Technical Report

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Science Club: ROV Team

California Academy of Mathematics and Science
1000 E. Victoria Street Carson, CA

2007 MATE International Competition
June 22-24, 2007

Project: Baby Betty

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I. Abstract

An ROV (Remotely Operated Vehicle) is a mechanical device that is used to accomplish tasks in environments where it is hazardous for humans to enter. The CAMS (California Academy of Math and Science) ROV team came together in late 2006 to compete in the Southern California MATE regional competition in San Diego. The team designed and built a working ROV system consisting of an ROV, control box, and tether. The ROV was built to accomplish the three missions in an efficient manner. The frame was made from PVC and had motors to move it through the water. It is connected to the tether which links the ROV to the control box. The control box acts as an interface between the operator and the vehicle.

The team was able to save money by using inexpensive parts for the system and was able to raise money by presenting their work to different organizations. They tried to keep the cost as low as possible and were able to stay within a reasonable budget of $2000. They are now prepared to compete in the international competition in Newfoundland, Canada in celebration of the International Polar Year.

Figure 1-1: The 2006-2007 CAMS ROV Team

II. Introduction

ROVs (Remotely Operated Vehicles) are mechanical devices that are used to aid people in difficult tasks, often in areas where it is hard for people to go. The first ROV, Poodle, was developed by Demitri Rebicoff in 1953 and have since been used in military operations, offshore oil missions, and law enforcement. The MATE institute along with the MTS formed a competition to increase ocean career opportunities. The CAMS ROV team, consisting of eight members, was formed in September 2006 to compete in the So Cal regional MATE competition. They were able to place first and were invited to the International Competition in Newfoundland, Canada. Since then they have been working hard to perfect their ROV system and have also introduced ROVs to the rest of their class by teaching them how to build and operate them. They look forward to competing in the International Competition in June and spreading knowledge about ROVs to future team classes.

Table of Contents

III. Design Rationale

When designing the ROV, the KISS principle, or the law of parsimony, was always kept in mind. The team tried to design the vehicle to reduce drag, time, and costs. The most unlikely materials were used in payloads as ingenuity and originality are key in crating an effective ROV.

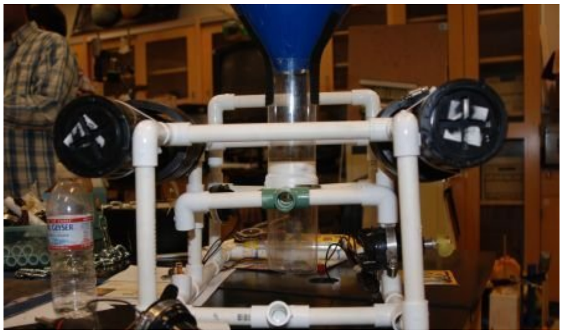


Figure 3-1: Baby Betty under construction

1. Frame Design

When beginning this project stability, buoyancy, mobility, and simplicity governed our vehicles design. We chose to build a simple box frame from PVC (Poly Vinyl Chloride) and attached six motors for movement. Our original design was 80cm x 60cm x 40 cm. It could move forwards/backwards, up/down, right/left, and turning horizontally. Holes were drilled in many places on the ROV to allow water to seep in. We realized there would be currents in the water, so we decided to have a strong buoyancy system to keep the ROV stable. We strapped two large 7.62cm ABS pipes along the top that was the same length as the top. To counter this we had to put on 3 kg of weight which we later realized restricted our movement dramatically. Eventually we knew the ROV was much too big and it weighed 11.5 kg. After seeing some of our mistakes we redesigned the ROV to be much smaller and lighter. We shrunk the frame down as much as possible and we were able to get the frame down to 60cm x 30cm x 20cm. We shrank the length of the floats to 27cm which we calculated would provide 3.6 kg of buoyant force. Luckily our ROV weighed approximately 3.5 kg and we knew there was a small amount of buoyancy that the vehicle supplied so we found that a 1kg weight would make our ROV neutrally buoyant. With the two floats at the top and the heavy weight at the bottom, this gave our ROV a maximized stability. When testing the ROV we found that it was now much more mobile due to the decreased weight.

2. Propulsion

Six 12V DC bilge pump motors are to provide the ROV with maximum mobility. There are two for forward/reverse/turning, two for up/down, and two for strafing. Each motor provides about 2.5 Newtons of thrust and draw about 3 amps each. The props we used are secured with prop adaptors and are 3.08 cm in diameter. The motors are mounted to PVC pipe using hose clamps allowing us to position them anywhere while they stay secure.

Figure 3-2: A bilge pump motor, fully assembled with mount, prop and adaptor

3. Payloads

We designed the payloads to be as simple as possible. They are interchangeable for each task to minimize space and are designed to simplify each situation.

Figure 3-3: Harpoon for task 1

To accomplish mission one, a messenger line needs to be threaded through a buoy's anchor ring and returned to the surface. The most important part of designing the ROV was the Payload tools. We tried to find the simplest, but most effective way to accomplish the missions. For the first mission, we thought about the fastest way to accomplish it and we came up with a simple floating harpoon. The ROV simply pushes a plastic bottle with small hooks in the front through the anchor ring and pull back, freeing the bottle which then rises to the surface.

The second mission requires the retrieval of one 'jellyfish'. A harpoon was fashioned out of yet another hose clamp. The clamp is attached to a PVC elbow mounted to the front of the ROV. The hose clamp will poke through the jellyfish and holds it in place as it is carried to the surface.

Mission two, task two is to collect one sample of 'algae' in the form of a ping pong ball. This will be accomplished using a vacuum located in the center of ROV. The vacuum was built using a metal stopper, plastic tubing, and a motor. It will be capable of sucking down the algae that floats above the ROV.

Figure 3-4: Jellyfish retriever

Mission two, task three, involves a buoy that needs to be redeployed. This is done by using a curved forklift that will carry the buoy to the designated area in the bottom of the ice tank. The forklift is made of PVC and fittings, and held together by self tapping screws.

In mission three, a hot stab needs to be inserted into a wellhead. This last task seemed to be the most complicated, but we realized we could just divide it into many basic tasks.

A hot stab needs to be inserted into the wellhead. This is accomplished using an inserter made of PVC. There is a support for the hot stab on the back that is at the designated angle of the wellhead. It sticks off of the front of the ROV and is removable. Bent strips of plumber's tape holds the hot stab in place, along while it sits in a PVC fitting.

Figure 3-5: Vacuum to retrieve algae

Figure 3-6: Hot stab inserter

The mission also includes the removal of a wellhead cover, insertion of a gasket, and replacement of the wellhead cover over the gasket. A few of the payloads will be used more than once. The team has decided to use the jellyfish retriever to remove the well head and insert the gasket.

4. Sensors

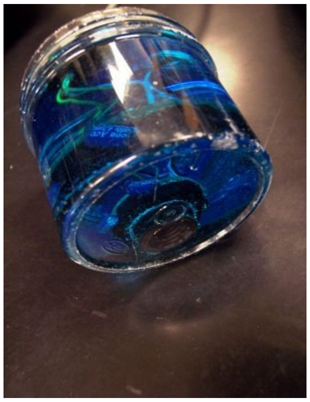


Figure 3-8: Camera

Four waterproof cameras are mounted onto the ROV. Camera 1 is pointed forward to see where the ROV is going and to give the driver a general overview of the environment the ROV is in.

Camera 2 is mounted in the front to view the payload tool, a forklift or a bottle which can be used interchangeably and the harpoons in the front of the ROV. Camera 3 is facing up to view the vacuum and the balls on the surface of the water. Camera 4 is facing the back of the ROV to view the claw and to see what is behind when reversing the ROV. All the cameras have microphones inside, which allows the driver to hear the motors underwater during the competition. The driver can distinguish whether or not the motors are moving and working by the microphone noises.

A compass was mounted to determine the direction the ROV is going and the level is used to determine if the ROV is flat or at an angle while it's moving.

The thermometer will determine the temperature of the water to see if the ROV will be able to operated under such temperatures and conditions.

Figure 3-7: Camera Sensors: Compass, thermometer, level

5. Tether

Figure 3:9 Tether in a coil

There are 44 conductors in the tether: 12 for the steering motors, 4 for the payloads (a vacuum and an arm), 8 are spare lights and 20 for the cameras (five conductors for each camera). Each motor is connected to 16 gage speaker wire. The wires are enclosed in/tied together with tape and covered with a netting material for protection and to keep them together. Pipe insulator is attached at intervals to create neutral buoyancy.

The tether length is 13.614 meters.

The tether was the last part of our ROV system. We simply lined all 44 conductors up and wrapped them with tape. We then threaded the conductors through a black netting and wrapped it with small foam floats.

Conductor	Function
1	positive for left steering motor
2	negative for left steering motor
3	positive for right steering motor
4	negative for right steering motor
5	positive for up/down motor front
6	negative for up/down motor front
7	positive for up/down motor back
8	negative for up /down motor back
9	positive for strafing motor left
10	negative for strafing motor left
11	positive for strafing motor right
12	negative for strafing motor right
13	positive for camera 1
14	negative for camera 1
15	Video input camera 1
16	Video output camera 1
17	Audio camera 1
18	positive for camera 2
19	negative for camera 2
20	Video input camera 2
21	Video output camera
22	Audio camera 2
23	positive for camera 3
24	negative for camera 3
25	Video input camera 3

Conductor	Function
26	Video output camera 3
27	Audio camera 3
28	positive for camera 4
29	negative for camera 4
30	Video input camera 4
31	Video output camera 4
32	Audio camera 4
33	positive vacuum
34	negative vacuum
35	extra
36	extra
37	extra
38	extra
39	extra
40	extra

6. Control System

The control system is designed to be able to set up quickly and easily. A monitor is mounted inside the case so the camera that is used the most can always remain plugged in and ready to be used. The control box has a main power switch that can be turned off to stop all power from flowing through the control box. There is an LED mounted next to the switch to allow the pilot to easily see if the control box is on or not. A 25 A in line fuse is present between the main positive control box power line and the control box itself. The control box is made from Plexiglas to let the pilot see if any fuses have burned out without having to open up the control box. The box is easy to open to replace a fuse if one is burned out. Fuses are used for each switch, and are arranged on a fuse block.

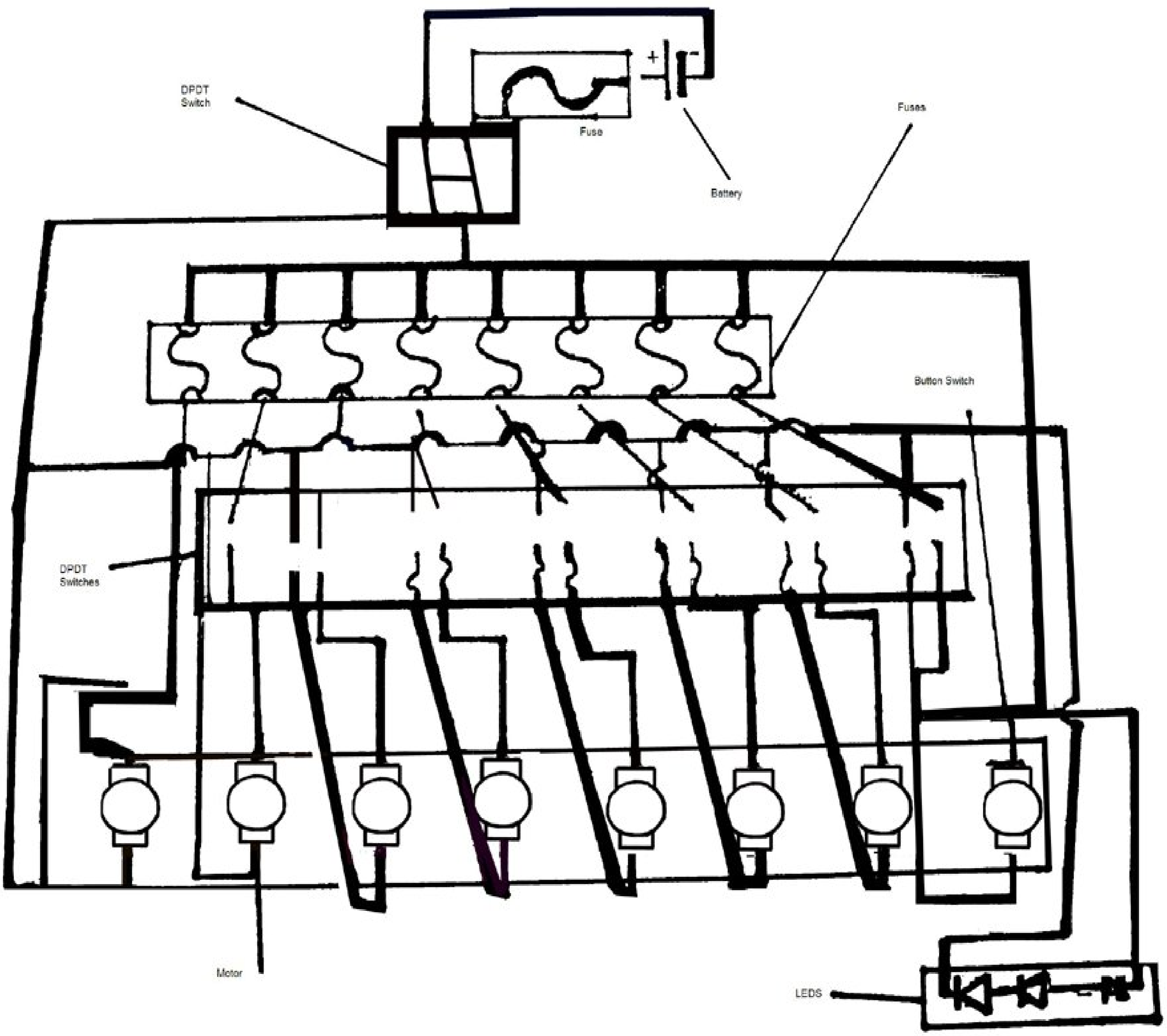
There are a total of six switches on the control box and joystick. Two switches are mounted on the left of the steering portion of the box and can be used if additional payloads are needed. One button present that is used to turn the vacuum on and off.

Figure 3-10: Control System

The control box features a PVC joystick which controls all of the ROV's movement. It has one switch for the up and down motors and one for the strafing motors mounted onto the handle. The switches are laid out so they can all be operated with one hand. The operator uses their thumb to control the strafing motors and their fingers on the back of the joystick to control the up and down motors. The forward and reverse motors are controlled by two toggle switches that stand erect. There are two holes on the bottom of the joystick that the toggle switches fit into. This easy removal and the internal connections between the switches and the box make it a detachable.

Figure 3-11: Joystick, detached from Control Box

IV. Electrical Schematic



V. Challenges

While building the ROV, the team ran into several challenges. One of the first challenges they encountered was a buoyancy issue. The ROV, at the time was very heavy, and the floats were doing little to make the ROV neutrally buoyant. The floats consisted of ABS pipe, which were heavy enough to add substantial weight and mass to the ROV. The team used the ABS pipes at the regional competition, and they did their job. After the competition, the team still did not feel satisfied with the ROV's performance. So we made a few changes to the frame, shrinking it in size, and redesigned the ballast system using much smaller floats. The ROV shrank in mass and weight. It now weighs just under 4.5 kilograms.

The ROV's control system was a big problem , even during the competition. The original plan for the control box was to create one large box with all of the payloads and controls. Unfortunately, the team could not find the right size box in time, so the team opted for two control boxes. One control box was devoted to payloads, while the other was used for steering. The two boxes were a big hassle for the team, especially because the connectors were badly wired. The connectors between system parts were the worst problem of all, since several of the connections were damaged, and the team members were forced to stay up past midnight to fix the connections. Even then, the team feared the connections would not hold up throughout the competition. Luckily, the connections held. After San Diego, the team made a unanimous decision to change the control box. The idea of storing the control box and a monitor in a suitcase was make everything much neater and easier to carry. The two control boxes would be ditched in favor of a new more compact control box, made of Plexiglas. The control box would need to be made a lot smaller to leave room for the monitor, which forced the team members to be neat and precise with all the wiring and connections. The idea worked well and it looks pretty cool, too.

Figure 5-2: Original control boxes.

VI. Expenses

The team tried to keep costs as low as possible. Many donations were made by the advisor Mr. Thomas Jett. The ROV system was meant to cost less than two thousand dollars. This budget was met.

Grants Given				
	Donor	**Amount given**	**Amount spent**	**Remaining**
	CAMS PTSO	$ 1,500.00	$ 720.00	$ 780.00
	Northrop Grumman	$ 5,000.00	$ 547.00	$ 4,453.00
	Item	**Source**	**Quantity**	**Balance**
Structure				
	PVC fittings- tees	Home depot	23	$ 4.60
	PVC fittings- corners	Home depot	4	$ 0.56
	PVC fittings- 45 degree fitting	Home depot	2	$ 0.90
	PVC fittings- four way	Home depot	4	$ 1.20
	1/2 in PVC	Home depot	3.05 meters	$ 3.10
	self tapping screws	donated	not counted	$ -
			subtotal	$ 10.36
Control Box				
	5 position fuse block	Torrance electronics	1	$ 7.50
	5 amp fuses	Torrance electronics	10	$ 4.00
	LED holder	Torrance electronics	1	$ 1.65
	Red led	donated	1	$ -
	10 position terminal block	Torrance electronics	2	$ 5.50
	Resistor 60 ohm, 1/4 Watt	Torrance electronics	1	$ 0.10
	Electrical tape	Fry's	1	$ 0.89
	shrink tubing	donated	1 strip	$ -
	Push off switch	Radioshack	1	$ 2.49
	Bannana plugs m/f	Torrance electronics	2	$ 2.20
	35-012 dpdt sub-minature toggle switch	fry's	2	$ 5.78
	nk-s332 toggle switch	fry's	1	$ 12.95
	Plexiglass 1/2 in sheet	donated	1 meter	$ -
	b4304h1-10linr	fry's	1	$ 12.95
	Chassis box	donated	1	$ -
	Flatscreen Television	donated	1	$ -
	hinges for tv	donated	2	$ -
	Plexiglass sealer	donated	1	$ -
	In line fuse	donated	1	$ -
	4 way connectors	Torrance electronics	4	$ 4.00
	PVC 1 1/2 in and fittings for joystick	scrap from tasks	n/a	$ -
			subtotal	$ 60.01
Sensors				
	Cameras		4	$ 280.00
	Thermometer		1	$ 5.00
	Carpenter's level		1	$ 5.00
	Compass		1	$ 3.00
			subtotal	$ 293.00
Payloads				
	Various PVC fittings	Home Depot	1 meter	$ 5.00
				$

Propulsion				
	bilge pump motors	donated	6	$ 150.00
	Prop adaptors	donated	7	$ 21.00
	Props	donated	7	$ 21.00
	Locktite	donated	1	$ 4.00
			subtotal	$ 196.00
Buoyancy System				
	4x4 flxcouplg	the home depot	4	$ 11.86
	ABS cement	the home depot	1	$ 4.79
	abs pipe	the home depot	1	$ 9.60
	coated weight	big 5	1	$ 3.00
			subtotal	$ 29.25
Construction of task				
	abs cut pipe	orchard supply hardware	1	$ 3.36
	drainage cap 4"	orchard supply hardware	1	$ 0.99
	pipe increaser hub	orchard supply hardware	1	$ 3.29
	tees sxsxs	orchard supply hardware	2	$ 4.12
	cap slip	orchard supply hardware	2	$ 5.98
	ell sxs	orchard supply hardware	1	$ 1.69
	nyon hank 3/16" x5	orchard supply hardware	3	$ 12.87
	"U" bolt	orchard supply hardware	1	$ 1.09
	male adapter reduc	orchard supply hardware	1	$ 0.66
	insert tee-1 threa	orchard supply hardware	1	$ 0.84
	proof coil chain #	orchard supply hardware	30 cm	$ 1.19
	#100 Décor oblong	orchard supply hardware	2	$ 2.76
	fit all drain gask	orchard supply hardware	1	$ 1.99
	galv anchor shackl	orchard supply hardware	1	$ 3.19
	red hot blue glue	orchard supply hardware	1	$ 4.39
	u-bolt	orchard supply hardware	1	$ 3.29
	2"x5 pvc sch40 pipe solid	Lowe's	1	$ 5.08
	wiretie dlock 8 nat 500 b	Lowe's	1	$ 17.47
	80# profinish quikrete 50	Lowe's	1	$ 4.54
	halex 1-star 24 pk tt blls	Big 5	1	$ 9.99
	general mdse	Big 5	1	$ 2.97
	6qt drain pan	kragen auto parts	2	$ 6.98
	Oball Jelleis	Shopatron	1	$ 6.95
			Subtotal	$ 105.68
Display and Misc. Costs				
	white sheet of foam	Joann fabric store	2	
	Elmer's Adhesive glue	Staples	2	$ 10.80
	Elmer's rubber cement glue	Staples	3	$ 18.60
				$ 20.49
			Subtotal	$ 49.89
Travel expenses Canada				
	Plane fare		9	$ 5,274.00
	Rooms		6	$ 720.00
			Subtotal	$ 5,994.00
Travel expenses San Diego				
	Rooms	Del Mar Inn	5	$ 547.00
			Subtotal	$ 547.00
			Total cost of travel:	$ 6,541.00
			Total cost of ROV system:	$ 749.27
			Overall cost:	$ 7,442.84

VII. Troubleshooting Techniques

In the event that something goes wrong while operating the ROV, we have developed a troubleshooting procedure to fix possible problems. The following are events that could happen while on deck with the ROV.

The challenge that is most likely to occur will be a decrease in movement. If the ROV is still at the surface, we can check the motors to see if there is anything blocking the propeller rotation. If it is submerged or there is no visual problem with the motors, we will check the battery connections. If the battery is connected, we will check the fuses (from main to individual). If there appears to be no problem we will replace the motor as quickly as possible.

The next problem we are concerned about is with the buoyancy. If the ROV is sinking too rapidly or cannot submerge, we will attach a different sized set of floats. By designing an interchangeable floatation system we can quickly and easily adjust the buoyancy of the ROV by swapping out the floats or adjusting the weights.

VIII. Lessons Learned

Collectively the ROV team has learned a lot. We had to watch the size parameters on the ROV, as we were only given 80 centimeters by 80 centimeters to work with. Because our motors began to slow down very noticeably with all of the excess weight, we decided that we had to make the ROV smaller. We needed to meet a size limitation and not overburden the motors. This took many weeks to perfect. We discovered exactly how much weight and mass are related and how much of a difference every millimeter makes. This helped us to refine our design and planning skills and taught us the value of precision.

IX . Reflections

Figure 9-1: CAMS ROV team before competition at the San Diego Fly off

The ROV competition has provided an excellent experience for our team to learn new concepts of mechanics, and design. We have learned many concepts and most importantly we have learned how to be a responsible and fully functional team. We learned to communicate with each other, relying on each other to complete the ROV. During the competition, we learned the importance of teamwork, quick thinking and fast action. These experiences have given us skills no textbook could ever give us.

Future Improvements

In the future, the CAMS ROV Team hopes to make several improvements to enhance the capabilities and agility of the ROV and to make maintenance of the ROV less of a problem. The team would like to reduce the size and weight of the ROV and have a better and more efficient buoyancy system, a system that can control buoyancy with hydraulics to eliminate the use and need for up and down motors, which will reduce the size of the ROV.

XI. Cultural and Historical Aspect of Life at the Poles

Figure 11-1: Scientists involved in IPY studies.

This year is the International Polar Year and we are celebrating this by having the international competition in Newfound land, Canada. This year MATE is trying to spread knowledge of the quickly changing environments at the poles as well as their main purpose, to increase knowledge of underwater career opportunities.

The International Polar Year (IPY) is a widespread scientific plan to focus underwater research and technology on the Arctic and Antarctic poles. For the past few decades, scientists have noted that there has been a great change in the poles. Permafrost has been greatly affecting the regions by degrading the soil and hydrological systems. The Ice caps have begun to melt and there has been a severe climate change. This has been affecting many species of animals as Well as people living in northern regions.

Figure 11-2: IPY logo

XII. Acknowledgements

The ROV team has accomplished much over the past two semesters. This team could not have come so far without the support of friends and family. With this in mind, the CAMS ROV team would like to thank the following:

Mr. Jett, our mentor and science teacher, for advising the team.

The MATE (Marine Advanced Technology Education) Center

The team would like to thank the school staff and PTSO for donating items and supplies and giving the team the funds to build and compete the ROV.

Thank you to Mr. Jerry Scheneman for investing time and energy into this project.

Thank you to Mr. Jim Yap for his moral and technical support.

Thank you to Mrs. Cathy Arakaki for input regarding the management of the team.

And lastly, all of the parents of the ROV team members for their support and investment.

XIII. Works Cited

Bohm, H. (1997) Build You Own Underwater Robot and Other Wet Projects. West Coast Words, Vancouver, B.C. Canada

"Mate ROV." Marine Advanced Technology Education. MATE. 1 Mar.-Apr. 2007 <http://www.marinetech.org/rov_competition/index.php>.

NOAA. NOAA. 9 Apr. 2007 <http://www.noaa.gov/>.

"ROVs." Habbardin Shore. Habbardin Shore. 9 Apr. 2007 <http://www.hibbardinshore.com/>.