St. Augustine High School

ROV Team

Top: Sam Julian (11), Kevin Bretney (12) (Team Captain), Matthew Gandolfo (10), James Belasco (12), Daniel Heinrich (11) Mr. Weber (moderator)
Bottom: Alfredo Perez (09), Andrew Shao (12) (Co-Captain), Peter Garcia (09), Philip Nguyen (10)
Not Pictured: Ryan Savino (12), Jack Loehr (12), Carlo Yubane (09), Paul Ventura (09)

Abstract

An ROV (remotely operated vehicle) is an unmanned underwater vehicle used to collect objects and data (pictures, video, samples, measurements, etc.) from remote places in the ocean, for various reasons. They have evolved into retrievers of artifacts, mappers of the ocean floor, and even platforms for cameras recording material for documentation and research.

The St. Augustine ROV team has worked hard in the past several months on an ROV for this year's competition. We have grown much from our experiences at last year's competition. We have improved upon innovations made last year and made further leaps this year. We will be operating 2 ROVs off one tether to accomplish the tasks. The Main one will insert the communication link and pick up the probes. The secondary one will take the temperature and sample the liquid. We are using our Playstation controller system again to control it.

We have worked together not just towards this competition, but also on our friendship and teamwork. This competition has helped to tune our teamwork and leadership skills as we have all collaborated on this project. We divided up the tasks and brought them all together to create the final ROV design, research report and documentation for this endeavor. We worked on presenting our ideas and explaining them in detail to the rest of the team. This experience has awakened our hidden talents and brought forth an ROV that we are proud of.

Design Rationale

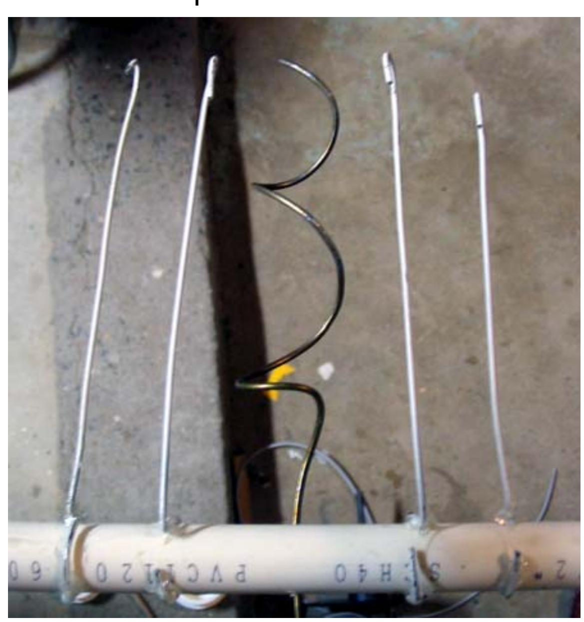
Our ROV considered several different component areas of an ROV: the frame, retrieval methods, thrusters, the umbilical/tether, electronic and control systems, and the 'underwater eyes'.

Frame

We are building our ROV in two stages, in the first stage we built our frame out of PVC to get our dimensions and the look correct. We chose PVC to experiment with since it is cheap and very easy to work with. Our second stage will consist of 80/20 brand Quick Frame. It is an aluminum box material that utilizes plastic connectors. Our material for this is due to arrive the first week in June but we are still using our PVC frame to test with. Our electronics are is two water tight containers formed by 2 inch PVC pipe with compression fittings and tubing for connectors and a rubber end cap to access the inside. In one of the containers on the main ROV are the voltage regulators and the ESCs and in the other is the rest of the electronics. On the other ROV the batteries are in one and the ESCs and the electronics are in the other.

Retrieval Methods

For retrieval on our ROV, we decided to split the tasks up between two ROVs. We divided the tasks according to location at the bottom of the pool. The primary ROV will work on the Science Package and the other will explore the crevice and the vent. The first task for the Primary ROV is re-inserting the communications link. After pondering over many design possibilities and devices for dropping the probe into the cup, we decided to go with the simplest design possible that required the fewest moving parts. Since the



probe is relatively easy to manipulate we decided that we could forgo a full-fledged claw, which would require more material and work, and simply use an Archimedes screw powered by a simple waterproofed motor. The beauty of this design is in its simplicity. All we have to do to make it work is attach the screw to the shaft of the motor, which is then mounted on the front of the ROV, and then when the time comes, put the probe on the screw. The screw will prevent the probe from detaching while the ROV is moving, but at the same time when the motor is turned on the probe will simply move along the screw and fall of exactly into position negating any hazards we might have with attachment substances. For its second task on the science package the ROV has a series of hooks sticking out the front of the ROV. These hooks are intended to catch the rings on the top of the probes and pull them up. Again we could have gone with a complicated claw design however we wanted to minimize the moving parts. In fact there are no moving parts. The hooks are made of coat hanger since it is the perfect blending of rigidity and flexibility meaning that it will stay in shape with a probe on it and is easy enough to bend into position if it gets screwed up. The wires are turned up at the end so that the probe will not fall back off once we retrieve it. We are using an array of hooks so that we can increase our chances of getting as many as possible at one time so that we can get back to the surface quickly.

Our second ROV is going for the liquid and the temperature. We plan on starting with the liquid since the temperature takes some time to get to a level temperature so

leaving it last allows more time to find a solid temperature. Now in our quest to keep everything simple we have combined the two tasks into the same device, or at least the same front end. Both our liquid tube and our temperature probe are on the same probe. The probe is situated in the center of a hole in the top of a funnel. We are using the funnel to line up with the protruding pipe and center ourselves. Once we are centered the tube will go up the center of the funnel and the probe will go down the tube allowing the probes the deepest possible sample level. First the liquid; our design idea for collecting the 500mL of fluid that we want to collect is slightly complicated, and is still being tested for its effectiveness, but we believe that it will work well. This design consists of many syringes, the backs of which are attached by metal rods to a screw which is then turned by a motor to pull up the backs of the syringes and thereby collect the fluid sample. We chose this design in the interest of getting the purest sample possible since the syringes minimize water absorption as well as eliminate the air that might be mixed in using other collection devices and would thereby limit our collection capacity. The syringes will be attached to one tube leading down to the probe so they suck from a common source. Since the exact technical workings of this design are difficult, we have also thought of using a tube and pump system powered by a bilge pump motor and are actively testing that idea as well and the choice of which to use has not been made for sure. Finally we come to the last task, the temperature. We spent a lot of time trying to find a thermometer that was accurate to .1 Celsius, and cheap. Finally our computer nerds had a revelation. Computer enthusiasts measure case temperatures and there are many stores that have these thermometers. We found one that displays to an LCD display. We waterproofed the display in a similar fashion to the cameras so we could see the readout with the camera. This thermometer is somewhat temperamental and tends to fluctuate a bit too much for our tastes but if we leave it for a while it stabilizes.

Thrusters

This year we decided to stay with the bilge pump motor idea and expanded upon it further. Since we were going to be operating at a much deeper depth we decided we needed fluid compensated motors. Most bilge pumps were sealed up well but tended to leak at depth however we found Piranha bilge pumps which had 2 screws with o-rings that we could take out. We took these out and filled the inside with non-conducting baby oil (baby oil is mineral oil with fragrance, we wanted a different smell and it was available.) We also are using larger motors designed for 1000 GPH bilge pumps as opposed to 500 GPH ones giving us more power. Again we are changing this year and we are using plane propellers instead of boat props since a lower pitch and longer blade worked better at giving power at slow speed (moving speeds not RPM). We are currently sing 2 bladed props but are considering going to a 4 bladed one for more power.

Umbilical/Tether

Our tether this year is the thinnest yet for us and in fact it could probably be thinner but we want room to expand. We are using an 18 gauge speaker wire pair for power

which should be able to handle the max of 10 amps. For everything else we are using a single cat 5e cable which is an 8 conductor cable. 8 is way more than enough since we only really need 4 but we will expand out and use 6 leaving room to expand with another camera or two if we wanted. We are using cat 5 since it is very flexible and dirt cheap at less than 15 cents per meter. We have a total length of 30 meters to the main ROV which is more than enough. Our second tether to the second ROV is a single cat 5e cable to cover video and data transmission between the surface and the second ROV. The second tether will be 15 meters long and will pay out as the second ROV moves away from the first and will stay out back up to the surface.

Electronic and Control Systems

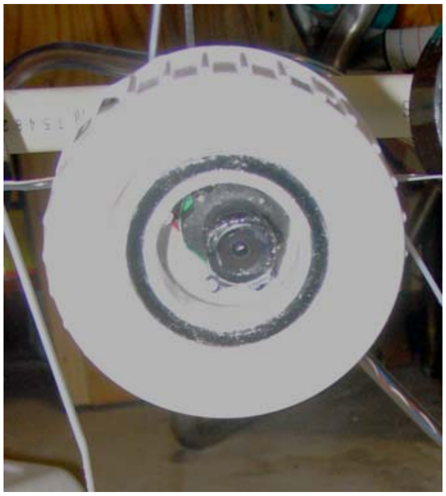
This year we decided to continue the use of the Playstation controllers. Starting from the top down we opted for the use of a dual joystick analog Playstation controller for driving and the buttons for the pump and screw. The controller could be interpreted by many microcontrollers. We decided to use the BASIC STAMP microcontroller due to the support and readily available add-ons.

The microcontroller allows us to use a much smaller tether since all commands could be sent through one serial signal cable. At the opposite end of the tether the signal is received by a Parallax Servo Controller (PSC) in each of the ROVs electrical containers. This device takes a serial signal and with one module allows for control of up to sixteen servos (or other devices using the system). This allowed for all components we want as well as room for expansion if the need arises. The PSC outputs signals the speed controllers for the thrusters. This relatively simple design allows for less chance of problems as well as troubleshooting options through a separate programming computer if need be.

We decided to take advantage of both the topside 48 volt maximum and the underwater 12 volt power sources. We are actually only using 36 volts down the tether and the amps will stay less than ten. The reason we are only going with 36 volts and not 48 is because the voltage regulators we are using on the ROV to convert the power back down to 12 volts for use with the thrusters and 6 volts for the electronics. We are converting the power down using 12 volt 2 amp voltage regulators. We have more than enough with 12 amps worth for each speed controller so they will not heat up too much since we expect a maximum draw of only 5 amps per thruster at stall. The schematic reflects only one per ESC however there are actually 6 per ESC. The reason we are stepping the voltage up is to reduce the size of the tether. We plan on a maximum current draw on the ROV itself to be approximately 25-30 amps at 12 volts so converting to 36 volts the current traveling down the tether is less than 10 amps allowing us to use a very thin tether. We are using the tether power for the main ROV and the on board power with the second ROV. On the second ROV we are using C-cell HI-MH rechargeable batteries in a 10 cell configuration to give us about 12 volts. These batteries should provide enough power to power us through the duration of the competition assuming continuous 20 amp draw which of course will probably not happen.

‘Underwater Eyes’

The cameras that we are using are X-10 cameras. We purchased them on sale and they are all color. We have one main camera on each ROV which wave wide angle lenses



(120 degrees) thus allowing us to see more in the confined space in which we will be working. This way we do not need any moving parts so it lessens risks. We used a PVC coupler and a series of pipe diameter reducers to bring the back end from an opening to a compression fitting for the wires. On the other end half of the PVC coupler was removed and replaced with a piece of lexan. Since the coupler has an o-ring built in the container was very easy to build and holds up very well under water. They are connected to two televisions so that each of the drivers can see what they are doing.

Challenges

Our team lacks the proper equipment and the necessary funding that would enable to most efficiently and professionally build our ROV. Nearly every part that goes on it is built using hand tools; our workspace is a one-car garage that our team captain has donated. The team tries to compensate by recognizing this limitation and planning a design that is within our grasp. We use our team members' ingenuity and creativity to build a highly sophisticated and effective robot that meets all the mission requirements. To deal with our funding issues, we peruse various websites and stores looking for the lowest prices. We recycle parts from previous years and competitions to minimize the amount of redundant parts. Team members' spend time adapting these parts, customizing them to work in an underwater environment. We meet these two challenges with determination, ingenuity, creativity, and thrift. It challenges our minds to improvise, to adapt, and to succeed as best we can with what we were given.

Another challenge lies within ourselves as a whole. Many of us because of our schedules cannot dedicate enough time to the MATE competition as we would like. Oftentimes we fail to push ourselves work or we procrastinate. We try to make up for this our collective failing by working intensely during our design and building sessions.

Troubleshooting Techniques

One of the most important troubleshooting techniques was to test everything at various stages of development so that any problems could be identified right away. For instance with the thruster control circuit we tested the thrusters directly with the battery, with the speed control circuit directly to the STAMP, with the speed controller through an extended line, and finally connected through the entire circuit, tether and all. Many of the other systems were tested in such a manner as well.

Another technique was to use the trusty multimeter to check voltages and amperage draw on all of the individual devices so that any jumps in voltage or drops for that matter would alert us to any potential problems. We also worked with fuses less than the specified maximum so that we knew how close, or far, we are from the maximum allowed.

The most time consuming but effective technique is the method of elimination. If something happened to leak, we would put it in a shallow tub to find the location of the bubbles, if no bubbles then it must be a slow leak through a through-hull connection. We would seal off that entry point for water and see if that fixed the problem. We would continue in this fashion, eliminating different variables each time until we arrived at the underlying problem.

Lastly the most common would be trial and error. If a problem arose we would use method of elimination to isolate the problem, find out how to fix the problem, and fix it, keeping in mind the mistake so as not to make it again.

Lessons Learned/Skills Gained

Each team member lacks certain skills. Some of us have never touched a soldering iron before, others have never programmed, others never picked up a pen to draw a blueprint. However, we discovered the value and skill of working as a team. We help each other learn, debate ideas, mull over plans, and execute the building as a collective unit. Some who had never learned to use a hand tool were taught and soon were assembling crucial parts of the robot under another member's supervision. Through this sort of relationship, the apprentice gains confidence in his own abilities, and the mentor learns how to teach another, to lead others to improve, and thus better the team as a whole. We regard this acquired skill of teamwork as one of our group's greatest strengths. It is how, despite our busy schedules and lack of time, that we are still able to effectively compete against other teams. Additionally, we hope that the newer or younger members of our club will be able to replace older members and keep the team alive and vibrant.

Future Improvements

There are many improvements that we can make. We would like some sort of feedback system so that we know better how we are oriented in our environment. With the desire to keep conductor counts low we decided against having a bi-directional serial signal which would allow for communications from sensors onboard the ROV up to the surface. Such things as a collision sensor if part of the ROV that cannot be seen by the cameras runs into part of the structure we could have the controller shake or ‘rumble’ as in a force feedback joystick.

Another idea that we did not have a chance to look at is the use of a ‘fish finder’ to tell where we are located in respect to surrounding obstacles. We could use transponders at various locations to give a 3-D idea of where we are situated. An idea that goes along with this would be a computer program which would give a real time image of the location and surroundings of the ROV.

An idea to keep the tether smaller which we did not have the time or facilities to test was the use of a fiber-optic strand to carry signal and video. It would allow for the potential of only one fiber, and two power cables, greatly shrinking the size of the tether.

Another idea we have that can be implemented easily enough is a tether reel. A hose reel would work well or one of our own manufacturing could work as well. Due to the complicated nature of the tether it would probably not operate with the tether still on the reel, but that might happen in the future.

Benthic Exploration

Some of the most inhospitable places on Earth are the oceans. It has been said that we know more about our solar systems than we do about the ocean floor. Due to the depth, high pressure, and extreme cold of the ocean depths, designing and building a vehicle that would sustain human life is extremely impractical especially in areas where sustained data collection and monitoring is required. In response, engineers have collaborated to develop a fleet of autonomous underwater vehicles. At the Woods Hole Oceanographic Institution engineers designed the Autonomous Benthic Explorer (ABE) to be able to guide itself and take photos of thermophilic bacteria that thrive in the extreme heat vents that dot the ocean floor. It is designed to work down to 5,000 meters which is roughly the equivalent of 500 atmospheres, 500 times the pressure felt at sea level and far beyond the service of man. Our ROV, being a less ambitious, amateur project, is not capable of such depths, but we too must be conscious of water pressure. We operate at depths of approximate 12-14 meters at a pressure of 1.15 atmospheres; no small feet for a robot designed from PVC piping and stock aluminum.

Another of the tasks of the ABE is to produce thermal maps of areas of interest. Its temperature probes keep track of the locations of higher temperature streams of water, the data being used to pinpoint heat vents in the ocean floor. These vents allow scientists to map the movement of "plumes" of high heat as it spreads out from the ocean floor. Marine biologists enjoy the opportunity to identify possible dwelling places of thermophilic bacteria. Similarly, our robot must take a temperature reading using its own probe and report the data back to the observers.

One of the most crucial pieces of information that we lack about the deep sea is what the floor actually looks like. Even the best sonar images can only provide us with an approximation of its actuality. Plus, part of the human condition is placing great importance on actually seeing the unknown to prove one's hypotheses. Thus, the ABE is equipped with stereoscopic video cameras. While we primarily use the cameras on our ROV for guidance, it does give us a visualization of the actual course, allowing us to analyze the area and perform accordingly.

ROVs such as the ABE allow humanity to expand its vision of the world and its knowledge by traveling to places almost impossible to visit in person. We send out these underwater servants to do our bidding to relay us information. They collect, process, and deliver data faithfully all with limited expense and danger to human life. Working on our ROV, we face the same difficulties, concepts, and challenges that all the engineers working on deep sea reconnaissance have dealt with in their own designs.

http://oceanexplorer.noaa.gov/technology/subs/abe/abe.html

http://www.whoi.edu/institutes/instruments/abe.htm

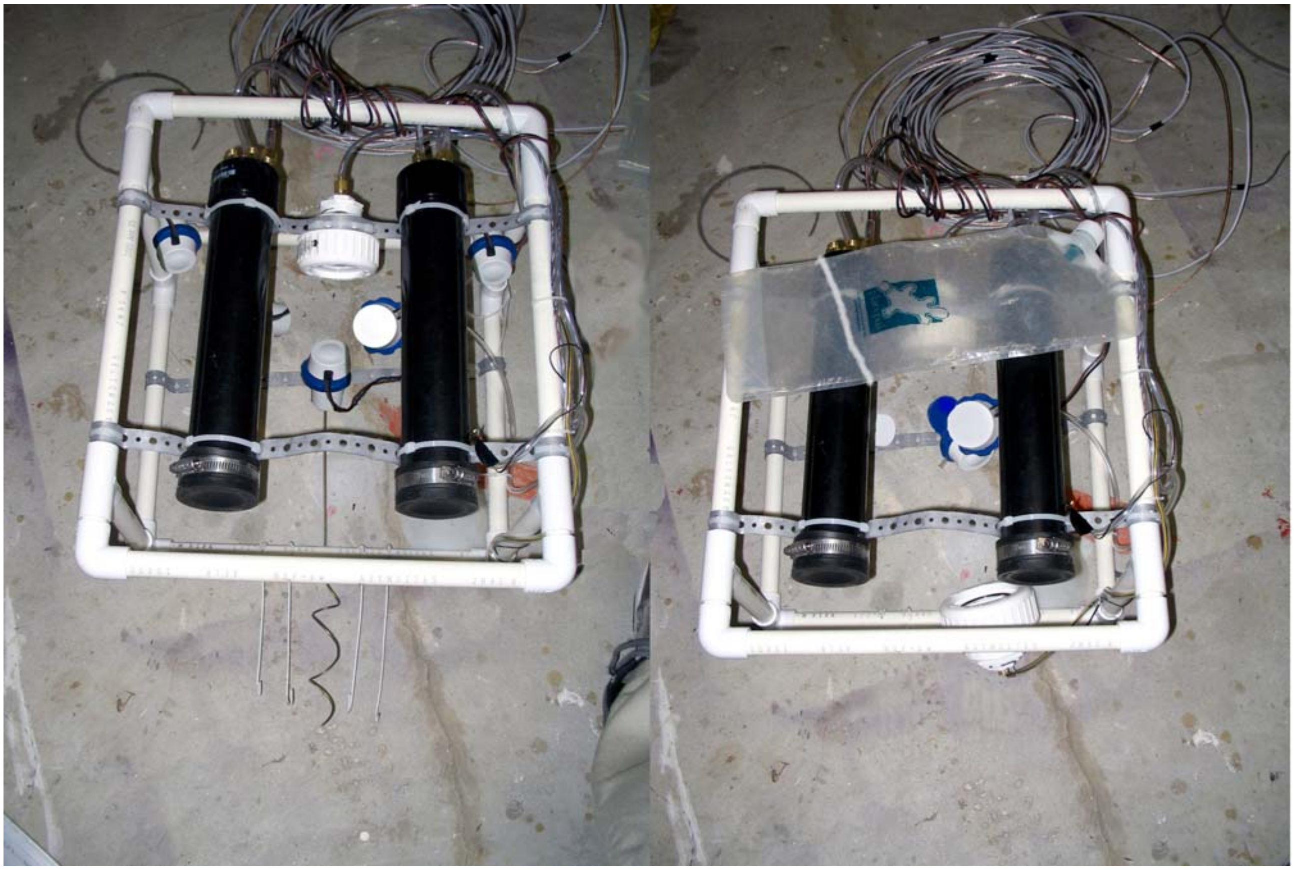
Acknowledgements

The team would like to thank all of our parents for providing transportation and the initial funding for the project. We would like to acknowledge the Saints Booster Club for again providing $2,200 for the project and MATE for their support of $100. Without their support we would have not been able to build anything, much less an ROV.

We would like to thank the employees at F and L Industries especially Mr. Fanolla for donating the aluminum for the frame. We would also like to thank the Heinrich and Belasco families for allowing us to use their pools.

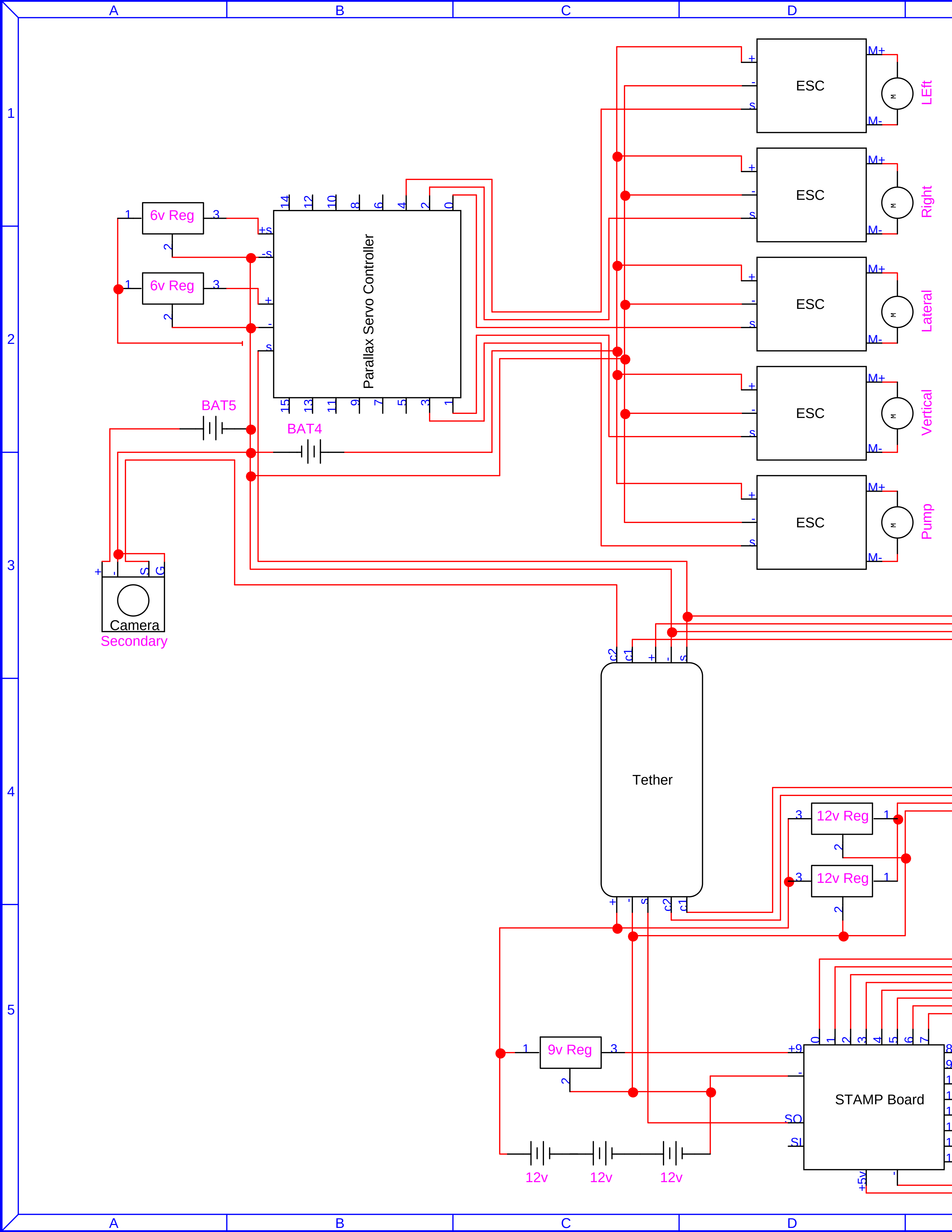
We would like to acknowledge Mr. Weber for allowing us to use his classroom for our meetings and providing communication between the team and the competition officials On that note thank you to everyone who helped to organize this event and make the competition possible.

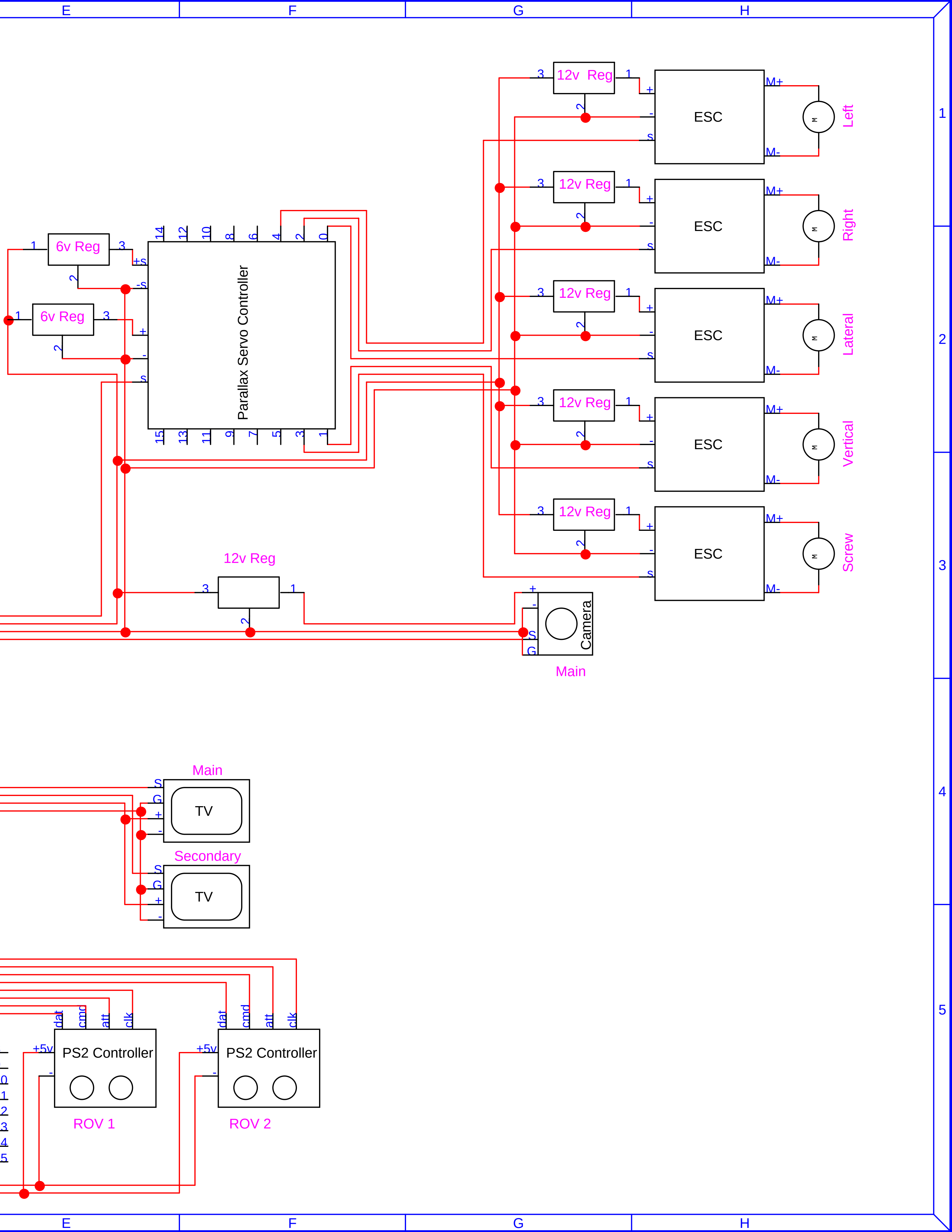
Pictures



At the point that this picture was taken we had not had the resources to construct both ROVs so we simply swapped components for the picture to give you a general idea however the frame will change to aluminum by the time we get to the competition. The two will look remarkably similar to each other at the competition as well.

		Expenses	Assets
Donations			
MATE	100		
MATE (travel)	1500		
Saints Boosters	2200		
Total			**3800**
Thrusters			
Budgeted			**300**
Bilge pumps	191.6		
Props	48.37		
Subtotal		**239.97**	
Net:		60.03	
Electronics and Control			
Budgeted			**400**
Speed Controllers	298.49		
Misc.			
Subtotal		**298.49**	
Net:		101.51	
Vision			
Budgeted			**200**
Cameras	90.99		
Waterproofing	15		
Subtotal		**105.99**	
Net:		94.01	
Retrieval			
Budgeted			**150**
Coathanger	0		
Bilge pumps	39.9		
Tubing	9.96		
Temp Probe	20		
Subtotal		**69.86**	
Net:		80.14	
Frame			
Budgeted			**100**
PVC	50		
Aluminum	0		
misc.	10		
Subtotal		**60**	
Net:		40	
Tether			
Budgeted			**150**
Main tether	90		
Tubing	40		
Subtotal		**130**	
Net:		20	
Travel and Transportation			
Budgeted			**2500**
Plane tickets		1500	
Van rental		400	
Gasoline		200	
Subtotal		**2100**	
Net:		400	
Total Received:			**3800**
Total Alloted			**3800**
Total Spent:		**3004.31**	
Net:			**795.69**


ESC
LEft
Right
Lateral
Vertical
Pump
M+
M-
6v Reg
6v Reg
Parallax Servo Controller
BAT5
BAT4
Camera
Secondary
Tether
12v Reg
12v Reg
9v Reg
STAMP Board
12v
12v
12v
+9
SO
SI
+5v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