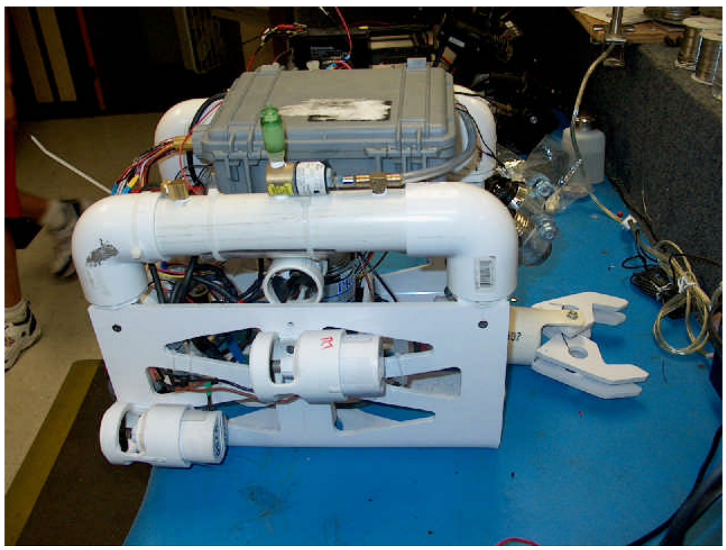
USDHS ROV TEAM

Project Propel

May 26, 2005



Team Members:
Juan Batiz-Benet
Michael MacIntyre
Nicholas Prsha
Dominic Schmied

Team Mentors/Instructors:
Melinda Berry
Scott Berry
Jeff Prsha
Michael Schmied

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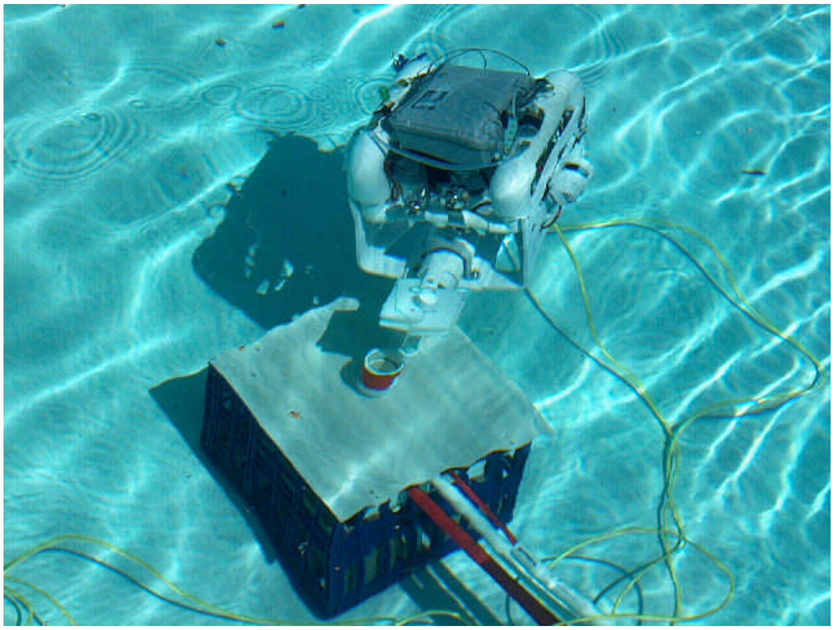


Abstract

The USDHS team strove to show the adaptability and versatility of remotely operated vehicles (hereon referred to as ROV's) throughout the course of the project. The ROV requires mechanical flexibility in order to complete three different, independent tasks. The tasks include capping an oil well, attaching a communications probe, and amending a part of the Hubble space telescope with a unique instrument module. Between tasks, the team must modify the ROV within five minutes to prepare it for the next task. The ROV must remain durable, yet become as efficient as possible to effectively finish each task under five minutes (hence the competition name "Underwater Olympics"). Using engineering plastic resins such as polyvinyl chloride (PVC), the team created a light, easy to transport, and tough ROV. Primary power, coming from batteries on-board the ROV, allowed a miniature coaxial cable to be used for optimal tether management sending a signal both to and from the ROV and the topside control box. The motor system, designed for a combination of speed and maneuverability, derived from four horizontally and two vertically placed bilge pumps along with two used for turns placed atop the vehicle. A single claw, which can be easily repositioned depending on the task, performs all three tasks with ease. The simplicity coupled with strong efficiency of the ROV is anticipated to sweep the competitors due to superior engineering.

Design Rational

FRAME

The frame of the USDHS ROV is designed from PVC because that particular engineering plastic is both light and easy to use. The shape of the frame, a rectangular prism, is simple and easy to adjust, allowing the motors to be shifted when needed, based on test results. Drilling another hole and moving some screws and clamps can place the motors at various locations around the body. While PVC piping makes up the top of the ROV frame, the lower half is made up of a PVC sheet complete with designed holes (see Figure 1.1) to aid in placement of ROV parts and minimize drag and mass contributing to a very minute loss of momentum due to friction as the ROV traverses through the water. The claw is placed at the bottom of the vehicle, and the PVC sheet frame allows it to be placed either within the vehicle housing or on the outside up in front of the vehicle (depending on the desired task). The thrust motors are placed on either side of the ROV to allow for easy maneuverability. The lift motors are placed on the inside (see Figure 1.1) to cut down on surface area thus reducing friction with the water and to help protect the motors from any damage. The motor wires, contained inside the frame, and the coaxial cable, which connects the ROV to the topside control box, work to minimize the chance for obstacles becoming entangled with the ROV while allowing for less friction and more maneuverability. The prism shape is small enough to fit through all known locations and has a tight enough turning radius to be able to make its way out of tight situations.

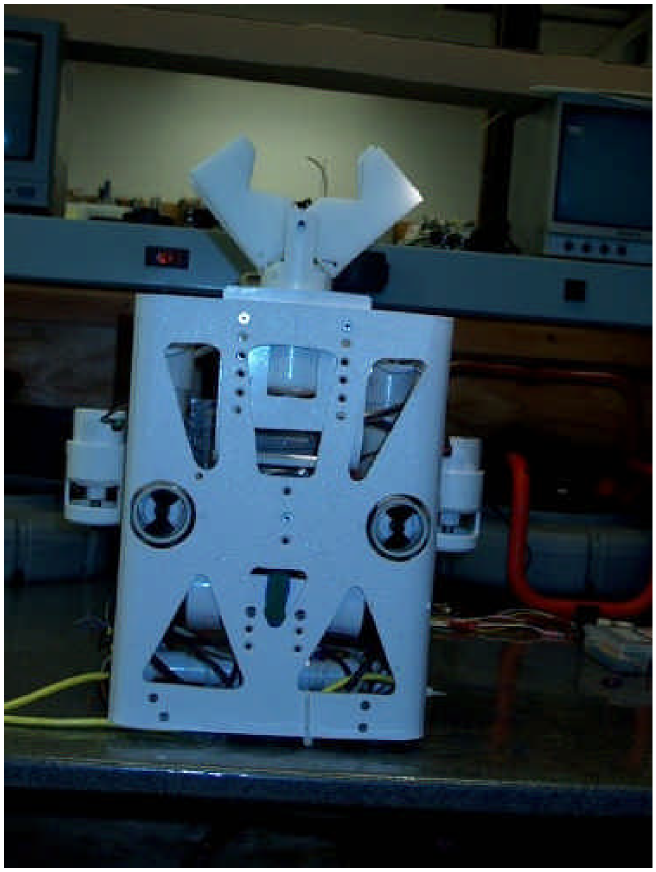


Figure 1.1 ROV Bottom

Two waterproof cameras, embedded with light-emitting diodes (LEDs) as the source of illumination, were salvaged from old sewage inspection equipment and positioned on the bow of the ROV. One of these cameras is used for driving. Positioned higher on the ROV, it provides a wider view that allows the driver to see most of the terrain in front of him. The second camera gives the driver a close up view of the claw for accurate work. These camera angles can be easily adjusted to allow maximum field of view. A relay switches between the two cameras. The camera video signal is modulated onto TV channel 3 by a surplus video game modulator and sent up the tether to the pilot.

MOTORS

Eight bilge pumps were used to create the eight-motor system. Twin thrust motors on each side were developed from Atwood 750 bilge pumps, while the lift motors and "side-control motors" were modified from Atwood 500 bilge pumps. To determine the necessary size and number of motors, the team tested a variety of models and shroud configuration prior to motor development (see Appendix A for test results). The team found that shrouding the propellers considerably increased the thrust they produced. The lift and side-control motor are located within the frame for protection from impact with obstacles in the water. The two sets of twin thrust motors are mounted on the outside (on each side of the ROV) of the PVC frame with a simple screw and nut (see Figure 1.2 left). The two lift motors are placed vertically, halfway along the length and height of the ROV, and are attached with clamps screwed into the PVC frame (see Figure 1.2 right).

The two side control motors are attached towards the top of the ROV along the center lines. They are held in place by zip-ties and help the ROV move side to side in either direction without requiring much action from any of the other motors. Each motor was built by cutting off the bilge pump body with a band saw, in order to reduce weight and size.

MOTOR CONTROLS

The motors run off of a pulse width modulation (PWM) system. The pilot's console sends a 70Mhz RF signal down to the radio receiver in the ROV. The receiver outputs pulses representing the position of each of the pilot's 7 controls which are each 1-2 milliseconds wide for each channel. Each of the 7 channel outputs of the receiver is routed to a PIC16F684 microcontroller with built in PWM output. The program in each PIC rejects pulses shorter then 1 ms and longer then 2 ms as errors. A pulse width of 1.5ms corresponds to the zero position of each control. Pulse width greater than 1.5 but less then 2ms represents increasingly positive input. Pulse widths less than 1.5ms but greater then 1 ms represent increasingly negative input. Each PIC translates the pulse width for its channel into a duty cycle (speed) and direction for the motors it controls. A MOSFET H-Bridge driven by each PIC then controls power to the motors.

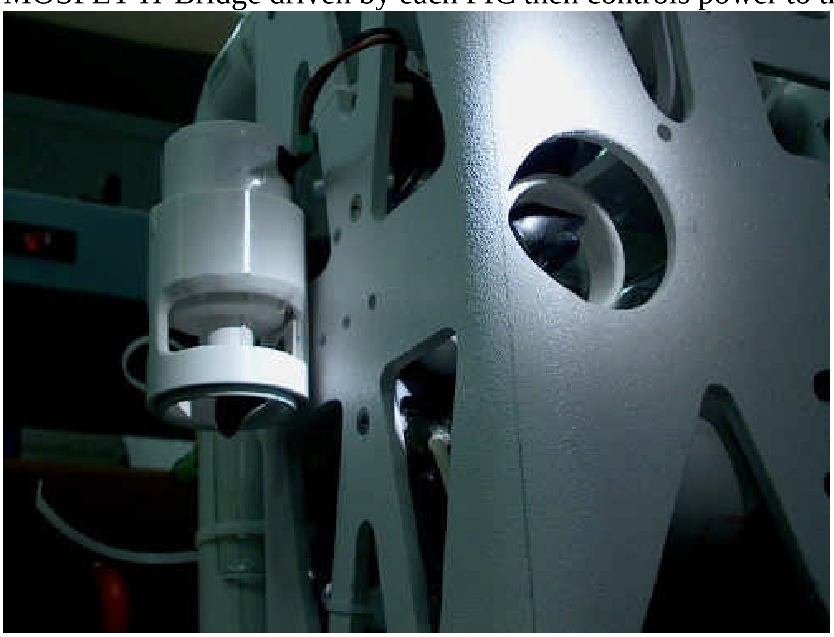


Figure 1.2 Motors

BALLAST AND CLAW

Both the claw and ballast run off a pneumatic system. See Appendix C for schematics. Liquid, environmentally friendly 1,1 difluoroethane from a pressurized can, boils to gas to provide the power for both ballast control and claw actuation. The entire system utilizes four electric valves, one for the claw and three for ballast. Since each valve can only take up to 20 psi, a pressure regulator is placed between the can and the. After being regulated, the gas passes through a manifold, supplying the claw and ballast.

The claw system (see Figure 1.3) consists of a three-way valve that leads to a pneumatic piston. When the valve has no power, gas is released from the piston into the aqueous surroundings. When the valve is powered, gas passes through, pushing the piston forward. The piston applies pressure to all "fingers" of the claw, forcing it to close tightly. When the gas is released, springs in the claw then pull "fingers" back to their original locations along with the piston. The claw is now open.

For the ballast system (see Figure 1.4), a one-way valve allows gas to pass into the two pontoons atop the ROV when powered. When off, unlike the three-way valve, the one-way valve performs no action; it neither releases gas, nor lets gas pass. As gas fills the pontoons, the vessel becomes more buoyant. In order to release gas, two additional one-way valves (one on each pontoon) let gas out into the water. The advantage of the one-way valve is that it prevents undesired water from entering the pontoons. As air leaves the pontoons, they vehicle becomes less buoyant and sinks.

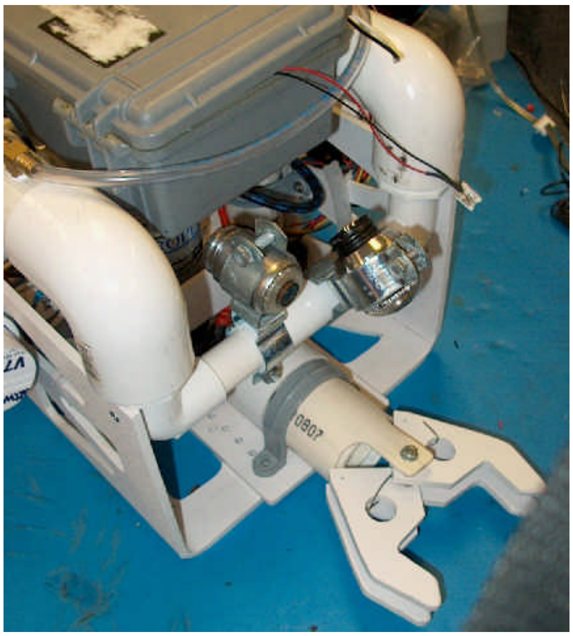


Figure 1.3 Claw

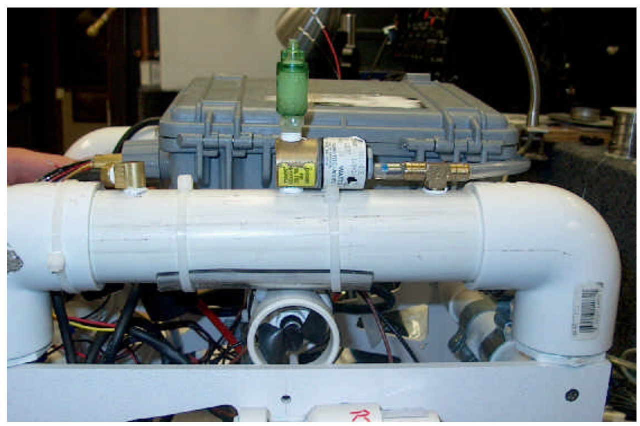


Figure 1.4 Ballast valves

TOPSIDE CONTROL BOX, BATTERIES, and TETHER MANAGEMENT

By using a seven channel model airplane remote controller as the pilot's console, enough channels exist to run each motor group separately (one on each channel), power the ballast system and claw, and switch between cameras. Topside control connects, via a miniature coaxial cable, to the PC board within the ROV. One compartment contains the entire control box for easy organization and simple access to all parts and topside electronics. A flipover top works as a top to the box and, when flipped over, stores the controls that are simply mounted and slotted into a wood frame. This allows pre-competition preparation to be less burdensome. The remote controller being used holds two joysticks built into its body. A VCR demodulates the video signal and feeds it directly to a monitor. The use of a smaller tether causes less drag and greater maneuverability, but forces the batteries (see Figure 1.5) to be placed on-board the ROV. The batteries used are nickel-zinc batteries donated by Powergenix Corp. While regular C-cell batteries are bulky and put out about 1.5 volts, nickel-zinc batteries are more compact, provide 1.6 volts, are rechargeable, environmentally friendly, and have a much lower internal resistance. A battery pack of 8 cells provides 12.8 volt and contains a 25 amp circuit breaker for safety.

Easy storage and good cable management prevented tangles in the cable and made life easier for us all with a PVC box that holds a wood-composite winch (see Figure 1.6). A slip ring allows the wheel to freely rotate, either releasing or retracting cable as it turns. When electrical power is added, the slip ring will turn the wheel to provide perfect and clean cable management. The ingenuity of the design lies within the knot and bend free method of containing the cable in a small volume. A negative aspect of coaxial cable is the relative ease with which it may kink. The nature of these kinks prevents signal from traveling through the coaxial-cable and prevents data from being sent to the ROV. The clever design helps to solve all problems related to the cable management.

Figure 1.5 Batteries and battery pack

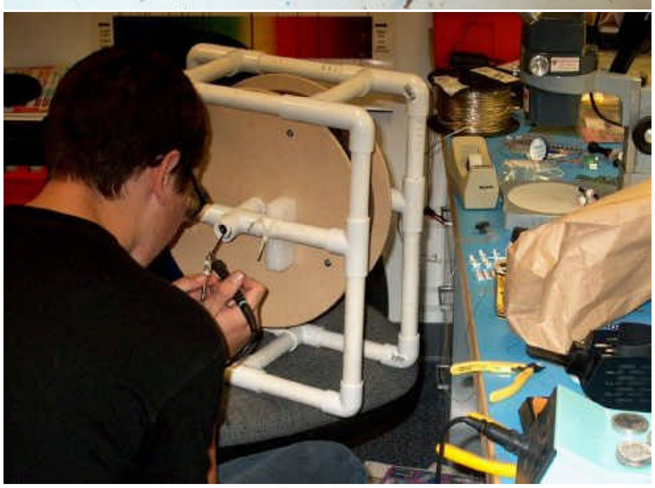


Figure 1.6 cable management

FLOOD ALARM

The team created an onboard flood alarm to detect water within the drybox. This allows the team to detect problems within the drybox immediately and return to surface with minimal harm to the onboard electronics. Strips of copper tape rest along the inner base of the drybox. When water connects a grounded copper-tape line to powered copper-tape line, the power line is grounded, reaching a designated PIC. This PIC then drives a speaker on the board. The speaker can be heard from inside the drybox in case the box is wet before actual flight. The board also has a microphone that outputs signal to speakers on topside, in case the leakage occurs below surface.

Microcontroller Code

Three sets of code were programmed in Assembler Language for a) motors, b) camera relay switch and c) flood alarm speaker. The code drives PIC Microcontrollers manufactured by Microchip Technology Inc. A Microchip MPLAB IDE was used to program, debug, and test the code.
Much

Electrical Schematics

For schematics see Appendix C.

Budget

Much of this year's ROV parts remained or were developed from the team's past ROVs. Also, many parts were salvaged, such as the sewage cameras, in an effort to create the most cost-effective machine possible. See Appendix B.

Challenges

As with every year, the first and foremost problem was the creation of a team. Numerous participants expressed interest, but dropped out after many tasks had already been assigned. This left a huge void to be filled. However, the ROV team was finally created and consisted of five (four by the very end) team members. Much of the drama delayed the time of creation of the ROV. Time (as always) became an issue as the deadline crept closer and closer with more and more needing to be done. Working long hours and at least three days a week compensated for any time lost earlier in the year or still needed due to the enormity of the project.

Stupid, unnecessary mistakes also contributed to difficulties within the project. Parts were often lost, making working on a part of the ROV immensely difficult. Accidents such as the burning of an electrical board while soldering also contributed to team frustration.

More frustration can be attributed to the team's high standard of excellence and ideals of perfection. At least four frames were actually created (while many more were designed) until the team reached one they felt was perfect. With every frame, some flaws could be found. The team just had to stick with a persistent attitude and make adjustments, no matter how small, until they believed they could do no more. The claw also provided some difficulty since it would not close enough or open efficiently. However, lots of work, models, and drawings (and lots of attempts at failed claws) finally figured out perfect dimensions that made the claw work perfectly.

Troubleshooting Techniques

Brainstorming, planning, and re-evaluating previous failures (see Figure 2.1) solved many technical problems before they occurred. In the first two years of competition for USDHS (2003 and 2004), minimal planning went into the project and numerous problems were encountered with very little time to fix them. However, this year, months of planning and brainstorming reduced time loss during the actual building process. Each extra brainstorming session for a given challenge produced greater results since team members proposed new ideas every time. When technical problems occur, checking all possible problems helps to find the true deterrent and the optimal solution.

Models and sketches helped to prevent problems before they occurred. During the process of ROV completion, numerous models were made for the various aspects of the project. Four different frame models were made separately. Each time the team improved upon the last design. Also, three separate claws were made until the perfect dimensions and body for the claw was achieved. Numerous cardboard models of the claw were made also to ensure that the dimensions were correct before team members spent time creating the actual working claw.

Another problem with the ROV was its initial size. Its large and bulky frame would have been awkward to maneuver in water. By locating parts (such as unnecessarily long sections of PVC pipe) and removing them or cutting them down, the team altered the ROV to a much smaller size. A big contribution to a smaller size was locating a propellant can half the size of the original one. Since the can had to be placed in the center and placed vertically to maximize efficiency, the smaller can allowed the team to remove over four inches of height from the ROV.

Containing all the wires within the ROV turned out to be a more difficult task then at first anticipated. The team selectively gauged the wire based on their previously contemporary requirements to minimize size as much as possible without getting rid of their transmitting capacity. One other technical problem was the high pressure of the Propel can, being well over the maximum pressure for the valves to work properly. The team resolved this problem by attaching a regulator to limit pressure reaching the valves to less than 20 psi.

Programming the PIC also proved daunting. The original PIC was chosen for size and cost. However, upgrading to a larger part that incorporates PWM solved this difficulty.

Figure 2.1 Nick, Dominic, and Mr. Prsha planning the ROV

Description of Lessons Learned

Juan Batiz-Benet: "I learned how to complete programs using Assembly language. I also learned the virtue of organization and being able to locate required parts at will." (see Figure 3.1)

Michael MacIntyre. "I developed the necessary dispositions of time management and a desire to get things done as soon as possible (DON'T PROCRASTINATE!). I also became acquainted with many new tools, eg. The band saw."

Nick Prsha: "By the end of the project I mastered the skill of surface mount soldering. I also found out that life can be much easier when you actually organize electronic parts rather then just search through a pile every time you need something." (see Figure 3.2)

Dominic Schmied: "I learned a lot about electrical parts including resistors in series, the functions of capacitors, and how to distinguish various amplifying parts (ie. MOSFETs). Also, WIRE NUTS ARE THE DEVIL'S ADVOCATE!!!"

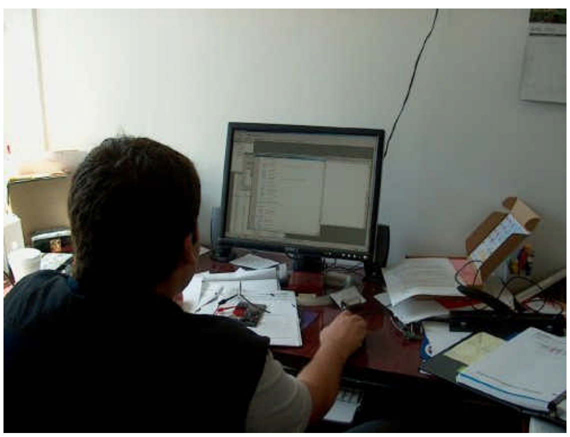


Figure 3.1 Juan working hard on code


Figure 3.2 Nick soldering surface mount

Discussion of Future Improvements

Next year, prior to the commencement of the project, the team needs to have all ideas completed and all necessary parts for building, neatly organized and easily accessible. Organization is key, as it will allow budget reports to be tackled with ease and will result in only one purchase of various items (especially the smaller ones that are often misplaced).

Another beneficial feature would be a more efficient test module (see Figure 4.1). While complicated code, boards, and wires are being created and arranged, it would be nice if the team could easily perform basic tests with the ROV submerged in water to analyze ballast, speed, turning radius, etc. This would allow the team to attack frame and other general problems without having to wait for the entire ROV to be completed.

In the future, time management will be improved. Next year, the project will begin even earlier and time will be used as valuably as possible. Also, brainstorming sessions are very useful. The ideal situation would be to make full models and sketches of the ROV and its schematics before even beginning to work on a tangible version of the vessel. Also, an onboard schwarma maker would be a nice accessory.

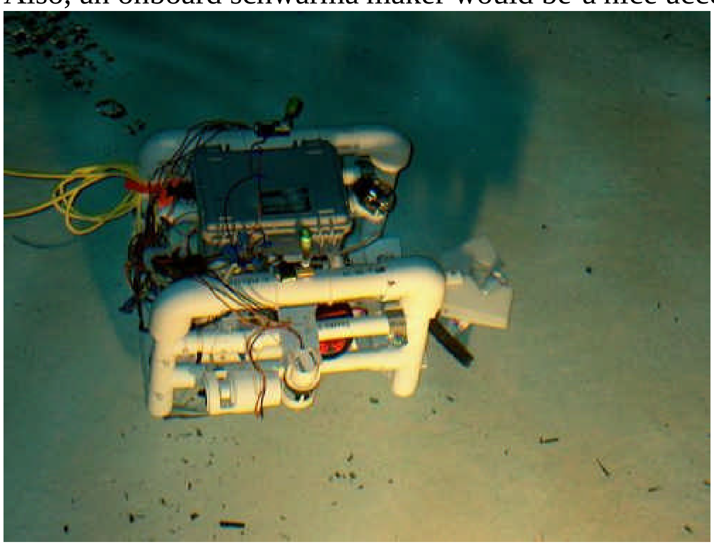


Figure 4.1 Early prototype in test runs

Description of a Support for the Mission Themes

In today's world, fiber optic cables are used for voice, data, and communication (to name a few of many functions) needs around the globe. According to the U.S. Department of Education, over 70% of all American houses contain at least one computer while over 98% of homes have a telephone. Most businesses today require increasingly complex integrated network systems involving both voice and data systems. Centered on fiber optic systems, businesses today need skilled technicians to install and maintain these systems. They also need highly trained engineers and administrators to help create and keep the systems safe and working. A person who wishes to develop an interest in fiber optic cables and systems should look into the newest careers of the twentieth century including Telecommunications and Information Technology, both of which are highly dependent on a refined knowledge of the workings of fiber optics.

Right now, the Hubble space telescope (see Figure 5.1) orbits the Earth. It was launched in 1990 through both NASA and the European Space Agency and began sending high-quality images back to the planet in 1994. The project is expected to last until 2009. Due to its well-placed location, just outside of the Earth's atmosphere, images are not obscured and come in very clear. The telescope performs numerous functions through its use of diverse instruments, each performing various astronomical projects from all around the world. The Hubble space telescope has confirmed the existence of dark matter, supported the contemporary accelerating universe theory, and added to scientists' knowledge of extrasolar planets. Fields involving the Hubble space telescope (or the James Webb Space Telescope which is planned to be launched in 2011) are ever growing. In 1993, optical errors were discovered until the telescope could send back high quality images from around the universe. This problem coupled this year's themes of fixing (or adding new products) the telescope and dealing with optical problems.

Figure 5.1 HST in flight

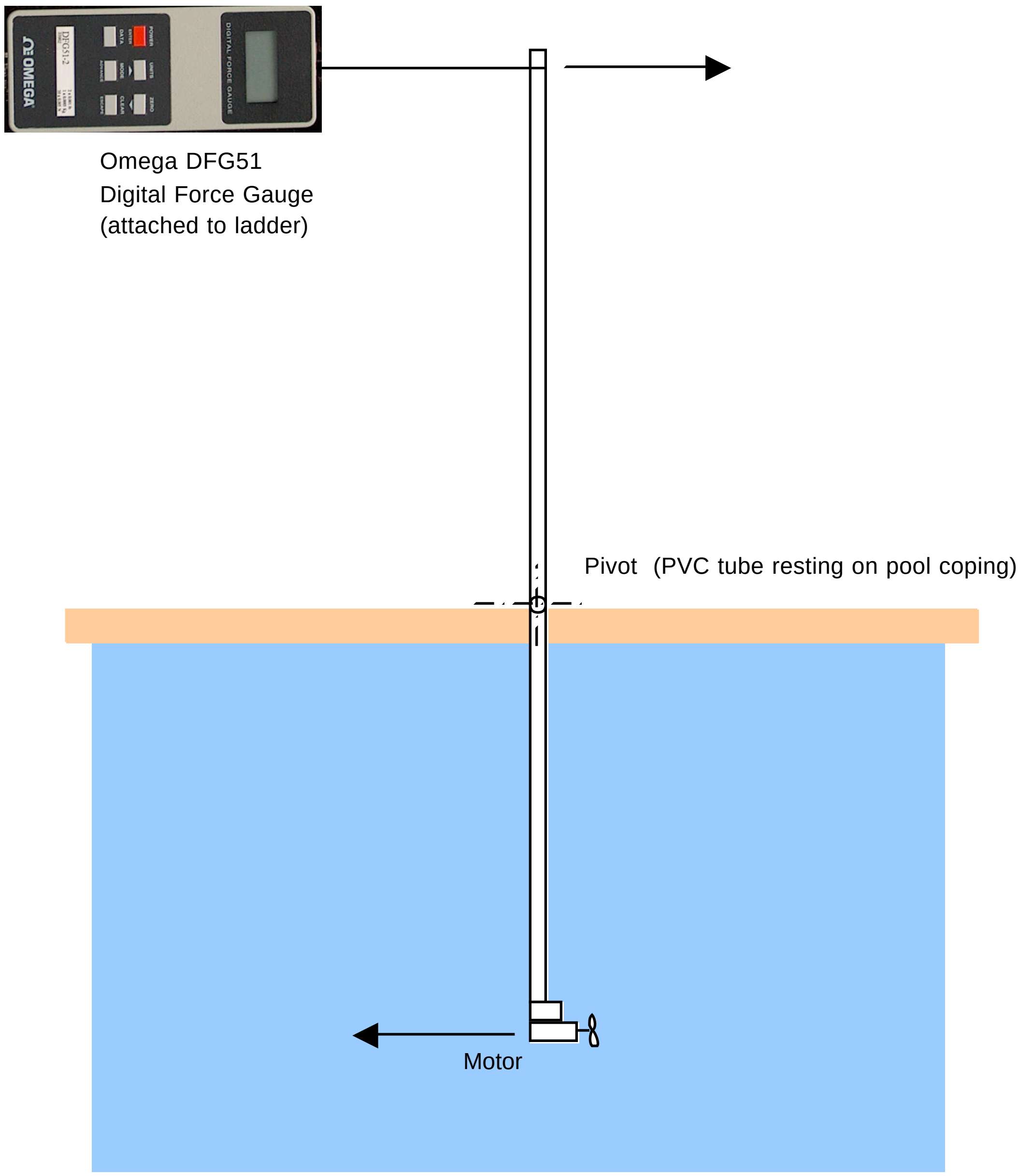
Sources:
http://www.natpoly.edu/Careers/CareerPaths/Information.html
http://en.wikipedia.org/wiki/Hubble_Space_Telescope

Acknowledgments

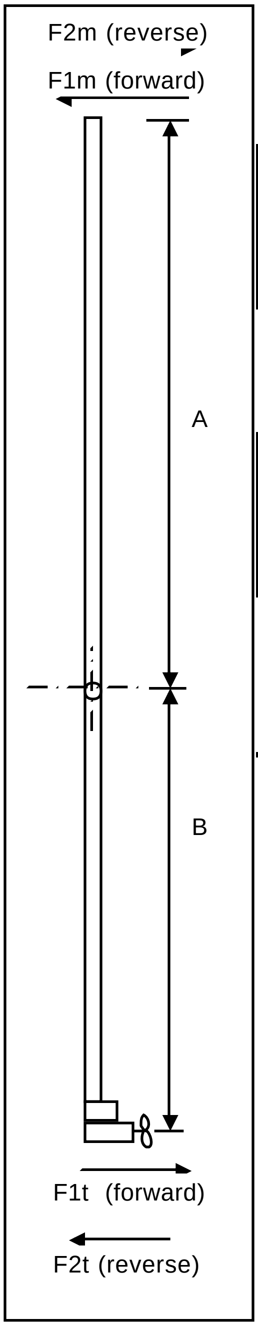
Our team would like to thank both of our mentors, Jeff Prsha and Michael Schmied, for all of their time and effort involving this project. We would also like to thank Scott and Melinda Berry for being our team instructors. We would like to thank Mark Olson for allowing us to use his facilities at Deepsea. We would also like to thank Jan Soukup for allowing us to use many of his supplies and guidance during the absence of our mentors. We acknowledge Scott Mau and Jill Zande for their help and guidance during the project. We would like to thank our competitors, for with out them there would be no competition. We appreciate all the help of Dan Squiller from Powergenix for batteries and an explanation of the battery technology. Our final thanks goes out to you, the judges, for sacrificing your time to read and score our report.

APPENDIX A

Motor Test Setup 3/5/2005 to 3/6/2005



APPENDIX A



3/5/2005 **Atwood 500 Motor**

			(forward)		(reverse)	
	Know	Know	Know	x	Know	x
	[cm]	[cm]	[N]	[N]	[N]	[N]
w/Shroud	Distance A	Distance B	F1m	F1t	F2m	F2t
1	100	100	2.00	2	1.30	1.3
2	90	100	2.40	2.16	1.45	1.31
3	70	100	2.80	1.96	1.90	1.33
4	60	100	3.20	1.92	2.20	1.32

Average Forward Thrust (w/Shroud) 2.01
Average Reverse Thrust (w/Shroud) 1.31

No Shroud			(forward)		(reverse)	
1	100	100	2.35	2.35	0.70	0.7
2	90	100	2.50	2.25	0.80	0.72
3	70	100	3.50	2.45	1.00	0.7
4	60	100	4.00	2.4	1.20	0.72

Average Forward Thrust (no Shroud) 2.36
Average Reverse Thrust (no Shroud) 0.71

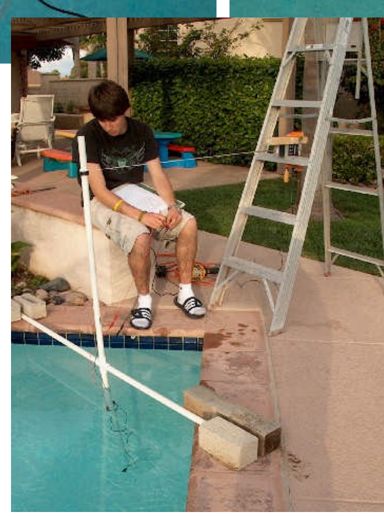
$$\frac{DA}{DB} = \frac{x}{F1m} \quad F1t$$

x*DB = DA*F1m
x = DA*F1m/DB

Enigine Used: Atwood 500, Black Modelboat propeller
Shroud: PVC 1.5'' Pipe

no Shroud

with Shroud

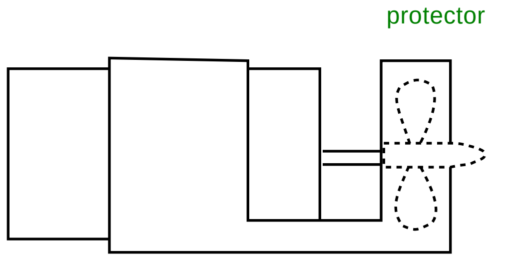


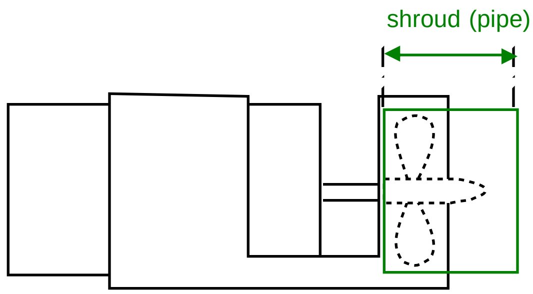
APPENDIX A

3/6/2005 **Atwood 750 Motor**

			(forward)		(reverse)	
w/Shroud	Know	Know	Know	x	Know	x
[mm]	[cm]	[cm]	[N]	[N]	[N]	[N]
Shrowd Pipe	Distance A	Distance B	F1m	F1t	F2m	F2t
protector	90	67.5	3.5	4.67	0.85	1.13
18	90	67.5	3.90	5.2	1.70	2.27
29	90	67.5	3.75	5	1.80	2.4
40	90	67.5	3.85	5.13	1.70	2.27
65	90	67.5	3.80	5.07	1.70	2.27

Average Forward Thrust (w/Shroud)	6.27
Average Reverse Thrust (w/Shroud)	2.07





MATE/MTS ROV Committee Student Competition

APPENDIX B **USDHS ROV 2005 PROJECT** Budget/Expense Sheet

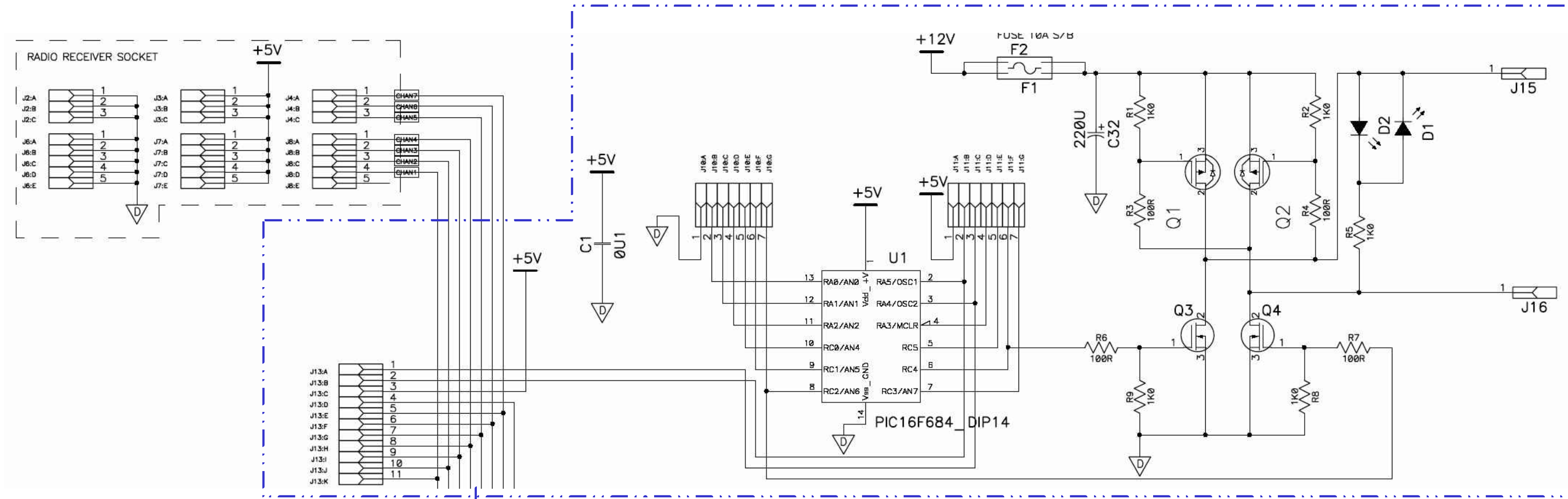
Period:

School Name: University of San Diego High School From: 12/1/2004

Instructor/Sponsor: Scott Berry, Melinda Berry, Jeff Prsha, Michael Schmied To: 4/28/2004

Funds Date	Deposit or Expense	Description	Notes	Quantity	Amount	Balance
	Borrowed	VCR	Borrowed	1	$ -	$ -
	Borrowed	Video Distribution Amplifier	Borrowed	1	$ -	$ -
	Donated	Topside Casing	Donated	1	$ -	$ -
	Donated	Model Airplane Remote Controller	Donated	1	$ -	$ -
	$75	Circuit Board	$ 75.00	2	$ 150.00	$ 150.00
	$3.90	2 in. Plug	$ 3.90	2	$ 7.80	$ 157.80
	$5.00	PVC Pipe (in meters)	$ 0.50	10	$ 5.00	$ 162.80
	$40	Dry Box	$ 40.00	1	$ 40.00	$ 202.80
	1	Hose Clamps	$ 1.00	2	$ 2.00	$ 204.80
	Salvaged	Cameras	Salvaged	3	$ -	$ 204.80
	$10	Atwood 500 Bilge Pumps	$ 10.00	4	$ 40.00	$ 244.80
	$15	Atwood 750 Bilge Pumps	$ 15.00	2	$ 30.00	$ 274.80
	Varied	PVC fitting, coupling and caps	Varied	16	$ 20.00	$ 294.80
	$1	Straps	$ 1.00	2	$ 2.00	$ 296.80
	$8	Box of Cable Ties	$ 8.00	1	$ 8.00	$ 304.80
	$0.15	Pipe Adapters	$ 0.15	6	$ 0.90	$ 305.70
	9.3	Propel Can	$ 9.30	1	$ 9.30	$ 315.00
	18	Propel Can cap and ten in. of tubing	$ 18.00	1	$ 18.00	$ 333.00
	5.3	Tinnit	$ 5.30	2	$ 10.60	$ 343.60
	3.6	Circuit Breaker	$ 3.60	1	$ 3.60	$ 347.20
	15	Coaxial Cable (30m)	$ 15.00	1	$ 15.00	$ 362.20
	.3	8 pin Socket	$ 0.30	2	$ 0.60	$ 362.80
	.55	14 pin Socket	$ 0.55	4	$ 2.20	$ 365.00
	.4	caps	$ 0.40	34	$ 13.60	$ 378.60
	1.8	HEX/MOS P-CH -55V	$ 1.80	20	$ 36.00	$ 414.60
	.2	CONN Pin 14-20 AWG TIN CRIMP	$ 0.20	60	$ 12.00	$ 426.60
	.35	CONN HEADER 2POS VERT .250 TIN	$ 0.35	16	$ 5.60	$ 432.20
	Donated	Various electric parts: diodes resistors, capacitors etc.	Donated		$ -	$ 432.20
	0.25	Various Connector plugs, caps, sealse	$ 0.25	70	$ 17.50	$ 449.70
		TOTAL ESTIMATED COSTS				**$ 449.70**

Appendix C – Wetside PC Board Schematics
USDHS ROV 2005 Project

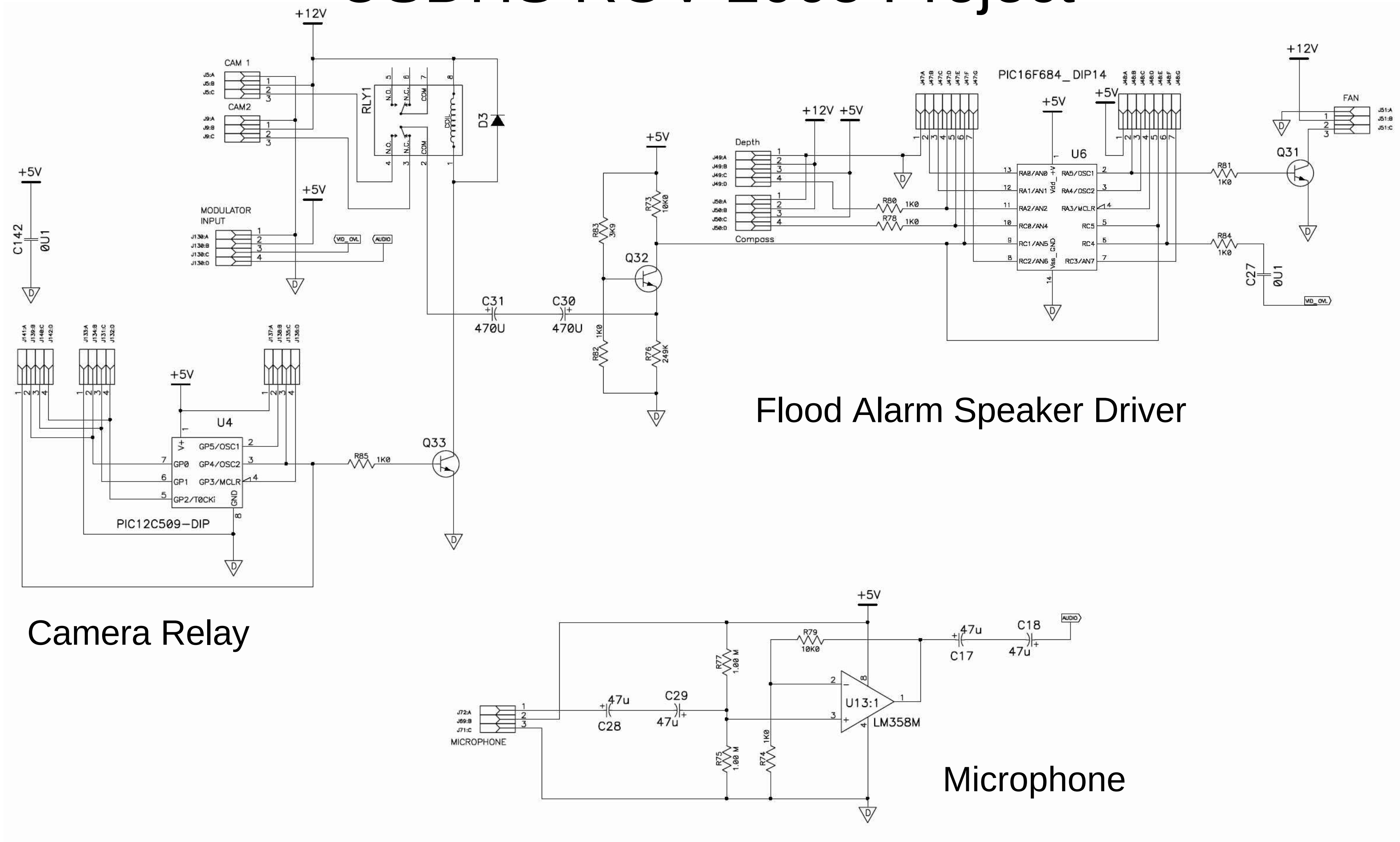


Motor Driver

Repeats for
7 Channels

Appendix C – Wetside PC Board Schematics

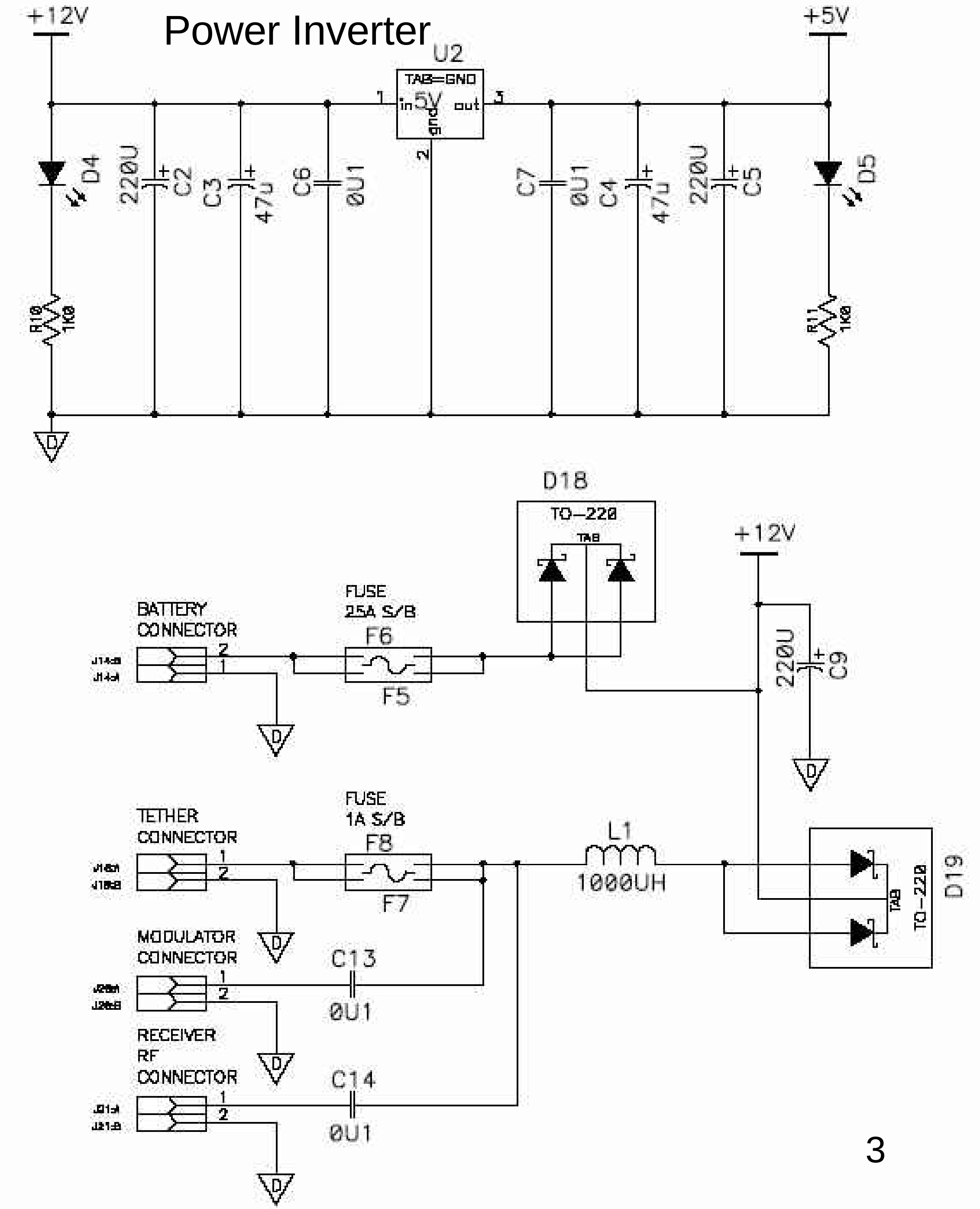
USDHS ROV 2005 Project



Appendix C

Topside PC Board Schematics

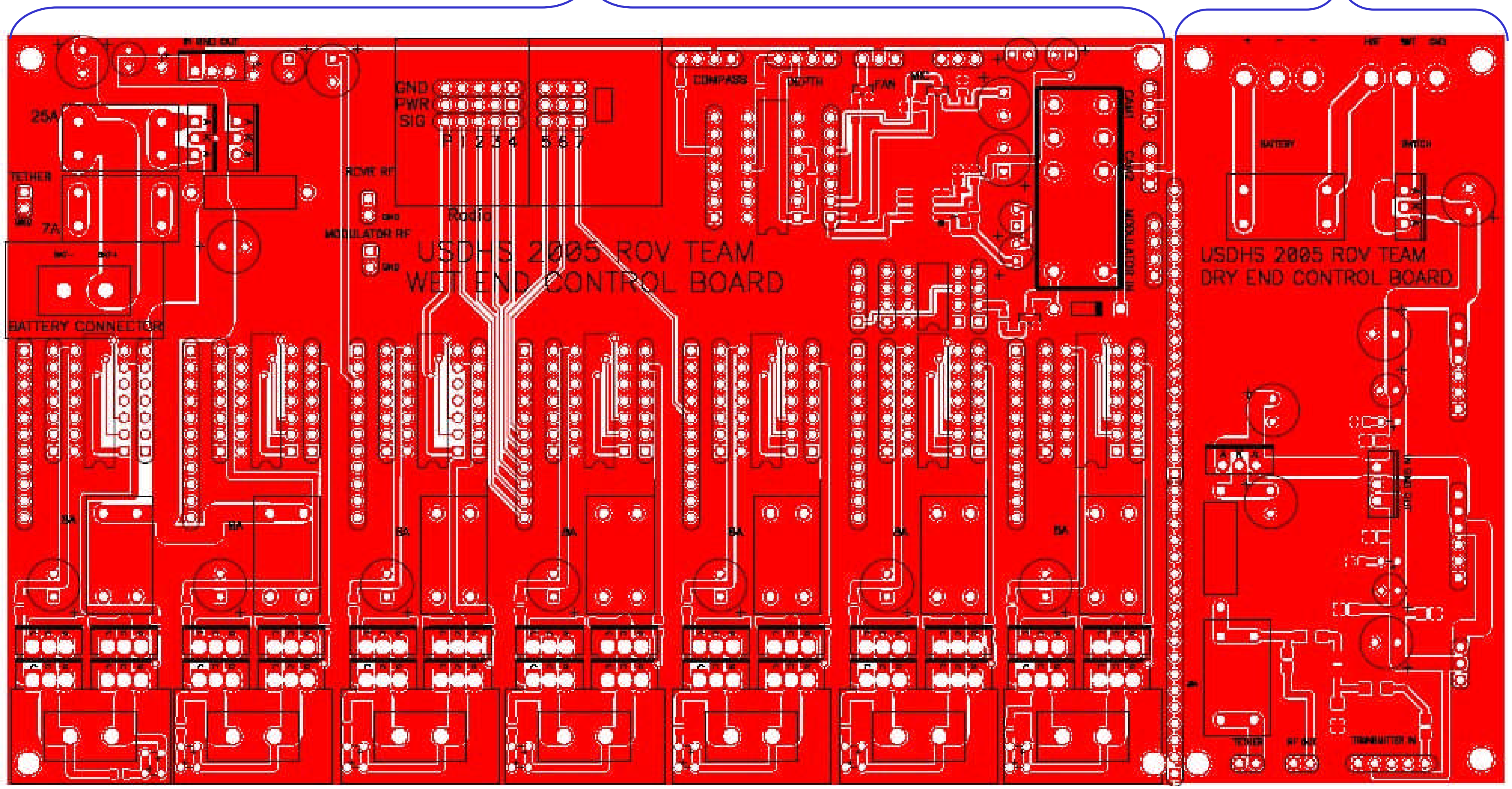
USDHS ROV 2005 Project



Appendix C – PC Board Layout

USDHS ROV 2005 Project

Wetside PC Board Topside PC Board



Appendix C – Pneumatic System Schematics

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