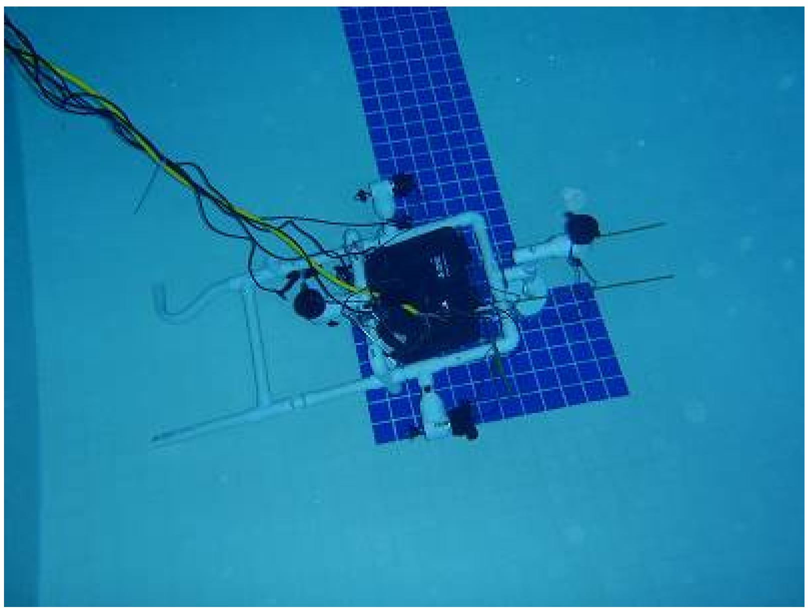
Technical Report

Marine Academy of Technology and Environmental Science (MATES) ROV Team

The International MATE ROV Championships 2009



The Enterprise

Team Members:

Curtis Giddings 2010, William MacDowell 2010, Priya Uppal 2010, Sara Goheen 2010, Ashley Millet 2010, Shane Ackerman 2010, John Stackable 2010, Harsha Prasad 2010, Tom Zdyrski 2011, Douglas Baily 2011, Devon Gonzales 2011, Yifan Zhang 2011, and James Priestly 2011, Ashley Louth 2011, Nick Lavrov 2011, Walter Church 2011, Danielle Judka 2011

Team Mentors:

Karyn Quigley, Advisor/Mentor

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I. Abstract

The Marine Academy of Technology and Environmental Science ROV team has constructed a fully-operational, underwater ROV capable of competing in the 2009 International MATE ROV Competition. The mission tasks for the competition revolve around submarine rescue systems relating to four primary tasks. The first task is to survey and inspect the submarine for damage. The remaining tasks at hand involve posting the pod, followed by ventilation and finally the RORV (remotely operated rescue vehicle) mating. The general purpose of our team, in addition to the completion of these tasks, is to ascertain more about the history of submarine rescue and its use in today's society.

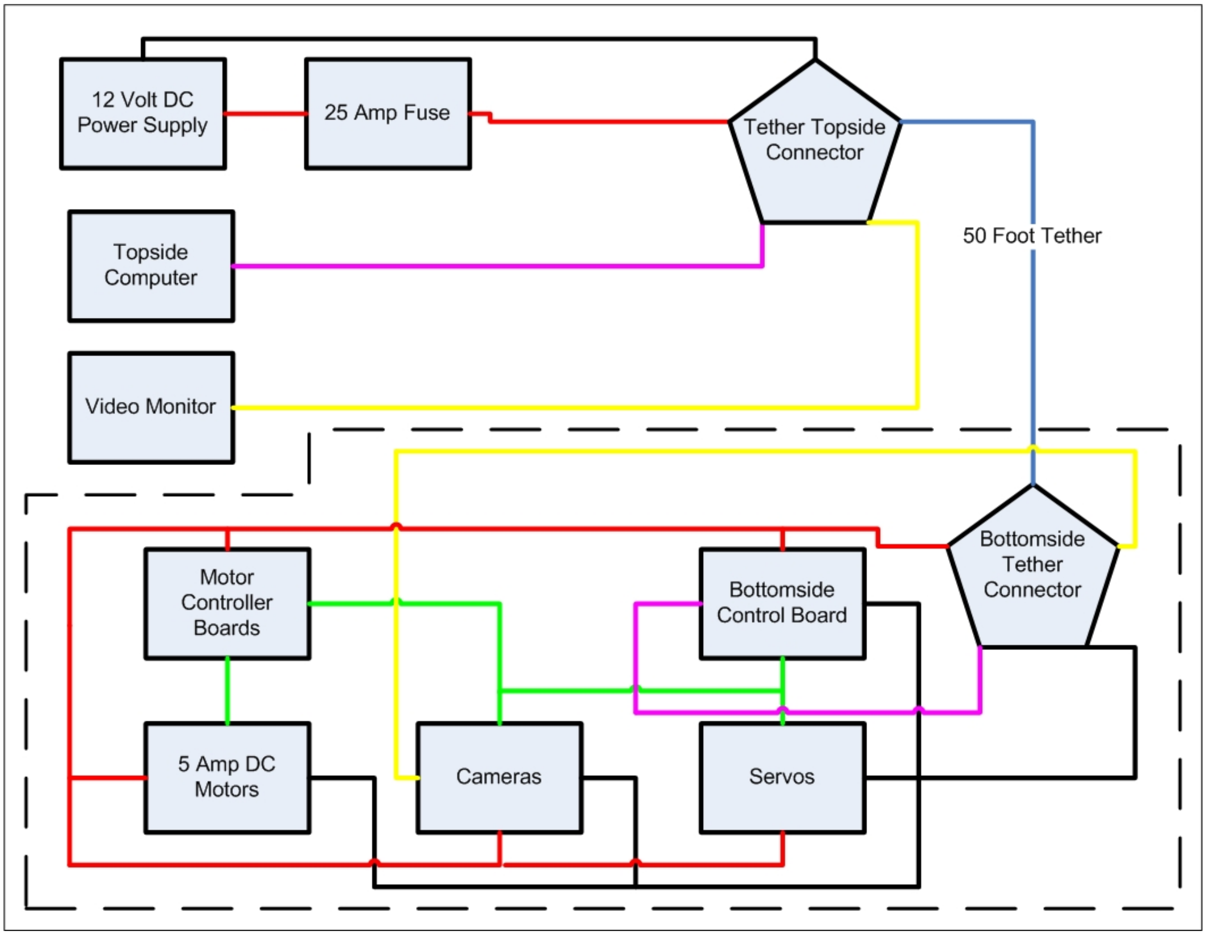
Figure 1. The first pool testing of *The Enterprise*.

With modern technologies becoming ever so prevalent, newer technologies have been invented to make submarine rescue not only quicker, but also more efficient. The goal of our team is to construct an ROV that is capable of not only locating the damage on a submarine wreck, but also to fix this potential problem. We wanted to take this problem beyond the mission specs and to apply it to every day life and rescueEvery step along the way in order to accomplish this overall mission - from research to brainstorming to designing the ROV itself - our team has put forth hours of research and dedication to construct what we feel is the most efficient in completing this task.

II. Budget and Expense Sheet

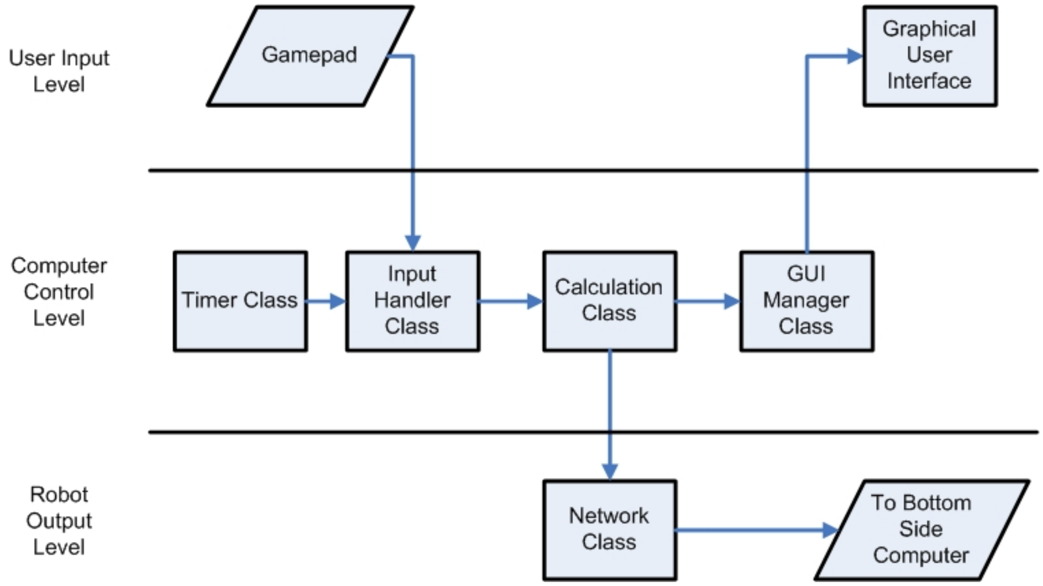
School: MATES		from: september 2008				
Instructor: Ms. Karyn Quigley		to: june 2009				
Item	**Date**	**Vendor**	**Cost (of 1)**	**Quantity**	**Total Expense**	**Funds**
Grant		OCVTS Foundation	donation			5,000.00
Cameras		Michael Bilyak	donation	4	n/a	
Servo	11/12/08	Midwest Technology Products	15.95	1	15.95	4,984.05
PVC pipe	12/12/08	Home Depot	1.89	2	3.79	4,980.26
Spring link	12/12/08	Home Depot	1.06	4	4.24	4,976.03
2ft ABS	12/12/08	Home Depot	9.61	1	9.61	4,966.42
BJC Hex bolt	12/12/08	Home Depot	0.75	1	0.75	4,965.67
1/2in tee	12/12/08	Home Depot	0.32	20	6.42	4,959.25
Fitting	12/12/08	Home Depot	1.41	1	1.41	4,957.84
1/2 90degree elbow in PVC	12/12/08	Home Depot	0.27	20	5.35	4,952.49
Hinge	12/12/08	Home Depot	3.19	1	3.19	4,949.30
Hinge (b)	12/12/08	Home Depot	2.45	1	2.45	4,946.85
Braid cord	12/12/08	Home Depot	4.03	1	4.03	4,942.81
Nuts/Bolts Bag	12/12/08	Home Depot	1.05	1	1.05	4,941.76
1/2 45degree PVC Elbow	12/12/08	Home Depot	0.54	19	10.17	4,931.60
U bolt	12/12/08	Home Depot	1.74	1	1.74	4,929.85
1/2IN PVC cross	12/12/08	Home Depot	1.61	2	3.21	4,926.64
3/4 M Adapter	12/12/08	Home Depot	0.34	1	0.34	4,926.30
PVC bush	12/12/08	Home Depot	0.37	1	0.37	4,925.93
Lid	12/12/08	Home Depot	1.05	1	1.05	4,924.88
Sharpie mini	12/12/08	Home Depot	1.06	1	1.06	4,923.82
PVC pipe	1/14/09	Home Depot	1.89	1	1.89	4,921.93
1/2 M Adapter	1/14/09	Home Depot	0.33	1	0.33	4,921.60
3/4 PVC Brush	1/12/09	Home Depot	0.37	2	0.74	4,920.86
PVC side outlet	1/14/08	Home Depot	1.74	1	1.74	4,919.12
1/2 M Adapter	1/21/09	Home Depot	0.33	3	0.99	4,918.13
3/4 PVC Brush	1/21/09	Home Depot	0.37	5	1.85	4,916.28
PVC side outlet	1/21/09	Home Depot	1.74	3	5.22	4,911.06
3/4 PVC cap	1/21/09	Home Depot	0.34	1	0.34	4,910.72
12/3 50' Power Block	2/23/09	Midwest Technology Products	34.41	1	34.41	4,876.31
Digital Multimeter	2/23/09	Midwest Technology Products	30.00	1	30.00	4,846.31
Solider Wick	2/23/09	Midwest Technology Products	1.60	1	1.60	4,844.71
Heat Gun	2/23/09	Midwest Technology Products	40.00	1	40.00	4,804.71
Tweezer Kit 3pc w/case	2/23/09	Paxton/Patterson	11.95	1	11.95	4,792.76
Pipe Cutter, ratcheting	2/23/09	Paxton/Patterson	40.01	1	40.01	4,752.75
Pelicase w/o foam insert	2/24/09	B&H Photo - Video, Inc.	54.60	1	54.60	4,698.15
8" Pipe Wrench	2/25/09	SATCO supply	7.95	1	7.95	4,690.20
Moto-Tool Multipro Super kit	2/25/09	SATCO supply	83.63	1	83.63	4,606.57
7CR curved jaw	2/25/09	SATCO supply	9.39	1	9.39	4,597.18
Visegrip 10" w/cut 05	2/25/09	SATCO supply	11.87	1	11.87	4,585.31
Heat Shrink Tubing Assortment	2/25/09	SATCO supply	4.35	1	4.35	4,580.96
Solder pencil stand	2/25/09	SATCO supply	18.02	1	18.02	4,562.94
Soldering iron-pencil	2/25/09	SATCO supply	9.34	1	9.34	4,553.60
Visegrip 9" Long Nose 15	2/25/09	SATCO supply	14.02	1	14.02	4,539.58
VIA EPIA N700-15 nano ITX mainboard	3/9/09	EPRO ITX system, LLC	302.32	1	302.32	4,237.26
3/4" x 1/2" PVC side outlet	3/11/09	Home Depot	1.63	12	19.56	4,217.70
3/4" x 1/2" PVC male adapter	3/11/09	Home Depot	0.64	12	7.68	4,210.02
Threaded Rod 2 foot	3/11/09	Home Depot	1.76	1	1.76	4,208.26
9x11 3x sheet 80-c HP	3/11/09	Home Depot	3.97	1	3.97	4,204.29
9x11 3x sheet 120-m HP	3/11/09	Home Depot	3.97	1	3.97	4,200.32
PC plumbing putty epoxy 2ounce	3/11/09	Home Depot	3.97	1	3.97	4,196.35
U bolt 1 1/4	3/11/09	Home Depot	1.50	2	3.00	4,193.35
3/4x60ft elect tape	3/11/09	Home Depot	0.59	1	0.59	4,192.76
1/2x260" teflon tape	3/11/09	Home Depot	0.99	1	0.99	4,191.77
Plastic bag goods	3/11/09	Home Depot	0.98	1	0.98	4,190.79
5/16"x6" clothes line hook	3/11/09	Home Depot	1.50	1	1.50	4,189.29
4" drain pipe cap styrene	3/11/09	Home Depot	1.44	1	1.44	4,187.85
Loctite quick set epoxy .85 ounce	3/11/09	Home Depot	3.79	1	3.79	4,184.06
Tube cutter hose/PVC	3/11/09	Home Depot	12.98	1	12.98	4,171.08
Econo mag catch with strike white	3/11/09	Home Depot	0.89	1	0.89	4,170.19
Mag catch with L strike tan	3/11/09	Home Depot	1.49	1	1.49	4,168.70
Nuts/Bolts Bag	3/23/09	Home Depot	1.05	3	3.15	4,165.55
Plasti Dip	3/23/09	Home Depot	7.36	1	7.36	4,158.19
Silicone	3/23/09	Home Depot	4.16	1	4.16	4,154.03
Dissconnect	4/3/09	Lowes	2.48	1	2.48	4,151.55
Push in connector	4/3/09	Home Depot	1.89	1	1.89	4,149.66
Putty	4/3/09	Home Depot	1.86	1	1.86	4,147.80
Wire	4/3/09	Home Depot	4.69	3	14.07	4,133.73
Splice 22-18	4/3/09	Home Depot	6.58	1	6.58	4,127.15
3/16ths brass rods	4/23/09	Home Depot	3.85	2	7.70	4,119.45
				Total Expenses:	**880.55**	

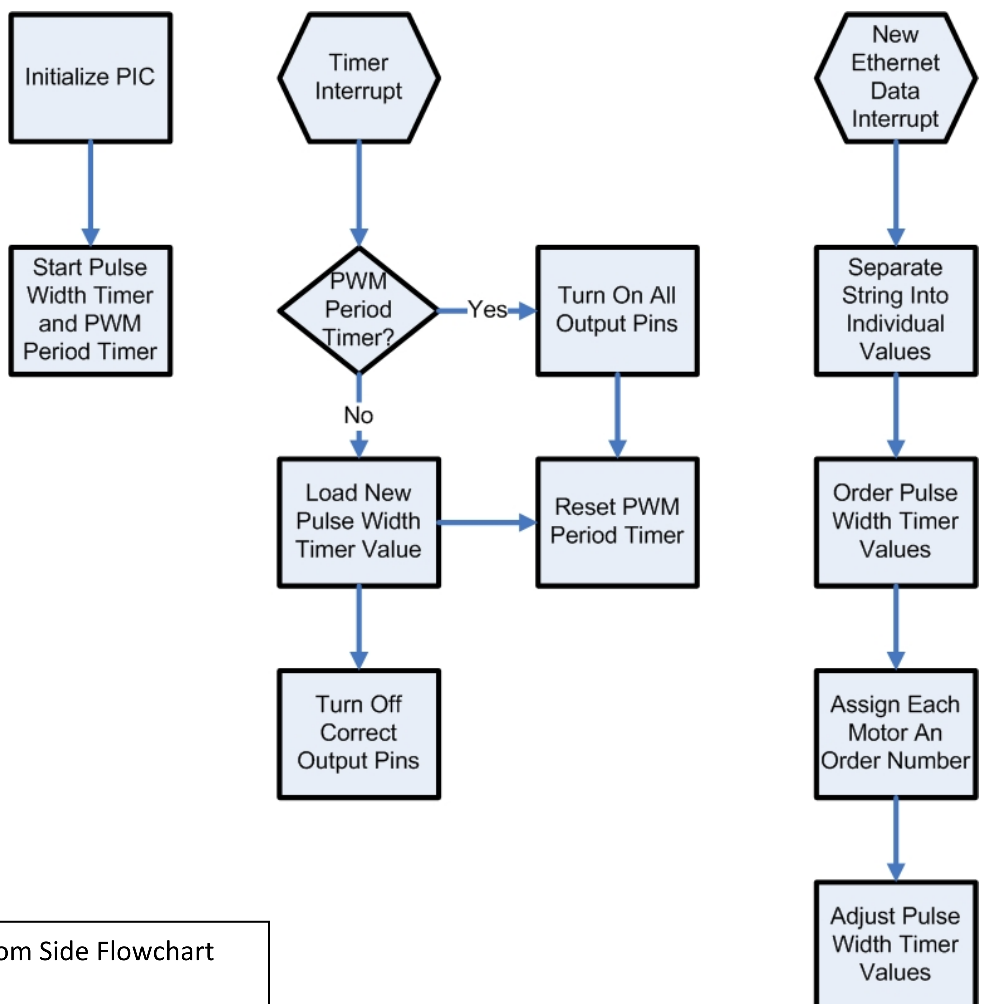
III. Electrical Schematic



Electrical schematic control scheme

Top Side Flowchart





Bottom Side Flowchart

IV. Design Rationale

- **Frame –** Based on the past experiences of the MATES ROV team, PVC (Polyvinylchloride) has proved to be modular enough to suit the needs of the team while still maintaining cost effectiveness. The team concluded that PVC is the most efficient material for the frame. After some testing, we found that the ¾ inch PVC catered to our needs the best because it is neither too big nor too small thus providing a balance between drag and sturdiness. As with any project like this one, it is important to minimize materials. Furthermore, less material in the water creates less drag. With those thoughts in mind, we came to a simple rectangular frame design with a minimal height. Then, we simply attached all of the mission arms to the outside of the frame as necessary. The PVC pipes are all connected with T-shaped or elbow shaped fittings. The motors are placed inside 1 ¼ inch T-shaped joints which are in turn attached to the frame via reducer couplings. In addition, the cameras are placed in their necessary locations and are attached to the fame with metal brackets. Also, a water tight box is located in the center of the rectangular frame. The water tight box contains important electrical connections required for the motors and cameras. After rigorous experimentation, we, the MATES ROV team, finalized this frame design to maximize overall efficiency.

- **Mission Systems –** The first task at hand for the Enterprise to complete is to scan around the simulated stranded submersible. Along the outside of the submarine there are five damage points simulated by reflective lettering. The Enterprise must center its cameras on each of these damage points using Speco black and white cameras. The majority of this task is reliant on already in place systems on the ROV thus making only minimal modification necessary.

  Following this, the Enterprise must ventilate the submarine by transporting the airline down to the valve hatch, opening the hatch, and inserting the line into the valve. The ROV then must travel to the other side of the submarine to open the valve to allow air flow before closing the valve and retrieving the airline. In order to be able to both grip and release the airline, a single servo is utilized to serve as a mechanical grabbing arm.

  Finally, the ROV must mate with the RORV located at the end of the submarine. This is accomplished through the use of a single three inch PVC end cap that is attached to the ROV via a ¼ inch threaded rod.

Throughout the design and construction of the Enterprise our team ensured that the completion of the tasks could be accomplished with a minimal number of mechanical parts to minimize the possibility of mechanical failure.

- **Propulsion System -** Our propulsion system uses four bilge pump motors. These motors are attached to PVC piping and have a 0.371-0.4762 centimeter propeller shaft with a .371 centimeter smooth coupler and a 0.4762 centimeter drive dog. A 7.62 -centimeter propeller is attached to the shaft with notches attaching into the drive dog and another drive dog on the end of the propeller. There are two bilge pump motors for horizontal movement and two bilge pump motors for vertical movement. This was easy to work with because the motors are submersible to begin with, making it unnecessary to waterproof them. The motors have been tested underwater to ensure that they perform to the standard required. The motors will be pushing the water rather than pulling it. The motors can pump at 1,000 gallons per hour (lph) and the torque of all of the motors is 16 Newtons. Our team also considered the use of brushless motors to propel the ROV because of their increased torque and speed. However, the motors were eventually ruled out because the brushless motors do not come in the sizes we desire. Through the rigorous testing of several prototype configurations, our team has found the current set up to be most efficient in completing the required missions.

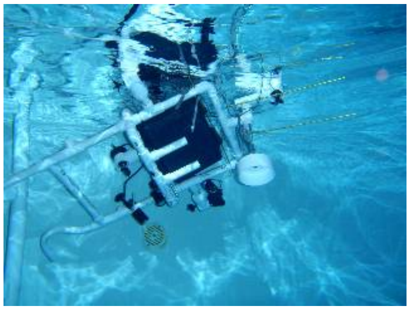


Figure 2. Practicing steering *The Enterprise* and perfecting buoyancy.

- **Buoyancy System –** While many different methods of buoyancy were considered and tested, we ultimately used 3-inch PVC pipe and end caps to create two air pockets that are situated on opposite sides of the ROV for buoyancy and stability. The use of foam was considered, but most foam available absorbs water with time and is therefore not ideal for buoyancy. Several holes were drilled throughout the frame to enable it to flood

Figure 3. Team member adjusting *The Enterprise* while testing in the pool.

quickly and evenly. We flooded the frame so that the shape of the ROV does not create uneven air pockets to hamper buoyancy, and it is more stable in the water. Air volume within PVC tubes is easily calculated, and was used to calculate how long to make the PVC air pockets. A waterproof box centrally located on the ROV also provides buoyancy, so the exact buoyancy desired, slightly positively buoyant, was achieved after testing in the water and modifications were made.

- **Camera Systems –** We strategically fastened four black waterproof bullet cameras on the frame of the ROV in various places that provided the optimal angle for viewing the mission arms and providing an expansive frontal view. Each camera was mounted on the frame of the ROV with two metal brackets that were bolted on each side of the PVC frame and allow each camera be project out from the frame and be calibrated to the most ideal viewing angle. We chose to use black and white Speco Technologies cameras, model number CVC320WP, because of the mounting bracket provided on the back of each camera and because we feel that they provide superior depth perception. Each camera has a 18-meter wire that runs along the tether to the surface where they are all plugged into a flat screen monitor that will provide the team members on deck with the views necessary to complete the missions. To switch between camera views, a button on the monitor is pushed.

- **Tether –** Our Tether consists of an 8 conductor line, 6 22-gauge conductors and 2 18-gauge conductors. Though there are two different sizes in the wires, it will not make any noticeable difference in the performance of the vehicle with the amount of energy we are putting through them for the short time span that our ROV will be active. Our tether was donated to us by Ocean Innovations.

- **Power Monitoring –** The Enterprise has two main sources of power monitoring. First is a switch which acts as a one-time circuit breaker. The circuit breaking switch is attached to the positive line on the 12V battery via a banana plug. This switch will break the circuit if the current exceeds 25 amperes. In other words, the maximum power flow at one time in our circuit

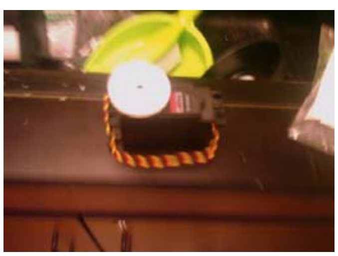


Figure 4. Servo used to transport the air line for the mission task.

is 25 amps. If, for any reason, the current exceeds 25 amps, the switch will interrupt and break the circuit. The second source of power monitoring comes from 4 fuses. Each fuse is connected to a motor and they can withstand current up to 5 amps at a time. In other words, if a current of more than 5 amps flows to any of the motors, the fuse will blow thus breaking the circuit. The rules of the competition stipulate that the current cannot exceed 25 amps. With these two systems, the current actually cannot exceed 20 amps which give us 5 amps of security.

- **Microchip Control Scheme –** The Microchip control scheme utilizes a PICDEM.NET 2 Development Board hosting a PIC19F97J60 chip (and optional ENC28J60 dedicated Ethernet chip). It was donated to us by Microchip Inc., along with a MPLAB ICD 2 Module to program and debug the board.

The purpose of this control scheme is to act as the primary means of controlling any propulsion and movement based devices (motors, servos, etc.). This control scheme is meant to offer an easy to use interface that will allow easy maneuverability and high customization so as to allow for optimum control over said ROV. The DirectX compatible HID, will relay the information to a laptop where, after computation and compilation into a string of TCP/IP compliant data, will be transmitted through the tether to the ROV. Here, the bottom side computer will analyze this data and proceed to operate the correct attached device.

This system is very customizable and scalable, thus offering many advantages over conventional systems. This allows for new components, which might become necessary in future missions, to be easily equipped. Secondly, this system is cost efficient. If the need arises due to some unforeseeable cause, then the board can be replaced very inexpensively. Another, useful feature of this control scheme is, due to its native TCP/IP compatibility, that it can be controlled remotely via the Internet. This may be useful in future applications: a satellite internet card and battery need only to be implemented, and this control scheme can be used to control an ROV or AUV on far-reaching missions without a tether. Due to this control scheme’s precision control over nearly every aspect of the system, from memory management to clock operating speeds, the system can be optimized to achieve very efficient performance. Finally, it is this combination of control and customization that allows for the manipulation and utilization of many off-the-shelf items without the need of separate daughter boards.

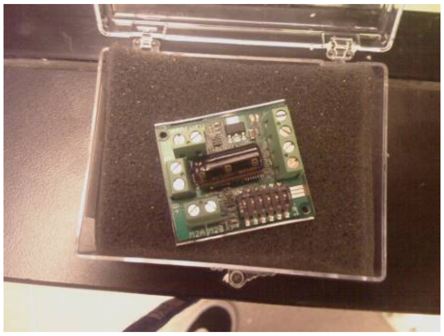


Figure 5. Motor controller used to control the speed of the propellers.

This system, by gaining a high degree of customization and efficiency, must inevitably sacrifice a small degree of simplicity. However, while the programming of this board is somewhat difficult, it can be done in a quick and efficient manner if the programmer has a background in the native language.

Construction began near December of the 2007-08 ROV competition year. This idea was proposed because it offered various benefits over traditional "hard-wired" methods. However, after weeks of planning, the team finally came to the conclusion as to which part was necessary: the Ethernet enabled PIC18F97J60 was bought for the small price of $6.65. This satisfied the original condition of being a very inexpensive condition. However, after the part was delivered, the team realized that, rather than being an entire system ready to be programmed and implemented, it was only the chip. This would require its own etched circuit board, which the team had neither the knowledge nor the means to create. After returning to the drawing board, the team came across an item, the PICDEM.NET 2 development board that, while being about $150 more costly than the original chip, did consist of the same chip already in a suitable circuit. At this point, Microchip was contacted, and agreed to generously donate the required materials. Programming of the parts began mid-February with the reading of many online tutorials and manuals. The first task was to configure the board to work with the In-Circuit Debugger (ICD) and with the ad-hoc network. Though this should have been an easy task, since no one on the team had networking experience, even this proved troublesome. Eventually, with the help of various manuals and hours of trial and error (not to mention a copy of HyperTerminal ripped from a Windows 95 OS disk), the board was finally properly configured and recognized on the network. The next step was to move on to the actual programming of the board. Originally, it had seemed that the board needed to be programmed in Assembly language; this proved to be a daunting task since no member of the team had any background knowledge of Assembly. Various team members tried to learn Assembly, but it appeared that even toggling simple I/O ports was an immense task; communicating over Ethernet, which had been a main objective, seemed nearly impossible. Thankfully, a free, student version of the Microchip C compiler was found on their website. This greatly simplified many of the simple tasks, such as addressing various memory banks. However, many obstacles remained: though some students had a background in related languages, such as C#, a comprehensive knowledge of the C programming language was still absent. Many long hours and library books later, a vast body of knowledge in the fields of C and networking was eventually amassed, and actual programming could begin.

Though a vast amount of knowledge on the subject matter had be garnered, however, it still seemed nearly impossible to wed these two, seemingly unrelated concepts, of C and TCP/IP, together in a single, comprehensive program. Many long nights were spent attempting to achieve this holy grail; however, as the competition date drew near, it became apparent that they had only scratched the surface. Luckily, upon further investigation, it was found that the Microchip demo disk included a sample TCP/IP Demo App. Despite the apparent gift that Microchip had given, the code was very technical and difficult to decipher. Many weeks were spent attempting to grasp an understanding of the code, but to no avail. By early-April, with still much work to be done on this control scheme, the team was forced to abandon the concept and move onto alternate ideas. However, since so much time was invested in this project, and so much potential remained locked within the lines of code, it was decided that it should not be abandoned: it would merely be put off until next year's competition. After the competition, the team once again focused its efforts on the Microchip control scheme. All throughout the summer, hundreds of hours were invested, attempting to breathe life into the future control scheme. This board might never have seen the excitement of competition day if not for one new tool the team had acquired: a new version of the TCP/IP demo app. Unlike its predecessor, its code was well documented and easy to follow. With this new foundation, creating the code seemed almost easy. Over the course of about two weeks, code allowing the board to communicate with the host PC was added to the TCP/IP Demo. Many simple, though frustrating, obstacles had to be overcome: being mainly VB programmers, new conventions, such as capitalization and punctuation, had to be adopted; despite the constant effort to amend these old habits, the same problems would present themselves from time to time – however, finding them was often a challenge. Finally, when all the necessary code was added, it was compiled … but failed. The code was meticulously pored over time and again, but to no avail. Manuals were re-consulted, but the code failed to yield results. Eventually, the code was deemed fundamentally flawed, and a new attempt was begun. All throughout the summer, this new code was worked and reworked in an attempt to cajole cooperation from the board.

Finally, as September loomed, it became apparent that it was not the original code that was flawed, but the new one. A simple mistake, a misplaced variable declaration, had caused the compilation errors; besides that mistake, the original code had been perfect. After this annoyingly small issue had been corrected, the code was recompiled and … success! Finally, now that the interface between the topside computer and the bottom side board had been established, progress could continue and work on the other, various aspects of the board could begin. Eventually, a simple interface was coded, allowing a message typed in on the topside computer to be sent to the board, displayed on the LCD, and echoed back to the topside computer. This was a great proof-of-concept, but that was about all the board was good for at the time. Next came time to work on a motor interface. However, one reoccurring problem reappeared: a lack of knowledge. Though there were members of the team that had a background in motors, controlling them was a vast, unexplored subject matter. After many more trips to the library, it was eventually decided a control scheme utilizing PWM would be necessary. It was discovered that an industry standard of a 20-millisecond pulse period (50 Hz) with a 1-2 millisecond pulse width was shared between motor controllers, servos, and various other components. However, one more problem manifested itself: at the current oscillator frequency, the smallest pulse period that could be achieved would be 392 microsecond pulse period (about 2.6 KHz or 2600 Hz), which was much to fast. However, by slowing the oscillator, we would lose TCP/IP compatibility. The situation, and this board's development cycle, had begun to look grim. But the team was eventually able to find a passing reference to a more roundabout way to solve this problem on a Microchip forum. It seemed that, by using interrupts, it would be possible to achieve almost any desirable pulse period. How this was accomplished was eventually discovered, and after being implemented, proved to successfully solve yet another engineering problem.

Now that a communication link to the topside computer and a motor interface had successfully been established, the only major hurdle remaining was the human interface. It was decided that this part would be coded in C# for multiple reasons: some members of the team had prior knowledge of C#, it was much easier to code than C, there are copious amounts of information regarding C# that might be used as a reference, and many components (such as DirectX) have native compatibility with C#. The team was quite optimistic about this part of the project because some of the members had a background in C#, removing the learning curve of an entirely new language. This part of the code, which would be harbored on the topside computer, consisted of two major parts, the joystick interface, and the network interface. Thankfully, the code for the network interface had already been completed (based off samples found from various websites such as csharp-home.com), and the only remaining component was the joystick interface. The team did not have to search long before finding a joystick demo app bundled with the DirectX SDK. With some minor modifications, and some extra code to bridge the connection between human interface and the network interface, the topside computer's program was now completed. Finally, the entire program was written and the control scheme was finished.

But celebrations were quickly suspended when an embarrassing oversight was discovered: the control system lacked reverse! The team quickly set to work trying to correct this problem, but for some reason, the board would now cease to cooperate. What seemed to be a perfectly acceptable if-then statement never seemed to function properly, ignoring its conditional clause and never diverting program flow to the end statement. Learning from previous mistakes, all capitalization and punctuation were checked and double checked, but to no avail. It seemed as if the code simply never recognized the if-then statement. Finally, after many frustrating days, the team realized that yet another VB habit had crept into their code: a single equal sign assignment operator was used instead of a *double* equal sign comparative operator. After fixing yet another embarrassing mistake, the team finally managed to implement a fully function reverse routine. NOW, finally, the code was finished and ready to be implemented in the 2008-09 ROV.

V. Challenges

Figure 6. Team members working on mounting the motors.

- Our team faced several challenges while constructing the ROV; however, similar to last year, one of the greatest challenges was time management. In an effort to correct this problem, our team began meeting to brainstorm ideas two months before the mission specs were even released. One of our mistakes was spending too much time perfecting our design on paper rather than building the actual ROV and testing it for mistakes. Because of this, when it came down to crunch time to build our ROV, things were hectic and it was a challenge to complete our missions on time for the competition.
- Another difficulty faced was recreating the actual submarine wreck that would be simulated at the competition. One of our goals is to aim for perfection; therefore, we decided to recreate the set to the best of our abilities to test in the water. However, we ran into several difficulties in finding the right parts and once the set was built, we had difficulties navigating our ROV to accustom to the design. This caused several hassle-filled visits to Home Depot and multiple hours in the pool; however, after hours of meticulous adjustments, we were able to come through and finally accomplish what we wanted.
- A final challenge we faced was figuring out a way to successfully open and close the submarine hatch. Although we had brainstormed several ideas during our meetings, none of them seemed to work in operation. Our carabineer clips, for example, caused the most hassle because they frequently snagged on various mission parts. After the proper adjustments, we were able to get a modified hook to work and we overcame the challenge exhibited during this aspect of the mission.

VI. Troubleshooting Techniques

Many troubleshooting techniques were employed. One of these was based around design challenges. When faced with these challenges, we collaborated in a group, presenting various ideas meant to solve the problem. While the unreasonable ideas were quickly discarded, we then decided on the best possible solution, and this was then implemented into the design. Other design aspects that worked well on paper simply needed to be tested in the pool to see that they would not come to fruition as imagined. This trial and error process was equally important in the design of the mission arms.

The main troubleshooting was that of buoyancy. For the past two years our team has had a very difficult time in perfecting a buoyancy system, or even making one work. The trouble shooting can lead anywhere from removing capped PVC currently on the ROV to adding tools and heaving objects into hollow parts of the ROV or strapping weights onto the ROV. This is something the team has almost perfected, but there is always room for more improvement.

VII. Payload Description

The mission specs require that The Enterprise must transport the airline down to the valve hatch, open the hatch, and insert the line into the valve. Also, as stated in the mission specs, the ROV then must travel to the other side of the submarine to open the valve to allow air flow before closing the valve and retrieving the airline. A single servo is utilized to serve as a mechanical grabbing arm to grip and release the airline. Furthermore, the ROV is able to mate with the RORV located at the end of the submarine by using a single three inch PVC end cap that is attached to the ROV via a ¼ inch threaded rod. (Refer to Design Rationale for further information).

VIII. Future Improvements

Figure 7. A group brainstorming session to decide the frame shape.

In the future, there are many areas in which we can improve. First and foremost, our time management skills need to be improved. Although we did learn a plethora of lessons about time management last year, we still need some improving. One possible way of accomplishing this improvement task would be to set up a timeline at the beginning of the year. The timeline would consist of our own deadlines for completion of certain things. If the team uses this strategy, then the proper amount of time could be allotted for everything and time efficiency would increase greatly. Ultimately, improving this will help not only in competition, but in any project we pursue.

Another possible improvement next year is to investigate brushless motors more in-depth and see if we could possibly use them on our ROV. On a similar note, it would be nice to see that the whole team learns a specific programming language next year and that we implement it on our ROV. Overall, our team is comprised of many talented members, but there is always room for improvement.

IX. Lessons Learned

During the building the ROV our team gained the most important skill of all. This skill is that of working together. In the beginning of the task everyone thought that their ideas would be the ones that work. It was necessary to realize that never would everyone’s ideas be able to work at the same time. The most important thing is team work when working in a team. There can not be one single leader because nothing will be able to get done without help.

Another important skill that the team gained was that of failing and fixing. The team had many ideas that did not work on the ROV. These things needed to be fixed after it found that it would not work. Everything on the ROV needed to be tested and then adjusted so that everything could work together. Troubleshooting was a major skill that needed to be obtained by everyone in the team.

In our school all of the students are known for being big procrastinators. This is why making a timeline for this competition and trying to get everything done in time was very important for us. We needed to gain the skill of time management, which no one had before we started. If time management was not gained for this task, it would have never been finished in time. Our team has previous experience in trying to get things done in the last minute, so we tried to avoid it this time.

There is a lot of physics involved in our design rationale. This is something our team had to study and learn the skills to take on a challenge that they necessarily did not know how to do on their own. It was important for the team to take in to consideration many things involved ranging from buoyancy to fluid dynamics while building the ROV. Some of the members of the team already had extensive knowledge on these topics and it was important for the rest of the team to trust the people who were trying to help.

X. Submarine Rescue System: Description

Ocean Works International Inc. specializes in both manned and unmanned subsea technologies. Ocean Works also provides equipment, tools, and diving systems to many international marine industries as well as design services.

Since 1995, Ocean Works has been the cutting edge of submarine rescue technology. Their products range from Emergency Life Support Stores to Remotely Operated Rescue Vehicles that can venture as deep as 650 meters. Ocean Works has been contracted by the U.S. Navy to design and build a future submarine rescue vehicle, the Pressurized Rescue Module System, which will have the most advances rescue capability in the world.

Similar to the MATE ROV Competition tasks, Ocean Works vehicles are capable of docking onto a submarine hatch, and supplying the submarine with emergency supplies and oxygen.

XI. Reflections on the Experience

Building the ROV along with an extremely helpful team was an experience we all enjoyed. The best thing about the experience was the feeling of accomplishment we acquired from building something we could all be proud of. The experience was a great one because we got to know people from school who we may not have if they were not in the club with us. Everyone was extremely helpful to each other and helped build upon each other's ideas.

The experience was very fun because sometimes the team would just all work together in a tiny closet so everyone would have to be in a good mood. The building was one of the most fun parts that everyone enjoyed. There was no doubt that everyone on the team enjoyed the experience. Everyone got along for the most part throughout this competition, and this is directly related to being able to work well as a team. The teamwork during this process was completely necessary and our team did a very good job with building upon it.

The purpose of the competition is a simulated submarine rescue that must be completed. Through out the competition research needed to be done about submarine rescue. As a whole the team learned a lot about submarine rescue and how it is used. It is a very interesting topic and the whole team is very excited that they were able to gain the knowledge they have along this process. The submarine rescue knowledge is very interesting to all of us.

XII. Acknowledgements / References

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“Remotely Operated Vehicle Jason/Medea”. Woods Hole Oceanographic Institution. 17 April 2008. 18 April 2008. <http://www.whoi.edu/page.do?pid=8423>.

New Millennium Observatory. Pacific Marine Environmental Laboratory. 18 April 2008. <http://www.pmel.noaa.gov/vents/nemo/index.html>.

"OceanWorks International." Your Subsea Directory. 2007 Your Industry News. 27 May 2009. <http://www.yoursubseanews.com/directory/proRecord.php?listing_id=1193>.

"Submarine Rescue Systems." OceanWorks International. 2009. 27 May 2009. <http://www.oceanworks.com/submarineRescueSystems.php>.