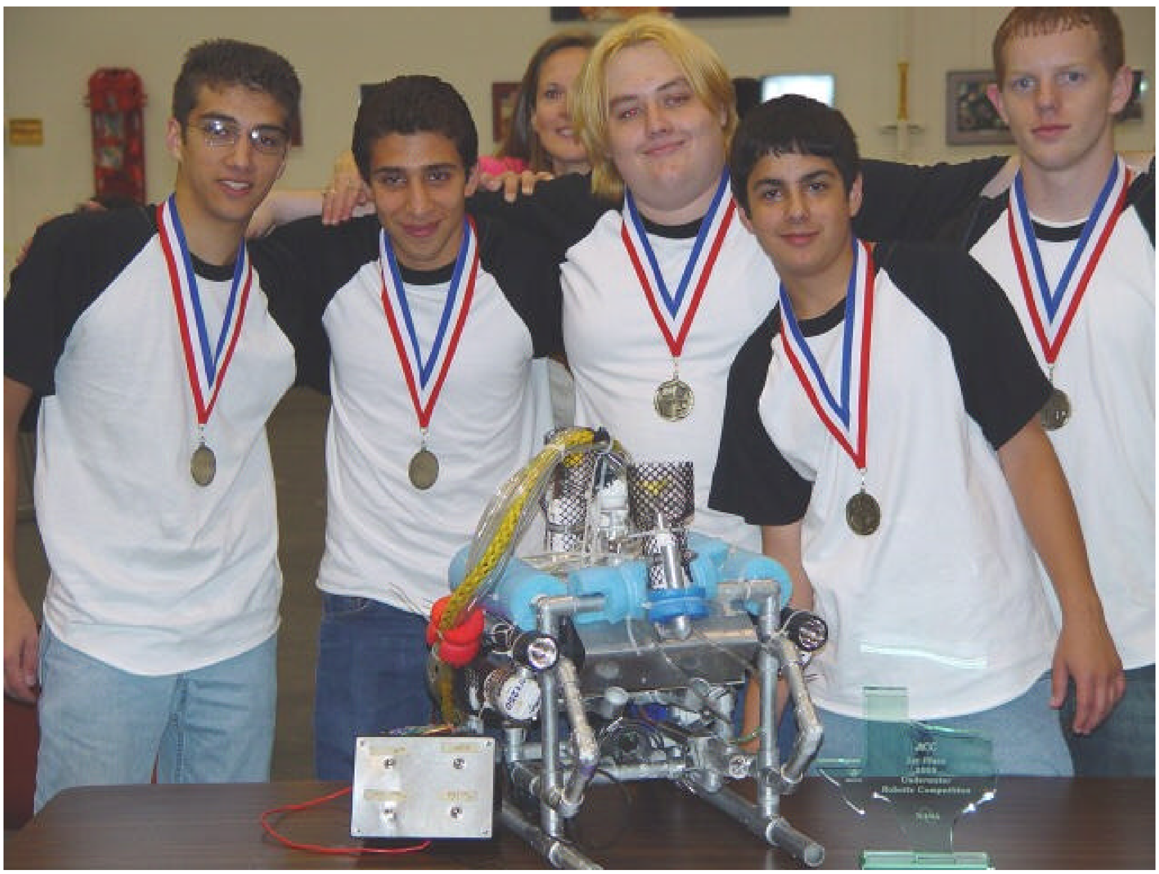
CATE Center ROV Team Technical Report

ROV - Thresher

Kingwood/Humble, Texas



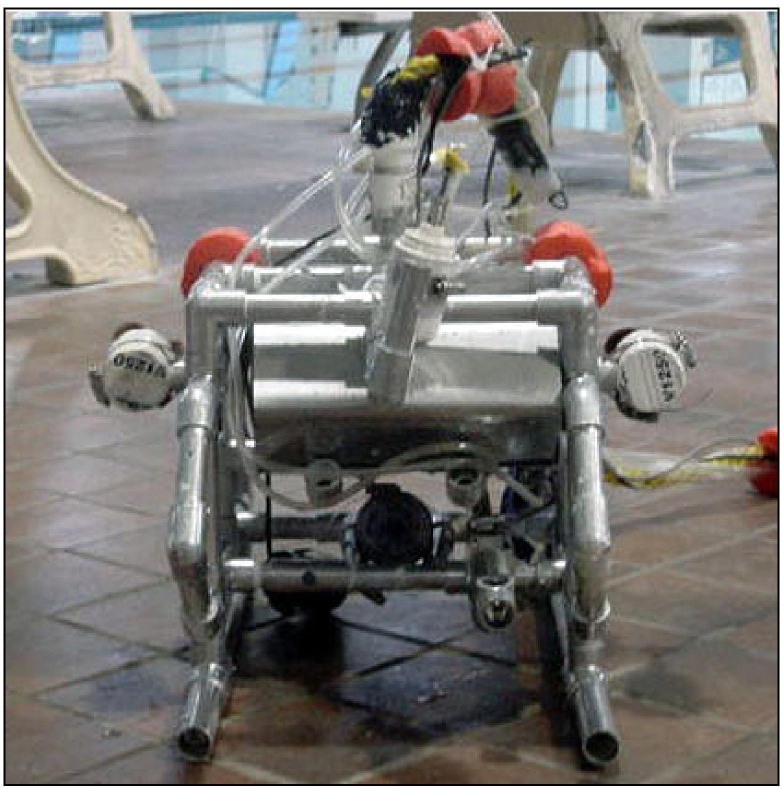
(From left to right : Adam McDowell, Angel Torres, Scott Pickle, Steven Boronyak, and Bill Cashmareck.)

<u>Team Members:</u>

Angel Torres - Captain
Bill Cashmareck – Buoyancy, Lever
Steven Boronyak – Patch
Seth Dunbar – Technical Advisor
Seth Chadwick – Technical Report
Scott Pickle – Visuals
Alvin Tang – Visuals
Adam McDowell – Payload

<u>Mentor:</u>

Quenton Hensley



Abstract

This technical report summarizes the design, testing, and construction of the CATE center ROV. Our intention upon the outset of this endeavor was to have the opportunity to compete at the national level. Fortunately, the knowledge we have gained about underwater systems has allowed us to progress to the 2005 MATE Center/MTS National ROV Competition.

Our project consists of extensive preliminary testing, followed by group discussion of the outcomes, and group decisions on how to proceed with design. In this manner, we were able to progress quickly from design to test and construction. We took a basic shape, the rectangular prism, and modified it to fit our particular needs to accomplish the mission tasks. Our ROV has been designed with the explicit purpose of completing the task quickly with as few complications as possible. To this end, the design was kept as simple as possible, in hopes that this would minimize the amount of possible situations that could go wrong, and make any repairs or modifications that had to be made simple and straight forward.

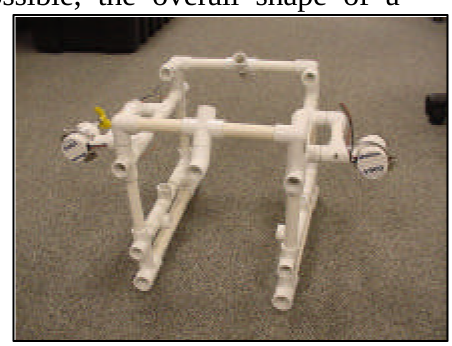
Design Rationale

ROV Dimensions

- 58 cm long
- 31.4 cm wide
- 39.7 cm tall
- Weight is 11.34 kilograms
- Tether length is 13 meters

Overview

To make our ROV as easy to work with as possible, the overall shape of a rectangular prism was chosen, with the slight modification of the front by adding a triangle on either side to provide a frame of reference for the camera view, which can be seen in figure 1-1. To the middle of the structure, a double "T" cross bar was added to hold the buoyancy compensator in place and position it in the middle of the structure to ensure that the top was the most buoyant area of the ROV so that it would remain upright during its operation. The motors were placed on the exterior of the prism to allow them to produce the greatest thrust on the ROV and therefore the quickest turning speed. Motors were oriented horizontally on the left and right, as well as two vertical motors on the top middle of the front and back of the prism to speed diving and ascent speed. The tether mount was located on the center cross brace on the top of the ROV, as seen in (Figure 1-2), to enable maximum maneuverability since the tether would come to the ROV from a station topside, and therefore location on top would put the least stress on the ROV from tension in the tether, should it arise. Two pneumatic cylinders were used, both mounted to the second tier of cross beams under the buoyancy compensator, one on the left facing forward to push the patch out of its recess in front of the cylinder, and the other facing to the rear to open the clamp located at the extreme aft port corner of the prism so that the probe can be released. It was determined that two cameras would be most effective to complete our mission tasks, so one was



mounted to the cross beams beneath the buoyancy compensator facing front center to give a clear picture of were the ROV is pointed, while another is positioned at an angle in the rear to give a view of the clamp and the area directly under it, so that the probe can be accurately placed.

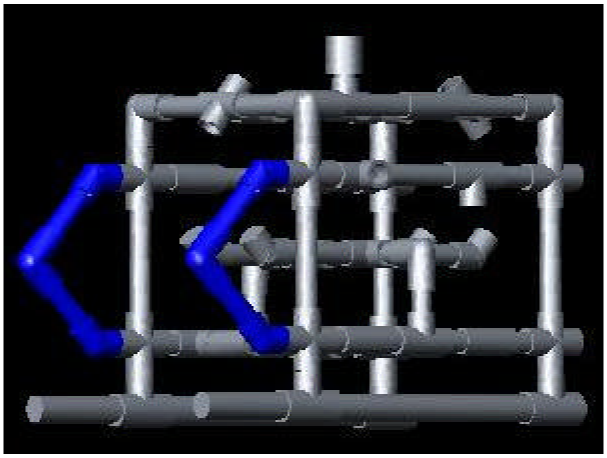


Figure 1-1

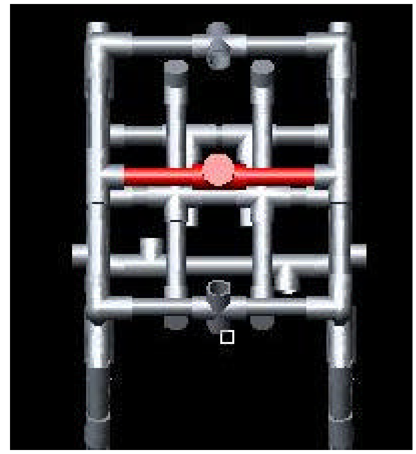
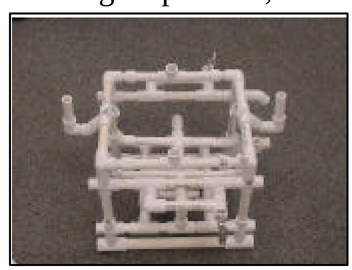


Figure 1-2

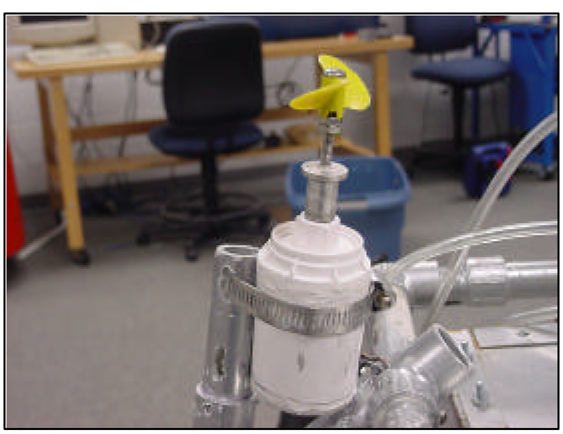
Frame

The frame needed to have structural rigidity with as little bracing as possible, but also be light enough to not seriously impair mobility. To do this, we decided upon ½ in. PVC piping and fittings. This was also convenient in that during testing, the frame could be dry fitted, and modified at will without any serious complications. When our design was finalized, all of the connections were permanently secured using PVC cement.



Propulsion

- ❖ Two Attwood 900 gph rated bilge pump motors
  - 12 volt**,** 3 amp, 4 ohms of resistance
- ❖ Two Attwood 2000 gph rated bilge pump motors
  - 12 volt, 4 amp, 3 ohms of resistance

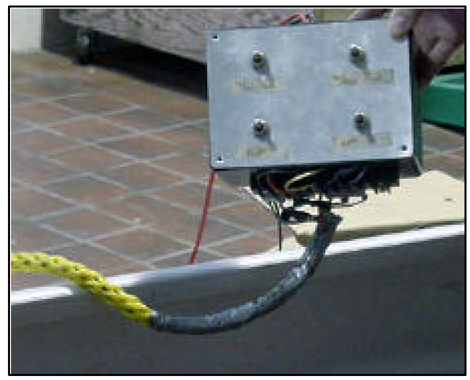


In the initial trials of the ROV, four Attwood 900 gph rated bilge pump motors were used in the design. It was found that more thrust could be produced by removing the outer casing of the pump and attaching a propeller to the shaft that had formerly turned the impeller. Using a motor suspension system, we were able to test the thrust of each of our motors by hanging them on a PVC framework that was suspended from a hand scale and measuring the weight and them comparing it to the weight when the motor was running full speed to determine the approximate thrust.

Four motors were positioned to give control in two axis to provide for pitch and yaw control. The two side motors, controlling horizontal motion and yaw, are Attwood 2000 bilge pump motors while the front and back motors, controlling vertical motion and pitch, are Attwood 1250 bilge pump motors. It was decided to increase the size of the horizontal motors because our amperage level was low enough to support an increase in power, and the added speed would aid us in getting to the objectives quicker.

Control

We had two options for our control system. Either an electronic system employing twin joysticks that gave variable motor control, or a toggle configuration, giving forward reverse control over each individual motor. The toggle configuration was used extensively during the preliminary test, with exceptional results. Ease of use and mobility of the ROV were high points of the momentary on/off/on toggle switches. The electronic joystick control was tested, but it was found that because each joystick controlled one horizontal and one vertical motor, it was difficult to control just one motor at one time, a capability that is needed in finessing the probe and patch into position.



The secondary control board consists of a stainless steel box that contains the valves, pressure regulators, and pressure gauges necessary to control the pneumatics and buoyancy compensator of the ROV.

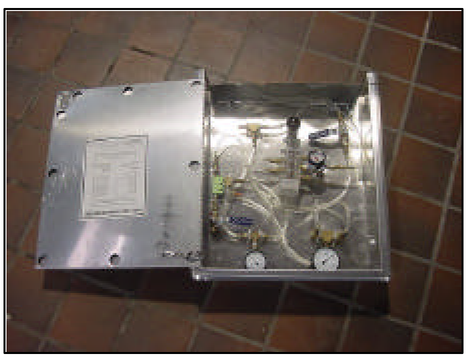
Tether

Our tether is 13 meters long and composed of poly threaded line sheathing the eight 16 gauge coated wires, supplying power to the four motors. The wires are connected to a junction box on the exterior of the control box to minimize the stress on the connections inside. All connections in and on the control box use spade connectors. On the ROV itself there is no junction box, all connections run to a 9 pin plug (we only used 8) while the poly line is glued with marine putty to a 1" screw in PVC connector so that the tether can be disconnected for travel. The wire connections to the motors are soldered and sealed using heat shrink wraps.

The six air lines used to power our pneumatics and two television cables are attached to the exterior of the tether by 12" zip ties placed approximately every two feet. It was concluded that to fit all the wires, cables, and air lines would make the tether much stiffer and could impede the mobility of the ROV.

Buoyancy Compensator

To aid in ascension and decent a buoyancy compensator was added in the form of two inner tube tires that are inside of a stainless steel and Plexiglas containment vessel occupying the interior upper half of the ROV frame. Both tubes are 10.16 cm inner diameter and 17.78 cm in circumference wheel barrow inner tubes. We only use one inner tube during normal operation; the second inner tube is reserved for a back up in the event of a failure of the primary inner tube. During our preliminary testing phase, we experienced an air leak in a ball valve, and thus an inability to shut off air to the tube, causing it to explode. The explosion not only destroyed the tube, but in turn the PVC buoyancy compensator we were using, and separated much of the ROV. From this event, it was decided that a new containment vessel must be constructed out of a stronger material. The problem was also raised of what we would do in the event of a tube failure, since we rely on positive buoyancy, and without it the ROV is very negatively buoyant. We tested the idea of simply putting another tube inside the containment vessel, so that if the primary should explode, we could use the secondary. The concern was that if the first exploded, would the secondary be damaged? To find out, we conducted a destructive test of the primary tube, placing it in the same containment vessel with the deflated secondary tube. The secondary tube was not damaged in the ensuing rupture of the primary tube.



The buoyancy compensator is controlled from the secondary control board by a two way directional control valve (DCV). On the positive side of the DCV a line runs to a pressure regulator and then to a ball valve. If the ball valve is open the air continues through a T joint and out to the ROV. However, if the ball valve is closed, and the DCV is pushed the other direction, a vacuum is formed which draws air out of the ROV by way of the other branch of the T joint using an Air-Vac.

(Average decent and ascent speed: 10 seconds)

Cameras

There are two cameras mounted on the ROV. One of which is mounted in the center of the ROV for a front view, while another is mounted in the back to help us position the probe. For the regional competition we used large, heavy cameras that did the job, but they weighed us down more than necessary. We have replaced them with cameras that are only 2.8cm by 4.3 cm long. They are also equipped with LEDs to enable us to see in poor light conditions. The cameras run on a 12V DC power supply. During our testing phase, we obtained new cameras which were small and had night vision. This was possible using infer red lights with sensor detecting a change in the

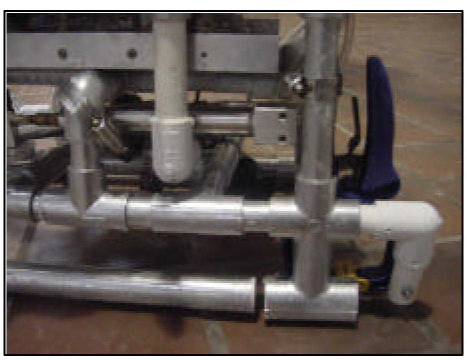
environments lighting. This eliminated the need for adding weight in the form of lights, unfortunately we were unable to seal these lights to the point of being water tight. Therefore we had to revert to using our old inferior cameras. Although we had to use the old cameras we did find a resource for the exact duplicates of the previously described cameras. These cameras on the other hand come in a stainless steel container which is already waterproof up to ninety feet and matches our ROV and stainless steel containment for the buoyancy.

Oil Well Valve

To close the oil well valve, we found that the easiest way to accomplish this was to use the motors of the ROV to push against the valve until it rotated closed. To ensure that the ROV would get adequate purchase on the valve and not slip off prematurely, skids protruding out from the bottom of the frame were added, as well as triangular protrusions from the front of the frame to give us a larger target area on the front of the ROV of which to approach the valve from.

Average time in testing and competition: 40 seconds (This was done however with the 1250 gph bilge pump motors. Our estimated with the superior 2000 bilge pump motors is 20 to 30 seconds.)

Fiber Optic Repair



To position the ROV over the probe site we placed a camera on the starboard bottom of the rear of the frame at a 45 degree angle inward so that we could see the clamp that holds the probe. Initially, we had used a rear facing camera which gave us a rear view. Although giving us a wider angle the camera gave us no depth perception on the probe and probe site.

To place the fiber optic repair probe, we used a plastic locking clamp secured jaws facing down on the back port corner of the ROV. To open the clamp a pneumatic cylinder is positioned to push on the release lever of the clamp. The clamp releases its hold on the probe, and it falls into place.

Average time in testing and competition: 1 minute (we however faced a few complications, which have now been fixed. So our estimated time for the probe at nationals is between 40 to 50 seconds.)

Hubble Space Telescope Patch

To attach the patch to the Hubble Space Telescope, we must first attach it to our ROV. We do this with a PVC coupling that holds it securely in place. Since the patch is now mounted in the front of our ROV, we

can easily drive up to the target and connect it using only the front camera. Once we get the patch hooked onto the telescope, we must disengage it from the ROV. To accomplish this, we mounted a pneumatic cylinder, with a ram that runs into the PVC coupling. When triggered topside, the ram will then quickly, and easily disengage the patch from our ROV.

The average time for the patch in competition was 3 minutes (We experienced major difficulties with the patch. These problems however have been solved and our time has now been improved to 1 minute and estimated to decrease to 40 to 50 seconds with the new 2000 bilge pump motors.)

Challenge Faced

One challenge that was faced by the team was over how to employ conflicting theories related to the buoyancy compensator. During the preliminary testing phases, the inner tube exploded once early on in construction due to a leaky regulator valve and another distended during pool test when a hand operated valve failed to seal completely. It was the overall conclusion that a design modification should be made to deal with the possibility of an inner tube failure, considering that without it the ROV would be unable to surface. One line of reasoning stated that the containment vessel should be divided into two separate volumes by a rigid divider, with an inner tube in each volume. The assumption in this reasoning was that in the event of an inner tube explosion, it must be separated from the spare inner tube to prevent damage to the spare. The opposing line of thought stood that the inner tubes could be housed in a single volume without danger of damage in the event of pressure induced rupture because the primary inner tube does not have any sharp edges that could puncture the secondary, and considering that the second would be folded flat, it would not tear due to the pressure. If the volume had to be divided, then the overall lifting capacity of the system would be reduced, however, if both primary and secondary inner tubes could be stored in the same volume then the maximum lifting capability could be utilized, and therefore would be optimal.

To test the ability of the secondary inner tube to survive an explosion of the primary, the inner tube that was distended (and therefore no longer usable in competition or testing because it would be in danger of exploding at lower than rated pressures) was placed in a sealed container with a new secondary tube. The one concern for the inner tube was being torn by the valve stem of the first, to prevent this, the valve stems of both were made to stick out of the containment vessel, like it would be in competition. Then the vessel was placed in a closed room that was rigged with multiple cameras so that the progress of the experiment could be monitored at all times. After the primary inner tube exploded, the vessel was disassembled and it was confirmed that the secondary inner tube had survived the explosion without damage, and that it was therefore possible to place both inner tubes in one volume without time consuming or volume consuming modification

Troubleshooting Techniques

The troubleshooting technique employed by our group was that of a group meeting. Whenever a problem arose, or a design decision needed to be made, the whole team was called together. First the problem was presented by the team leader, with explanations of possible solutions, their benefits, and shortcomings. After the initial introduction to the problem, the floor was open to suggestions from other team members on solutions to the problem or a redefinition of the problem itself. When all possible remedies had been presented and discussed, the team voted on the solution that would be implemented.

Lessons Learned

One critical lesson that was learned in the process of final construction was that CAT 5 cannot handle high amperage. In our preliminary testing, the CAT 5 cable operated within normal operation parameters, however, it was later uncovered that the test were done with a length of cable shorter than the tether length; as well as being conducted above water rather than submerged in it. These factors that were not taken into account during the testing phase led to an unrealistic view of the capacities of the cable, causing us to believe that it could be used for a task for which it was not designed: high voltage motor operation over long distances while submerged.

Discussion of Future Improvements

It is our hope that in the future we will be able to improve several areas of our ROV. Chief among them is our tether. With the failure of the CAT 5 cable, the cross section of our tether increased dramatically, much to our disappointment. It is hoped that with a smaller profile tether, drag can be reduced as well as dexterity increased, simple because there would be less physical mass for the ROV to pull along behind it.

Another area in which improvement can be made is that of motor efficiency. If we could get more power out of our motors without going over our allotted amperage, we could potentially accomplish our task faster and give ourselves a larger advantage over the competition.

The Hubble Space Telescope

The Hubble Space Telescope was launched into orbit by the space shuttle *Discovery* in 1990 for the express purpose of gathering images of distant galaxies and celestial bodies that were not possible with earth bound equipment. Soon after its launch, however, a flaw was discovered with its main gathering mirror. This flaw was remedied with the installation of new components during a series of repair missions in 1993, 1997, 1999, and 2002.

The Hubble Space Telescope's orbit lies approximately 380 miles above the earth which allows it to take extremely clear pictures because it is not hampered by the distortion of the earth's atmosphere. The Hubble Telescope utilizes two separate instrument packages, imagers, which snap pictures of objects and spectrographs which interprets light waves. The imagers convert light to electronic signals which are then transmitted to the ground to the control station at NASA's Goddard Space Flight Center or to the European Space Agency (ESA). The spectrograph spreads light into its component colors (also called a spectrum) which is later studied to determine the composition of galaxies and stars. The Telescope can also record infrared and ultraviolet light that would normally be blocked by the atmosphere. This ultraviolet light originates from disks around black holes, and exploding stars. Infrared light data is analyzed and yields information on calmer events, such as the formation of dust clouds around stars.

NASA Photo: Hubble Ultra Deep Field

The Hubble Space Telescope is entering the end of its service life and the decision was made in 2004 to cancel any further repair missions to the platform. This decision was made because it was decided that after the space shuttle Columbia disaster that the risk to astronaut lives was too high and that it was better to let it fall into disrepair and eventual destruction. This decision has drawn fire from various politicians, scientists, and astronomy enthusiasts, so NASA officials has agreed to study various options for the repair of the platform, the most promising of these options involves a plan to use remotely operated space craft to accomplish needed repairs.

Barnbaum, Cecilia. "Hubble Space Telescope." World Book Online Reference Center. 2004. World Book, Inc. http://www.worldbookonline.com/wb/Article?id=ar265630. (www.nasa.gov).

Expense Report

Quantity	Part Name	Unit Price	Total Cost
1	Terminal Strip	$ 5.00	$ 5.00
16	PVC T joint	$ .69	$ 11.04
8	Hose Clamps 23-70 mm	$ .33	$ 2.64
6	PVC 90 elbows	$ .33	$ 1.98
4	propellers	$ .5	$ 2.00
4	propeller adaptors	$ .89	$ 3.56
1	WirePro	$ 3.26	$ 3.26
2	V900 motor	$ 20.00	$40.00
6	PVC 45 elbow	$ .33	$ 1.98
4	Lenova 1x ½ T	$ .30	$ 1.20
10	½" PVC 4-way	$ .75	$ 7.50
1	7" diagonal pliers	$ 4.20	$ 4.20
1	tube cutters	$ 1.20	$1.20
1	HD inline fuse holder	$ 5.00	$ 5.00
2	machine screws (qty. 50)	$ 1.25	$ 2.50
1	¼" nylon rope 50'	$ 5.00	$ 5.00
2	inner tubes	$ 8.00	$16.00
2	spare fuse pack for controls	$ 5.00	$10.00
2	6.5" pneumatic cylinder	$ 6.00	$12.00
2	20" TV/VCR recorders	$ 120.00	$240
2	V2000 motors	$ 75.00	$ 150
2	DB9 cable 25'	$ 29.50	$59.00
6	air tubing 40'w/ fittings	$ 20.00	$120
2	underwater color mini camera w/ LED	$ 175.00	$ 350
2	electrical tape	$ 2.00	$ 4.00
1	air compressor	$120.00	$ 120
1	noodle floats	$ .50	$ .50
2	battery	$ 20.00	$ 40.00
1	Contico Box	$ 30.95	$ 30.95
		Total:	$1276.51

Acknowledgements

The CATE Center ROV team would like to thank the following people:

Quenton Hensley – Mentor

W.W. Dive Center - Sponsor

Technip Offshore, Inc. - Sponsor

Engineering Drawings

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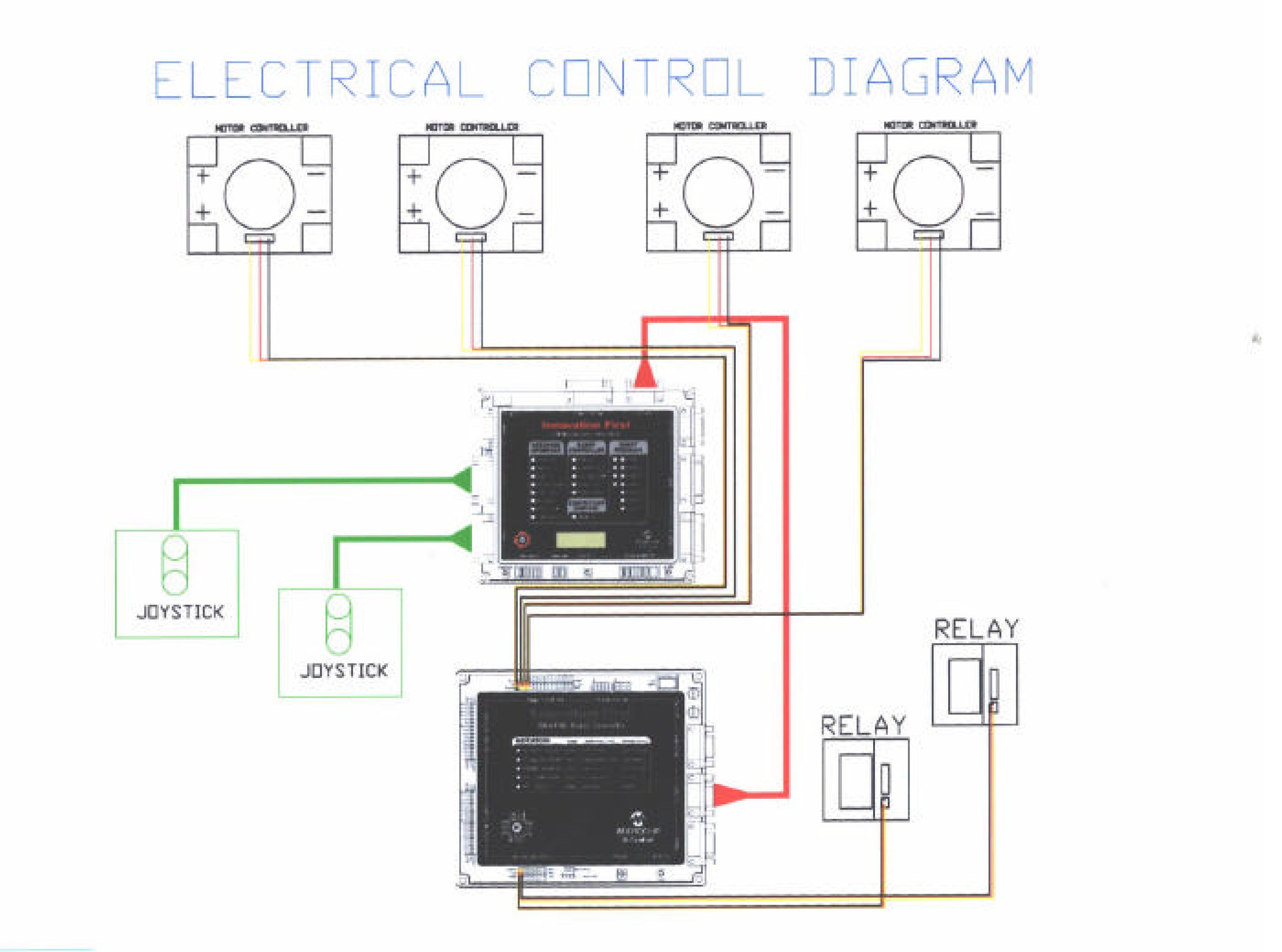
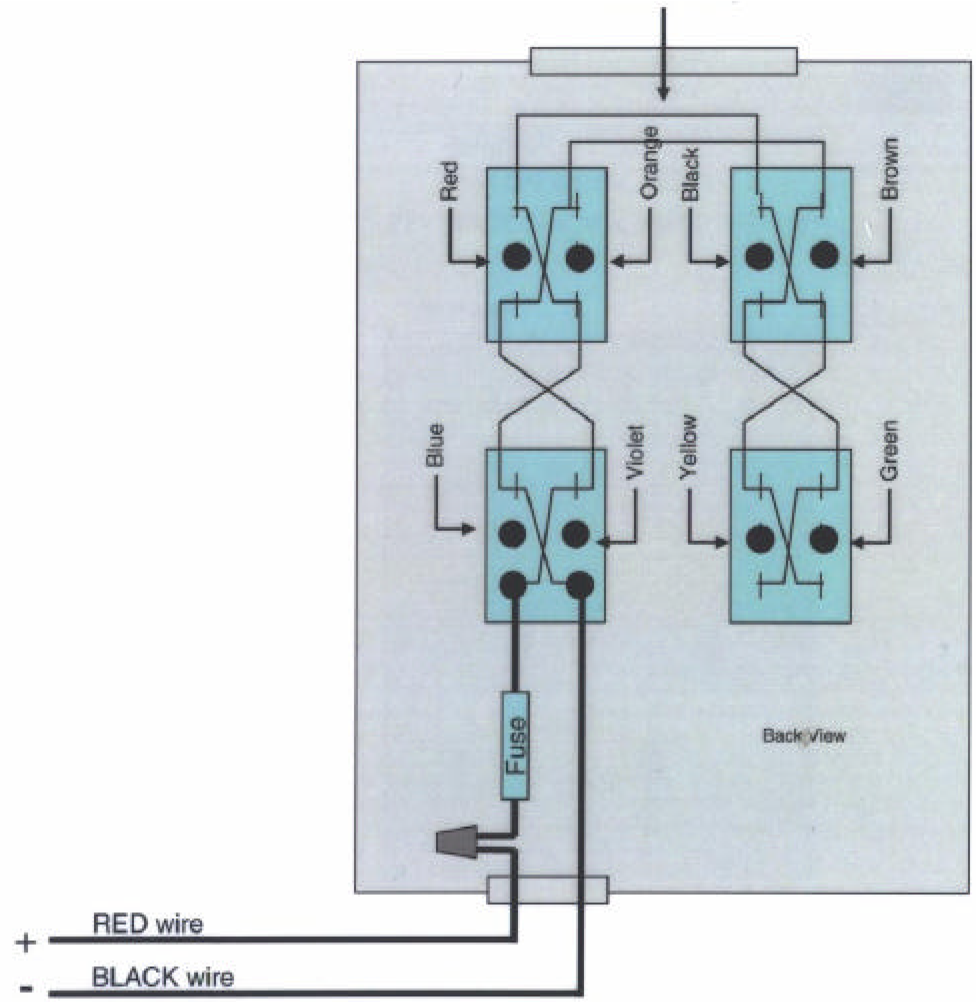
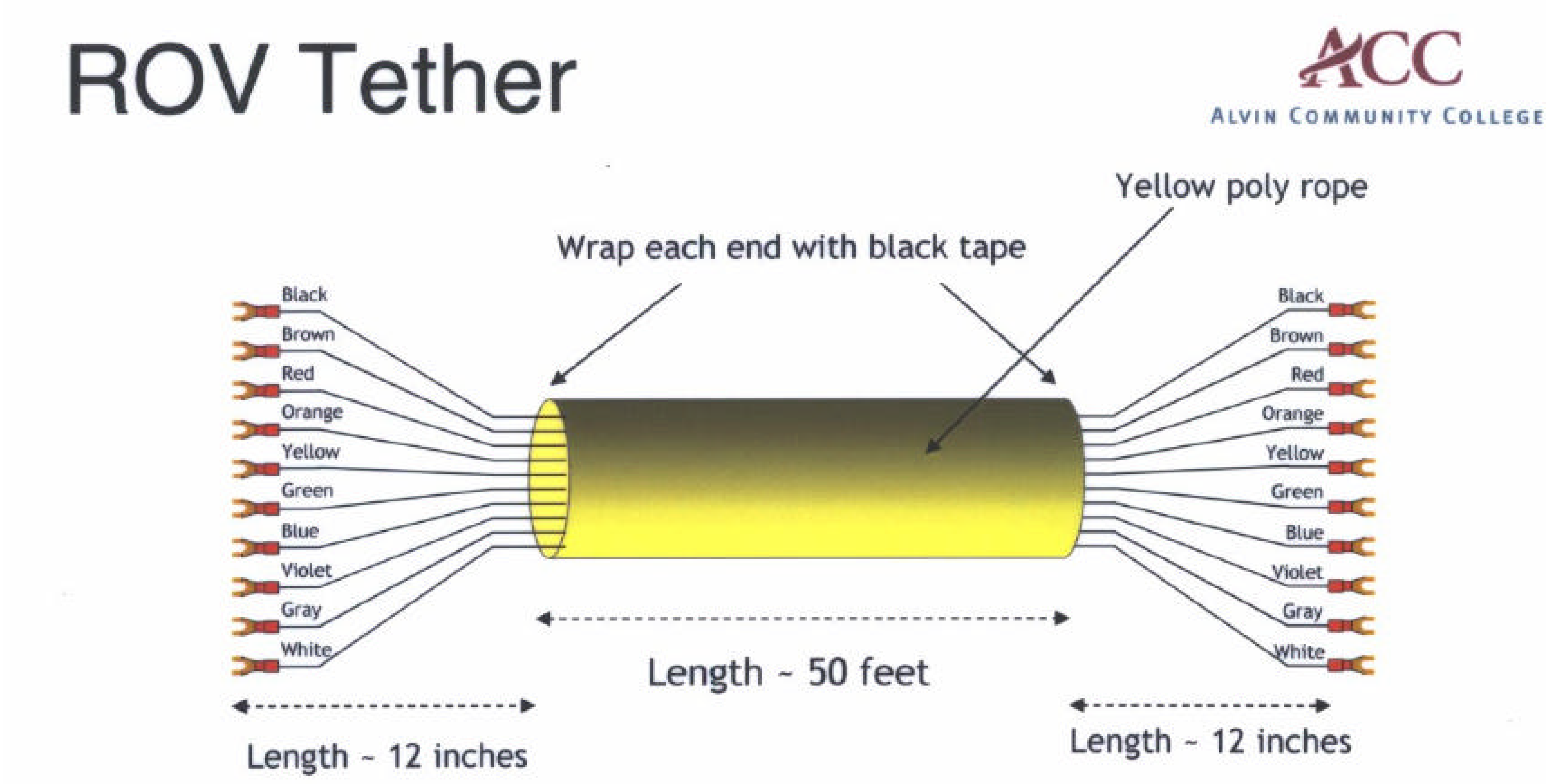
Electrical Schematic For The Variable Control System



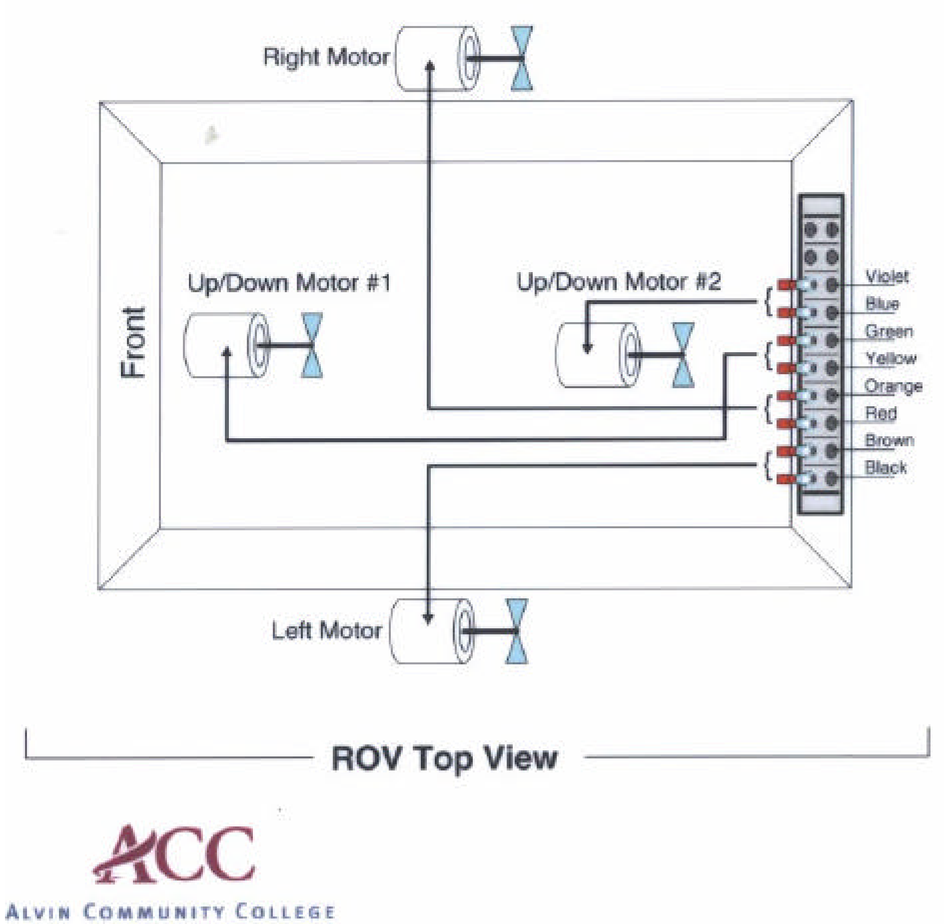
Electrical Schematic Part 1



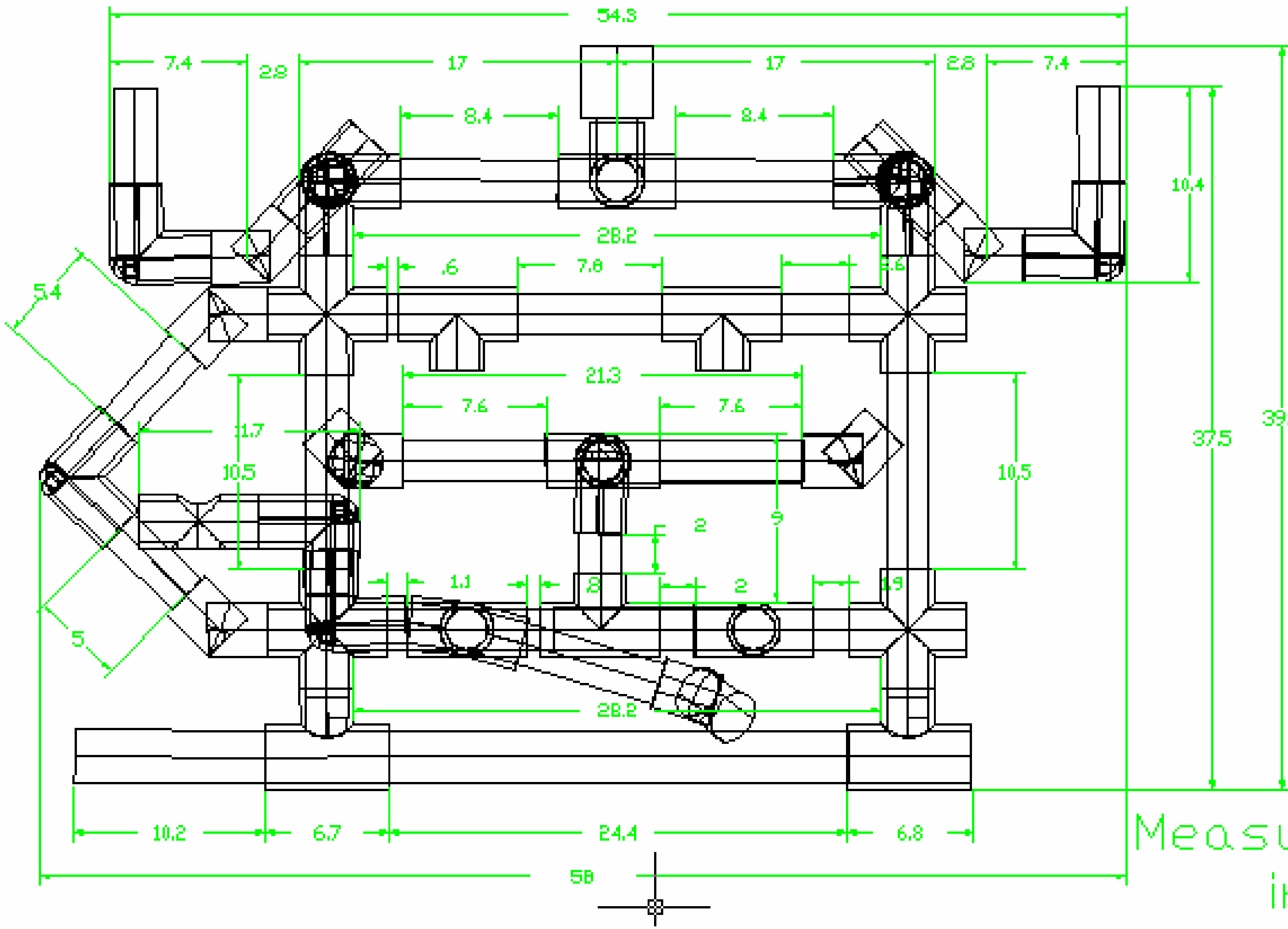
Electrical Schematic Part 2



Electrical Schematic Part 3



Front View



All Measurements in cm.

Top View

All measurements in cm.