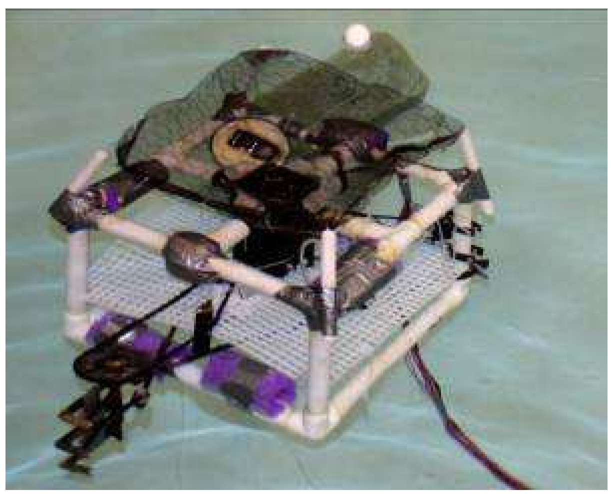
Technical Report

Cape Henlopen High School
ROV Team

The 6th International MATE Center ROV Competition
2007



The Titan

Team Members:
Samantha Bateman, Roy Collins, Sean Mock, Andrew Verderame, Daniel Ware Jr., Garrett Williams, Michael Willey (2007) and Nicholas Faircloth (2008)

Mentors/Coaches:
William Geppert, David LaFazia

I. Abstract

Over the past six months, the Cape Henlopen Robotics Team has planned, designed, engineered, and tested the CHHS Titan. Each stage was tackled by two or three team members with support from the others, and overseen by Collins. Initially, our data analysis team (Ware and Bateman) worked on interpreting the rules. Once they had laid out all of the tasks and regulations in the order in which they had to be completed, they began work on the mission props. Then the structural team began work. The structural team (Williams and Mock) met over the course of several days and, along with Collins, laid out the Titan's basic design, its features, schematics, and materials required. Testing, calculation, and experimentation were very important. Once the Titan was operable, the operations team was brought in to start preparations for final testing. Then, the practice really began. New techniques were hammered out and protocols were established. Soon we were ready to compete.

One of the key factors in the success of the team was the careful division of the work amongst the team members. Ware built our Website and prepared rule interpretations. Bateman was the driving force behind our poster. Mock designed the structure and worked on buoyancy. Verderame built and mounted the camera housing. Collins designed the Claw and was responsible for motor mounting/housing. Williams designed and built the switchboard. Faircloth built the tether and developed protocols for prop management. And last but not least, Willey is the pilot.

II. Budget

Compiled from 1-1-07 to 4-21-07

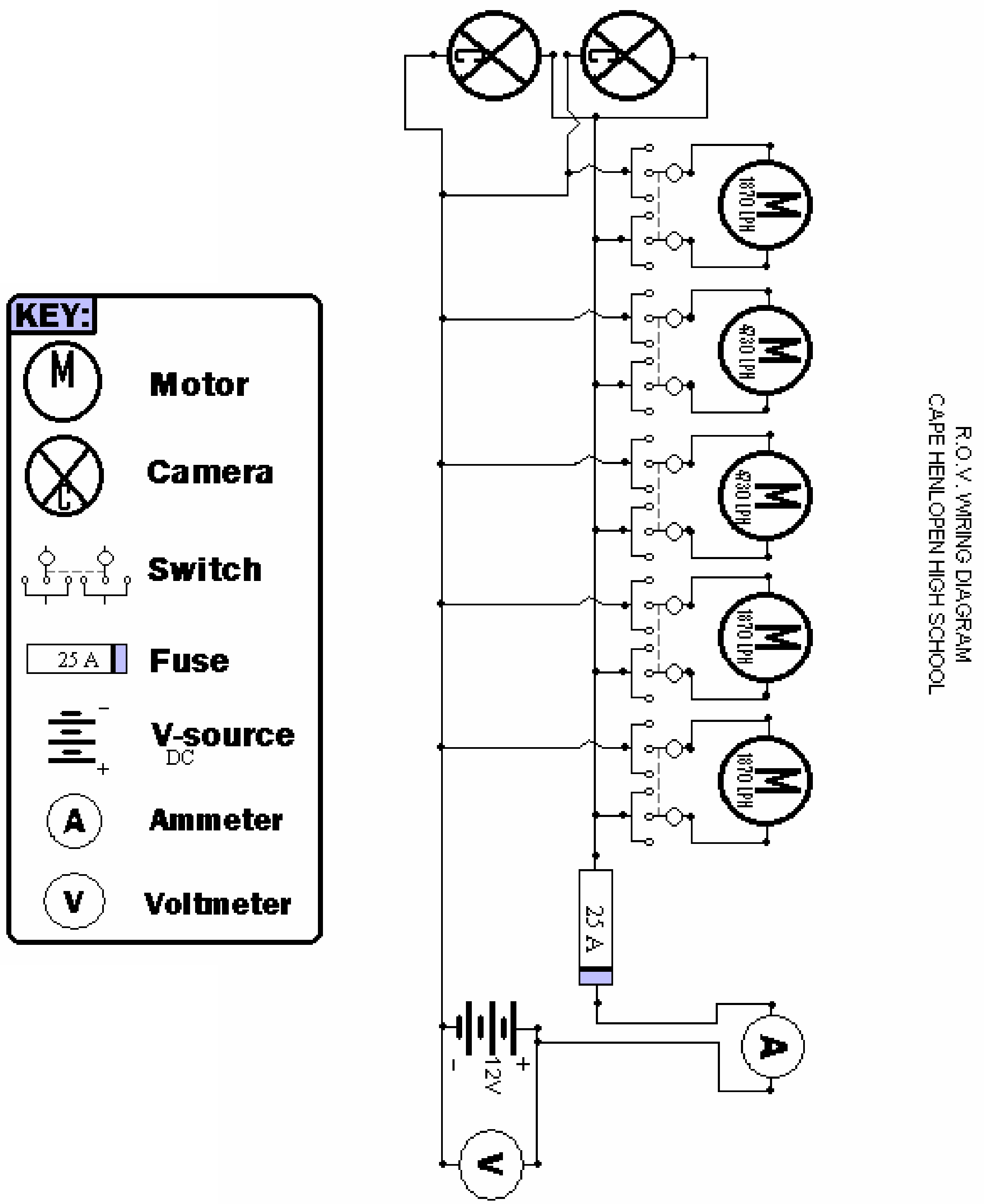
ROV EXPENSE SHEET

Date	Description	Monies IN/OUT	Balance
1/1/2007	Overall Donations	$625.00	$625.00
1/5/2007	3" DWV PLUG MIPT	$2.28	$622.72
1/5/2007	3"X 5' S40 PVC-DWV	$8.94	$613.78
1/5/2007	3" PVC F ADAPTOR	$4.88	$608.90
1/5/2007	2D RUBBER	$5.98	$602.92
1/5/2007	D-CELL ENERGIZER	$5.47	$597.45
1/5/2007	2-1/3 IN B/W IN/OUT CAMERA	$79.94	$517.51
1/7/2007	R/C CAR	$19.88	$497.63
1/7/2007	LED LIGHT	$11.96	$485.67
1/7/2007	FLASHLIGHT 2D	$2.79	$482.88
1/7/2007	25 AMP INLINE FUSE HOLDER	$2.99	$479.89
1/7/2007	25 AMP FUSE	$2.29	$477.60
1/7/2007	EPOXY SEALENT	$3.99	$473.61
1/11/2007	RING TERM	$1.98	$471.63
1/11/2007	5 PACK TAPE	$3.98	$467.65
1/11/2007	ZIP TIES	$4.99	$462.66
1/12/2007	SILICONE CAULK	$4.97	$457.69
1/12/2007	16-14 AWG 12-1/4S	$7.52	$450.17
1/12/2007	500' 14 GUAGE WIRE	$25.00	$425.17
1/13/2007	12 3-WAY PVC CONNECTORS	$39.63	$385.54
1/23/2007	30' X 1" PVC	$13.02	$372.52
1/23/2007	LIGHT GRATE COVER	$10.96	$361.56
1/23/2007	16 GUAGE WIRE	$7.97	$353.59
1/23/2007	TOGGLE SWITCH	$3.96	$349.63
1/30/2007	X-10 ANACONDA CAMERA	$63.15	$286.48
2/5/2007	3 X WATER NOODLES	$3.00	$283.48
2/10/2007	2 X 2OA DPDT SPG RETN	$8.98	$274.50
2/10/2007	2 X SPDT BLK FLIP SW	$5.98	$268.52
2/11/2007	WIRETIE 11 BLK 100 BAG ID	$7.13	$261.39
2/15/2007	FIBERGLASS RESIN	$13.98	$247.41
2/15/2007	BLACK SPRAY PLASTIC X 3	$14.94	$232.47
2/15/2007	JOHN DEERE YELLOW	$4.17	$228.30
2/17/2007	FOAM BOARD X 2	$5.94	$222.36
2/17/2007	QUAD SUBJ NOTEBOOK	$2.49	$219.87
2/17/2007	POSTERBOARD X 2	$3.06	$216.81

2/17/2007	CONCRETE MIX 40LBS	$2.69	$214.12
2/18/2007	THREAD SEAL TAPE X 2	$4.98	$209.14
2/18/2007	GLUE EPOXY X 2	$7.58	$201.56
2/18/2007	ELBOW PVC	$0.99	$200.57
2/25/2007	4" CAP PVC DWV	$10.88	$189.69
2/25/2007	4" X 5" PVC -DVW CELLCORE	$7.63	$182.06
2/25/2007	18" X 24" ACRYLIC CLEAR	$7.96	$174.10
2/25/2007	14 THN STRD CP WIRE 500'	$35.00	$139.10
2/27/2007	500 GPA BILGE MOTOR	$36.99	$102.11
3/2/2007	ASSORTED HARDWARE	$16.34	$85.77
3/5/2007	2"10' PVC	$6.00	$79.77
3/5/2007	3" X 2" PVC COUPLING	$2.44	$77.33
3/5/2007	4" CAP PVC DWV	$5.44	$71.89
3/5/2007	1/8" X 48' NYLON CHORD	$2.68	$69.21
3/5/2007	1/2" TEE SSF	$0.48	$68.73
3/5/2007	2" 90D SHRT ST ELL	$1.42	$67.31
3/7/2007	ASSORTED HARDWARE	$22.63	$44.68
3/7/2007	VINYL TUBING	$9.71	$34.97
4/20/2007	CALORIC INTAKE UNIT	$9.70	$25.27
4/20/2007	BRIDGE TOLLS	$24.00	$1.27

Net worth of ROV team- $1.27 US
~ $1.36 CA

III. Electrical Schematic



IV. Design Rationale and Vehicle Systems Breakdown

The Frame

The Titan is enclosed in and supported by a rigid PVC skeleton. PVC was an immediate choice for materials because of its high strength to weight ratio. In addition, the ability of the pipe to retain air within it when properly sealed aids buoyancy. Each joint and connection in the PVC is sealed with a combination of epoxy and fiberglass sealant. The entire frame was then coated with a spray-on watertight sealant. The team decided to go with a cage-like design in order to protect the Titan's cameras, motors, and to support the suction column as well as the claw protruding from the front.

The painted cage frame.

For Buoyancy

For simplicity and school spirit, our team decided on using blue pool noodles for buoyancy. Careful measurements of the volume, mass, and density of a sample of the foam were compared with experimental results in order to calculate a buoyant force to length ratio. The team put their experience in a simple physics lab and the basic equations for buoyant force to use and “ball-parked” the total amount of noodle necessary. Experimentation and test trials then fine-tuned the amount of foam required to achieve neutral buoyancy. Two heavy rods placed within the bottom side PVC pipes keep the Titan upright and level at all times.

Blue Pool Noodles →

Cameras

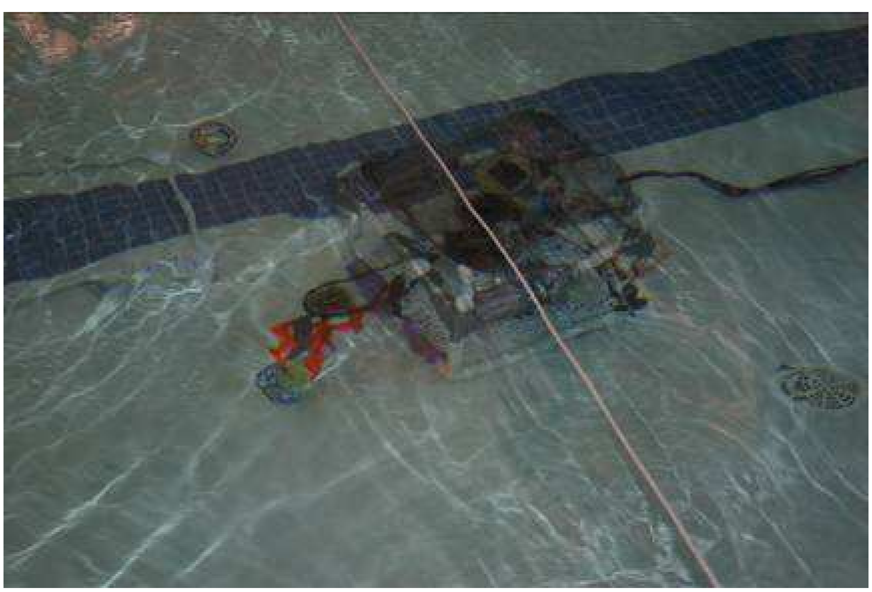
The Titan sports two infrared-enhanced cameras. Each camera is encased in homemade camera housing capable of withstanding the water pressures associated with each dive. The housings are made of a Plexiglas screen sealed to a large PVC end cap. The placement of each camera is designed to give the driver the visibility necessary to perform the required tasks as well as drive the Titan.

← Our ROVs forward camera projecting on a monitor.

The Maul

The Maul: Simple but Deadly!

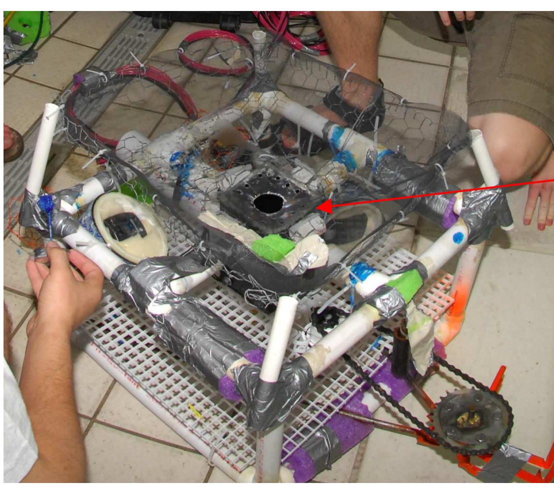
The Maul is a stainless-steel, improvised claw capable of grabbing and releasing objects underwater. The Maul is powered by a gear attached to a motor. This gear is attached to a larger gear via a taut bicycle chain. This larger gear is attached to two mobile digits ("thumbs") that swing to join three additional digits ("fingers"), forming a hand-like grip. Bent digits reduce the chance of objects escaping the claw's grip. A frontward-facing camera allows the operator to position the Titan just right for grasping the necessary items. The Maul's .969 kg mass is carefully countered with the buoyant force exerted by the foam on the lower front bar of the Titan's skeleton: the same piece that prevents the Maul's supports and the skeleton from making contact.



The Maul in Action.

The Suction Column

The Suction Column is an appropriately named vacuum feature designed especially for catching floating ping-pong balls. The initial concept of the vacuum resulted from a physics lesson describing the Bernoulli Principle of mediums flowing through containers with differently sized openings. The vacuum is a metal box with a bilge pump motor forcing water through it. The mouth of the box is smaller than the end from which water escapes, creating a powerful suction capable of pulling down its buoyant prey. When accompanied with a funnel-like attachment to help guide in the ping-pong balls and another attachment to prevent the ping-pong balls from escaping, the column is able to catch ping-pong balls and then hold them after the motor powering it has been turned off. An upward-facing camera allows the pilot to guide the Titan into just the right position for obtaining a sample of "algae".



Our Patented "Ball-Catcher" Device

Propulsion System

The Titan is powered by five bilge pump motors. Two 1890 LPH bilge pumps control lateral movement while a third powers the claw. One 4730 LPH bilge pump controls vertical movement while the final motor (4730 LPH) lures ping pong balls into the suction column.

The Propulsion and Tether Systems →

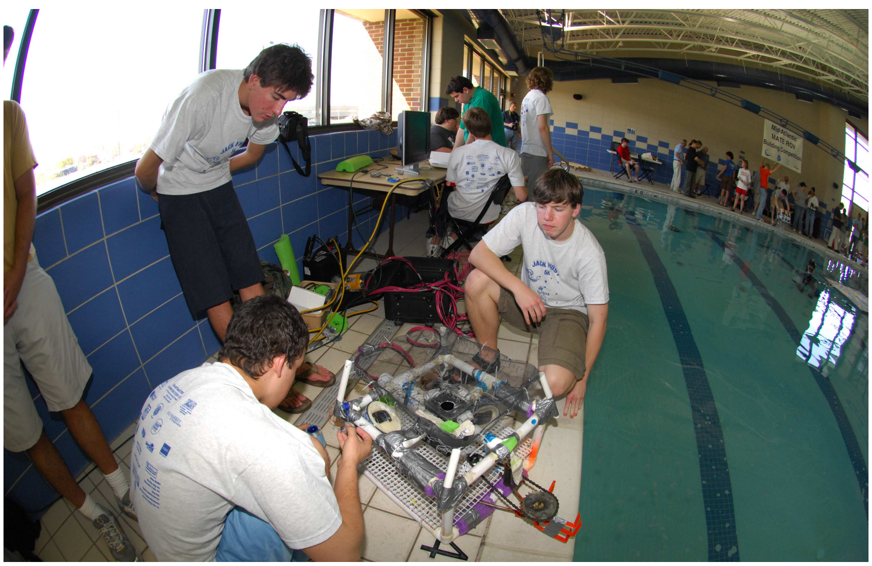
The Tether

The team learned from past mistakes when selecting wire with which to make the tether this year. This year's tether is made of 14 gauge stranded wire as well as the two fiber-optic cables that carry the feeds from the cameras back to the pilot. These wires are lighter and more flexible than past tethers. Each individual wire is capable of carrying 25 Amps within safety limits, with circuit protection provided by the fuse. A special attachment to the skeleton of the Titan protects against cable interaction with the lateral propellers.

V. Challenges

One of the challenges we faced was achieving relatively neutral buoyancy in the ROV. In preparing for the regional competition, too much time was spent cutting and taping on foam material to add buoyancy to the ROV. Our method was guess and check: we would cut out a piece of foam, tape it to the ROV, and test its buoyancy in a pool.

After several tedious days of readjusting the buoyancy, we knew we had to find a more efficient, calculated method. Collins and Mock decided to calculate the buoyant force per unit length of foam (which is really a force to volume ratio because the cross sectional area of the foam is constant.) This way we could simply weigh the ROV under water using spring scales, then convert this weight to a length of foam needed to counter it.



Collins, Faircloth, and Mock overcoming the buoyancy obstacles before the Mid-Atlantic Regional Competition.

On the matter of how to find a buoyant force to length ratio, Collins and Mock could not agree. They decided to part ways, use their own methods of calculation, and then keep the most accurate result.

Collins took an empirical approach to finding the foam's buoyant force. He began with a metal weight with a downward force of 9 N underwater. He then attached foam slices, 2 cm long, to the weight until he achieved neutral buoyancy. The number of slices (16) times 2 cm divided into 9 N produced a force to length ratio of .28 N/cm.

Mock decided to use a more mathematical approach. He first found the volume of a 1 cm slice of foam by using Archimedes' "Eureka" method of submerging it in a beaker and noting the change in water level. Then, the mass of the foam was measured. The difference in the mass of the foam and the mass of the water it displaces times the gravitational constant (9.8 N/kg) yields a buoyant force of .3 N per centimeter of length.

Both methods produced a surprisingly similar result, proving that there can be more than one accurate way to solve a problem. Before, we were trying to complete a task from scratch, but now we have produced a ratio that makes each time we adjust buoyancy a great deal easier. Thereby, this challenge taught us the value of creating a tool, such as a formula, device, or plan, to make a repetitious job simple.

Our ROV having water poured out of a small hole.

VI. Trouble Shooting Techniques

The main problems that we encountered with building this ROV were with buoyancy, balance, and leaks. In order to determine our mistakes in buoyancy, we used trial and error. The team enjoyed a few hours at poolside, meticulously adding pieces of foam to the ROV, setting it in the water, observing the effects, and then pulling it out and adding foam again. The end product was a neutrally buoyant ROV, a relieved team, and a heap of pool noodle scraps.

Collins trouble shooting the suction column function with teammates Mock and Williams.

Balancing the ROV became another problem that we had to overcome. We wanted the claw far enough out from the Titan that we could perform our tasks from a safe distance. However, the further out we placed the claw the more its torque dragged the front of the vessel down. We solved this once more with trial and error, setting the claw further back while at the same time countering its weight with pool noodle. Our tether man, Faircloth, also perfected his technique of pulling in the tether so to give the ROV some slack in its tether and prevent disrupting the balance of the Titan.

Tetherman Faircloth carefully giving the ROV slack to prevent instability.

Leaks were by far the most frustrating problem our team faced during this project. There was nothing more disheartening than to see our hard work sinking to the bottom while bubbles rising to the surface indicated that something was not right. Our team did not take chances with guessing the source of the leak. We drilled a hole in the Titan to allow all of the trapped liquid to escape, then sealed the hole and added sealant to every joint so as to ensure no future leaks.

VII. Future Improvements

- **More Practice Time**: Practice time was the key to our successes this year. However, we did not get as much pool time as we would have liked. Practice makes perfect and so practice we must.
- **Better Adhesives**: We had frequent troubles this year with our epoxies and sealants not being efficiently used in waterproofing. Leaks frequented the Titan, and we were forced to add layer upon layer of epoxy on each joint. Using a better epoxy that is and will remain watertight would make the building process much less painful.
- **Better Balance of Weight**: Early on in the project, we had problems with balancing the Titan underwater. We were able to overcome this problem by shortening the distance between the claw extension and the ROV itself. However, in the future it would be better to evenly distribute the weight in the front and back.
- **Lighter Body**: Our craft is heavy with a lot of metal parts. This makes it a little more sluggish in the water (due to its relatively greater inertia) than it could potentially be. Next year the use of lighter materials would be most beneficial.
- **More Efficient Buoyancy**: The pool noodles that we utilized were simple and easy to use, but in the future a more precise method of buoyancy would save time and energy. Adjustability is the key to our success.

VIII. Lessons Learned and Skills Gained

- **Problem Solving**: By this point in the competition, our team has become well acquainted with adversity. We have experienced numerous problems with leaks, buoyancy issues and mechanical breakdowns, all of which we have overcome using our ingenuity and a little elbow grease.

- **Understanding of Physics:** Throughout this project, our team has used our basic knowledge of physics in order to conceive and build the Titan. From our Bernoulli-inspired suction column to our mathematically calculated buoyant forces, the use of physics was a major part of the building of this ROV.

- **Teamwork**: This ROV team has overcome incredible odds and put in long hours together in order to make it this far. We have mastered delegating tasks and working together in order to accomplish our common goals.

- **Staying Positive**: There were many occasions during which the odds were against us, but we met every challenge with a positive attitude. It was no doubt this positive attitude that helped us go from last place to first from last year to this one.

IX. Culture, History, and Society at the Poles

The International Polar Year is a collaborative effort sponsored by the International Council of Science to celebrate and coordinate observations of our planet's polar regions. The North and South Poles harbor unique conditions unlike those of any other areas found on Earth. Such conditions as severe cold, strong gale, and icy pockets of sea make the regions inhabitable only to the most specifically evolved creatures and best-adapted peoples. The Inuit people are believed to have inhabited the North Pole region since approximately 1000 AD, when their ancestors replaced the native race of giants known as the Dorsets (or *Tuniit* in Inuit). They have survived this long under such harsh conditions thanks to the help of dogs and unique technologies and hunting techniques specialized for their frozen home.

The harshness of life at the Poles as shown in this picture of an Inuit residence.

Researching wildlife and the world under the ice of these Polar Regions is a hazardous task too dangerous for the direct involvement of humans. In order to minimize the risk to researchers, real life ROVs are used to explore and perform underwater tasks where humans cannot. This makes the International Polar Year a very appropriate time to celebrate and learn about the use of ROVs in the real world.

These photos show both the beauty and the starkness of the Polar Regions.

Works Cited

Arctic. Quark Expeditions. 11 May 2007, <http://www.quarkexpeditions.com/arctic/culture.shtml>.

International Polar Year 2007-2008. 2007. International Council for Science. 18 May 2007, <http://www.ipy.org/>.

X. Reflections

Coming into this competition, the main goal of our team was to redeem ourselves after last year's disappointing performance. At the regional competition we had the "Duck Tape Award" bestowed upon us after our ROV sank and we finished in last place. In a remarkable comeback, our team put together our talents and ingenuity to take first place and qualify for the international competition. We learned to delegate tasks to different members of the team so as to divide the work and accomplish the objects of our endeavor. In retrospect, we have far surpassed our previous performance and now are eager to give it our all and show what a small town school like Cape Henlopen High School can do on the international level.

XII. Acknowledgements

We would like to recognize the following:

For their charitable contributions to our travel:

M.A.T.E
Nauticus
NOAA
Verizon
University of Delaware / Sea Grant
SPI Pharmaceutical
Browseabout Books

For their time, patience, and capital resources:

Cape Henlopen School District
William Geppert
David LaFazia
Edwin Hayes
Kinsale Glen Homeowners Association
Admiral Jewelers
Harold Hovis
Peter Olson

And lastly…

TO ALL THE PARENTS AND EMPLOYERS OF THE TEAM MEMBERS WHO LET US GO TO CANADA!