Chester W. Nimitz Senior High School
Varsity Team One

Engineering Captain: Joshua Miller, **Deck Captain:** Maria Cabello
Primary Driver: Gary Cooper, **Tether Management:** Marshall Lloyd
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Advisor: Gary Rodgers

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I. Abstract

The Chester W. Nimitz High School team constructed a Radio Operated Vehicle (ROV) capable of competing in the 2008 Marine Advanced Technology Education (MATE) competition. To help achieve victory our team set three goals: 1^{st}, have a fully functioning robot before February, 2^{nd}, have the technical report finished before March, and 3^{rd}, to win Regional Competition. In order to make a sizeable headway, into the assembly we opted to design and build a frame that we could adapt to any conditions that the competition set forth. After deciding on the dimensions of the frame, the group added four motors that made up our propulsion system. Each motor was placed within the frame to give the ROV the most favorable driving force within the electrical and frame restrictions. Together, both motors provided the ROV with vertical and horizontal movement. To successfully complete our predetermined missions, three appendages were costume designed and built. Mission #1, a temperature probe encased in a PVC pipe with a funnel on the end was used to take the temperature of the water as it leaves the black smoker. Mission #2, a bent angle iron was built to separate the rocks from the black smoker and a net placed underneath to capture the rocks. Mission #3, ten 4 ott treble hooks were attached to a rig that stretched on the underside between the sides to collect the crabs from the ocean topography. The ROV was naturally negatively buoyant, but, the pieces of boogie board help counteract the weight and achieve neutral buoyancy. The tether supplied us real-time image monitoring, supplied the ROV with power, and encased the cables from damage. With the help of the special modifications and the ROV's able bodied team members Nimitz Team 1 was able achieve all of its goals.

II. Frame Design

Early this year we opted to design a ROV frame that we felt would give us the durability we would need for the tasks at hand. We used polyvinyl chloride pipes because of its rigid structure and durable strength. Also our robot had to be able to attach and detach several appendages to the frame without dismantling the entire structure. After we modified the frame dimensions, we fastened the pieces together using rivets. The frame consists of : four three-way joints with a .95 cm. radius, four “T” joints with a .95 cm. radius, four “T” joints with a transverse cut (also .95 cm. radius), .95 PVC tubing, boogie board foam, and several scraps of noodle foam.

Overview of the Robot

Height: .04064 meters

Width: .3302 meters

Length: .762 meters

Tether Length: 20 meters

III. Propulsion System

The propulsion system consisted of four motors: two vertical and one of the right and left sides of the robot. The side motor pods were pivoted at a fixed position and roughly 6 cm. away to give the ROV the best thrust possible.

For this year's pod design, every member of the team created a pod in Autodesk Inventor and made a replica which was tested then tested. To ensure reliability of the results each pod design was tested with the same exact motor and frame. After the best pod was chosen, we started making the final product. To keep human error from potentially destroying the pods the team opted to have each machined using an Expert Mill. A specially made jig was used to keep the pod in place as the Expert Mill worked to ensure that each hole was carved out every 60 degrees.

The pods consist of a : 3.8 cm. radius PVC tubing cut to a length of 13.3 cm., covered with roughly 26.7 cm. by 5 cm. chicken wire, a motor screen machined out of Plexiglas, a chicken wire end screen, and a motor. The side propulsion pod was screwed to a .95cm. "T" joint with a transverse cut on the horizontal end, and then joined to a .95cm. radius PVC tube 10 cm. long which is attached to the top frame using another "T" joint with a transverse cut. The transverse cuts allowed the pods to cuff the ROV's top frame securely where they can be adjusted depending on the motors strength. Vertical propulsion pods were laced into the boogie board at the top of the robot. Using a 3.8 cm. circular incision the pods were secured to the board using super glue. Through trial and error, our team learned that the position of the pod relative to the boogie board had a great

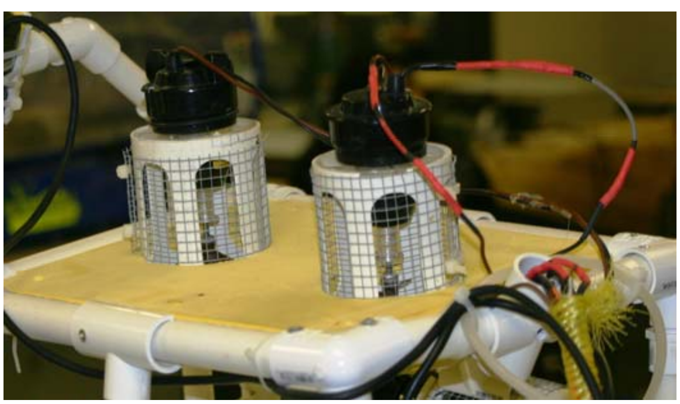


Fig. 1 Vertical Motor Pods

effect on the overall functionality of the robot (Fig. 1). If the pod was placed below the boogie board with its motor side up, then the only way for the water to enter the system was through the 3.8 cm. hole up top. If the pod was placed motor side down and above the boogie board then water was allowed to enter the system through the side vents and greatly increase the ROV's overall thrust.

The results of each member's pod design are shown on the table below:

	Thrust, Intake, Exhaust Calculations			
testing			motors attached to pod	
motor 1 black motor with 2 bladed 6cm prop			and pod attached to test stan	
motor 2 black motor with 2 bladed 6cm prop				
12 volt battery			exaust area 49.6cm^2	
Motor Designer	Intake Area	Thrust		
No Pod	cm^2	kg		
Clifford	3.1	0.13		
Maria	84	0.46		
Omar	90	0.53		
Travis	97	0.53		
Rodgers	97.5	0.54		
Marshall	100.63	0.33		
Original	120.05	0.44		
Original	120.55	0.535		
Jesus	138.13	0.55		
Gary and Josh	162.55	0.455		
Jose	176.24	0.615		
Jennifer	48	0.37		
No pod	N/A	0.39		

IV. Robot

Mission 1 Appendages

For the first mission, the appendages were the temperature probe and its casing. The temperature probe is a standard bimetal Dwyer thermometer that reads from -10º to 110 ºC. The team built a casing out of PVC pipe to help funnel the water onto the thermometer. The PVC pipe was 3.8 cm. diameter and 12.7 cm. long and had several holes that allowed the water to exit and not push the ROV up. The funnel that is attached to the PVC pipe allowed the operator to easily position the probe over the smoker with minimal time.

Mission 2 Appendages

To successfully complete the second mission the team opted to design a way to separate the rocks from the Velcro and allowing them to fall into a container. To make this design come true a piece of angle iron that was bent to the contour of the black smoker and attached to two pieces of CPVC. For the rock to be safely returned to the surface the ROV had a basket that was located directly behind the angle iron to catch the rocks. The basket was made out of interwoven wire that was fit to several CPVC pipes which kept the rocks from falling out (Fig. 2).

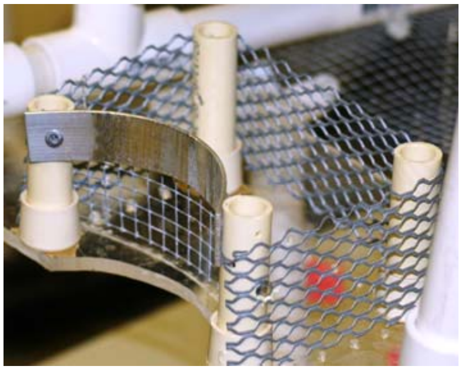


Fig. 2 Rock Collector

Mission 3 Appendages

Fig. 3 Crab Collector

In order to fish out the crabs that will be placed at the bottom of the ridge, we installed ten 4 ott treble hooks to the bottom side of our robot. To complete the mission, we placed the ROV on top of the crabs, and shifted our position until three crabs become entrapped within our hooks (Fig. 3). Our team placed a 4 ott treble hook on a CPVC to retrieve the crab within the ocean topography. Our plan is to pull the crab out of the topography with the hook attached to the CPVC pipe, in order to move it to where we can collect it with the hooks on the bottom side of the robot.

Tether

A tether provided the ROV with power, control; via a control box, and it protected the wires from the water. A twenty meter pre-braided nylon rope surrounded ten wires that make up the electrical system of the robot. On the exterior of the tether were the tubes for the air system and the wires for the cameras which were secured using zip ties. The zip ties allowed us to easily remove and repair any cables or tubes that might malfunction. To keep the tether from creating drag the team attached several pieces of noodle foam at regular intervals to compensate for its weight.

Buoyancy System

In order for the team to successfully complete the missions, the ROV needed to maintain neutral buoyancy, so power would be used efficiently while moving the ROV around. To help us achieve neutral buoyancy we PVC pipe and tubing due to its lightweight and durability characteristics. Also aiding is the boogie that holds the two vertical motors in place. Since the boogie board was too buoyant, we drilled holes in the PVC tubing to allow water to seep into the ROV and counteract the boogie board.

		Bouyancy Calculations				
Description	Length (cm)	Width (cm	Height (cm)	Volume (cm³)	Mass (g)	Density (g/cm³)
Blue A	9	3	3	81	8.2	0.101
Blue Board				4592.4	367.1	0.080
Blue D	10.3	2.2	2.9	65.714	7.5	0.114
Blue E	3.5	3	2.3	24.15	2.4	0.099
Blue F	5.1	3.9	3	59.67	6.3	0.106
Blue G	3.5	2.5	3	26.25	2.7	0.103
Yellow B	8.5	2.8	3.1	73.78	7.1	0.096
Yellow Board				4852.3	335	0.069
Yellow C	9.5	2.1	2.9	57.855	5.6	0.097
	The objective of this process was to calulate the density of the foam boards					
	This table was used to estimate size of the board needed to support the weight to achieve neutaral boyancy					

Camera

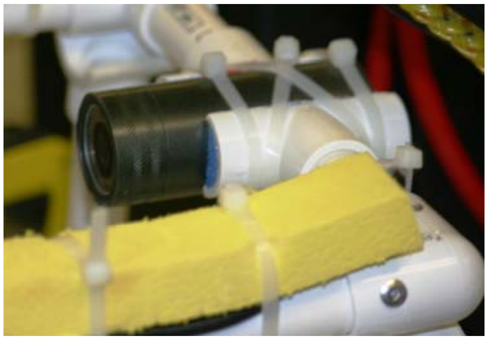
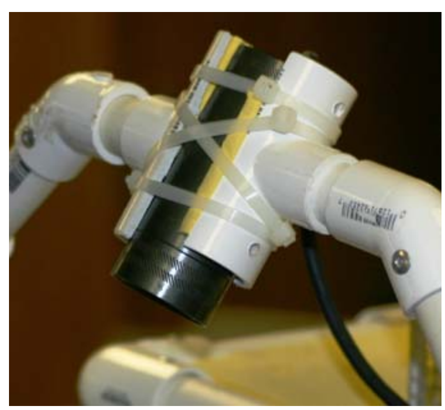


Fig. 4 Rear Camera

Our ROV used cameras which incorporated an ultra sensitive color module that allows for 380 TV lines of resolution. Another justification for this model was because the cables supported a RCA adapter that worked well with the type of screen we used. The only problem we faced was that we had to solder on a RCA plug because we had issues with the adapter recognizing the monitor.

The rear camera was fixed between two "T" joints with transverse cuts in order to cuff the camera and allow the operator to adjust it to any degree (Fig. 4). To keep it secure, the camera was encased with scraps of noodle foam to allow a stronger grip when the zip ties were added. The top camera was held in a similar position as the rear camera except that it is held above the ROV by using a A-frame made out of PVC pipe (Fig. 5). The "T" joints held the camera in place and allow the operator to adjust the camera angle to view that suited them.

Fig. 5 Front Camera



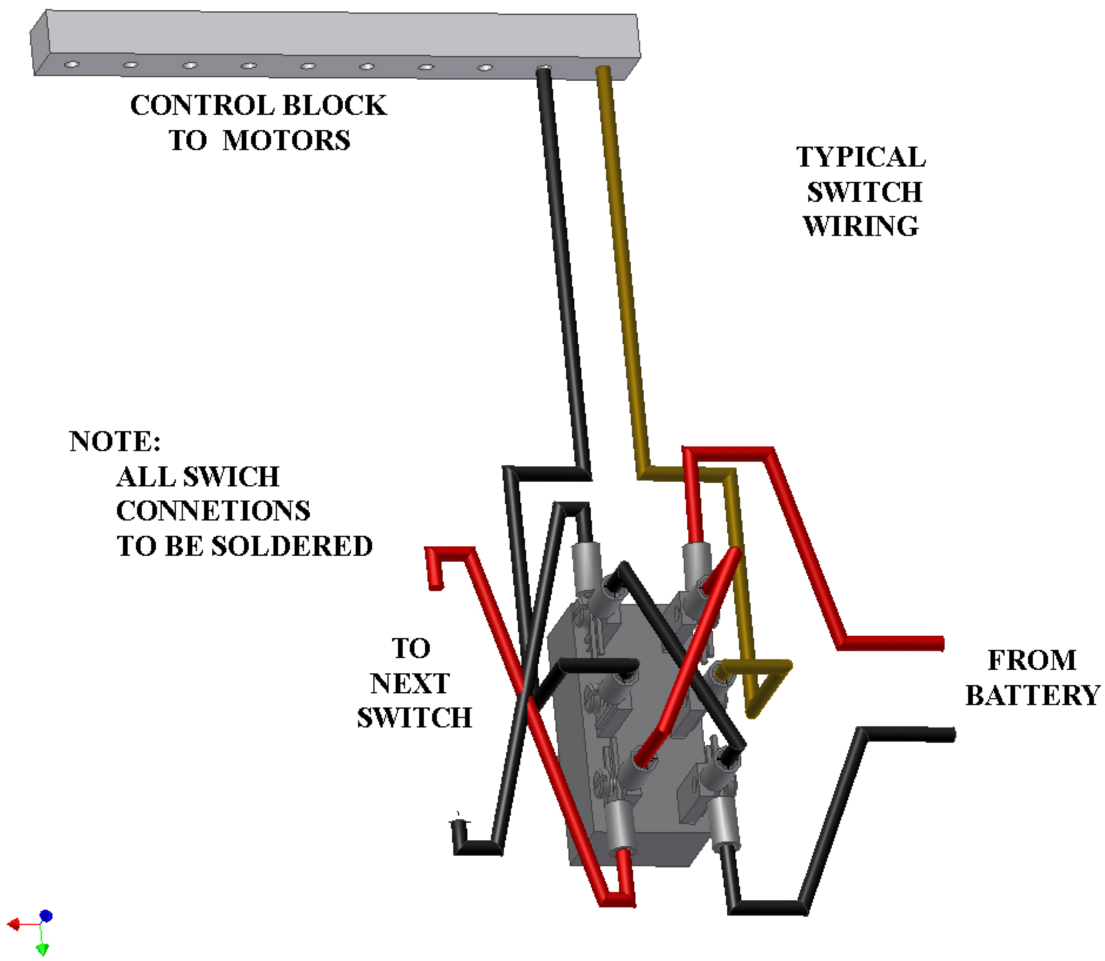
Electrical

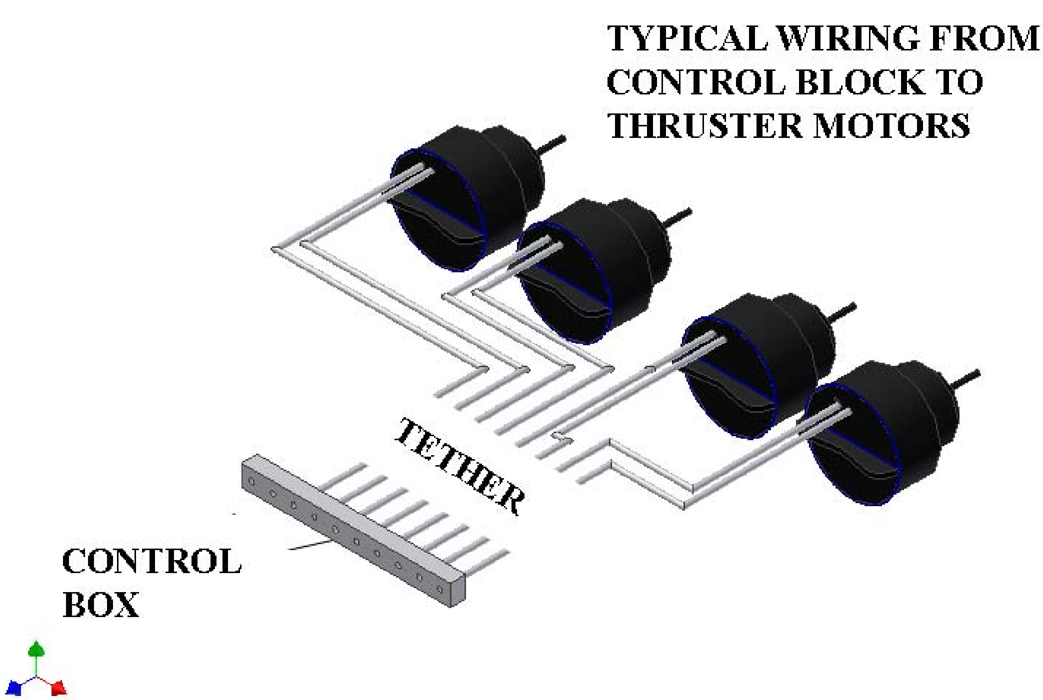
Electrical components for the ROV included: control panel, meters, fuses, switches, controls, banana clips, and the cameras. The control panel was laced with wires from the motors that were color-coded to its corresponding motor and then screwed into the control box to protect the wires that allow it to run and allowed for easy access in case if electrical mishap. Switches similar the wires, were color coded to identify the side motors and vertical motors. A fuse was connected to positive cable to conduct, and stabilize the current, and protect the ROV's electrical systems in the case of a shortage. Voltage and current were measured using portable meters to ensure that we stayed within the required limit.

Switches: Our control box utilized four switches. Two switches allowed the operator to control the horizontal motors and the remaining two allowed them to operate the vertical motors.

Cameras: The rear camera was fixed at the back end of the ROV, zip tied to two .95cm. radius "t" joints with a transverse cut on the vertical end. To keep the cable from getting tangled up as the ROV maneuvers about the course the tea, opted to attach the cables to the tether with zip ties. The reason the team used the cameras is because they are very durable and they require very little power to operate efficiently. Also due to the camera's design we are able to easily connect them to a portable television screen via a RCA adapter.

Tether: The tether's primary function was to protect the eight wires that allow our motors to run, protect the two camera wires, and protect the air hose. It also allows all the wires and tubes to be neatly organized, and it allows for the easy attachment of flotation to compensate for the tether's weight.


CONTROL BLOCK
TO MOTORS
TYPICAL
SWITCH
WIRING
NOTE:
ALL SWICH
CONNETIONS
TO BE SOLDERED
TO
NEXT
SWITCH
FROM
BATTERY


TYPICAL WIRING FROM
CONTROL BLOCK TO
THRUSTER MOTORS
TETHER
CONTROL
BOX

Controls: The four switches that controlled the motors gave the operator excellent control of the two separate planes of motion.

Switch Configurations for Horizontal Motors.

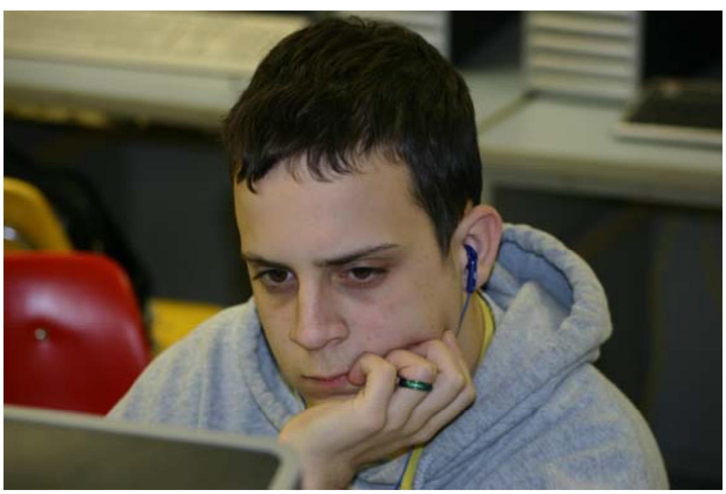
Both Switches Forward: Forward Horizontal Thrust
Both Switches Backward: Backward Horizontal Thrust
One Forward and One Backward: Turns the ROV

Switch Configurations for Vertical Motors

Both Switches Forward: Upward Vertical Thrust
Both Switches Backward: Downward Vertical Thrust
One Switch Forward and One Backward: Tilts the ROV

Protocol for Underwater Electrical Splices were as Follows:

1. Strip wiring 19.05mm.
2. Place two black 6.35mm. diameter heat shrink wrap on each side of the splice 38.1 mm. long
3. Place one red 3.175mm. diameter heat shrink wrap 50.8mm. long
4. Twist the wires together and solder
5. Wrap approximately 12.7mm. of electrical tape over the soldered splice
6. Slide the two black heat shrink wraps over the connection
7. Using a 1400 Watt heat gun and shrink the heat shrink wrap
8. Slide the red heat shrink wrap over the splice
9. Heat the heat shrink wrap with the gun



Member Joshua Miller works on the thrust and buoyancy calculations.

V. Challenges

This year's missions are complex in the design, yet mirror the tasks of a modern ROV. The main problem faced was to achieve neutral buoyancy and to attach or detach appendages to the fame of the ROV as needed. Then to achieve neutral buoyancy with the tether because of the weight of the tether hindered our ROV by decreasing speed with increased drag. The bottom frame of the structure had to be specifically designed to house the all of the appendages that were needed to complete the missions. Wire coding for the tether was another problem we faced.

Fixing the buoyancy of the ROV was a simple task of using just the right amount of boogie board. This helped calibrate of the appendages and of the mission packages for the buoyancy to reach zero. With this in mind we zip tied scraps of foam to the appendages and insulated the inside of the top frame with the same boogie board which counter balanced the weight of the ROV. The previous design was to join all appendages to the ROV to allow more practice time. However, this substantially decreased the speed of the ROV in both the vertical and the horizontal direction.

All appendages where constructed first and were made of PVC piping because the material is light weight and durable. Also each appendage was zip tied or screwed to the frame work of the ROV. There was also a problem with the spacing of the appendages to allow better view of all of the movement and mission at hand, so we improved this design by placing all appendages to the side on the upper or lower frame of the structure of the ROV. For increased visibility, we made some of our appendages to where they could be easily detached using the air hose.

The tether proved to be a challenge that created multiple problems both on the ROV, and the control box. One problem that caused the most trouble was the organization of the cables and air pressure system that needed to be secured to the ROV, along the tether, and finally the control box or manifold. This problem was solved by securing the cables and air tubing to the inside of the ROV’s frame and along the tether with zip ties. The tether had too much weight, so we zip tied a number of scrap floatie foams to keep it aloft. This also helped with the balance of the ROV when it is submersing or surfacing. Another problem that occurred was that the wiring inside the tether made it difficult to exchange motors or to rewire a motor that were already mounted onto the ROV. Therefore, we made a coloring system to help identify which wires lead to which motor. This coloring system involved the use colored electrical tape to identify the wiring for the one motor, and the corresponding wires at the control box.

Another problem we had was that we were not getting enough vertical thrust, so to solve this problem we moved the motor to a location above the robot instead of below the boogie board.

The final problem involved altering the bottom, to hold the appendages, that was very crucial to the ROV. At first, the appendages were fixed to the bottom PVC but this created another problem, there was no way to fix them to the frame and keep them stable. So then, the bottom PVC pipes were removed and two sheets of plexiglass were screwed to the base of the ROV along with he appendage holders.

VI. Troubleshooting Techniques

1. Identify the problem
2. Brainstorm possible solutions
3. Build test materials
4. Test the possibilities
5. Evaluate the results
6. Implement final product to the ROV
7. Watch over that area for any further problems
8. Repeat as necessary

Team members decide upon a frame to house the top camera

VII. Skills Gained

***Attitude:** As a team, we learn to refine our attitudes because it kept our morale high and helped create an efficient working environment. We learned how to deal with a variety of conflicting personalities and take advice from people that a people that have already been through the same problems. Lastly, we learned of to take constructive criticism without missing a stride. These skills will be invaluable in our future careers no matter the job.

***Analytical Thinking:** While working with our ROV we learned a skill that proved invaluable in the long run, analytical thinking. We learned how to quickly analyze difficult problems and situations, and brainstorm within our group for possible solutions.

***Dependability:** Another crucial skill we learned is that we should spread out the workload evenly so all members have an even stake in the project.

***Experience:** The most important thing the new students on our team learned was, experience. This project gave them the chance to meet other officers from other schools and region that share similar interests. These skills gave us a the chance to do something most people never get to do in their lifetime, build a ROV and compete at NASA.

***Knowledge:** With the competition of the ROV our members received an understanding of engineering and physics. The project required us to build and design a ROV that would suit the completion and the restrictions. They learned the valuable hands-on-skills by working with several tools to complete a functioning ROV. For the ROV to be fully functional a general knowledge of physics was required, i.e. how to calculate thrust, buoyancy, power, current, and velocity.

***Problem Solving:** To be successful our team had to learn to face difficult problems and come out the winner. We learned by experimenting with the various systems and developed new and innovative solutions to our problems.

***Teamwork:** The members of our team learned how to deal with a bunch of conflicting personalities, and we learned how to take the best for each person and utilize it for better good of the team. We could take the expertise of each member and funnel it into creating the best underwater robot and technical report possible.

VIII. Budget and Expense Sheet

Description	Units	Cost	Expenses/Donations		Purpose
batteries	ea	$69.00	expense		Run ROV
black motor	ea	$12.00	expense		Part of propulsion pods
white motor	ea	$12.00	expense		Part of propulsion pods
original camera	ea	$257.00	expense		Camera
fishing net	ea	scrap material	donation		Part of the net
1/2 pvc pipe	ft	$0.13	expense		Made frame and appendages
3/4 pvc pipe	ft	$0.17	expense		Part of buoyancy system
paddle board	ea	scrap materia	donation		Made frame and appendages
1/2 elbo	ea	$0.32	expense		Made frame and appendages
3/4 elbo	ea	$0.38	expense		Made frame and appendages
1/2 tee	ea	$0.32	expense		Made frame and appendages
3/4 tee	ea	$0.66	expense		Made frame and appendages
3/4 cross	ea	$0.66	expense		Made frame and appendages
3/4 to 1/2 tee	ea	$0.66	expense		Made frame and appendages
inside 3/4 to 1/2 reduc	ea	$0.43	expense		Made frame and appendages
3/4 to 1/2 double tee	ea	$0.47	expense		Made frame and appendages
1/2 double tee	ft	$0.47	expense		Made frame and appendages
15 gage wire	ea	$0.16	expense		Part of electrical systems
toggle switch	box 20	$0.16	expense		Part of electrical systems
solderless connector	box 20	$5.65	expense		Part of electrical systems
16-14 awg connectors	ft	$1.92	expense		Part of electrical systems
cat 5 cable	ft	$1.98	expense		Part of electrical systems
3/8 yellow rope	ft	$0.10	expense		Part of electrical systems
fuse holder	ez	$2.10	expense		Part of electrical systems
12 volt dvd tv	ea	$295.00	expense		view screen for camara
Total		$662.78			

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