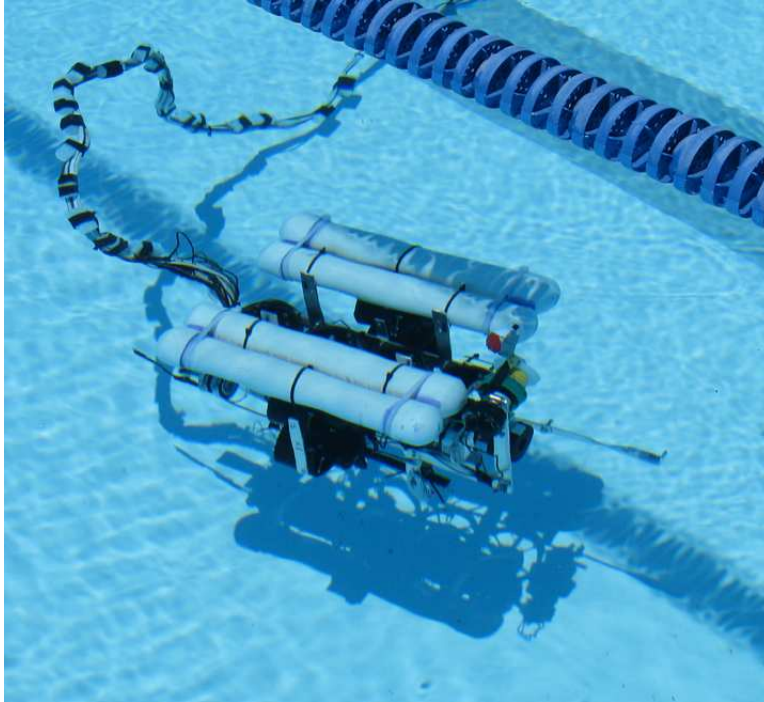


**Phoenix Country Day School 8th Grade
Blue Tide Underwater Robotics Team
National Underwater Robotics Challenge 2008**



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Industry Advice:

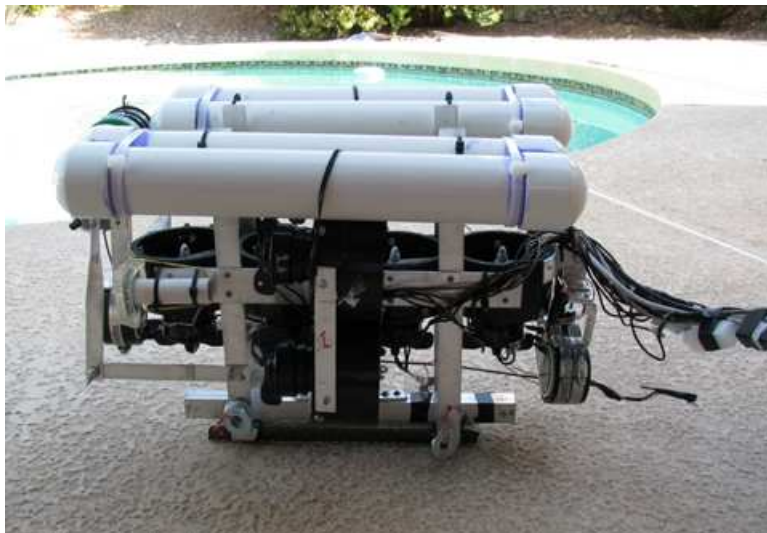
Don Kohlman, Peter Wetenstein,

Introduction

Our team bought and assembled a ROV-in-a-Box kit from Inventivity, Inc. before joining the NURC competition. We melted our first power switch, while learning how to solder. We decided the simple control box was too awkward for fine maneuvers. We decided to upgrade to a VEX programmable control system and Victor speed controllers to give us a controllable gradient of power to the thrusters. When we tried to recover a mock-up of the flight controller, the ROV thrusters bogged down. It seemed like the load was too much for the little motors. We decided to upgrade the motors and build propeller guards. In the process we ended up building a separate ROV. This report is about that ROV, we affectionately call Lloyd.

Design

The design of our ROV was based on function and cost. By testing we determined the optimal size of the propellers that our affordable Mayfair motors could run under full load, built propeller guards to fit those, and used the propeller guards as part of the structure of the ROV. To meet the loads needed for competition, we added pairs of motors where there had been single thrusters. We added strips of aluminum to make the structure rigid and an undercarriage to attach ballast to help the ROV maintain stable orientation and attach arms, hooks, and the depth gauge. For buoyancy we attached four 2 inch PVC pipes capped on both ends.

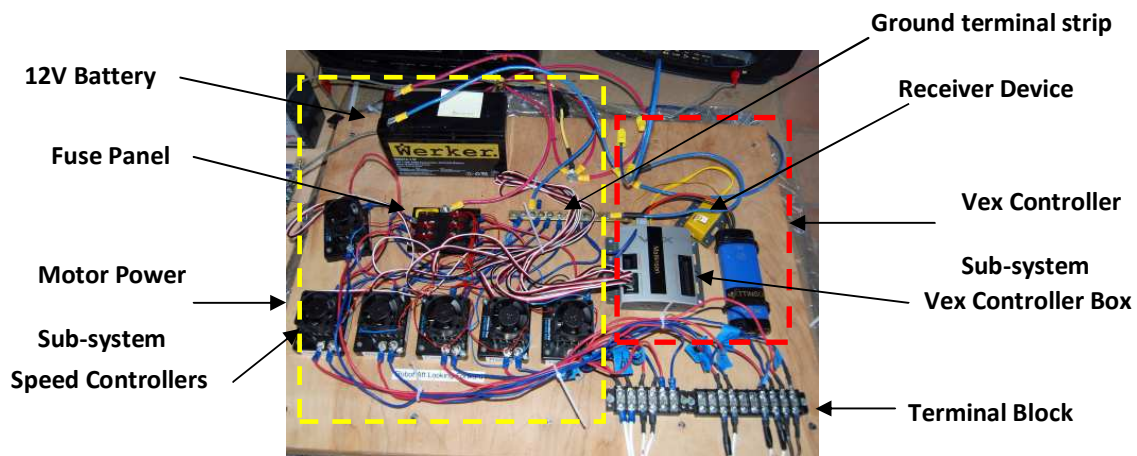


Power and Circuits

Since this was our first attempt at an underwater robot, we decided to have our electrical power systems separate from the robot. We utilized a one hundred foot tethered wire system to

connect the power circuits to the robot. Our power systems consist of a main power circuit and a camera/light power circuit.

The main power circuit consists of a motor power sub-system and a Vex Controller sub-system. A photograph of our main power circuit is shown below, and a schematic of the main power circuit is shown in Appendix X.



Main Power Circuit

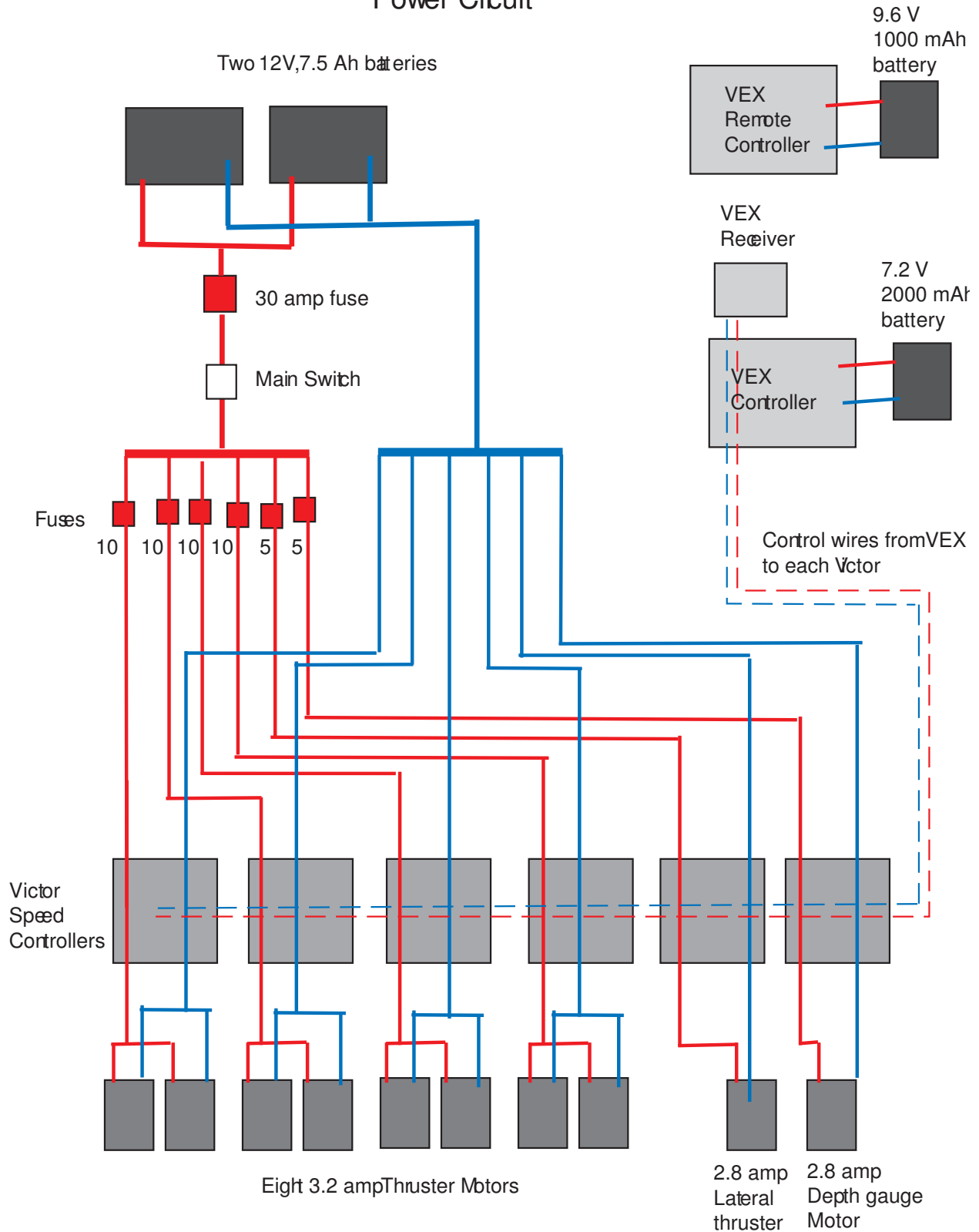
A 12-volt, 7.5 amp-hour rechargeable battery powers our motor power sub-system. The positive terminal from the battery is connected through a switch to a Buss ATC fuse panel, designed to handle six separate fuse controlled circuits. The negative terminal of the battery is connected to a common ground terminal strip.

The fuse panel contains six fuses, five of which are ten amps and one is five amps. The fuse panel is connected to six Victor 844 Innovation First speed controllers, each equipped with a cooling fan. The positive wires from the speed controllers are connected to one of the six fuse terminals on the fuse panel, and the negative or common wires from each speed controllers are connected to the common ground terminal strip. The positive wires for each of the cooling fans are tied together to the positive input on the fuse panel so that the fans are in operation at all times when the system is powered on. The negative wires of each cooling fan are connected to the common ground terminal strip.

Five of the speed controllers are each connected to one of the ten amp fuse terminals on the fuse panel, and the sixth speed controller is connected to the five-amp fuse terminal on the fuse panel. The negative terminals on the speed controllers are each connected to the common ground terminal strip. Four of the speed controllers on the ten amp circuits are each wired to control two one thousand GPH motors on the robot. The positive wires on each pair of motors were soldered together and the negative wires on each pair of motors were also soldered together in the tethered wire system on the robot. The fifth speed controller is connected to the five amp terminal and wired to control our depth gauge motor. The sixth speed controller is connected to the last ten amp terminal and wired to control a five hundred GPH motor configured to control fine lateral movement of the robot.

We used a conventional wire terminal block to connect the speed controllers to the tethered wire system. We found this convenient to trouble shoot and to make any changes to our robot power system. In connecting the battery to the fuse panel, we used ten AWG wire, which is rated up to fifty-five amps. For connecting the fuse panel to the speed controllers and the speed controller to the wire tethered system, we used fourteen AWG wire. Our wire tether consists of sixteen AWG wire, which is rated up to 22 amps.

Power Circuit

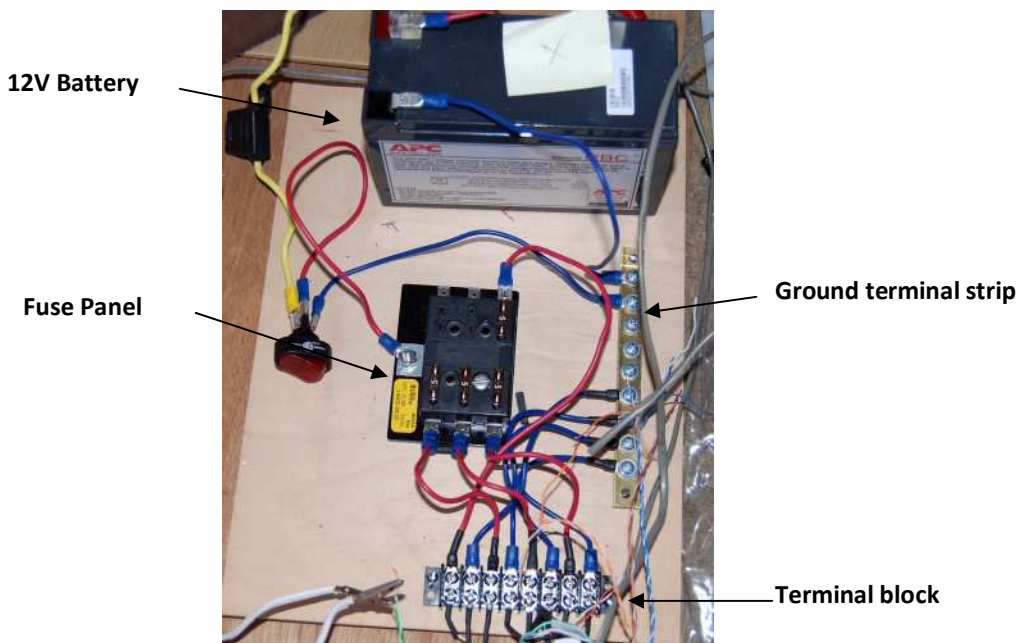


B. Vex Control Sub-System

We used a standard Vex Controller unit to control our speed controllers. This sub-system consists of a programmable Vex controller box powered by a 7.2 V 2000 mAH rechargeable battery. Our remote radio controller unit is coupled to the Vex controller box by a radio frequency receiver device. Our Vex controller box includes six output wire bundles that are each connected to an appropriate speed controller. We selected these connections to correspond to achieve an appropriate motion control response from the joysticks on the remote radio controller unit.

II. Camera/Light Power System

Our Camera/Light Power system is designed to provide power to two color cameras, one black and white camera, and three LED light units. A photograph of our camera/light power circuit is shown below, and a schematic of the main power circuit is shown in Appendix Y.



Camera/Light Power System

We used a second 12 volt, 7.5 AH rechargeable battery to power this system. The positive terminal of the battery is connected through a switch to a Buss ATC fuse panel designed to handle six separate circuits. We used only four circuits for this system, each with a five-amp fuse link. The negative terminal of the battery is tied to a common ground terminal strip.

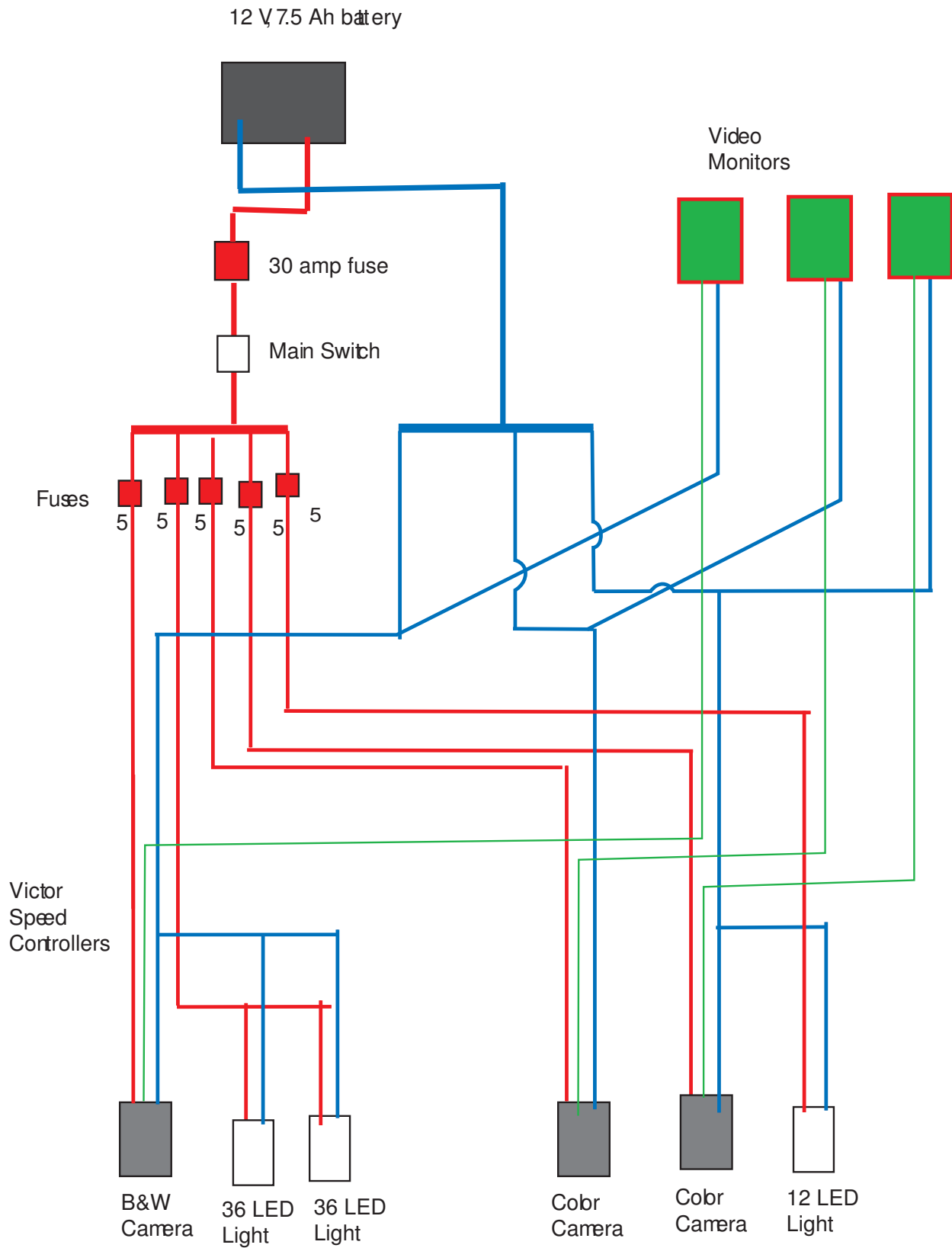
Our black and white camera is configured with two of the LED lights on the front portion of the robot. On the robot, we soldered the negative terminals of both LED lights and the negative terminal of the black and white camera together to a common wire in the tethered wire bundle. The opposite end of this wire in the tether bundle is connected to the common ground terminal strip through a terminal block.

We also soldered the two positive terminals on both LED lights together to a common wire in the tether bundle. The positive terminal on the black and white camera is soldered to a wire in the tether bundle. The opposite end of that wire is connected to another five-amp positive circuit through the terminal block. We also tied the negative wire of this circuit and the signal terminal of the black and white camera to an RCA plug, which we connected to one of our TV monitors.

Both of our color cameras and the third LED light are mounted to the aft portion of the robot. For the first color camera, we soldered the negative terminal of the camera to the negative terminal of the LED light on the robot, and connected the other end of that wire to the common ground terminal strip through the terminal block. The positive terminal of the first color camera is connected to a five-amp positive circuit through the terminal block, and the positive terminal of the LED light is connected to another five-amp positive circuit through the terminal block. The signal terminal on the first color camera and the common negative circuit on the camera and light are tied to another RCA plug, which is connected to another TV monitor.

The positive terminal on the second color camera is connected to its own five-amp positive circuit through the terminal block, and the negative terminal is connected to the common ground terminal strip through the terminal block. The signal terminal on the second color camera and the negative terminal are tied to a third RCA plug, which is connected to another TV monitor.

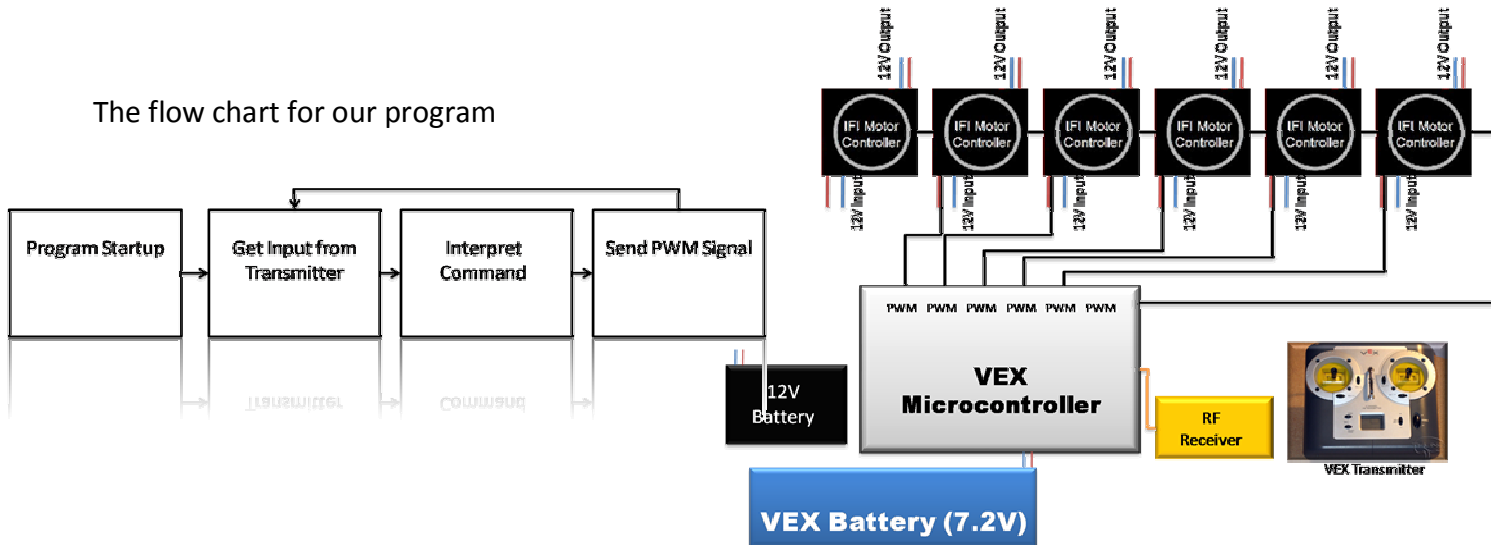
Video Circuit



Vex Controller & Programming

For our ROV, we decided to go the cheaper, although very effective, route of using a VEX control system. The VEX control system consists of a VEX transmitter, a VEX RF receiver, a VEX microcontroller, batteries, and motor controllers. The way our program works is the transmitter first sends a wireless signal at 75.410 MHz using FM waves to the VEX RF receiver. The RF receiver then takes this wireless signal, converts it to a wired one, and sends this by wire to the microcontroller. (Note: If there is interference on this frequency, it is also possible to either change frequencies by swapping out parts or to tether the VEX transmitter to the microcontroller using a telephone handset extension cable.) The VEX microcontroller then interprets this signal as a command. It takes this command and sends a PWM (Pulse Width Modulation) signal out of one of eight motor ports. This signal is received by the motor controller on the other end of the PWM cable. The motor controller then takes a 12-volt input from an external power source and uses the PWM signal to determine how to change the current so that the motor at the output side of the motor controller spins either faster or slower. For example, if the motor controller receives a forward signal, it will send out a positive voltage with an amount of current specified by the PWM signal. If the motor controller receives a neutral signal, it will not send out any output. If it receives a reverse signal, it will send out a negative voltage with an amount of current specified by the PWM signal. This simple and cheaper solution worked very well for the problem we were trying to solve.

The flow chart for our program



The organization chart for our robot control interface

Thrusters & Propellers

When our team first started, we bought the starter kit, which included three 500 GPH bilge pumps and 4.2" airplane propellers, which gave us .7 pounds of thrust each. Two motors were used for horizontal motion while one was used for vertical motion. We purchased two more 500 GPH pumps, one more for vertical motion and one in the center to move laterally.

After a month of problem solving and testing, we concluded that the ROV needed more thrust. We looked at BTD150 thrusters, but bought eight 1000 GPH bilge pumps instead since we thought they might give equivalent thrust for much less money. 1000 GPH motors gave us 2 pounds of thrust, but drew up to 8 Amps with our original propellers. To reduce the current drawn, we cut down the propeller blades so they would push less water. By doing this, the cropped propellers were able to rotate faster and allowed the motor to reach its rated speed. We lost ½ lb. of thrust. Now one motor draws 3.75 Amps, a safe margin from their 5 Amp maximum rating.



Cameras and Lights

For the ROV there are two kinds of cameras. There is a PC303XS micro lens camera and a PC302XS. The PC303XS camera is a color camera. It has a 3.66mm fixed lens with a 90° field of view. Without water proofing it is a 1¼ square. A pair that can be used for stereo visualization are placed on the ROV looking at our claw so that we will be able to pick up the flight recorder and see other things that might catch.

The PC302XS is a black and white camera with a micro lens. It can see in the pool at night with an IR illuminator, we are using clusters of LED lights. This camera is stationed at the front of the ROV because it has a wider field of view. We have noticed that it needs a lot of light to see far away so there are two LED clusters that have 36 LEDs in each. The more light we use with the better resolution the camera seems to get at distances. The PC302XS has 420 bars of resolutions.

Hooks and Arms

Because many of the mission tasks involve returning objects to the surface, we constructed a variety of gripper-like attachments. At first, we turned our attention to retrieving the vials. We experimented with clothes hangers and later metal rods bent into hook-like shapes and zip-tied onto the ROV. These worked fairly well for retrieving the vials, but were very time-consuming. They also required a great deal of manouverability, which our original ROV lacked.

We then worked on retrieving the flight recorder box. We experimented with aluminum strips bent and twisted into hooks. They worked well for pulling the box vertically, but it tended to drift off the hook when we maneuvered or slowed the ROV.

To recover the flight recorder box, we finally created a spring-loaded aluminum hand based on a carabiner. It consists of two aluminum strips bent into "u" shapes, with hinges attached to the wide end. Small pieces of aluminum bent at right angles are fixed to the hinges, allowing them to open one way but not the other. Small springs are fixed to the aluminum pieces, keeping them closed except when something is pushed between them, like the handle of a flight recorder. The advantage of this design is that it requires no power and is simple to use. The pilot simply has to line up whatever they want to attach with the gripper before ramming the object between the aluminum pieces. The disadvantage is once something is in the gripper, it cannot be removed except by an operator on the surface. We have to be careful not to run into things we could get hooked on.



To retrieve the vials, we developed a number of different attachments. The first is a metal rod bent in such a way that the vials can be hooked, but cannot come off easily by themselves. It doubles as our thermistor boom, saving space on our ROV. The second is a sheet of acrylic plastic with a grid of holes drilled in it. These holes contain many plastic weed trimmer whips, melted into hook shapes. This attachment works in a similar way as a large sheet of velcro. The ring on top of the vial becomes entangled with the hooks, allowing it to be removed easily. With luck, the hook assembly can retrieve all the vials at once, saving time and effort.



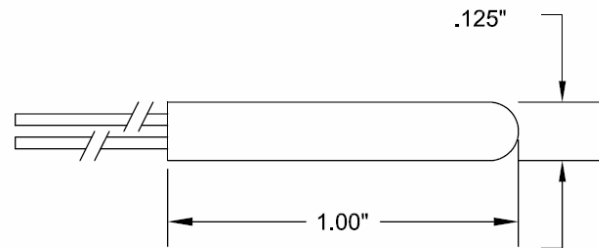
We initially thought we would need to rotate a bolt to open the flight recorder cabinet and spent a little time looking at waterproofing a servo motor that would have a socket wrench head attached. It is not part of the final design.

Temperature

We decided to use a thermistor to measure the temperature because they are accurate,

they work underwater, and they are not very expensive. Thermistors work by measuring the resistance using a multi meter based on the temperature. The multimeter runs on its own 1.5 V AA battery. The temperature is then calculated by taking the resistance and putting it into an equation or using a chart.

The equation is $\Delta R = k\Delta T$; ΔR = change in resistance, ΔT = change in temperature, k = first-order temperature coefficient of resistance



Acknowledgements:

Jon Fishback, Quality Thermistor, Inc., jfishback@qualitythermistor.com

For assisting us in selecting the right thermistors and giving them to us for free.

Depth Measurement

Few initially looked at pressure gauges to measure depth. Inexpensive ones seemed like they would not be accurate enough at the depth of a pool. Expensive accurate ones were out of our price range. We decided to build a motorized measuring tape with one of our left over waterproof Mayfair bilge pump motors. We attached one end of a tape ruler to a fishing bobber and the other to an extension of the motor axial. We added side guides to create a spool. We programmed the motor to run at 1/8 its total power so as to not destroy the gauge and the

measuring tape. In tests the float pulls with enough force to rotate the motor when it is not powered. We added a screw adjustable brake to create a little extra resistance to keep that from happening. In order to get a clear measurement of the depth we attached a 15ft section of measuring tape with the 0inch marker at top so as the motor turns it unravels the tape with the measurement in inches and feet of how far down the aircraft is being shown in front of our front camera.

Hydrophone

Essentially, the hydrophone uses a microphone to receive sound vibrations in the water, then convert the sound the electrical signals that are transmitted to the controllers. However, it is more complicated than that. There is the problem of waterproofing. The microphone is waterproof in a balloon that is stretched over the end short piece of PVC pipe filled with spray insulation foam. This swelled up to block any cavities. The thin wall of the balloon conducts the passage of sound waves much more than the PVC would. Inside the microphone, a very small metal diaphragm warps due to air pressure, changing the shape of a coil of wire attached to it. Because of electromagnetics, this increases the amount of current that comes from the microphone. The computer can now convert this to sound. The current microphone can pick up sounds from 100 to 100,000 khz.

Buoyancy

One of the main problems we encountered when building our ROV was keeping it neutrally buoyant. This was important because if the ROV was too positively buoyant or “floaty,” it will float up, bob, and be difficult to maneuver downward; if it was too negatively buoyant or heavy, then the ROV would sink and it would be difficult to bring it to the surface. To keep neutrally buoyant, Floyd has an extensive weight system. There are four ‘ballasts’ at the top of the ROV made out of PVC pipe and caps which prevent water from entering the pipe.

These pipes are 18 inches long and two inches in diameter, which leads to about 226 cubic inches of water displacement of all four pipes combined. Also, at the bottom, there are two iron bars, each adding two pounds of weight to the ROV.

At each corner of the ROV is a metal clip holding medium sized half-ounce washers. Depending on the temperature, water changes density, and the ROV could get more buoyant or heavier in that water. As a solution, we are going to add or subtract washers as needed.

The tether is made neutrally buoyant by means of two inch by one inch by one inch Styrofoam blocks taped with electrical tape to the tether.

Expenditures

Expenses of Lloyd				
Item	Quantity	Cost	Total Cost	Other
TV	2	19.99	38.98	
Black Tape	1	5.93	5.93	
12 V batteries	2	29.87	29.87	
12 V charger	1	24.88	24.88	
Zip Ties	1	3.19	3.19	
PK 6 Phono Plugs	3	4.32	4.32	
1000 GPH motors	8	171.5	171.50	
Nuts and Bolts		7.81	7.81	
Wire		6.99	6.99	
Wire connectors		2.49	2.49	
Brass Strip	1	12.49	12.49	
More Nuts and Bolts		12.28	12.28	
Propeller Adapters	9	4.50	40.50	
Propellers	9	2.00	18.00	
Camera	1	84.20	84.20	
500 GPH motor	1	68.95	68.95	
16 gauge speaker wire	6	18.04	108.25	
LED lights	2	25.00	50.00	
Speaker wires	6	72.53	72.53	
Fuse	1	9.00	9.00	
6-Fuse Terminal Panels	2	5.00	10.00	
Main On/Off Switches	2	3.00	6.00	
Main Fuse Holders	2	4.00	8.00	
Aluminum Strips	4	4.20	16.80	
Aluminum Frame	1	30.00	30.00	
PVC Piping		40.00	40.00	
Hinges	2	5.00	5.00	
Speed Controllers, Breakers, PWM	6	125.0	750.00	
Misc. (washers, fasteners, other small bits)	many	250.0	250.00	
			Total:	
			1,887.96	