel on the ROV would have weighed it down and interfered with the overall buoyancy.

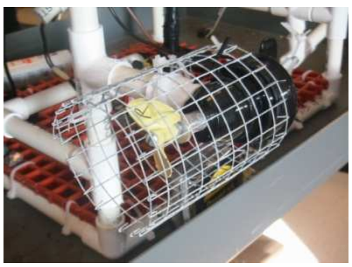


Figure 8. Thruster

4.5 Propulsion System

The ROV relies on a propulsion system comprised of six 12 volt, 500 gallon per hour (gph) bilge pump motors. 12 volt, 500 gph motors were specifically chosen for a variety of reasons. First and foremost, they were readily available in the supplies from years past and had proven themselves to be reliable in other missions. Additionally, these motors matched the voltage requirement for the Ranger Class Mission which made wiring them into the electronics system a simple task. Finally, our bilge pump motors had a compact size and readily modifiable motor shaft. Consequently, it was easy to experiment with different motor placements and to outfit the motors with propellers.

After thorough team discussion and some trial and error, the company settled on a simple yet practical placement of thrusters. Two are positioned in the middle of the top edges of the frame with the propellers facing downward, parallel to the vertical braces of the ROV. These motors provide the thrust to move the machine up and down in the water column. Two other bilge pump motors are placed on the back end of the ROV with their propeller shafts at a right angle to the vertical braces of the machine. These motors are responsible for providing all forward, left, and right horizontal thrust. This basic design of four thrusters--two for vertical movement and two for horizontal movement--provides the foundation of the ROV's propulsion system. However, the basic design had to be supplemented to address one of the mission tasks.

For the team, one of the most difficult portions of the mission proved to be measuring the length of the *S.S. Gardener* because our thrusters are extremely ineffective when operating in reverse. As is common with most propeller designs, the airfoil-shaped blades attached to the bilge-pump motors are only designed to push water efficiently in one direction. In addition, the motor housings and drive dogs blocked much of the water flow generated by the propellers when they ran in reverse. As a result, pulling the tape measure backwards along the length was painfully slow. To solve that problem, the company decided to add two thrusters to the front of the frame which could be powered up as the ROV measured the wreck or whenever else it needed to move backwards. With this extra thrust, the ROV is able to complete the measurement more quickly so that it can move on to other mission tasks.

4.6 Cameras

There are a total of three cameras on the ROV which are situated in the most beneficial places for the team to get as many underwater visuals as possible. The first camera is positioned to give the pilots a few from the front to maneuver the ROV. The second camera is positioned directly over the payload tools so that the pilot can monitor the tools when they are in use. Finally, the third camera gives the pilot a rear view when backing up.

4.7 Electronic Control System

The *Annabelle Lee* relies mainly on the commercially available MATE ROV control board designed by Scott Fraser. The vertical and horizontal thrusters connect to the motor ports on the board while the two front thrusters connect to two of the analog ports of the board. Embedded within the board is a Basic Stamp microcontroller programmed with modifications that allows the team to control the two front thrusters with the Logitech

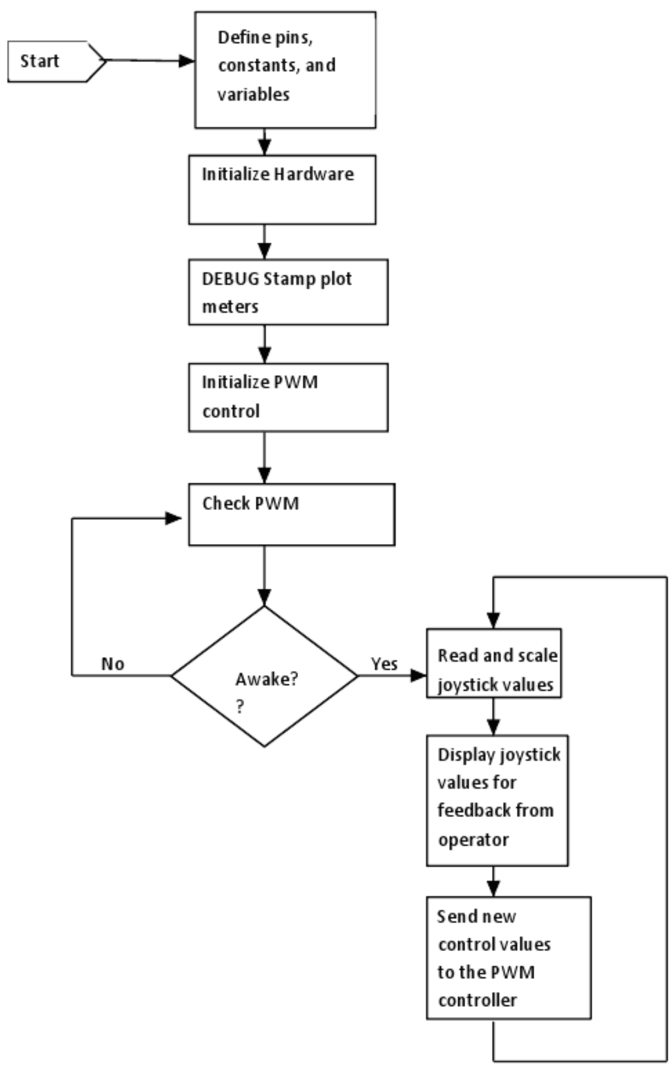
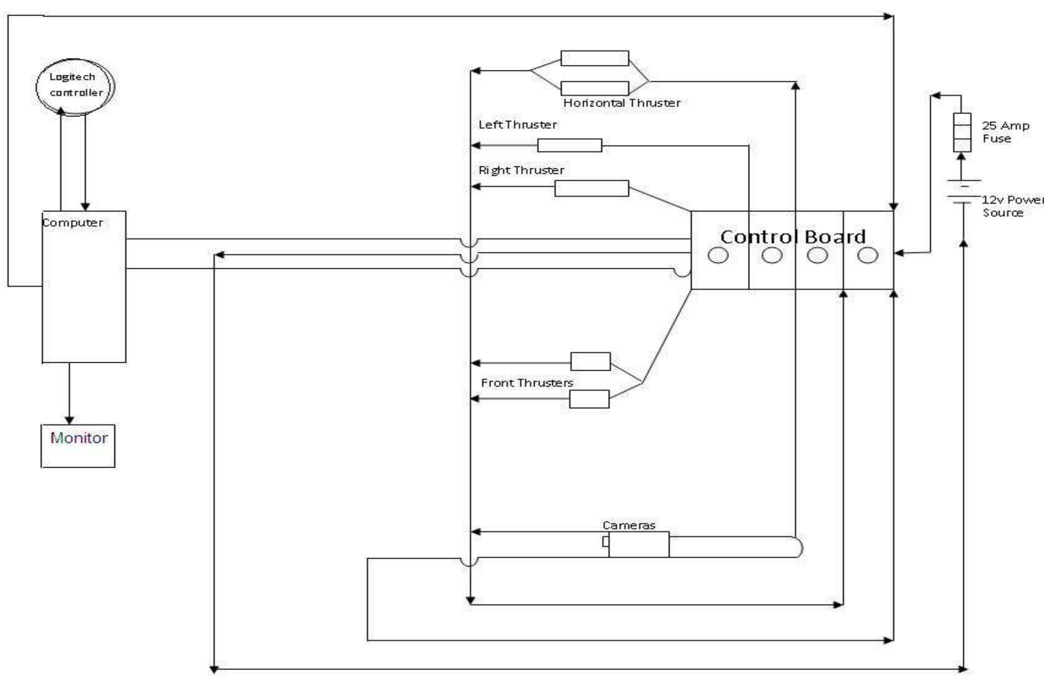


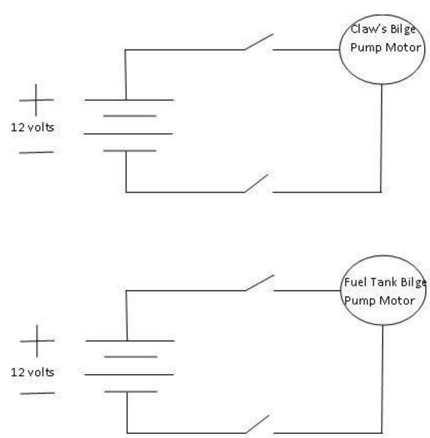
Figure 9. Software diagram

controller in addition to the four main thrusters.

Within the code there are several DEBUG commands that set up electronic meters in a program called Stamp plot. These meters display the state of the thrusters as well as the joysticks and push buttons of the Logitech controller. In addition to these meters, there are video outputs from the payload camera, front-facing camera, and rear-facing camera that are displayed on the monitor in our company's mission area. Using the video images as well as the Stamp Plot meters, the pilot and copilot guide the ROV through the water with the Logitech game controller. The circuit diagram below illustrates the layout of the main electronic control system. Please see Appendix A for a precise schematic of the control board itself.

The company opted to connect the bilge pump motors through the board because of the more precise control the software facilitates. For example, the four thrusters controlled by the joystick can have a variable speed thanks to the thruster control of the code. Being able to vary the thrust output on the controllers allows for more precise maneuvering.





Hardware-Only Components

The main control system of the board is supplemented by two switch-operated components: the electric claw bilge pump motor and the fuel extraction bilge pump motor. Due to a lack of time and programming difficulties, the company decided that to take a hardware-only approach to constructing these two components. The switches for them are housed alongside the control board in the wooden controls box. When the ROV is positioned either to grip the corals or begin pumping the fuel sample to the surface, the copilot simply flips the appropriate switch. The above diagrams illustrate the circuits for these two components.

4.8 Safety Features

The *Annabelle Lee* is equipped with several safety features. First, all of the propellers are surrounded by metal wired cages to prevent propellers from slicing team members. Second, safety labels were placed around all moving parts to alert team members of the hazards present. Third, the use of fuses prevents the board from being over-loaded with current. Fourth, the bus minimizes wire clutter thereby reducing the chances of a short circuit due to crossed wires. Finally, safety officers or the team mentor, Mr. Geppert, always supervised vehicle construction and practice sessions. Safety is a top priority for the Cape Robotics Company.

5. Challenges Faced

5.1 Managing Our Time

The biggest challenge that our company faced was learning the skill of time management. Scheduling around school became an issue due to the fact that the robotics class only met three times a week and additional work was required, not just making the ROV. With a class full of juniors and seniors it was also hard to schedule outside of school due to extra-curricular activities. To overcome such challenges, we knew from the beginning that we would need to plan our time wisely. Each member was given a list of tasks that they needed to accomplish and a personal calendar so that they could plan the days to work on these tasks. By using time wisely, we were able to overcome the challenge of tight deadlines and build a successful ROV.

5.2 Constructing a Working Claw

Our company's original plan to extract the corals was to construct a bilge-pump powered screw-drive claw. We believed that this would give us the most precise control of the claw possible which we knew would be especially important to the mission task of removing corals from the side of the shipwreck. First, we modified the bilge pump motor by adding a screw-drive to its shaft via a drive dog. Unfortunately, the screw-drive was only able to accomplish the task of closing the claw. The device fell apart each time the claw was opened. To solve this problem, we changed the medium by which the mechanical energy was transferred to the claw. To do this, we removed the bilge pump's screw-drive and tied fishing line to its drive dog. The other end of the fishing line was then tied to a string that pulled the claw shut. When a switch was flipped to power up the claw motor, it would pull back on the string and close the claw. Though this design was much less technically elegant than a screw-drive, it still resulted in a working claw.

6. Troubleshooting

Testing multiple prototypes was vital to the success of our finished ROV. The prototype pictured at the left is an earlier version of our ROV. During pool testing and even at the Regional competition this particular machine had a few issues. Most of problems were identified by asking a series of questions:

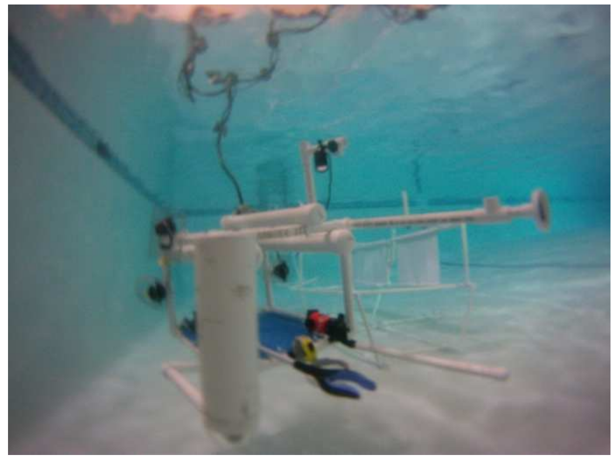


Figure 10. Prototype Underwater

1. What is task is the ROV attempting?
2. To what extent is it failing at the task?
3. Which subsystem is responsible for completing that task?
4. What are the component pieces of that subsystem?
5. Is each component piece functional?
6. Consider what can be done to repair or enhance the ineffective component piece.
7. Choose the best option after a group discussion.

An example of decision-making following the logic of this trouble shooting technique is our modifications to the propulsion system after the regional competition. We found that the ROV was taking too long to measure the shipwreck and consequently was unable to complete other mission tasks. The subsystem responsible for moving the ROV across the shipwreck was the propulsion system and the component parts of the propulsion system were four bilge-pump motor thrusters. Each bilge-pump motor was functioning, but just not well enough in reverse to measure the wreck in a reasonable amount of time. The modifcation options included changing propeller blades, modifying the motors so that the propellers would be less obstructed operating in reverse, or adding two new motors to the front of the ROV to enhance backwards thrust. A vote was taken in which our group settled on adding front thrusters. The thrusters were connected into the board, programmed, and tested. Thus, the problem was solved.

7. Lessons Learned

The team learned many valuable technical lessons over the course of the project. First and foremost, the team learned the waterproofing techniques that allow electronics to function underwater. We gained experience with computer code that allowed us to write a functional program. We also acquired new electronic safety skills and learned about to take a concept design from the whiteboard to the pool.

Many interpersonal skills were also gained during the construction of the ROV. In order to complete a project this large, email communications and group meetings were both necessary. An email system was set up so that if there was ever a problem with documents then an email would alert everyone of the problem. Also, because different documents needed to go back and forth between members, emails were very useful. Once a week, we also had team meetings to make sure that everyone was completing their tasks on time.

8. Future Improvements

In the future, the Cape Henlopen Robotics Team would like to compete at the Explorer level at the International Competition again. This year, due to many challenges, the team was only able to compete at the Ranger level but was still very happy for the opportunity to attend the International Competition. In the future, the team would also like to design tools that will be beneficial for many years so that a new design is not required each year. If the team could keep a base design and just change the specific components required for specific tasks each year it would help greatly with time management.

9. Reflections

Our ROV team has learned how to work together to build an ROV that we are proud of. When first learning that we would have to complete the task of building and maneuvering an ROV without the help of professionals, we thought it would be impossible. With hard work and determination, however, we were able to complete the project and make a working ROV that will complete the mission tasks that were assigned to us. This project has not only brought our team together in a learning environment but has provided us with memories for life. As a group, we built an ROV and gained valuable experience for next year's mission. Each member is thankful for the opportunity to compete.

10. Teamwork

Being a fairly large team, it was sometimes difficult to settle on one idea in the design process. Consequently, it was very important to make sure that each person on the team was aware in what their role was. In order to be successful, everyone used their skills to maximize time efficiency and build an outstanding ROV.

11. Acknowledgements

Cape Robotics would like to acknowledge the following people who have helped us make this project possible:

-Mr. William Geppert for being an inspirational and dedicated mentor

-Greene Turtle for their contributions and sponsorship

-MATE Center for hosting this competition and giving us an opportunity to share such a great experience with one another

12. References

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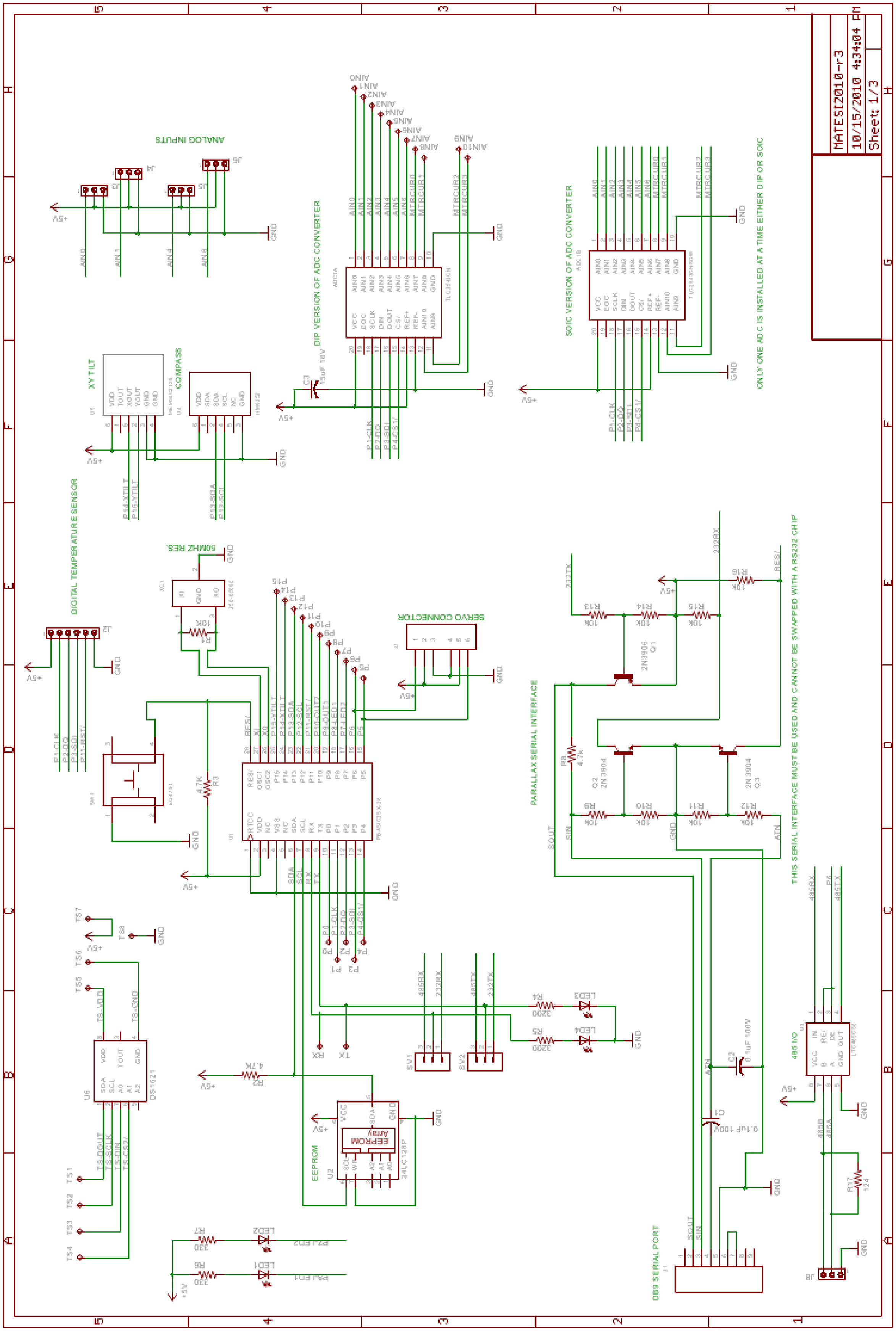
Appendix A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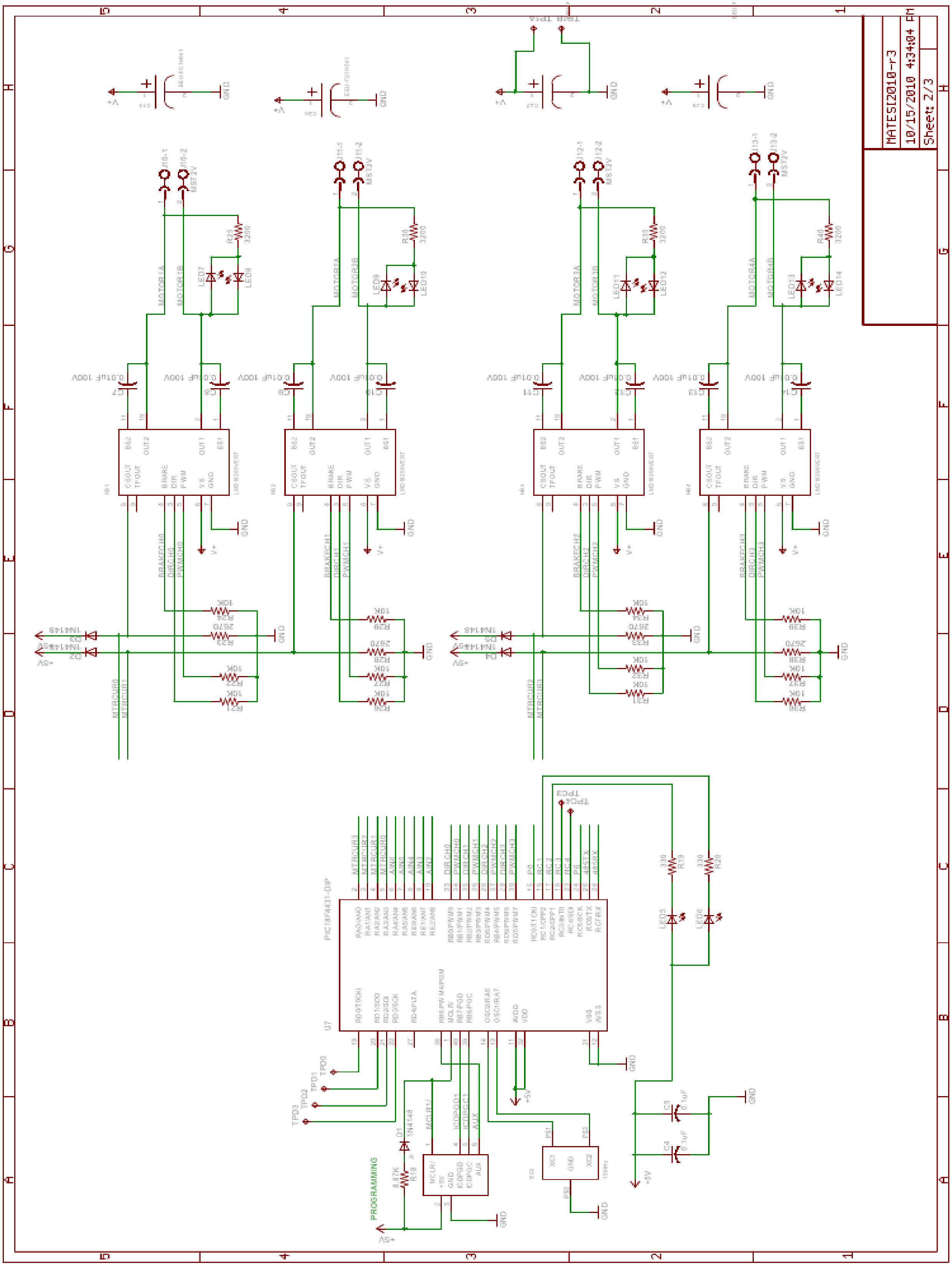
SOIC VERSION OF ADC CONVERTER
ONLY ONE ADC IS INSTALLED AT A TIME EITHER DIP OR SOIC
XY TILT
COMPASS
DIGITAL TEMPERATURE SENSOR
50MHZ RES.
SERVO CONNECTOR
PARALLAX SERIAL INTERFACE
THIS SERIAL INTERFACE MUST BE USED AND CANNOT BE SWAPPED WITH A RS232 CHIP
EEPROM
485 I/O
DB9 SERIAL PORT



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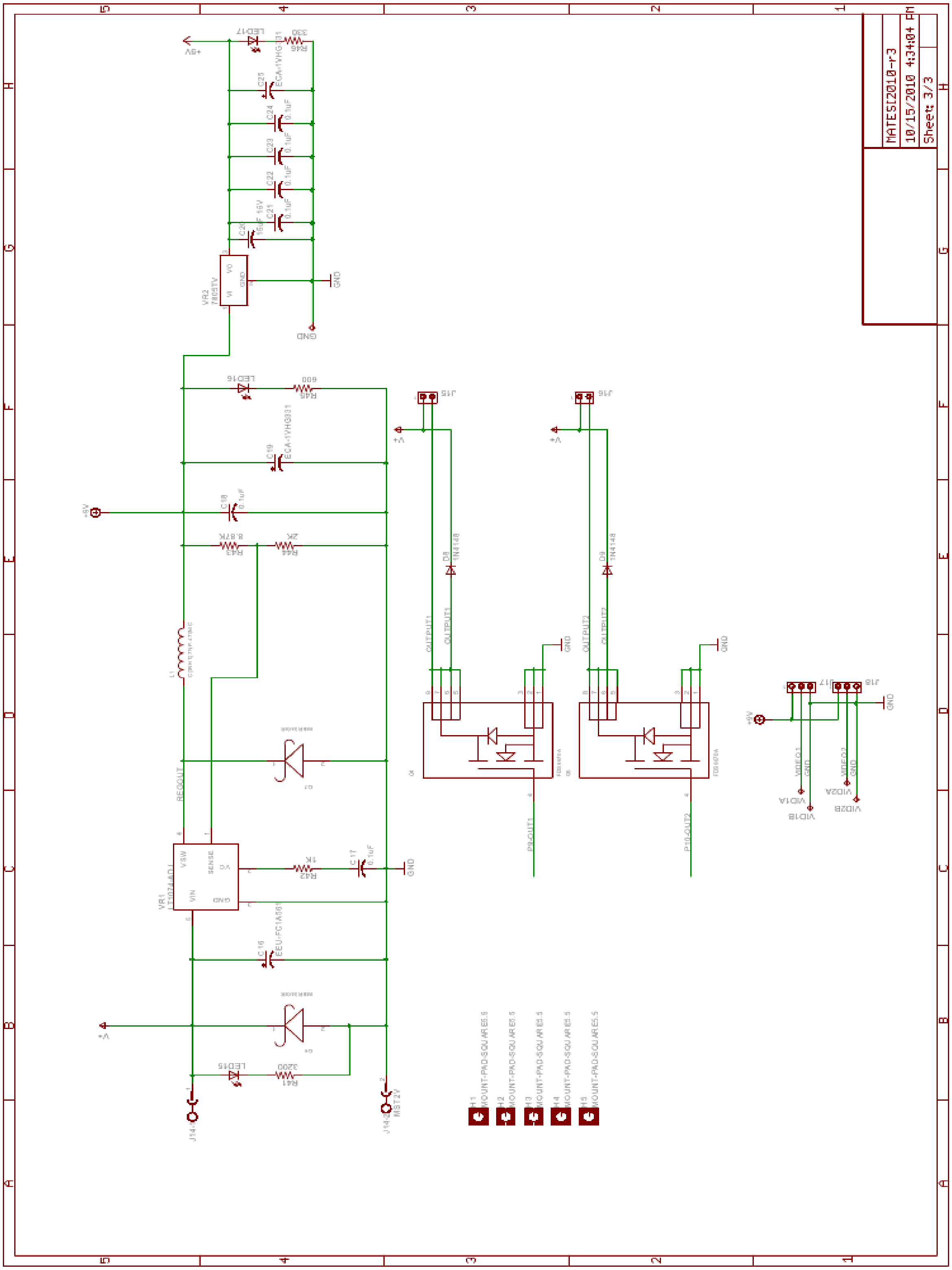

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Classification	Date	Vendor/ Donor	Product	Qty	Unit Price	Total Expense	Total Donation	Balance
START BALANCE	1/1/2012	Account Balance at beginning of year	-	-	-		$4,318.13	$4,318.13
Mission Props	1/27/2012	Home Depot	Mueller Streamline 1 in. x 3/4 in. PVC Schedule 40 Pressure Spigot x Slip Bushing	3	$0.62	$1.86		$4,316.27
Mission Props	1/27/2012	Home Depot	Mueller Streamline 1 in. x 1/2 in. PVC Schedule 40 Pressure Spigot x Slip Bushing	1	$0.64	$0.64		$4,315.63
Mission Props	1/27/2012	Home Depot	Mueller Streamline 1/2 in. PVC Cap	2	$0.26	$0.52		$4,315.11
Mission Props	1/27/2012	Home Depot	Mueller Streamline 1-1/2 in. PVC Schedule 40 Slip Cap	2	$0.78	$1.56		$4,313.55
Mission Props	1/27/2012	Home Depot	Mueller Streamline 1-1/2 in. PVC Slip x Slip x Slip Tee	1	$1.56	$1.56		$4,311.99
Mission Props	1/27/2012	Home Depot	1 in. PVC coupling	1	$0.37	$0.37		$4,311.62
Mission Props	1/27/2012	Home Depot	Mueller Streamline 1-1/2 in. PVC Pressure S x S x S x S Cross	1	$3.51	$3.51		$4,308.11
Mission Props	1/27/2012	Home Depot	1/2 in. PVC rods	10	$1.68	$16.80		$4,291.31

Mission Props	1/28/2012	Home Depot	24 in. x 36 in.Twinwall Plastic Sheet	2	$6.48	$12.96		$4,278.35
Mission Props	1/28/2012	Home Depot	FLT LANTERN	1	$4.97	$4.97		$4,273.38
Mission Props	1/28/2012	Home Depot	Cable Zip Tie Pack	1	$9.97	$9.97		$4,263.41
Mission Props	1/28/2012	Home Depot	Velcro Industrial Strength 15 ft. x 2 in. Tape	1	$28.97	$28.97		$4,234.44
Mission Props	1/28/2012	Home Depot	Loctite 0.85 fl. oz. Plastic Epoxy	1	$5.47	$5.47		$4,228.97
Mission Props	1/28/2012	Home Depot	Speciality 12 oz. Aerosol Paint	1	$4.48	$4.48		$4,224.49
Mission Props	1/28/2012	Home Depot	Velcro 4 in. X 2 in. Industrial Strength Strips 2 Pack	2	$2.97	$5.94		$4,218.55
Mission Props	1/28/2012	Home Depot	Sharpie Fine Point Permanent Marker	2	$0.97	$1.94		$4,216.61
Mission Props	1/28/2012	Home Depot	Iron Bridge 25 ft. Tape Measure	2	$2.96	$5.92		$4,210.69
Mission Props	1/28/2012	Home Depot	Crown Bolt 3/8 in. x 3-1/16 in. x 4-3/16 in. Coarse Zinc-Plated # 332 U-Bolt	1	$2.58	$2.58		$4,208.11
Mission Props	1/28/2012	Home Depot	BrassCraft Ratcheting PVC Cutter	1	$12.98	$12.98		$4,195.13
Mission Props	1/28/2012	Home Depot	Everbilt 1/8 in. x 48 ft. Braided Nylon & Polypropylene Cord White	1	$3.92	$3.92		$4,191.21

Mission Props	1/28/2012	Home Depot	Crown Bolt #6 x 1/2 in. Stainless-Steel Pan-Head Phillips Sheet Metal Screws (50-Pack)	1	$3.51	$3.51		$4,187.70
Mission Props	1/28/2012	Home Depot	GE 2.8 oz. Silicone Sealant	1	$5.24	$5.24		$4,182.46
Mission Props	1/28/2012	Home Depot	Oatey 3 in. Knockout Test Cap	2	$0.29	$0.58		$4,181.88
Mission Props	1/28/2012	Home Depot	galvanized steel pipe?	4	$2.21	$8.84		$4,173.04
Mission Props	1/28/2012	Home Depot	Mueller Streamline 1-1/2 in. PVC Schedule 40 Slip Cap	1	$0.78	$0.78		$4,172.26
Mission Props	1/28/2012	Home Depot	Mueller Streamline 1/2 in. PVC Cap	1	$0.26	$0.26		$4,172.00
Mission Props	1/28/2012	Home Depot	Mueller Streamline 1/2 in. PVC Slip x Slip x Slip Tee	8	$0.30	$2.40		$4,169.60
Mission Props	1/28/2012	Home Depot	3/4 in. PVC Schedule 40 90-Degree Slip x Slip Elbow	16	$0.30	$4.80		$4,164.80
Control Board	2/1/2012	RSK.com	DPDT 20-Amp Momentary Flip Switch	6	$4.99	$29.94		$4,134.86
ROV	2/1/2012	Leisure Pro: The Diver's Emporium	Subsalve USA Quad Bag 25 LB. (with shipping)	1	$42.40	$42.40		$4,092.46
ROV	2/22/2012	Digi-Key	Conn header Vert 6 postion	8	$0.30	$2.40		$4,090.06

			.100 Tin					
ROV	2/22/2012	Digi-Key	CER Resonator 10.00MHZ	4	$0.70	$2.80		$4,087.26
ROV	2/22/2012	Digi-Key	IC H Bridge 3A 55V TO220-11	16	$17.78	$284.48		$3,802.78
ROV	2/22/2012	Digi-Key	CONN Header Vert 3POS .100 Tin	16	$0.17	$2.72		$3,800.06
ROV	2/22/2012	Digi-Key	IC EEPROM 128KBIT 400KHZ 8DIP	4	$0.82	$3.28		$3,796.78
ROV	2/22/2012	Digi-Key	IC 12-BIT A/D W/SER CNTRL 20SOCI	4	$11.29	$45.16		$3,751.62
ROV	2/22/2012	Digi-Key	CAP CER 10000PF 100V 10% RADIAL	40	$0.45	$18.00		$3,733.62
ROV	2/22/2012	Digi-Key	CAP CER 0.1UF 100V 10% RADIAL	40	$0.46	$18.40		$3,715.22
ROV	2/22/2012	Digi-Key	LED 5MM 1500MCD SUPER RED WTRCLR	8	$0.50	$4.00		$3,711.22
ROV	2/22/2012	Digi-Key	DIODE SCHOTTKY 40V 3A C-16	8	$0.51	$4.08		$3,707.14
ROV	2/22/2012	Digi-Key	DIODE SGL JUNC 100V 4.0NS DO-35	28	$0.06	$1.68		$3,705.46
ROV	2/22/2012	Digi-Key	RES 3.24K OHM 1/4W 1% 1206 SMD	40	$0.08	$3.00		$3,702.46
ROV	2/22/2012	Digi-Key	RES 330 OHM 1/4W 1% 1206 SMD	40	$0.08	$3.00		$3,699.46

ROV	2/22/2012	Digi-Key	RES 604 OMH 1/4W 1% 1206 SMD	40	$0.80	$32.00		$3,667.46
ROV	2/22/2012	Digi-Key	RES 8.87K OHM 1/4W 1% 1206 SMD	40	$0.80	$32.00		$3,635.46
ROV	2/22/2012	Digi-Key	CAP ALUM 330UF 35V 20% RADIAL	8	$0.63	$5.04		$3,630.42
ROV	2/22/2012	Digi-Key	CAP ALUM 560UF 50V 20% RADIAL	20	$0.78	$15.60		$3,614.82
ROV	2/22/2012	Digi-Key	CONN RECEPT 3POS 22AWG MTA100	16	$0.43	$6.88		$3,607.94
ROV	2/22/2012	Digi-Key	IC REG LDO 5V 1.5A TO220	4	$0.56	$2.24		$3,605.70
ROV	2/22/2012	Digi-Key	CONN D-SUB RCPT STR 9POS GOLD FL	4	$4.48	$17.92		$3,587.78
ROV	2/22/2012	Digi-Key	IC MULTI CONFIG ADJ 5A TO220-5	4	$15.20	$60.80		$3,526.98
ROV	2/22/2012	Digi-Key	TRANSISTOR NPN GP 40V TO92	8	$0.42	$3.36		$3,523.62
ROV	2/22/2012	Digi-Key	TRANSISTOR PNP GP 40V TO92	4	$0.42	$1.68		$3,521.94
ROV	2/22/2012	Digi-Key	POWER INDUCTOR 47UH 2.5A SMD	4	$2.91	$11.64		$3,510.30
ROV	2/22/2012	Digi-Key	IC TERMOMETER/STAT DIG 8-DIP	4	$4.93	$19.72		$3,490.58

ROV	2/22/2012	Digi-Key	RES 2.67K OHM 1/4W 1% 1206 SMD	40	$0.07	$2.72		$3,487.86
ROV	2/22/2012	Digi-Key	RES 1.0K OHM 1/4W 5% 1206 SMD	40	$0.10	$4.00		$3,483.86
ROV	2/22/2012	Digi-Key	CAP ALUM 15UF 350V 20% RADIAL	8	$0.77	$6.16		$3,477.70
ROV	2/22/2012	Digi-Key	LED 3X1.5MM 590NM YW WTR CLR SMD	40	$0.21	$8.40		$3,469.30
ROV	2/22/2012	Digi-Key	LED 3.2X1.6MM 635NM RED CLR SMD	40	$0.23	$9.20		$3,460.10
ROV	2/22/2012	Digi-Key	RES 4.7K OHM 1/8W 5% CF AXIAL	16	$0.09	$1.44		$3,458.66
ROV	2/22/2012	Digi-Key	RES 10K OHM 1/8W 5% CF AXIAL	84	$0.09	$7.56		$3,451.10
ROV	2/22/2012	Digi-Key	MOSFET N-CH 150V 5A 8-SOIC	8	$2.85	$22.80		$3,428.30
ROV	2/22/2012	Digi-Key	SWITCH PUSH SPST-NO 0.01A 35V	4	$0.75	$3.00		$3,425.30
ROV	2/22/2012	Digi-Key	RES 2.00K OHM 1/4W 1% 1206 SMD	40	$0.10	$4.08		$3,421.22
ROV	3/29/2012	Home Depot	Wire <A>	1	$98.00	$98.00		$3,323.22
ROV	3/29/2012	Radioshack	500k-ohm control W/push switch	1	$3.99	$3.99		$3,319.23

ROV	3/29/2012	Radioshack	Ping Sensor	1	$29.99	$29.99		$3,289.24
ROV	3/29/2012	Radioshack	Banana Plug 3.9 DIA	1	$4.19	$4.19		$3,285.05
ROV	3/29/2012	Radioshack	Desolder Braid	1	$4.19	$4.19		$3,280.86
ROV	3/29/2012	Radioshack	Round Magnet 5pk	1	$3.19	$3.19		$3,277.67
ROV	4/29/2012	Lowe's	1 1/2" SCH40 CAP 447015	2	$0.78	$1.56		$3,276.11
ROV	4/29/2012	Lowe's	1 1/2" x 1 : SCH40 BUSHING	1	$1.09	$1.09		$3,275.02
ROV	4/29/2012	Lowe's	1" x 3/4" SCH40 BUSHING 4	1	$0.69	$0.69		$3,274.33
ROV	4/29/2012	Lowe's	1" SCH40 COUPLING 429010	1	$0.37	$0.37		$3,273.96
ROV	4/29/2012	Lowe's	5/16 X 2-1/2 X 5 U-BOLT	1	$1.37	$1.37		$3,272.59
ROV	4/29/2012	Lowe's	10# ANCHORIN G CEMENT	1	$8.45	$8.45		$3,264.14
ROV	4/29/2012	Lowe's	3M TOUGH 2" OUTDORR DUCT	1	$7.98	$7.98		$3,256.16
ROV	4/29/2012	Lowe's	3/4INX10FT S40 PVCPIPE PL	3	$1.97	$5.91		$3,250.25
ROV	5/1/2012	Lowe's	4"X5'S40 PVC-DWV CELLCORE	1	$14.78	$14.78		$3,235.47
Mission Props	3/1/2012	Home Depot	spray paint plasti-dip spray black	1	$5.98	$5.98		$3,229.49
Mission Props	3/1/2012	Home Depot	1-1/2 pvc elbow 90degrees	15	$1.21	$18.15		$3,211.34
Mission Props	3/1/2012	Home Depot	Dwv pipe	4	$4.65	$18.60		$3,192.74
Poster	4/27/2012	Staples	HP 74/75 Blk/Clr ink	1	$31.99	$31.99		$3,160.75
Poster	4/27/2012	Staples	Foam display board	1	$15.99	$15.99		$3,144.76

Poster	4/27/2012	Parcel Plus	Poster print out	1	$90.00	$90.00		$3,054.76
ROV	5/1/2012	Star Marine Depot	Rule Bilge Pump 2000 submersible(32)	6	$100.61	$603.66		$2,451.10
ROV	5/10/2012	ALREADY OWNED	Cameras	6	$100.45	$602.70		$1,848.40
ROV	5/10/2012	ALREADY OWNED	Motors	8	$47.89	$383.12		$1,465.28
ROV	5/10/2012	ALREADY OWNED	Spring Scale	1	$5.00	$5.00		$1,460.28
ROV	5/10/2012	ALREADY OWNED	Tape Measures	3	$7.00	$21.00		$1,439.28
ROV	5/10/2012	ALREADY OWNED	18.4 meters of 16 gauge speaker wire	5	$48.29	$241.45		$1,197.83
ROV	5/10/2012	ALREADY OWNED	fishing weights for ballast	10	$15.00	$150.00		$1,047.83
ROV	5/10/2012	ALREADY OWNED	pool noodle	1	$1.00	$1.00		$1,046.83
Donation	5/22/2012	SPI Pharma	-	-	-		$250.00	$1,296.83
Donation	3/28/2012	Self	-	-	-		$100.00	$1,396.83
Donation	5/18/2012	Delaware Anestesia Associates	-	-	-		$100.00	$1,496.83
Donation	5/18/2012	Aldred	-	-	-		$500.00	$1,996.83
Donation	5/18/2012	Spicer Real Estate	-	-	-		$250.00	$2,246.83
Donation	5/18/2012	Dan's Tackle Box	-	-	-		$25.00	$2,271.83
Donation	5/20/2012	Dr. Rowan	-	-	-		$10.00	$2,281.83
TOTALS						**$3,271.30**	**$5,553.13**	**$2,281.83**