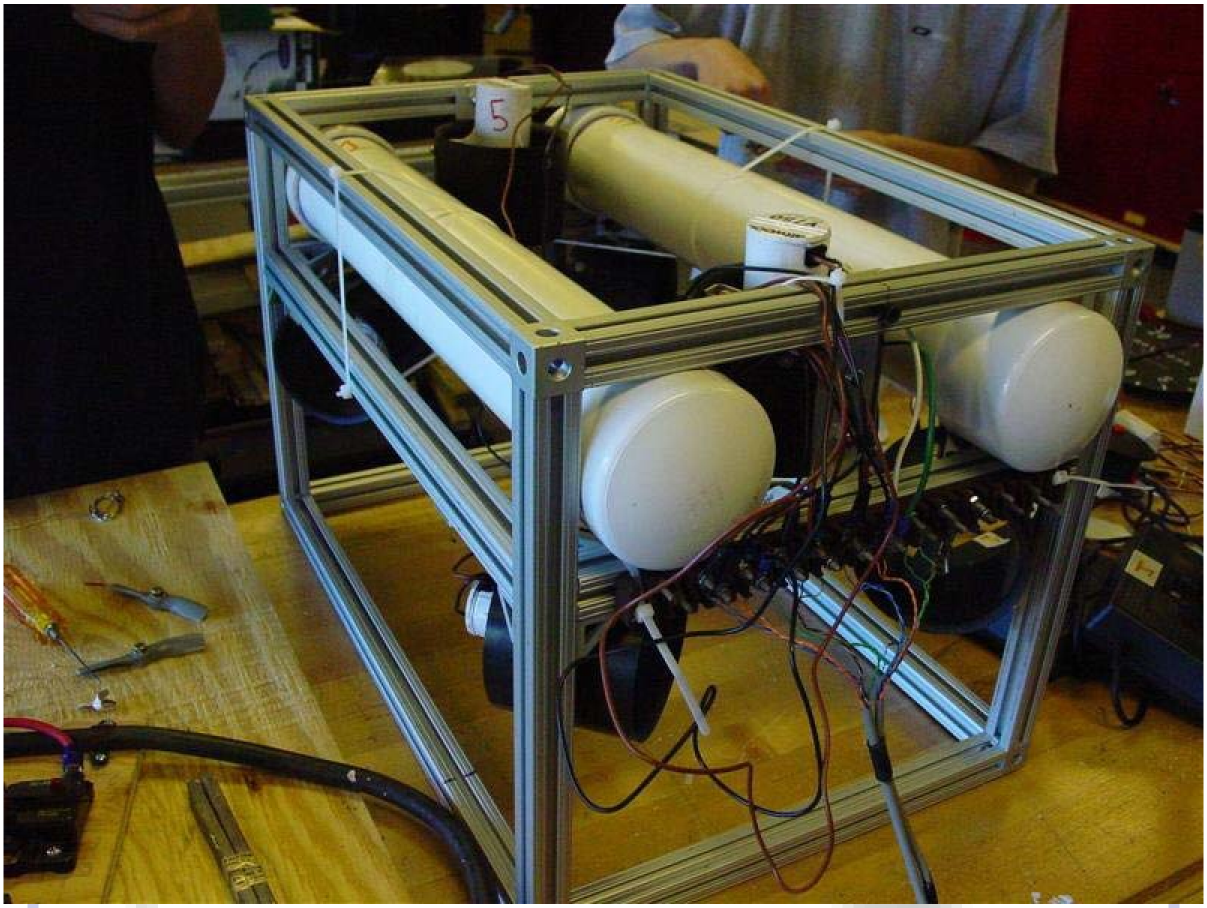
HTHS Fury
Technical Report

High Technology High School Presents:



"GLADT-Good Luck and Duct Tape"

HTHS Fury Team Members:

Teachers:	Mr. Michael T. Roche	Mr. Robert Dennis
Mentor:	Mr. Bill Wetzel	
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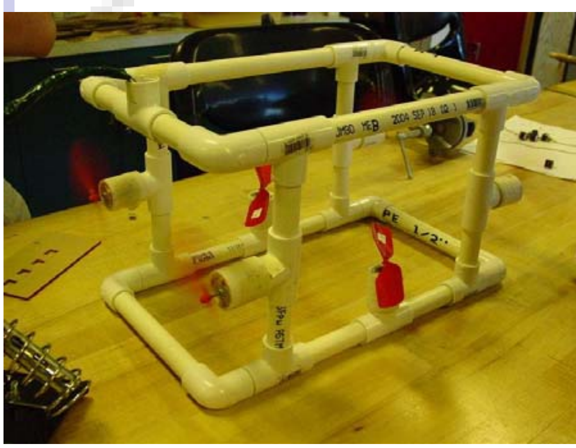
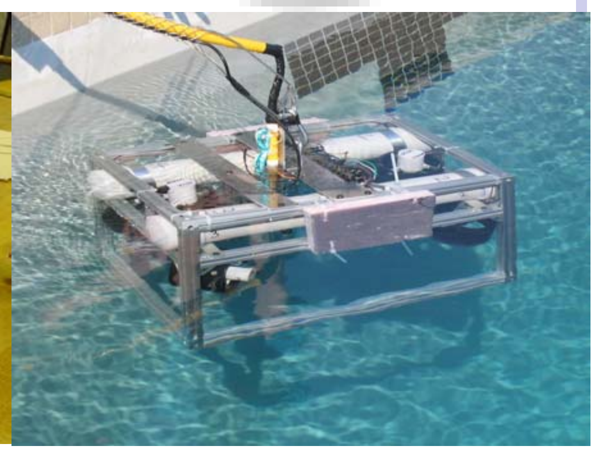
Abstract of Project

The HTHS Fury Robotics Team is from the High Technology High School located in Lincroft, New Jersey. The HTHS Fury Robotics Team concentrated time and effort into the completion of a functional robot for the Ranger Class Division of the 2005 MATE ROV competition that would efficiently and effectively perform the three tasks while adhering to the specifications and criteria outlined by the competition rules. The three tasks for this division include capping an oil well in the Gulf of Mexico, repairing a damaged fiber optic cable connection to reestablish a communications link, and installing a new instrument module on the Hubble Space Telescope. The rules for the competition outlined specifications for the ROV, which include a maximum voltage of 13 volts and a maximum current of 25 amps. In addition, the ROV needs to withstand the pressures of water at a depth of 5 meters, as well as a tether cable that can accommodate such a distance. Furthermore, the overall dimensions of the ROV were limited to an envelope of 80 centimeters by 60 centimeters by 60 centimeters. With the understanding of the limitations and the tasks, the team of students was sub-divided into groups to focus on the areas of design, testing, electrical systems, documentation, and an exploratory freshmen team. Each group independently worked on their assigned aspects of the project while exchanging information amongst each other to function as an efficient team.

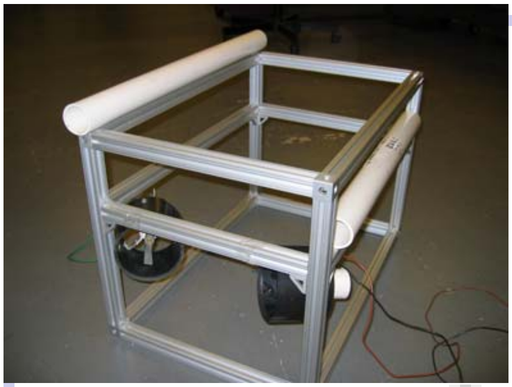




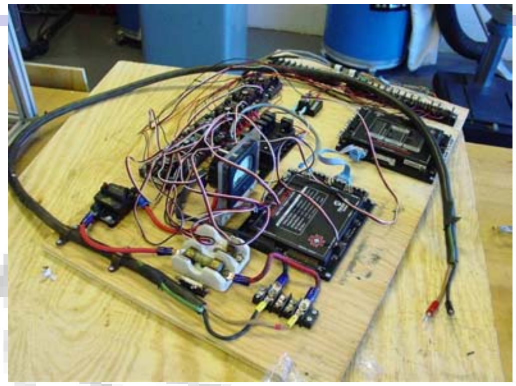
Photographs of Completed ROV

GLADT-Good Luck and Duct Tape

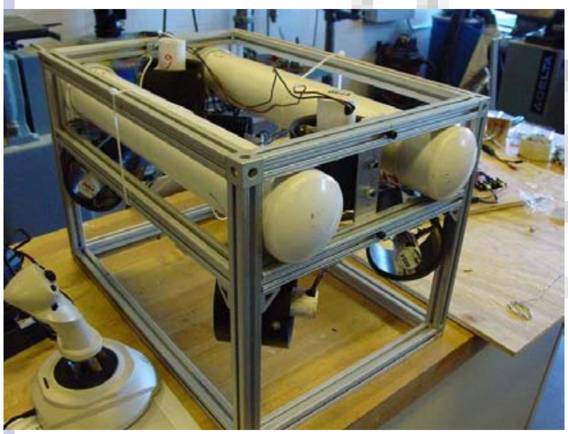
Preliminary Structure of the ROV

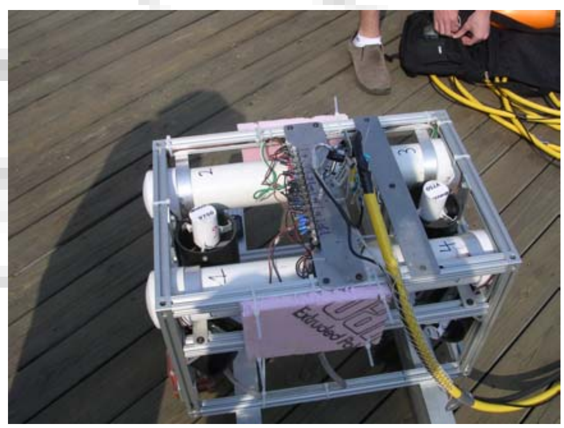


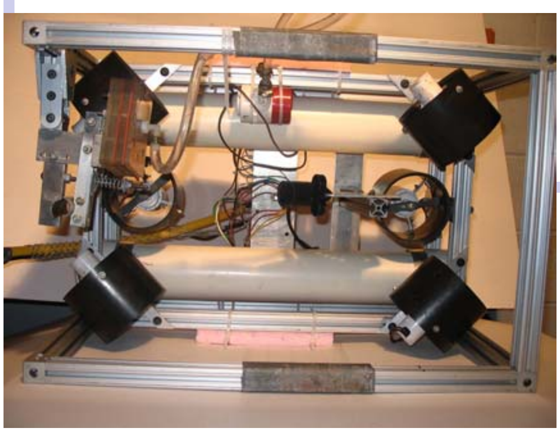
Electrical Systems of the ROV

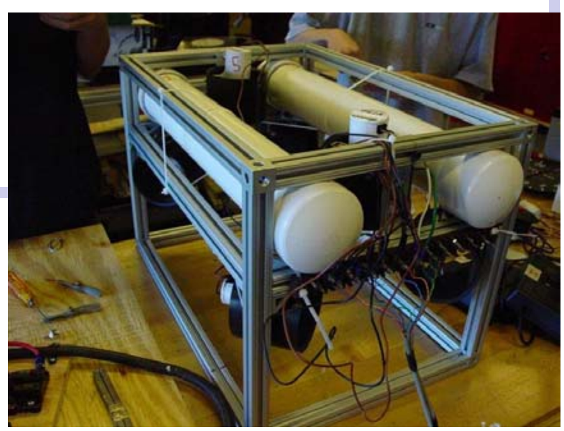


Final Pictures of the ROV after Completion





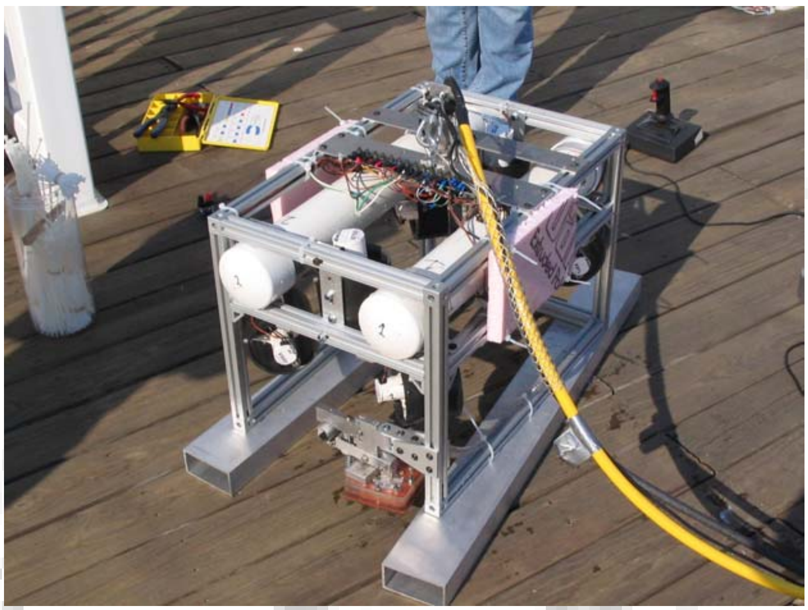




Budget and Expense Sheet

Source of Income for the ROV

The income for this project came in the form of the remaining funds from the remnants of the FIRST Robotics Team at High Technology High School, which was disbanded, but capital also came in the form of a donation. The major source of the income came in the form of remaining money in the account previously used for the FIRST Competition. Though, there was also a donation from Class Link to the sum of $3,500, which was used towards the costs of transportation. This amount was more than required to complete this project when factoring the nature of components that were donated or loaned to our team.



Expenses and Donations for the ROV

The materials for this project came in the form of purchases, donations, materials already in possession and loans. The purchased materials include an inflatable pool for testing, waterproof crimp connectors, bilge pump motors for propulsion, propellers for the bilge pumps, and the various beams and connectors comprising the structure of the ROV. The total cost of these materials was well within the budge for the HTHS Fury team. The donated materials include the 18.3 m long tether cable from Cortland Cable and the Rule 500 Bilge Pump to operate the end effector. Besides these two sources of materials for the project, additional materials were located within the school in the form of leftovers from previous FIRST Robotics. The key FIRST materials include all the necessary components for the electrical systems and control systems. Finally, the camera and television that comprise the visual systems were loaned to the HTHS Fury Team by the Marine Institute of Science and Technology.

Sheet Detailing Budget and Expenses

Deposit or Expense	Description	Quantity	Notes	Amount	Balance
Deposit	Total in Account	-	-	$2,089.38	**$2,089.38**
Expense	Inflatable Pool	1	Purchased	$300	$1,789.38
-	Victor 886 Speed Controller	5	Leftover from FIRST	$750 est.	$1,789.38
-	Spike Relay	1	Leftover from FIRST	$35 est.	$1,789.38
-	Power Distribution Block	1	Leftover from FIRST	$50 est.	$1,789.38
-	Breakers	-	Leftover from FIRST	$100 est.	$1,789.38
Expense	Waterproof Crimp Connectors	-	Purchased	$20	$1,769.38
-	Tether Cable	18.3 m	Donated by Cortland Cable	$50 est.	$1,769.38
-	Innovation FIRST 2004 Controller and Operator Interface	1	Leftover from FIRST	$1,500 est.	$1,769.38
-	Analog Joystick	2	Leftover from FIRST	$100 est.	$1,769.38
Expense	Attwood 500 and 750 Bilge Pumps	4 and 2	Purchased	$100	$1,669.38
Expense	Rule 500 Bilge Pump	1	Purchased	$20	$1,679.38
Expense	Propellers	6	Purchased	$30	$1,649.38
-	Connectors	-	Leftover from FIRST	$25 est.	$1,649.38
-	PVC Pipes	-	Leftover from FIRST	$20 est.	$1,649.38
-	Metal Components	-	Leftover from FIRST	$75	$1,669.38
Expense	Beams and Connectors	-	Beams are 80-20, Purchased	$250	$1,494.38
-	Camera	1	On Loan from MAST	$5,000 est.	$1,494.38
Expense	Transportation	-	Transportation	$231.62	$1,137.76
-	-	-	Remaining Amount	-	**$1,137.76**

Electrical Schematic

Introduction

Since the HTHS Fury team is composed of some students representing the remnants of the FIRST Robotics team, the electrical and control systems were based upon and utilized the systems found within the FIRST Competition. This was a justified decision based upon previous experience and experience with these electrical systems as opposed to any other electrical system that could have been chosen.

Power Supply

The electrical system begins with the power supply for the ROV, which is provided to our team at the competition. There is a 25A fuse assembly in series between the power supply and the rest of the electrical equipment as a safety precaution to protect the ROV. The wire from the fuse and the ground are then connected to a breaker block, which provides all of the devices with a common ground and independent 20A circuit breakers. This arrangement distributes power safely to the various components, as well as providing the ability to disable a particular component of the ROV independently from the rest of the components of the ROV.

Speed Regulation

The regulation of the speed of the six motors is done by five Victor speed controllers of the 883 and 884 models. Each one of these five Victor speed controllers receives 12 volts from a separate breaker located on the breaker block through 16 gauge wiring, which is also used for grounding purposes. The Victor speed controllers provide the ROV with fully proportional power output from -12 volts to +12 volts at a current up to 35A. Furthermore, there is a Spike DC relay connected to the breaker block to provide an output of with -12 volts, 0 volts, or +12 volts. For additional safety, there is a replaceable 20A fuse on the power supplied to the relay.

Control Systems

An additional feed from the breaker block is designated to power the First 2004 Robot Controller and Operator interface, which controls the movement of the robot. The Robot Controller provides Pulse Width Modulation outputs, or PWM, that are necessary to communicate with the Victor speed controllers and the Spike relay. Three connector PWM cables run from each motor controller to the Robot Controller. In addition, the FIRST Operator Interface provides inputs for analog joysticks with 25 pin connectors. There are two such joysticks used for the control of the ROV with one joystick utilized for linear X and Y axis movement in the directions forwards, backwards, left, and right. The second joystick provides linear Z axis movement in the directions up and down, as well as rotational XY plane movement to turn left or right. The claw, which is the end effector, is controlled by the trigger button located on the first joystick.

The key components of the electrical system include the Operator Interface and the Robot Controller. The Operator Interface takes the inputs from the joysticks and converts the inputs into a digital signal that can be sent to the Robot controller. The Operator Interface is connected to the Robot controller via a standard RS232 cable and is provided power through that same cable. The Robot Controller has a microcontroller that runs the code necessary to process those inputs which are in turn outputted to its PWM ports accordingly. The Robot Controller is programmed by team members by utilizing the C programming language. The Robot Controller provides great flexibility in control by setting minimum and maximum outputs to the motors through software as opposed to in the hardware.

Visual Systems

The final feed off of the breaker is to power the camera and monitor responsible for the visual systems of the ROV. The underwater camera was loaned to the HTHS Fury Team from the Marine Academy of Science and Technology, which is another school within the same district as the High Technology High School. The camera has a four connector tether cable which connects directly to the monitor with one contact for power, one contact to power the LEDs arranged around the lens, one contact for the video signal, and one contact for ground. In order to avoid modifying the camera in any way other then for mounting purposes, the camera and television are powered from the power supply and draw a current of 1.4 amps.

Tether Cable

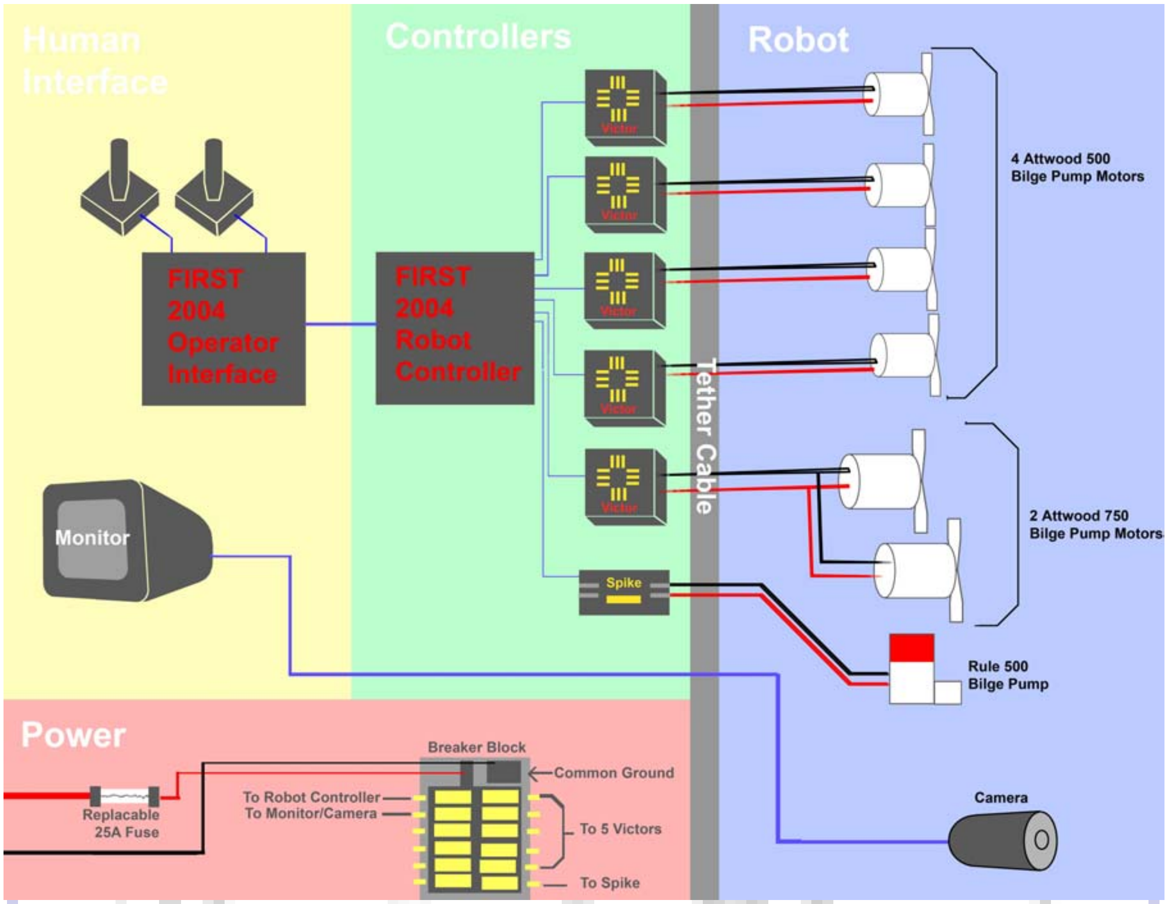
The 18.6 meter long tether cable was donated by Cortland Cable to the HTHS Fury Robotics Team. The cable has 17 conductors of approximately 18 gauge, and also contains coax and fiber lines not utilized for this project. Of the 17 power conductors available, only 14 are used for the ROV. Each motor receives an independent pair of wires in the tether. In this manner, all power, commands, and visual data is sent between the human operators and the ROV by means of this one tether cable.

Propulsion Systems

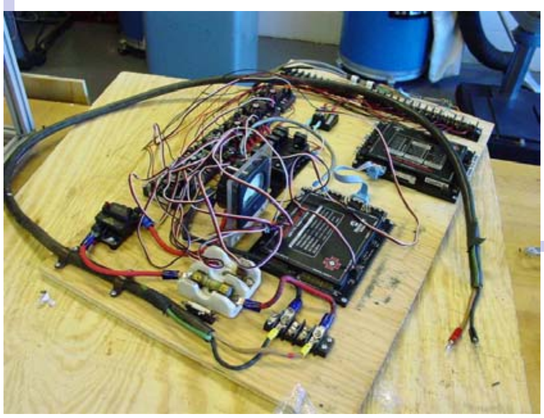
The propulsion system consists of the 6 thrusters and an additional pump to operate the end effector. The propulsion system consists of 7 bilge pump motors for great maneuverability. There are 4 Attwood 500 bilge pump motors and 2 Attwood 750 bilge pump motors for directional motion. The actual speed of the thrusters is controlled by the Victor speed regulators. In addition, there is an unmodified Rule 500 bilge pump to hydraulically actuate the end effector. This pump is powered by the spike relay since the bilge pump is only required to open and close the end effector and varying speed is not necessary for this application.

Electrical Schematic

Diagram of Electrical System



Pictures of Electrical System



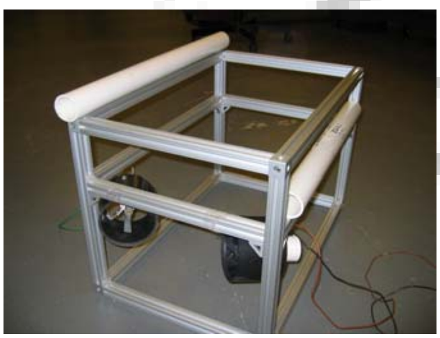
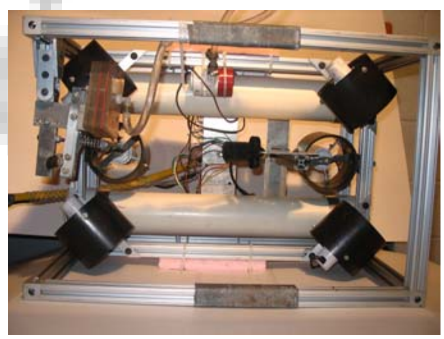
Design Rationale

Introduction

The design of the ROV is the culmination of the critical thinking in specific areas that govern the success of the performance of the ROV. For the ROV to function properly at the necessary depths underwater, special consideration was given to designing a structure capable of withstanding the water pressure. Maneuverability and directional accuracy in motion were crucial factors in the design of the propulsion systems of the ROV. These were subjected, however, to the restrictions placed upon the total current draw of the ROV. Thirdly, great concern was given to the visual system, which represents the only way for the operator to view the actions of the ROV. Finally, the end effector was carefully designed in order to perform all three tasks with little to no difficulty

Structure of the ROV

The overall structure of the ROV was specifically selected to be a rectangular prism comprised of 80-20 extruded aluminum beams that are held together through special connectors. The shape was selected based upon the simplistic nature of the design, which would serve as a strong shell for the ROV without consuming too much construction time. Furthermore, the selected material was the 80-20 extruded aluminum based upon its light weight in comparison to its great strength and the sheer availability of the material. All such characteristics are crucial in the design of the structure of the ROV.

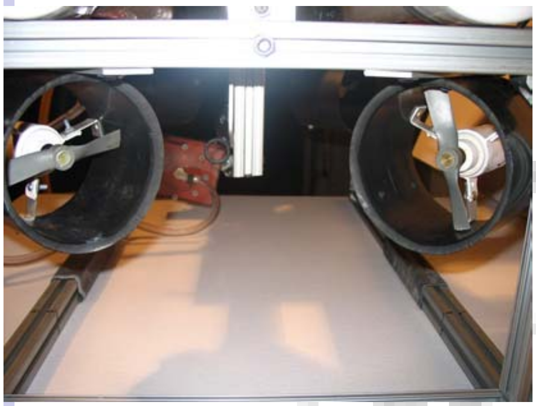



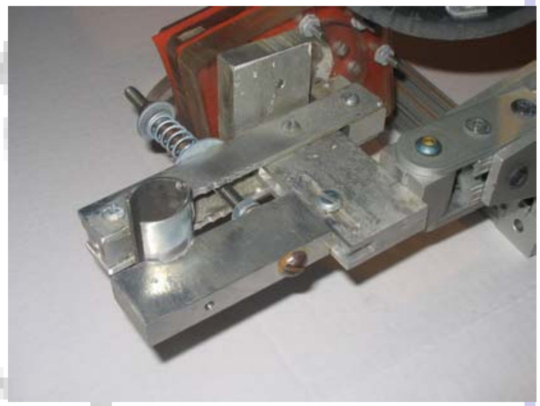
Propulsions Systems

The propulsion of the Robot required considerable thought regarding the ability to move in any given direction to ensure maximum maneuverability in the water. To meet this requirement, 4 Attwood 500 bilge pump motors and 2 Attwood 750 bilge pump motors were selected to provide the propulsion. The 4 Attwood 500 bilge pump motors could be placed at the four vertical edges of the ROV to provide the majority of propulsion for the ROV. In addition, the Attwood 750 bilge pump motors are utilized to provide the vertical motion in the water. The placement of the six motors allows for movement in any given direction as accordingly to the previously established goal for the propulsion system.

Design of Thrusters

The thrusters themselves were custom designed by the group in order to best accomplish the tasks and make maximum usage of the 6 bilge pump motors. The thrusters begin with removing the housing of the bilge pump motors as they are unnecessary for this application. The impeller of the motor was also removed and then replaced with a propeller commonly found within model airplanes and quite effective in an underwater setting. Finally, a four inch section of PVC pipe was adapted to form a nozzle for the thruster in order to concentrate the force produced by each bilge pump motor. In effect, the nozzle is similar in design to a Kort nozzle. Overall, this design allowed for maximum power output to govern the movement of the robot through the underwater environment.





Visual Systems

The visual system is in the form of an underwater camera and a television monitor to provide enough visual data for the operator to accurately control the motion of the ROV. The camera is mounted towards the front of the ROV to provide the best view of the path of the robot through the water and a perfect view of the end effector. This arrangement allows for one screen to display all pertinent information regarding the robot completing the given tasks.

Claw End Effector

The selected end effector design was essentially a claw that simply opens and closes as needed. This design was selected in order to avoid failure associated with more complicated designs, as well as being easier to operate than other designs. The end effector is mounted towards the front of the ROV and can be adjusted in between tasks to the optimum orientation. The end effector has two main positions which are switched as dictated by the nature of the tasks. The Rule 500 Bilge Pump is used to open and close this end effector.

Description of Primary Challenge

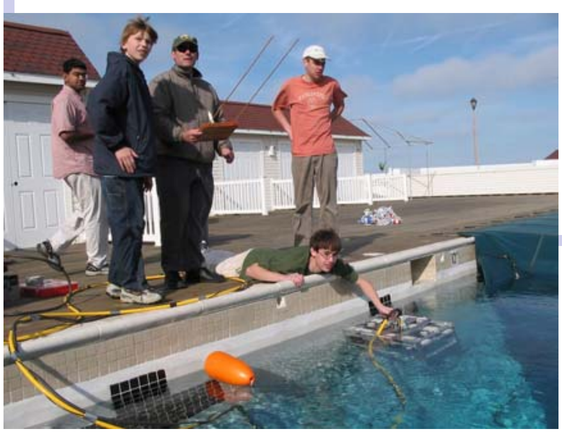
Introduction

Within this project, the primary challenge was in the ability to test the ROV in an environment similar to the one within the actual competition. In order to perform such testing, it was crucial to locate an underwater habitat, such as a pool or large container of water, in order for the human operators to conduct practice runs of the three tasks in order to hone their skills. The one distinct challenge resulting from the necessity for testing is the location of a suitable environment.

Finding a Testing Environment

Initially, the proposed idea was to construct a large containment unit for water at High Technology High School based upon easy access and relatively low cost. The ideal dimensions chosen for the container would be four feet wide by eight feet long by four feet tall. Such dimensions would allow for enough room to check the functionality of the ROV and test the control systems of the ROV. Though, this idea was dismissed based upon size limitations being inefficient based upon difficult to construct a waterproof containment unit. Though, a smaller tank was eventually improvised for testing.

The second idea was to locate a pool that could be utilized for testing various aspects of the ROV and allow for practice runs to be conducted. Eventually, a pool was located in order to fit the size expectations to conduct practice runs. The pool was an in-ground pool with depths similar to the depths found within the actual competition. In this pool, the practice runs could be conducted in order to hone the skills of the human operator and determine efficient methods for completing the tasks. In addition, another pool was purchased from K-mart in order to provide basic testing environment at High Technology High School. This particular inflatable pool had a diameter of fifteen feet and was four feet deep. This pool provided a suitable environment for testing the power of the thrusters and speed of the ROV.



Explanation of Troubleshooting

Introduction

As expected in any major project, problems will arise that will need to be identified and corrected. For an ROV competition, the ability to efficiently and quickly solve problems is critical to ensure maximum performance of the ROV in the competition. For the ROV, the FIRST system used to control the ROV has indicators to display particular problems that arise. Though besides indicators, another important factor is a methodology for going about solving the problems.

Indicators of a Problem

The electrical and control systems for this ROV are comprised of components from the FIRST Robotics Competition. As such, the various components have indicators that can be used for troubleshooting purposes. The Innovation FIRST 2004 Operator Interface contains numerous indicators that can show problems regarding power supplies and communication with the various components. Additional indicators are located on the Innovation FIRST FRC Robot Controller. Furthermore, each individual Victor 886 Speed Controller and the Spike Relay have an LED that can be used to determine if the component is working properly.

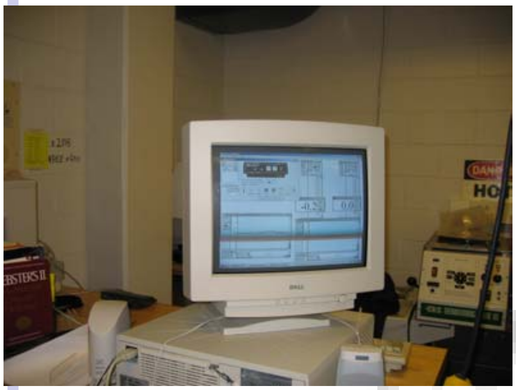
Process to Solve a Problem

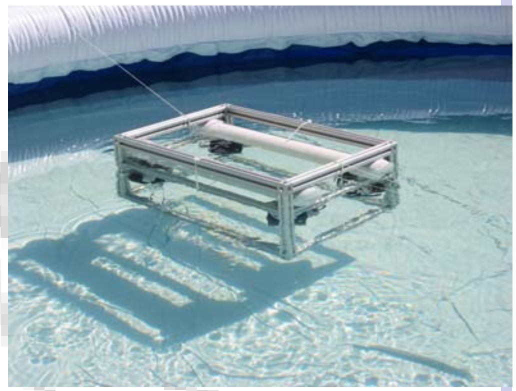
When a problem arises with the ROV, the first step is to try to identify the exact problem with the ROV. This step is accomplished by one or more team members examining all effected components of the ROV in order to isolate the problem. Once the problem is identified, the next step is to identify a proper solution to the problem or a way in which the problem can be preventing from reoccurring. This step begins by the initial team member generating solutions and determining the successfulness of those solutions. If that team member is unable to solve the problem, the team member calls upon other members to brainstorm other solutions. Most problems are solved in this manner, but if not, the ultimate step is to consult the mentor of the advisors to find the proper solution. This process clearly identifies a general process to solve problems through the team structure.

Testing of the ROV

Introduction

A crucial aspect of this project was the testing of the ROV and its various components in order to understand the limitations of components and catch potential problems at a point where solutions can be easily implemented. In this project, testing was conducted in regards to the visual systems, characteristics of the motors, velocity of the ROV, and varying propeller design.





Visual Systems

Testing was conducted regarding the interface between the robot sending data via a camera and a human giving commands based upon such data. The setup of the experiment was one team member would take the role of the robot. The team member would hold a sample end effector and the camera. Another team member would stare only at the monitor for the camera and give verbal commands to the team member pretending to be the robot. In this manner, the process by which the robot will be controlled was better understood, and despite not actually testing with the robot, experience was gained in regards to the limitations and difficulties with the method of controlling the robot. In essence, this testing allowed for the team members to understand the importance of factors, such as depth perception, and could then learn to compensate accordingly.

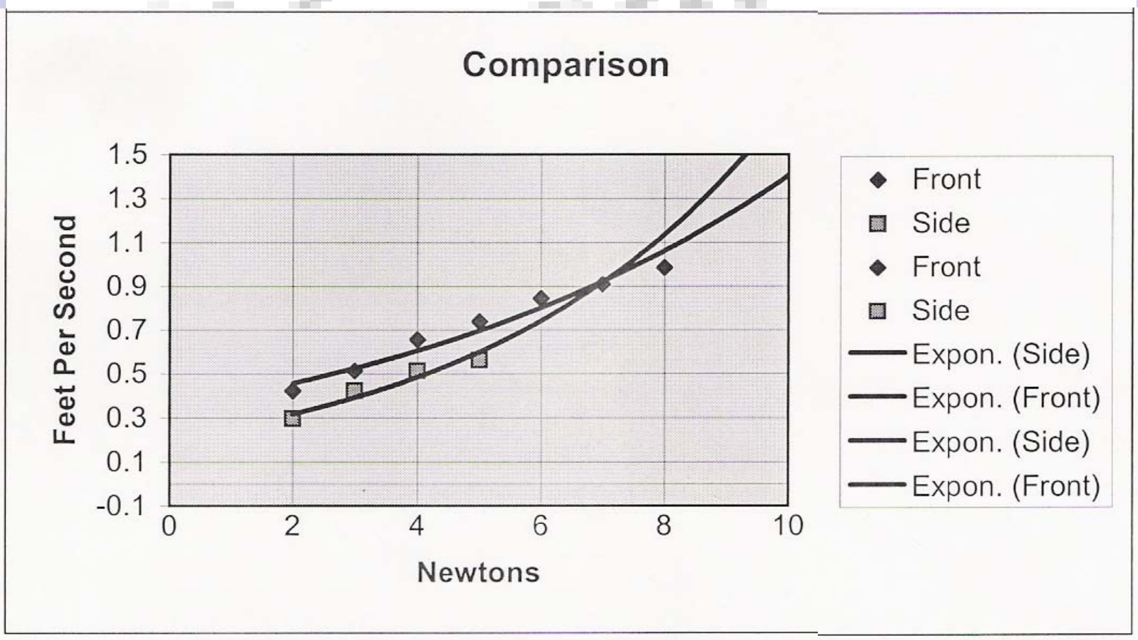
Characteristics of Thrusters

The first conducted test involved determining the performance of each motor underwater given the limitations of the motor in terms of voltage and current. In order to perform this task, one of the motors was placed in a special miniature tank and water and attached to an apparatus that would measure the force produced by the motor. In addition, the voltage and the current supplied to the motor were carefully recorded. The data gathered from this experiment was utilized in order to determine the amount of force one motor could produce from specific current and voltage values, which is vital information. Given the limitations of the power supply and motors, a combination can then be found to determine what settings are required for the motors to perform best.

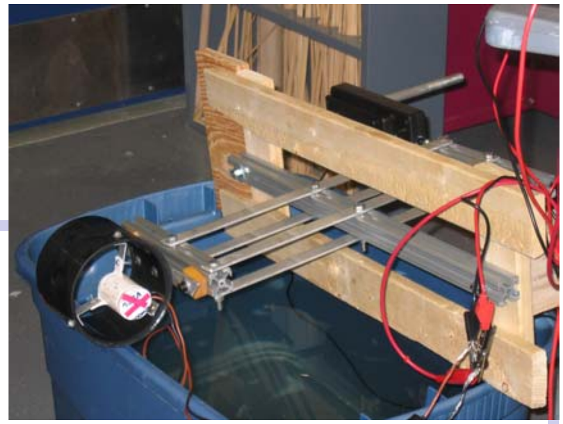
Current (amps)	Voltage (volts)	Power (watts)	Force (ounces)
0.74	1.74	1.29	0
1.01	2.3	2.32	1
1.25	2.81	3.51	2
1.5	3.3	4.95	3.5
1.75	3.77	6.60	4.4
2	4.2	8.40	5.1
2.25	4.7	10.58	6.1
2.51	5.2	13.05	6.8
2.74	5.7	15.62	7.5
3.01	6.3	18.96	8

Velocity of the ROV

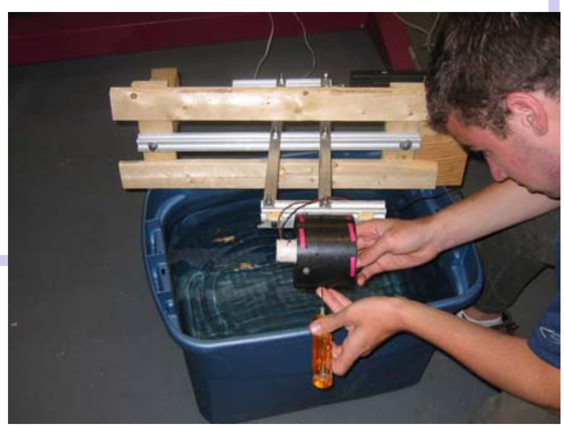
An important aspect of the movement of the ROV is to determine the overall velocity of the ROV. In order to earn a maximum number of points, time reduction is crucial and thus velocity becomes important. The velocity of the ROV in the forward and side directions were tested by running the ROV in the inflatable pool and using various techniques to measure the time required for the ROV to move a specified distance within the pool. From this raw data, a graph was created to provide rough estimates of the velocity can be tabulated.



Varying Propeller Design



In order to identify the most efficient propeller for make maximum use of the motors, testing was conducted to identify the best propeller. For the testing, a wide selection of propellers was gathered in order to increase the chances of finding the perfect propeller. Each propeller was placed within a motor attached to a special contraption. Essentially, the motor was connected to a series of metal bars that were in turn connected to an electronic device to measure force. The metal bars were connected by pivoting joints to a wooden frame that rested over a container of water. The pivoting joints allowed for the motor to move the metal bars and conversing pull on the force transducer, while limiting the ability of the motor to vibrate. The force transducer was connected through an interface to a computer, which in turn displayed a graph and the numbers for the force produced by the thruster. Also, a voltage measuring device was also utilized to send the data regarding voltage to the computer for comparison with the force. Finally, a current meter was used to record the current of the motor at the given voltages. The culmination of this data allowed for the current, power, and force at each voltage level to be determined for each propeller. From this data, the best thruster could be located based upon maximum force and minimum power, current, and voltage.



Sample Tables for Two of the Propellers

	3-Blade Metal Propeller					
	Forward			Backward		
Voltage (V)	Current (A)	Power (W)	Force (N)	Current (A)	Power (W)	Force (N)
3	0.2	0.6	0	0.25	0.75	0.1
4	0.3	1.2	0.1	0.4	1.6	0.2
5	0.55	2.75	0.3	0.6	3	0.4
6	0.9	5.4	0.6	0.85	5.1	0.5
7	1.25	8.75	1	1.15	8.05	0.6
8	1.6	12.8	1.3	1.6	12.8	1
9	2	18	1.6	1.9	17.1	1.2
10	2.4	24	2	2.25	22.5	1.3

	4-Blade Plastic Propeller					
	Forward			Backward		
Voltage (V)	Current (A)	Power (W)	Force (N)	Current (A)	Power (W)	Force (N)
3	0.2	0.6	0	0.2	0.6	0.1
4	0.2	0.8	0	0.2	0.8	0.1
5	0.3	1.5	0	0.3	1.5	0.2
6	0.5	3	0.2	0.45	2.7	0.3
7	0.9	6.3	0.4	0.7	4.9	0.5
8	1.15	9.2	0.7	1	8	0.6
9	1.5	13.5	0.9	1.25	11.25	0.7
10	1.85	18.5	1.1	1.5	15	1

Descriptions of Lessons Learned or Skills Gained

Introduction

The robotics competition is much more than working towards victory and success. Instead, there is also a learning aspect of the project that must be acknowledged in order to appreciate the other benefits of this endeavor. With this competition, the main lesson learned resides within the importance of passing down knowledge and experience from the older team members to the younger team members. The skill acquired from this project primarily is learning the importance of time management and coordinating progress of the project from start to finish.

Sharing Knowledge with Younger Members

The robotics team from the High Technology High School consisted of two distinct groups of members, which at times became intermixed. The primary team consisted of the older and more experience members that were members of a FIRST Robotics Team and better understand the concepts crucial to robotics. The second team consisted of the younger and newer members that were given the opportunity to construct their own ROV. The team of younger members was able to construct their own ROV while older and younger members alike worked upon the ROV that would be entered into the competition. The younger members received guidance from older members, but still retained independence in their creativity. Furthermore, the younger members were given the opportunity to seek the advice of older members and observe the work done by the older members to slowly and gradually become inducted into the area of robotics competitions. In essence, it is crucial for the younger members to gain experience as older members move on to college, but must retain a sense of independence to generate the revolutionary ideas necessary for victory.

Importance of Time Management

The crucial skill gained from this competition was the importance of time management in meeting specific deadlines with allowance time for problems that may occur throughout the process. Within a project, some aspects may take much longer than expected and thus hurt the overall timing of the project. Though, it is necessary to have a plan in place that can account for the time given to such tasks, while allowing for overtime required. If tasks are taking too long and the deadline is fast approaching, an actual plan would have been beneficial in determining time and man power able to be allocated to a given task at a given time. Essentially, this competition taught each group member that a plan is necessary so that deadlines are not missed, work doesn't have to be rushed, and man power can be better distributed to more efficiently complete tasks.

Future Improvements

Within any project, there is always room for improvement in regards to the performance, accuracy and efficiency of the robot. Though, time and deadlines do not allow for such changes to be utilized within the specified time period. Within this project, there are numerous improvements that could be made to the robot. For example, the number of motors could be reduced and stronger motors could be utilized. In this manner, the complexity of the electrical systems and mathematical calculations of the motion of the ROV could be simplified. In addition, the camera could be attached to an actuator to increase its range of sight to provide more visual data to the operator. Furthermore, the camera could be supplemented with sensors such as depth sensors that provide more feedback to the operators and thus make the tasks in the competition easier to perform. Finally, the overall size of the robot could be reduced by building a frame more suitable to the size of the mechanisms within the robot to decrease the weight of the robot, and consequently the amount of force from motors required to move the robot through the water.

Job of ROV in Oil Industry

As symbolized within the competition with the robot performing the oil well task, the ROV is of crucial importance within the oil industry. The ROV is utilized in areas within the ocean where it is unsafe or impossible for humans to travel. In particular, the ROV can be used for tasks from aiding in oil drilling, construction of pipelines, inspecting pipeline, and even repair work. The ROV can then perform such duties underwater and yet be controlled by workers at the surface. For the oil industry, the ROV can be used for what is deemed Special Intervention Systems. In that position, the ROV would be used for tooling. Another category includes the heavy work class of ROVs. The heavy work class includes the ROVs that are utilized for working at extreme depths of 3,000 to 10,000 feet for oilfield construction that no other machinery could perform. A third category is the intervention work class, which includes only the smaller ROVs that are used for inspecting the various underwater pipelines and machinery as well as conducting repairs if necessary. Finally, the observation class is the ROVs that are responsible for inspecting underwater oil pipelines and machinery and sending the visual data back to the workers controlling the ROV in a much more efficient and practical manner than sending a manned vehicle. Overall, the ROV is of crucial importance to the oil industry where there is a great depth of water. The particular oil well task in the competition is an example of one such job that an ROV could perform.

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More Information about HTHS Fury

For more information on this project, feel free to visit:

"High Technology High School Robotics Club". High Technology High School. <http://www.endeavour.zapto.org/fury/index.php/Main_Page>.