Technical Report
ROV Corbotics One

submitted by

Robotics Team
Corbett High School

submitted to

Marine Advanced Technology Education

in partial fulfillment for the requirements for the

5th Annual ROV competition
June 17th – June 19th, 2005

Team Members:

Logan Barnes, Nick Bechtoldt, Allen Baker, Britney Hanson, Drew Hatlen, Talon Hoke, David Kidd, Josh Marsh

Team Instructor:

Phillip Pearson

Team Mentors:

Michael Wilkin, Mark Bechtoldt

Section 0: Abstract

The ROV Corbotics One was designed for the purpose of completing the Ranger class challenges of the 2005 MATE ROV competition. The Corbett High School robotics class began the project in January of 2005 and by overcoming many obstacles arrived with a working ROV. The class started with two separate groups working on prototype ROV's that eventually merged together bringing the best elements of each prototype to the final model. The team managed to create a low-cost solution by focusing on a simple, yet effective design.

Control of the ROV is managed using simple manually-manipulated DPDT switches connected to a 12 volt power supply through a standard household 20 amp circuit breaker. The frame is constructed from PVC which combines low cost and high flexibility in design options. Propulsion is provided by 4 standard bilge pumps, two devoted to horizontal control, two devoted to vertical control. The manipulator provides basic functionality using a single bilge pump motor connected to a threaded bar and hook and housed in a PVC tube. A single black and white waterproof "bullet" camera provides the required remote visibility. Except for the camera, all components were constructed from readily available inexpensive materials.

Section 1: Record of Expenditures

School Name:		Corbett High School		**From:**	01/26/2005
Instructor/Sponsor		Phillip Pearson/Corbett SD		**To:**	05/23/2005
Funds					
Date	**Dep. or Exp.**	**Description**	**Notes**	**Amount**	**Balance**
01/26/05	expense	Bilge pumps, tether supplies		42.69	57.31
02/08/05	donation	PVC pipe and fittings	In kind contribution	225.00	57.31
03/01/05	expense	DPDT switches	CSD covered	40.00	17.31
03/05/05	expense	PVC fittings, switches		49.35	(32.05)
03/26/05	expense	500 gph pump x 4	CSD covered	59.96	(92.00)
03/26/05	expense	Glade air fresheners x 4	CSD covered	13.98	(105.98)
03/26/05	expense	PVC fittings	CSD covered	1.05	(107.03)
04/05/05	donation	750 gph pumps x4	In kind contribution	40.00	(107.03)
04/06/05	expense	Water proof camera	Corbett Education Foundation (CEF) covered	166.00	(273.05)
05/01/05	expense	900 gph pump x2	CSD covered	59.98	(331.01)
05/10/05	expense	tether supplies	CSD covered	54.87	(387.88)
05/15/05	expense	DPDT switches	CSD covered	7.98	(395.86)
05/23/05	expense	PVC cement and misc.	CSD covered	15.00	(410.86)
			TOTAL	**875.86**	
	Corbottics account ended in deficit. Balanced covered by CEF or CSD as indicated				

Section 2: Electrical Schematic

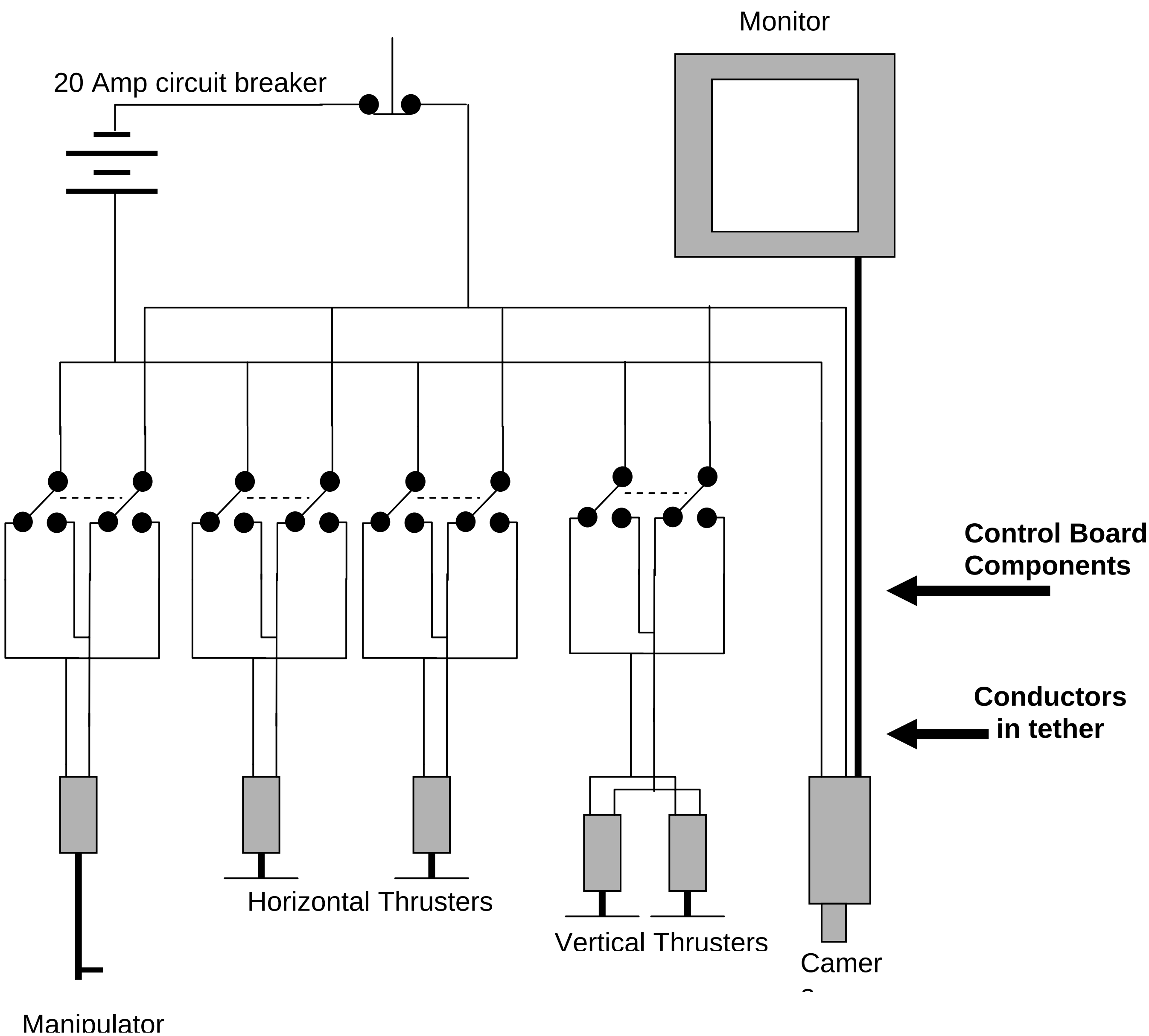


Photo of original control board incorporating most of the current features

Section 3: Design Rationale

At the early stages team mentor Michael Wilkin warned us that reliability was going to be a major concern, especially when mixing water and electronics. Because of this, our team began designing the ROV determined to keep things as simple as possible. The ROV had to be capable of:

- Maneuvering in 3 dimensions
- Completing the 3 tasks as assigned in the Ranger class
- Being moved from one location to another without breaking
- Operating reliably in 45 feet of water

The design of each subsystem is described below.

Frame

We designed the shape of the frame with style in mind. PVC was the natural choice for material. It had a low cost, was durable enough for our needs, and had a large range of pieces that we could use to make exactly what shape we wanted. We were originally going for a 'pill' design. We grabbed up all the elbow joints and basically put them wherever we could get one to fit. This created a rounded design that was more compact than a box and had more structural strength.

Buoyancy Control

From the beginning, our group was pretty set on creating a neutrally buoyant ROV. We had heard many concepts for adjustable ballast designs, but making it neutrally buoyant and using a propeller for vertical movement was far less complicated and didn't have as many things that could go wrong.

We decided to fill the PVC frame with water and use two 3" PVC pipes sealed with air inside for out ballast. These two pipes running the length of our ROV provided very positive buoyancy. This was good because we still needed to add a manipulator and camera when we acquired them and this gave us the positive buoyancy to leave room open. In the meantime, we found the ROV to be almost completely neutral when we added a single 1kg gram near the front

We placed our ballast at the top of the ROV making the center of gravity below them. This gave us a lot of stability, we can flip for ROV around under the water and it always reorients itself to the right position. When we put on the vertical motor, we placed the propeller at the top to give us more stability when coming up. Stability is very important for an ROV. Although the pool is a closed system, in a large body of water, it could be disoriented by underwater currents. Besides being very difficult to control under such situations, it could also cause it to do something like drop a payload it may have been carrying at the time.

Motors

Michael Wilkin recommended bilge pumps from the beginning. We began by using 500 gph pumps and hoses to redirect the thrust. We quickly decided to abandon this approach and started looking for a way to attach a shaft and reversible propeller to the motor. Eventually we chose to use shafts from old printers as propeller shafts. Initially we used propellers from computer power supplies. These provided good thrust, but also caused the motors to draw too many amps. We then tried smaller propellers from computer power supplies, propellers from Glade air fresheners, and even a hand-made corkscrew drive design. Our current machine uses Glade air freshener propellers. The table below gives test results for the 500 gph motors using two different types of propellers.

Propeller Type	Thrust	Amperage
Large power supply fan	2 N	4 Amps
Small power supply fan	1.4 N	2.5 Amps
Glade air freshener fan	1.4 N	2.5 Amps
Corkscrew propeller	0.7 N	0.7 Amps

Tether

Our original tether was constructed from recycled outdoor extensions cords. Though they were sturdy and capable of carrying plenty of power, the cords were also very stiff and pulled the ROV off course piloted underwater. This set the team in search of more flexible cord to build the tether with.
Control System. We knew that the cable we selected did not have to carry very much amperage. Each motor drew less that 5 amps at full power. Therefore, fairly small gauge conductors could be used. Eventually we settled 3 strands of 2-conductor speaker wire. The end of each speaker wire is terminated with a standard grounded plug as noted below.

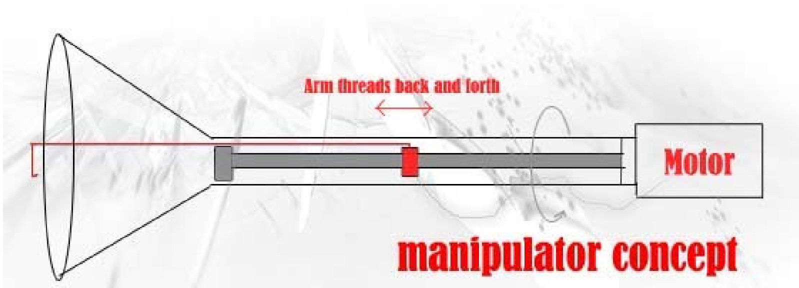
Control System

We originally planned on having 3 motors (2 for horizontal translation and 1 for vertical translation) and sort of manipulator to control. This wasn't too much, so we rigged up a simple control system. All we needed was 1 switch for each motor that was reversible. We found that because we needed the motors to be able to reverse directions independently, we could not share the ground as we originally thought and ended up with 2 wires per motor. Initially this design required a total of 6 conductors in our tether. Later, we added an additional motor for vertical control, which meant that our new tether required 8 conductors plus the cable for the camera. In the current design each set of conductors for the horizontal thrusters connects to its own switch and is capable of being controlled independently. The two vertical thrusters shares a set of conductors and a single switch.

Early on in the design process, 2 groups were working independently. Because both groups were going to be sharing the control board, we needed a system that we could easily plug into and unplug when we were done. We opted to use simple grounded plugs from the hardware store. We hooked up some power outlets to the control board allowing us to plug right into them. The control board also features a circuit breaker that flips if for some reason we draw more than our allowed 20 amps. It also serves as a good on\off switch. Although we originally thought we were going to have some sort of control box on the ROV itself, we found that it was much easier just to have the cords from each motor connected directly to the tether, leaving no electronics on the ROV

Manipulator

Because our ROV only has to perform simple missions, we wanted our manipulator to be as simple as possible. In March, Mr. Pearson outlined his idea for a simple manipulator that would only require 1 motor - It looked something like this:



In the center lies a threaded shaft the motor would spin. An 'arm' would be attached to a nut the would move backwords\forwards as the shaft spun. To pick something up, it would hook on, then pull it all the way in so that the object would be held against the funnel and be held vertically. Our current manipulator changes this concept only slightly. Instead of the nut moving and the threaded bar and motor staying stationary, the motor and bar move and the thread is held solidly in the back of the manipulator. This was done because it proved to be very difficult to attach the hook to a small nut. One problem with this design is that if the motor hits the back of the manipulator housing it places tension on the threaded bar and seizes the mechanism.

Video Camera

Choosing a video camera was somewhat tougher because we needed a camera which could provide adequate resolution, be used underwater, and still be relatively inexpensive. We settled on a black and white water proof “bullet camera” from Lashen Electronics. This camera is small, provides 420 lines of resolution, draws only 100 miliamps, and costs only $166 USD. It also came with 60 feet of ready to use underwater cable. After some struggles with adapters, we found that the camera gave use clear pictures and worked very well.

Section 4: Design Challenges

One of the main problems our team faced was with our motors, propellers, and shafts. Initially we started using large power supply fans from old computers. When we placed these on the motors, however, the motors drew too many amps. The 500 gph motor, for example, drew more than 200% of its rated amperage using the large propellers. In order to figure out how much trouble this would give use, we performed a stress test on one motor by running it with the large propeller until it died. The motor lasted for 20 minutes of continual use. This was probably not going to be good enough. We tried to address this problem by using different propellers. Smaller propellers caused the motor to draw fewer amps but also produced less thrust. Currently our ROV uses small propellers from Glade air fresheners. The motors have been used for numerous tests and have held up. However, our vertical thrust isn't quite sufficient. We have to solve this problem in the next few weeks.

We also had a problem with our propeller shafts. Originally the old printer shafts were attached to the motors by drilling a hole in the printer shaft and securing it to the much smaller motor shaft using a small set screw. This worked most of the time, but some shafts slipped when in use. We partially solved this problem by filing the small motor shaft flat on one side so that the set screw has a flat surface to tighten against. Recently we also glued the shafts to the motors use Dura-Weld. In our last pool test, this seemed to work well.

Section 5: The Design Process from Prototype to Current Model

Generation 0: Experimenting with buoyancy and bilge pumps
February 2005

Generation 1: Two prototypes under development simultaneously.

Generation 2: Current ROV incorporates features from both prototypes

Section 6: Trouble Shooting Techniques

We relied mainly upon trial and error to trouble shoot our ROV. In order to test our machine, we first had to build a test tank big enough to drive the ROV around in. We found a small shower stall in the basement of the middle school building. Using plastic and plywood, we constructed sides and a floor for the tank and relied on the drain in the shower to drain away any water that leaked. After several attempts, the tank finally held water and we were able to start testing.

We started working on buoyancy by experimenting with small pop bottle submersibles. In our later prototypes and the current ROV, we achieved neutral buoyancy by adding small weights and testing in the tank. Problems with the motors, control board, and video camera were all solved by trail and error experimentation. As we encountered each problem, we stuck to the principle of keeping things as simple as possible with still retaining the required functionality. A post from our team blog illustrates how our team generally solved design problems:

April 19th, 2005
Piloting

I (team member Logan Barnes) had the chance to do some more piloting of the ROV today. Controlling isn't too difficult at this point, the problem is our motors. Now that we have added more tether, a manipulator and a camera, the ROV is more massive and the motors aren't as effective. We built these as prototypes and didn't worry about quality as much as just getting the things finished. As a result, a lot of pieces are uneven. It is most noticable in some of are motors. Whenever we go forward, it pulls to the left a little because one motor has always been better than the other. We need to measure everything out on the new ROV and make sure that we get our motors aligned as precisely as possible. It would also be a good idea to move away from 'hanging weights' for bouynacy adjustments.

Allen and Chris at our first pool test

One prototype ROV at the pool test

Section 7: Lessons Learned

On the technical side, our team learned to overcome a number of challenges that none of us anticipated. We learned how tricky buoyancy can be to manage, how stability affects the control of underwater vehicles, how to wire our control board so that it was simple and dependable, and how to put everyday objects to unusual use. We quickly realized the importance of keeping things simple and about how quickly things can fall apart if not put together carefully. Some of our team members learned how to use hand tools for the first time and how switches work.

One the personal side, we saw how difficult it was to a group of people to work together on a consistent basis for a long time. It was sometimes hard to keep everyone working in the same direction. Occasionally the team got stuck in lost time. We worked hard to include everyone in the design and construction process so that no one felt that they had not contributed anything. In the beginning, we had no idea how to go about building a machine which could operate underwater. In the end, we built a capable machine which was constructed using ideas from everyone.

Section 8: Future Improvements

We still have not fully solved the problem with our propellers and motors. In the future we will try using propellers made for underwater use in order to improve thrust. We also decided to go with a very simple control board design which uses only 4 DPDT switches and no speed control. This gives the advantage of simplicity but makes the ROV more difficult to pilot. On future machines, we will consider a more sophisticated control board which uses a joy stick and pulse width modulation speed control. We will also pay more attention to the management of the overall process so that less time is spent spinning our wheels.

Section 9: Acknowledgments

The Corbett Robotics Team would like to acknowledge the following groups and individuals for their invaluable assistance:

- Ferguson for providing us the PVC pipe and fittings
- Mr. Marsh for providing technical assistance and the use of his shop
- Michael Wilkin for his advice and assistance in the early stages
- The Corbett Education Foundation for providing funds
- Corbett School District for providing funds for construction and travel and for allowing us to build a huge water tank which flooded the basement more than once.

- Jill Zande at MATE for her help and flexibility.