MPC Monterey Peninsula College Robotics Team

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Mentor: Jeremy Hertzberg

ROV - RIP TIDE

Abstract

The ROV (Remotely Operated Vehicle) *Rip Tide* was built by the MPC Robotics Team to compete in the 2010 MATE International ROV Competition. *Rip Tide* was designed to perform tasks relevant to an undersea volcano observatory, such as resurrecting HUGO (Hawaii Undersea Geological Observatory) by installing a new hydrophone and collecting different samples. The total for building this ROV and traveling to the MATE Competition cost approximately $8.500. *Rip Tide* was created with specially cut PVC (Polyvinyl Chloride) Foam Board connected by steel rods for its frame and integrated two Rule 3700 bilge pumps, two VSPs (Voith Schneider Propellers) for precision turning and three modified Anaconda Cameras. Also incorporated are six main payload tools: Sound detector, gripping device, crustacean collector vacuum, thermometer, height detector, and syringe for bacterial mats. The control system was programmed in Microsoft Visual C# and runs using a Parallax stamp. The ROV has an onboard electronics system that is inside a PVC Housing connected to the surface using a custom-built tether. The topside electronics consist of a joystick, control unit and two DC/DC converters. A major innovation this year was the installation and programming of four Servos to control our two VSPs. During this process, team members learned the importance of time management and why coordination must be done for work to continue when several students live with several different study and work schedules. Numerous hours were spent planning, building, testing and redesigning the different portions of our ROV.

Contents

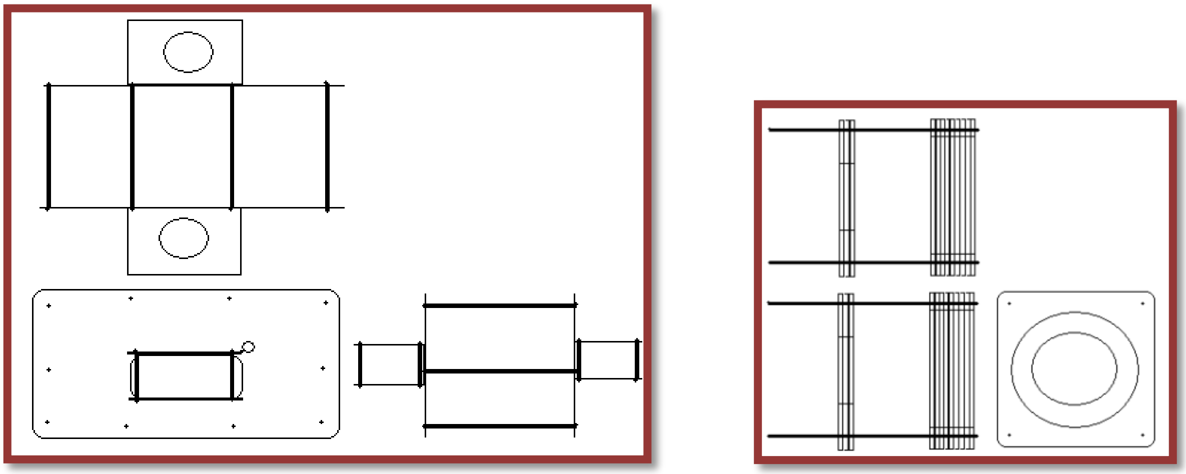


Figure 1 – Concept drawings for *Rip Tide's* frame (left) and motor covers (right)

PHOTOS OF ROV

Figure 2 - ROV *Rip Tide before payload items and buoyancy installed*

Figure 3 - ROV *The Beast* - Prototype - Used to test equipment and tools before attaching to competition ROV *Rip Tide*

VEHICLE SYSTEMS

ROV Frame


Figure 4 - Lisa setting up CNC Machine.

The main structural components of *Rip Tide* were made up of two specially cut 6.25cm PVC Boards. This year, the team wanted to get away from PVC piping and try something different. Time was spent working with carbon fiber, but it was found to be too difficult to work with. The safety procedures for cutting and sizing were too extensive for the time constraints we were in and the team moved over to PVC Foam Board. It was found to be light weight (550 kg/m^3) and easier to work with. The sides are two 30.4cm by 45.7cm boards connected together with ten 6.25cm threaded steel rods and spacers. These components were designed using CAD to allow for sufficient spacing for all the required payload tools and cut out in several weekend meetings using a CNC (Computer Numerical Controlled) Router. PVC Board was also used to create a cradle for the electronics housing and protection for the four motor systems.

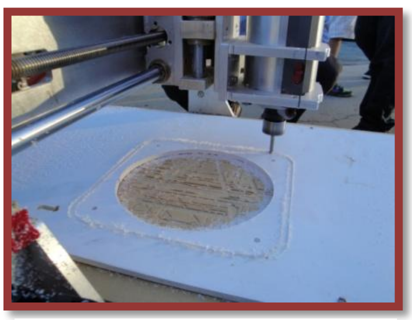


Figure 6 - CNC Machine cutting propeller protectors

Because our main motors were so powerful, we felt it was important to completely enclose the propellers so nobody lost any fingers. On our practice vehicle, poorly sized plastic buckets and mesh were used, but for our real ROV, we designed a cover based on a calculus problem of rotating a system around an axis. This was contrived after numerous shopping trips and an online search for a 17.75cm diameter cylinder that was too elusive to find. We were able to cut out eighteen large plates and six smaller plates and fasten them together with threaded steel rods. The rods had two purposes: one – to hold the plates together, and two – to keep the propeller parallel to the direction of movement we desired. Between the bottom two plates, we attached mesh screen to protect the propellers even more. We liked these plates a lot, as they both served our safety purpose and looked aesthetically pleasing, so we designed four more plates to protect our two VSPs, as well.


Figure 5 - View of propeller protection system with partially installed motor

Electronics Housings

Figure 7 - Watertight Cylinder

In an effort to reduce the size of our tether, we chose to place a large portion of our electronics underwater. To do this, we had to design a waterproof housing to keep those electronics dry while keeping it within a certain size to prevent throwing off our buoyancy too much. We needed a housing that wasn't going to be an enormous weight or an enormous float on our ROV. So we placed a majority of our electronics on a piece of PVC board to see what kind of dimensions we were looking at and our minimum sizing for our housing. We calculated that we'd need about a 25cm length of 3" ABS pipe and chose to use this as our "watertight cylinder."

The Electronics on *Rip Tide* are all submerged under water. This includes all voltage transformers and step down electronic systems that become very hot when in an isolated tube. Thus we had to create a way for the cool water from the outside of the water tight chamber to interact and cool the overheating electronics. The system we devised was a simple water jacket. The only altercation that was made to the tube to allow the system to function was drilling two 1.75cm holes in one of the end caps to secure two unique fittings that would allow a tube with water traveling in it to protrude through the cap; allowing the cooling water *Rip Tide* was surrounded in to be pumped in and then out of the water tight cylinder without any water leaking in the cylinder. From there, we routed the water to a home built water jacket. The jacket is made of two identical 10cm by 30cm plates of brass. One of the plates was formed into a half box by cutting squares out of the corners and folding the edges upward in a 90° angle. From there we water welled the top, flat, unmodified plate; the bottom half box plate; and then drilled two holes in one of the sides of the bottom plate to allow water to flow freely in and out of the jacket. This created a 30cm by 10cm plate that all of the overheating electronics could be mounted to by using the conductive double stick tape. The last step was to find a pump to drive the water through the piping and into and out of the jacket. The motor we used was a window washer motor that was quite efficient at moving large amounts of water through the block in a short period of time. The water block is so efficient at sucking heat from the system that we put a blow torch directly on the middle of it when the pump was on and then put our other hands 2.5cm away from where the torches flame touched the brass and we never felt it even get warm.

Thrusters

Based on the slow performance of last year's vehicle, the team chose to use some more powerful motors. After cleaning out our storage facility, we discovered several modified 32V, Rule 3700 Bilge Pumps and some old propellers. After extensive testing (because we broke our testing device twice), we determined that these motors would be powerful enough to get up to the surface quickly with a pretty heavy load. It is our understanding that the pumps came from The *Eagle2* ROV that Matt Gardner competed with many years ago and the propellers came from the ROV *X-Wing* which was also used several years ago. Luck was on our side.

Figure 8 – rule 3700 Bilge Pump before modification

Figure 9 - Voith Schneider Propeller

Maneuverability was also a strong desire, so our team started investigating some alternative solutions and discovered the Voith Schneider Propeller. As advertised,

"This propeller allows thrust of any magnitude to be generated in any direction quickly, precisely and in a continuously variable manner. It combines propulsion and steering in a single unit."

It is basically a rotor casing with five parallel blades that rotate about a vertical axis. To create thrust, each blade oscillates about its own axis.

The VSP well consists of a cylindrical shell. We used a 90® flange (see Fig. 10) to connect the top of the VSP to two Servos that helped control the direction of each individual propeller. The great thing about the VSP is that the propeller thrust can vary by a full 360° which allows for moving in every direction on the vertical plane. We purchased one of these to test out and were amazed at how precise we could maneuver and immediately started working on fundraisers to get a second one.


Figure 10 - Inside View of VSP well.

As stated previously, we connected Servos to help control our VSPs. A servo is a small motor with an output shaft that can be programmed to position itself in specific angular positions. We discovered the Traxxas 2056 High-Torque Waterproof Servo online and immediately ordered four. To our disappointment, they weren't as waterproofed as we needed and leaked after twenty minutes, at a pool depth of four meters. We still really wanted to use them, so we dismantled them and waterproofed them ourselves by immersing them in mineral oil and reassembling them. We then coated the outside with silicone rubber adhesive sealant. For our purpose, these servos are great little, light weight (45.0 g) high torque (5.76kg-cm) systems

Figure 11 - Dismantled Servo –2.17mm x 20.1mm x 42.9mm

Tether

Our tether consists of three separate 30m cables. One cable is a CAT5E Riser Cable. This cable has a temperature rating of 75°C and a voltage rating of 300VDC.This cable was used for connecting our computer on dry land to our stamp which is in the underwater cylinder. We also purchased and modified a ten gauge, high density, Ridgid extension cord. We chose this cord because we found it to be more flexible to handle in the water. We used this cord for operating our other payload devices. Although our third wire started out as your basic speaker wire, we changed it out with 12 gauge wire (See troubleshooting section for more details). This wire was chosen to ensure quality connectivity between our VSPs and our surface control box.

With three stands of cable running from the surface to our ROV, we thought it was best to add some buoyancy to our tether system. In past years, we preferred to have a little more buoyancy in the tether; but this year, the task of entering and exiting a cave made us decide to make our tether neutrally buoyant. To do this we added ping pong balls in small net fittings that we Velcroed to various locations on the tether.

Cameras

Rip Tide sees through three Anaconda Color Cameras that were modified at the MATE camera-waterproofing workshops held in previous years. Each camera draws only 0.2 amps from our battery supply. To waterproof these cameras, we removed the lenses from their original housings and glued them to the bottom of a clear plastic casing with silicone adhesive. The case was then filled with five-minute epoxy. Food coloring was added to the epoxy to make them pretty colors and had no other benefit to the operation of the cameras. It was just fun to do. The cameras were attached to *Rip Tide* with adjustable clamps to allow adjustment of these cameras into the best position and angle for highest visibility while maneuvering underwater. Since the focal length is only about 18.0cm, we had to change the placement of our cameras numerous times, allowing for the most optimal location without adding more and more cameras.

Figure 12 - Grant working on some wiring

LOIHI SEAMOUNT

Loihi seamount is sometimes thought of as the "youngest volcano" in the Hawaiian Islands. It is hidden beneath the waves, just off the coast of the Big Island of Hawaii. Until August of 1996, when Loihi came to life, it was thought to be an inactive volcano. It has been intermittently active ever since.

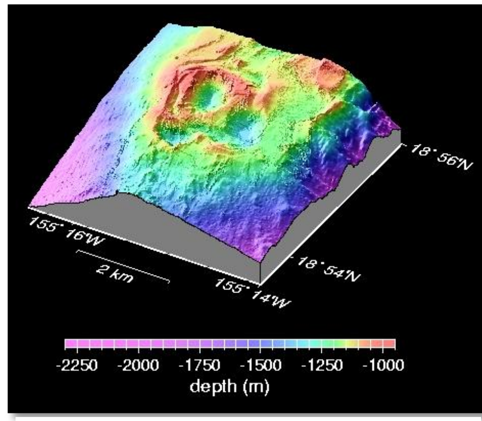


Figure 13 - Loihi Summit Region

Looking at Fig.14 you can see three craters in the center. The Southwest crater was newly formed in 1996 and is called "Pele's Pit." This pit was once the highest point of this underground summit until 1996. Higher even than Mt. St. Helens in the state of Washington. There are large spires on the western side of this crater left behind after the pit collapsed. Hydrothermal vents within Pele's Pit have had temperatures recorded of over 200® C. There is, also, an abundance of microbial mats surrounding these hydrothermal vents. Amazingly, they could reform themselves within a day after samples were taken. Pele's Pit was full of new and exciting activity.


Figure 15 - Preparing HUGOs fiber optic cable for deployment.

This is where the first undersea volcano observatory came to be. HUGO, shortened from The Hawaii Undersea Geo-Observatory, is located in a depression east of Loihi. HUGO was designed to monitor activity on Loihi and included a seismometer, a hydrophone and a pressure sensor. It was also used to monitor earthquakes, eruptions, geology, biology, hydrothermal venting and other activities on this underwater seamount. A 40 km long fiber optic cable provided power to the station from the Big Island. In October of 1998, this cable flooded causing the observatory to shut down. In 1999, HUGO's cable was repaired and it survived another four years before failing again in 2002. HUGO was recovered using ROV JASON fro University of Washington's Research Vessel T.G. Thompson. HUGO has been in-operational ever since.

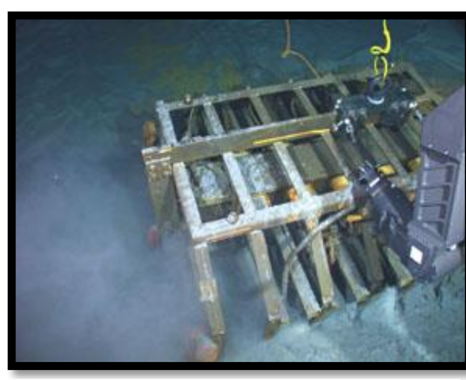


Figure 14 - HUGOs Junction Box being recovered by ROV JASON.

Just like the repairs made to HUGO in 1999, competitors will be resurrecting a simulated HUGO while observing vents, collecting spires and other samples at the MATE International ROV Competition. A challenge has been issued to see what team can be inspired enough to design an ROV that can perform the many tasks assigned within a fifteen minute time limit. ROV *Rip Tide* is traveling to Hawaii with its own Robotics Team for a chance to show their stuff.

DESIGN RATIONALE – TASKS

Task #1 – Resurrect HUGO

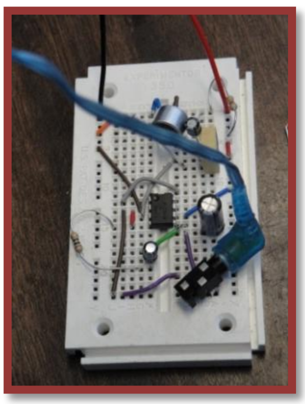


Figure 17 - wiring for sound detection device

There are several steps involved in the task of resurrecting HUGO. First, the site that is rumbling must be detected as well as the frequency of this rumbling. *Rip Tide* has a small sound amplifier wired to a DiSco oscilloscope. This oscilloscope is then connected to the computer that has a frequency analyzer programmed into it. At this point, we have it working above water, but are still working on getting it functional below water. Once we determine the rumbling site, we must remove two pins from each side of the elevator. To remove the pins, we allowed the already built in bar on the front of our ROV latch onto the hook and then applied a little bit of reverse thrust. No additional attachments were necessary for this part of the task. After the pins are removed, the high-rate hydrophone (HRH) must be separated from the elevator and installed at the rumbling site. Finally, the cap will need to be removed from the port on the HUGO junction box and the power/communications connector from the elevator must be installed into this port. We placed a couple threaded hooks on *Rip Tide* that would allow us to remove the cover, choosing to go with simplicity. We intent to use a simple hook device made from PVC Pipe to carry the power/communications connector to the junction box.

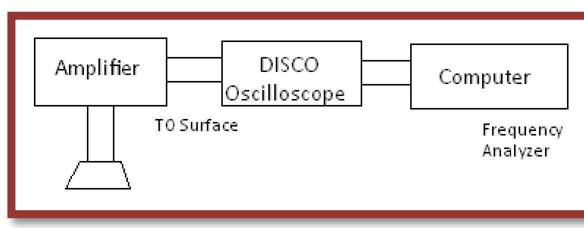


Figure 16 - Audio Amplifier Frequency Detector Scematic

Task #2 – Collect samples of a new species of crustacean

The steps involved in the task of collecting samples of a new species of crustacean involve entering the cave and making a ninety degree turn within this same cave. We were careful to design our ROV Small enough to navigate this turn. Upon reaching the back wall of this cave, three samples of crustaceans must be removed from the wall before maneuvering back out of the cave. Then the samples must be brought back to the surface.

Figure 18 - Rubbermaid Crustacean Sampling Device

To collect the samples, we used a Rule 27D Marine 1100 Bilge Pump. We connected this pump to the bottom of a clear, Rubbermaid container with silicone glue. We, then, fiberglassed a clear 45cm long tube with a diameter of 4cm to the cover of that same Rubbermaid container. By powering up our bilge pump, we created a vacuum that can easily suck the little crustaceans into our tube. The Rubbermaid container is our catcher and by removing the cover, we are able to easily remove our crustaceans at the surface.

TASK #3 – Sample a new vent site

The steps involved in the task of sampling a new vent site involve measuring the temperature of the venting fluid and three heights in the chimney, creating a graph based on this data, and collecting a sample spire.

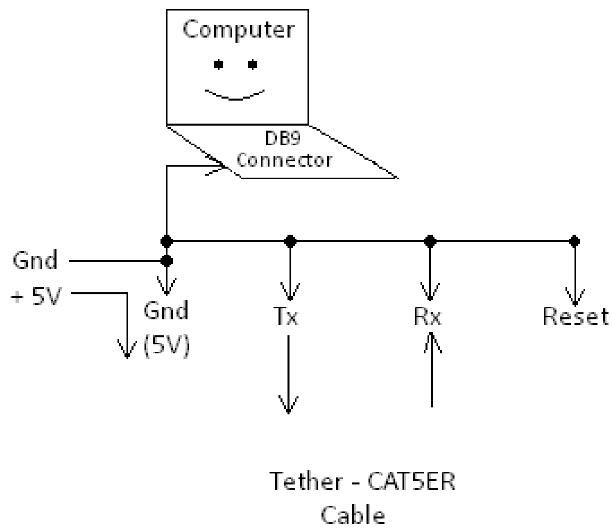
To complete this task, we waterproofed an old, digital aquarium thermometer and attached to the inside of a simple kitchen funnel. Our though process for the funnel was that we would be able to get an accurate reading by covering the vent hole with our funnel for a few moments and then taking the reading on our thermometer. Meanwhile our accelerometer will tell us where we are in the pool. It is our intent to have someone read off the results and another team member to manually input the data into a predrawn graph for the graphing portion of this task.

TASK #4 – Collect a sample of a bacterial mat

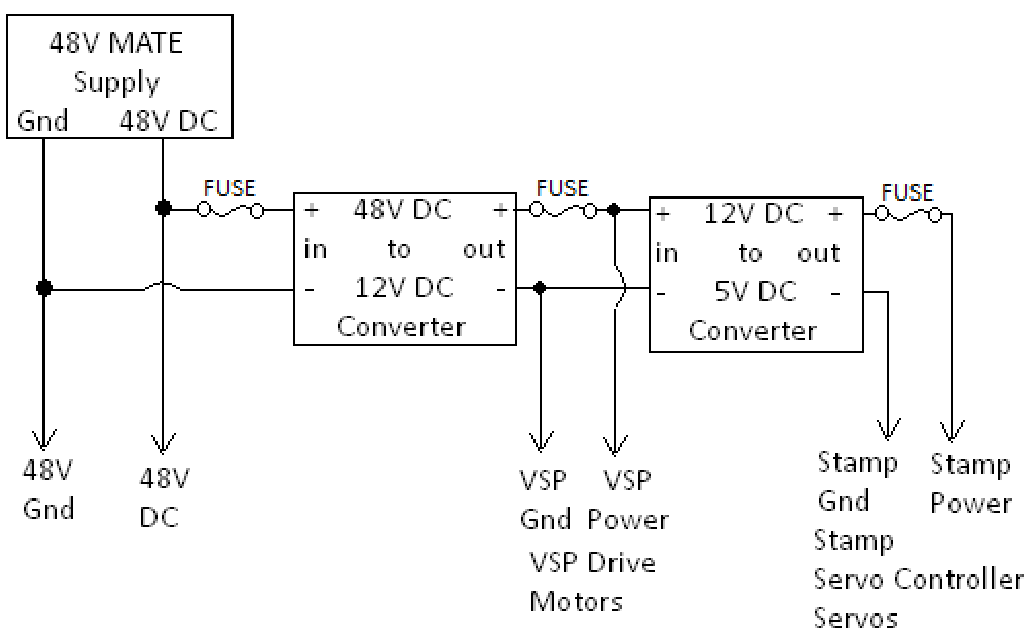
The task of collecting a sample of a bacterial mat and bringing it back to the surface sounds simple enough, but the added challenge of getting between 101mL and 175mL without going too far over or under created a bit of a challenge. We had to do a lot of experimenting to get this to work. To get the desired amount of a bacterial mat sample, we took a syringe and cut the tip off so essentially we had a tube with exact measurements written on the sides. On the top of the siringe we put on a rubber flap that acts like a one way valve. We also attached two much smaller tubes, with rubber flaps on the bottom, to the side of our syringe. With this design we can easily plunge into the bacterial mat with all the water exiting through the one way valve. Once we get deep enough and have the correct amount of sample, we lift the ROV, the valve shuts on the syringe, preventing water from getting back in and creating a suction on the sample. The smaller tubes on the side of the syringe makes two small holes between the bacterial mat and the syringe, allowing water to fill in around the siringe and preventing suction as we pull away from the mat. This made it easier to get our sample and tool out of the bacterial mat.

SCHEMATICS

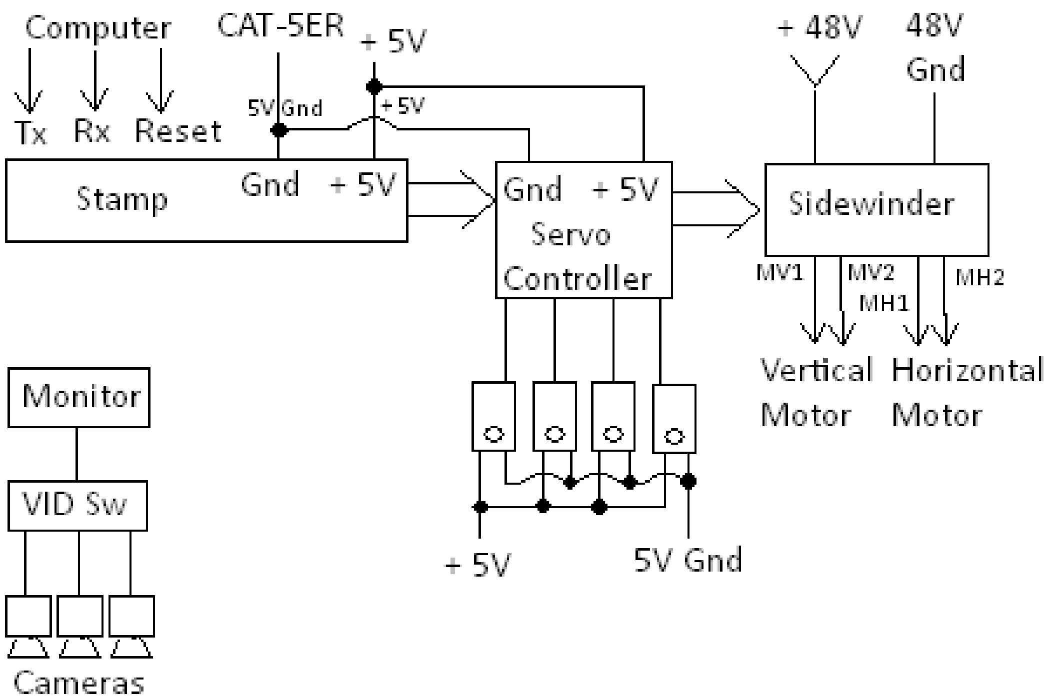
Computer Schematic



Dry Power Schematic



Watertight Cylinder Schematic



SOFTWARE

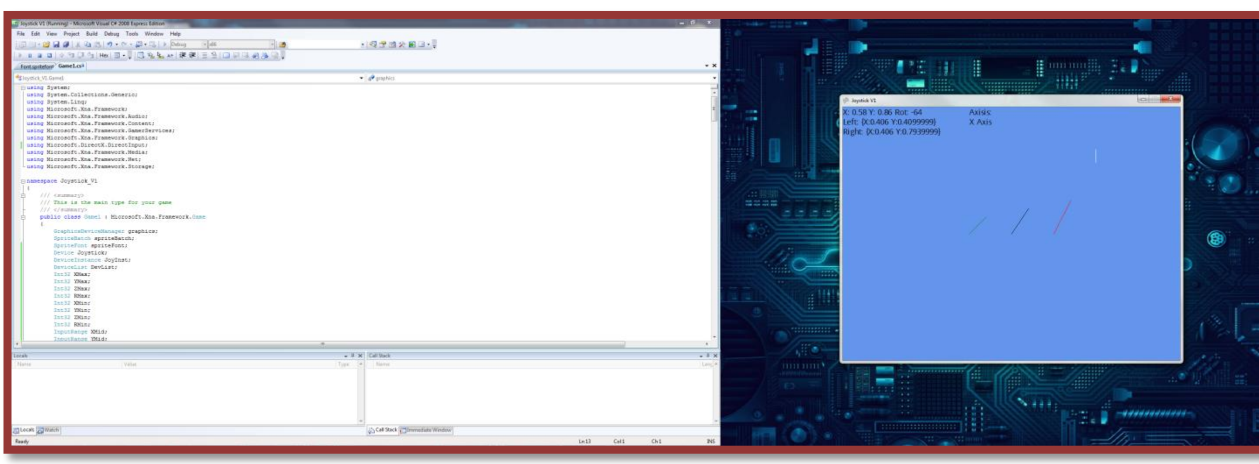


Figure 19 - Screen shot of our programmer's (Ben) computer as he gets our joystick up and running.

Using inexpensive technology, we installed a Joystick and created a basic interface with our program, Microsoft Visual C#. Because we still had to get signal through a 30 m tether, we used a Multichannel RS-232 Driver/Receiver by MAXIM that would allow us a 60 kbps data rate.

TROUBLESHOOTING TECHNIQUES

One of our most current problems occurred after the vehicle was completely together. We had *Rip Tide* in the water and noticed that our VSPs seemed weak and weren't really turning our ROV like it should. Since we were plugged into a fresh power supply, we knew this wasn't the problem. We immediately grabbed a multimeter to see what was up. We discovered that each VSP was only receiving five to six amps when they should have been getting twelve amps. When we put the voltmeter onto our control box, we observed that we were still getting the twelve amps we needed. It was a long Saturday of testing and repairing our 30m line. We started by using the multimeter in multiple locations only to discover the line was bad at the top (control box end). Since this was recycled from a previous year's ROV, we knew it was time to replace this part. With only a little money left in our budget, we had to run to the store to find 30m of 12 gauge lamp wire. Home Depot felt sorry for us and gave us a discount on our wire. Back at the shop, we spend the rest of the afternoon, resoldering and retesting. To our relief, the new wire was a perfect fix and we were back at twelve amps per VSP and with a little fine tuning, we were able to up the amperage to 13.5.

There were many instances where we had to troubleshoot the programming for the ROV's control system. The main one was debugging the communications loop that sends the data to the stamp. Because of the way windows handles serial ports, there was no way (short of an oscilloscope) to see what data was being sent to the computer without pausing the program, which of course would cause errors in the data stream. Because of this, both the loop on the PC and the Stamp had to be very carefully designed, step by step. to avoid ambiguity in the data. Perseverance was our only chance for success.

FUTURE IMPROVEMENTS

One area our team desperately needs to improve on is meeting our time goals. We often were sidetracked or delayed in some way that put us off schedule and we could never catch up again. Aside from classes, homework and reports to do, team members have jobs when they don't have school and on the weekends. With everyone's schedule being different and living in different areas of Monterey, it's difficult to get everyone together at the same convenient time and place. Fortunately, we found time on Friday nights and Saturday afternoons to get work done on the ROV with the entire team present but that wasn't enough. Some team members were able to meet during the week between classes and sacrificing lunch breaks. Slowly but surely, and with a big rush near the end, we completed our ROV *Rip Tide.* Bottom line is that next year, we are creating a timeline and sticking to it.

BUDGET/EXPENSE SHEET

As you can see by our chart, MPC Robotics team managed to get almost half of there expenses covered by donations.

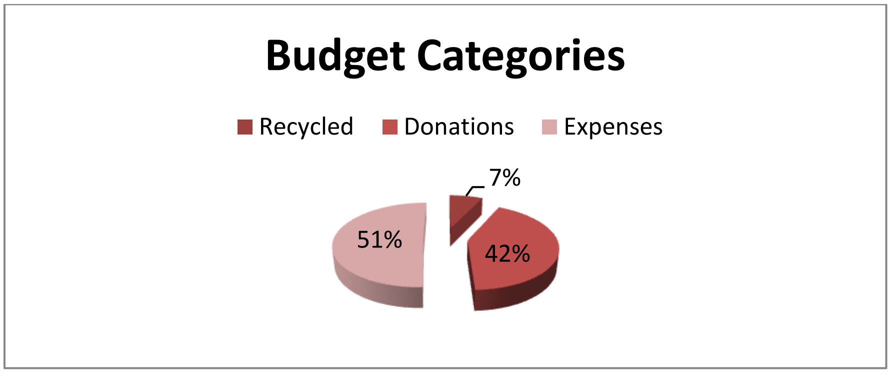


Table 1: Total cost of materials and travel to competition.

Amount		Item	Location	Recycled	Donations	Expenses
34	sq m	PVC Board	MPC Auto Tech	$ 257.58		
3	each	.0625 m - Threaded Steel Rods	Home Depot			$ 4.95
1	box	.0625 m - Nuts	Orchard Supply			$ 5.46
2	sets	Micro 2 Contacts	SubConn		$ 112.60	
2	sets	Micro 6 Contacts	SubConn		$ 112.60	
4	each	Traxxas Servo	ServoCity			$ 111.96
1	all	Shipping expenses	MPC Grant		$ 250.00	
1	Roll	3M Thermal Transfer Tape	iTapeStore			$ 17.58
1	each	5.5V 16A DC/DC Converter	Digi-Key			$ 18.40
1	each	12V 216W DC/DC Converter	Digi-Key			$ 56.00
2	each	PC Board 2-side PPH 2.0 x 3.0	Digi-Key			$ 12.52
1	each	Joystick	Previous ROV	$ 15.00		
1	each	Multichannel RS-232	Digi-Key			$ 1.55
7	each	Round Trip Tickets to HI	Hawaiian Air			$ 2,800.00
7	each	Lodging	Univ of Hawaii			$ 143.50
1	each	Academic Grant	George J Faul		$ 1,418.00	
1	each	Student Trave Funding	MPC		$ 1,000.00	
7	each	Meal Plan	Univ of Hawaii			$ 616.00
6	each	HydroVolt Bulkheads	AK Industries		$ 330.00	
8	each	.0625 m - Washers	MPC Auto Shop		$ 1.44	
2	each	Mongo Motors	Previous ROV	$ 270.00		
2	each	Mongo Propellers	Previous ROV	$ 50.00		
2	each	VSPs	Model Shop		$ 428.04	$ 428.04
SUBTOTAL				$ 592.58	$ 3,652.68	$ 4,215.96
					TOTAL	$8,461.22

CHALLENGES

Our most time consuming technical challenge was getting our underwater electronics to be water tight. Numerous emails passed between us with updates on leakage.

> *"The primary problem we are facing right now is the water tight cylinder. It leaked 30 psi over the course of 10 minutes, last night." --Lendz*

Apparently, creating an electronics tube was harder than it looked. Since visible inspection failed to locate the leak; we had to try something a little more creative. Our solution was to cover the cylinder in soapy water and positively pressurized the cylinder with a bicycle pump and looked for bubbles. After discovering we had more than one leak, we were able to epoxy the leaky spots and retest with our vacuum pump through a valve that was pre-installed into one end of the cylinder. We repeated this process again and again until the cylinder held pressure.

Our greatest challenge started from the beginning. Although our team members had many great ideas for our ROV, we really needed money to get started. MPC Robotics Team was not rolling in money and had to get really creative with fundraising solutions. We wanted to take our ROV to the next level and that required more money than in past years. Ross and Lendz were constantly writing up donation and grant requests, while Grant and Lisa put together ROV Scout kits to sell to young middle-school teams that were just starting out in the Scout category. Unfortunately, the process ate up a lot of our time and we didn't get most of our ROV parts until late February. By then, the majority of our team members were disheartened by continuously showing up for meetings and having nothing to do but talk about what we could do if we had the parts. Many dropped out leaving just a few to do all the work when the parts finally did arrive. After some serious discussion by the left over team members, we determined that next year, we would use the old ROV for all the testing while waiting for new ROV equipment/parts to arrive. This should help keep the competitive flow and interest while we work through new, less stressful issues. Meanwhile, we picked up the phone and called back some of our old team mates. We were down to about three members at the end of March and by May; we were back up to a steady seven.

Figure 20 - Chris testing the Frisbee factor on the disks cut from the CNC Machine

TEAM MEMBERS – REFLECTIONS/LESSONS LEARNED

Ross Williams – Team Leader

This is my third year on the MPC Robotics Team. I am currently studying Marine Science Technology and hope to tranfer into Marine Science or Marine Biology when I leave MPC. I pretty much worked on all aspects of the ROV, but my main focus was the watertight cylinder. As I had never designed and built anything like a watertight cylinder before, this was my biggest challenge and my largest lesson learned. I have also learned how to use many different tools and as the team leader, I learned new leadership and interpersonal skills.

Alex Hay

Once I finish my general education at Monterey Peninsula College, I plan to transfer to the University of California, Santa Barbara. I intend major in Oceanography. Although I helped with many parts of our ROV, I was responsible for working on the pump to suck up the fishing lures inside the cave, fiber glassing the sides of the ROV and helping with the circuit boards in the water tight cylinder. I learned a lot more about electronics in terms of wiring, electronic components and soldering. The tasks presented this year made my team and I think up and test many different tools and it challenged our creativity to solve each of these problems.

Lisa Rike

This was my first year on the ROV team. I joined because I spent the last four years watching my son have all the fun in his ROV club and not getting to touch his stuff. My contribution to the ROV was all the geeky Math and Physics stuff. I am a Math Major and hope to be a college Math instructor when I'm done with school. I designed the ROV frame and helped with most of the other parts. My learning curve was exponential and full of firsts: first time soldering, first time programming servos, first time working with AutoCAD, etc. My biggest lesson learned was patience, working with a group, and having to wait for a team decision when I prefer to just jump in and get it done.

Chris Pilland

This is my first year on the ROV team. I plan to become an aeronautical engineer. I designed the coolant system for *Rip Tide's* underwater electronics system. I also built *Rescue 1* which was the ROV that got Monterey Peninsula College into the finals.

Lendz Elliott

This is my second year on the MPC Robotics team. I am a Math, Physics, and Philosophy major; planning on transferring to the University at Santa Cruz for my Bachelors degree and Oxford University for my Masters. Before enrolling into Monterey Peninsula College, I attended the Massachusetts Institute of Technology where I stumbled upon and discovered my passion for Problem Solving. My emphasis with *Rip Tide* has orbited around Conceptual and Theoretical Design as well as being the go to guy for the copious amounts of paperwork lurking in the corners.

Ben Holland

My Name in Benjamin Holland, and I'm pursuing a degree in Computer Science. This is the second year I have programmed for the MPC ROV team. This year I wanted to experiment with using a PC for our control system. I wrote the interface for using a joystick to control our ROV. I learned that I prefer working with hardware that has a serial data buffer, and that serial communication loops are more complicated that you would think.

Chris Aramkul

This was my second year on the ROV team. I am currently pursuing a Bachelor of Science in Electrical Engineering. I was part of the group that worked on the tools for the ROV missions. My specific contribution was the Shrimp Catcher. My biggest discovery as a team member is that I would rather build something than do tedious soldering.

Grant MacGregor

My major is Computer Science, but I also have a hobby in robotics. My team efforts were focused upon small things like creating a hydrophone, testing out various types of leak sensors, and giving a helping hand to others. One of the most significant lessons I've learned this year relating to building the ROV is when someone says, "it's simple" or "it's easy", it's not. There are steps to learn, instructions missing, complications that always can occur. Sometimes buying some part can be easier than making one, but it doesn't reward you with the skills to step up to something a little more complex or just plain fix it. I believe that learning is better reward in my life.

ACKNOWLEDGEMENTS

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