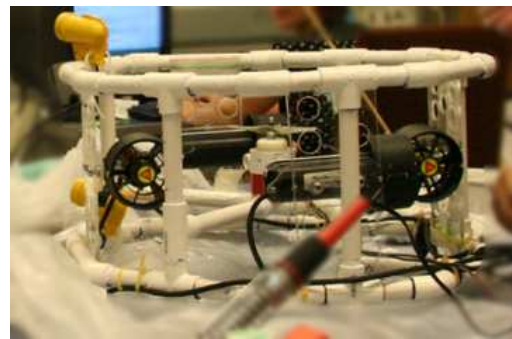
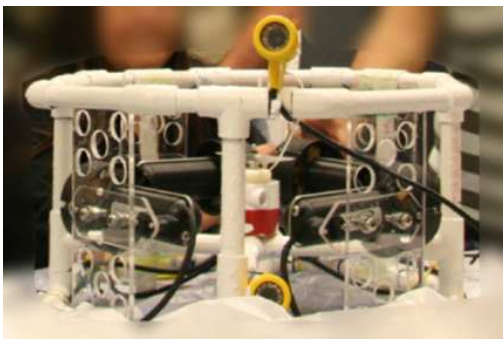


ASU-WISE

Arizona State University
Women in Applied Science and Engineering
Remotely Operated Vehicle Team



Team Members:

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WISE Staff:

Shawna Fletcher-Carey

Mentors:

Anna Haywood, Brandon Hunt, Fredi Lejvardi

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Abstract

The ASU WISE ROV Team is competing in the National Underwater Robotics Challenge (NURC) for the first time. There are eight women on the team from various academic disciplines and backgrounds. None of the team members had experience with this type of project however, we have worked to build a remote operated vehicle that is able to move easily through each aquatic environment and maneuver accurately during each mission. The ROV named A.U.R.O.R.A., which stands for ASU Underwater Remote Operated Robot in Action, is designed for accuracy, maneuverability, and simplified transport. The design is centered around a light weight PVC frame and perforated (circular) plexi glass motor mounts that were built to decrease drag forces and enhance laminar flow. Off- board power (12V battery) was used in order to assure that power requirements were met and not exceeded. Three cameras are mounted in various positions including, the front, side, and the bottom. This gives a wide range of perspective for locating objects and completing various tasks. Team members decided that three cameras were optimal for the NURC Competition and all three are mounted with adjustable clamps for individual mission tasks. Other design aspects discussed in the report include ballast system, thrusters, electrical wiring, and programming. A.U.R.O.R.A. was a challenging, innovative project that showed our team's hard work and best efforts to build our very first ROV



*not pictured: Ramune Auzelyte

I. Design Rationale

The design of A.U.R.O.R.A. evolved many times. Our final design came to life after we officially decided on an off-board power system. Knowing that A.U.R.O.R.A. would only need to have her motors, cameras, lights and arm on board, the design became smaller, and more compact. The use of PVC piping for our frame was based on both the properties and cost of PVC. PVC is inexpensive, easy to maintain, has a high tensile strength, and a low minimum temperature. It is available from local shops, therefore giving us the freedom to change the design multiple times on short notice before settling on the final shape of A.U.R.O.R.A. As shown in the figure to the top right. Sketches were done in Solid Work by Anna Haywood and then revised by Ramune Azuelyte. We placed our motors in a kite shape to give our robot more stability in the water. Another advantage of this design is that it gives us greater handling in water with rough conditions, such as currents and waves. With this set up, the sum of our vectors, when all of our motors are on, gives us a forward motion; but if some motors are turned off, or reversed, the robot is capable of making a circle, or moving diagonal. We see this as a competitive advantage, making A.U.R.O.R.A. less cumbersome. The resulting octagon shape resembles a turtle, something we had wanted to do from the beginning. The plexiglass the motors are mounted in is drilled with holes for less surface area; and therefore, less water resistance.

Control System

We used a VEX Control System to coordinate the flow of information and power of A.U.R.O.R.A. All components run through the VEX Micro Controller, which is powered by a 7.2 Volt battery. The transmitter (*see Figure 1a) which will control robotic movement is plugged into the control system in a RX1 port using a telephone cord (*see Figure 1b). Each speed controller is attached to the control system by male to male PWM cables and is wired to a 12 Volt battery for power. Our team used Victor speed controllers that individually have a 40 Amp capacity, low voltage drop, and peak surge capacity capable of making ideal drive systems. There are five speed controllers for 4 Seabotix motors and 1 bilge motor for vertical movement. In order to control the motors utilizing the Micro Controller, we used a laptop to program the control system using Easy C software.

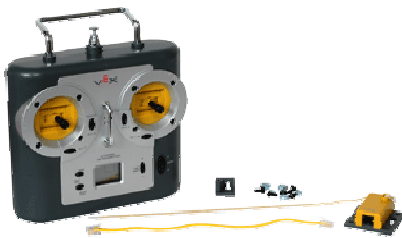


Figure #1a: VEX Transmitter



Figure #1b: VEX Micro Controller

Situated on the VEX Micro Controller, there are four ports for the motors: port 1 is assigned to motor #3, port 2 is assigned to motor #4, port 3 is assigned to motor #2 and port 4 is assigned to motor #1. Each motor is labeled in a clockwise direction, starting from the front, left side. The

programming assigns each ports on the control system to allow motor operation. The VEX control system is run by a program called Easy C, which is similar to C or C++. The VEX control system comes with a default program, which is capable of running up to eight motors from the VEX Micro Controller motor ports. In order to run the default code, the Micro Controller was connected to a laptop via a USB cable. Programming code was accessed from the Build & Download menu by choosing Download Default Code. The default code program is initiated when the Micro Controller is turned on. It looks for input from the motors that are connected to the VEX Control System. After detecting all four motors, individually attached to speed controllers, the program initiates spinning of the propellers in each thruster. For example, the motors are programmed to keep running until the joystick assigned to that particular motor tells the motor to stop. The bilge motor, cameras, and robotic arm are not attached to the VEX Control System. Instead, they are attached directly to 12 Volt D.C. battery source. The arm is designated to operate through using a control switch. The cameras are independently operating via direct attachment to a 10V D.C. battery source.

Maneuverability was accomplished through programming the transmitter. The transmitter includes two joysticks that are programmed to operate the ROV in numerous directions. The left joystick on the transmitter controls vertical and horizontal motion, depending upon the combination of motors #1 and #2. Moving the joystick #1 (situated on the left) along the horizontal axis, moves motor #1 clockwise or counterclockwise, depending upon the left or right directional placement. Moving joystick #1 vertically moves motor #2 clockwise or counterclockwise, depending upon the up or down directional placement. Joystick #2 (situated on the right) controls motors #3 and #4 in a similar fashion. Used in different combinations, the ROV is able to rotate forwards, backwards, and accomplish a 360° rotational movement.

Robotic Arm

The design and execution of the arm was a roller coaster. Due to time constraints the original arm design was abandoned and a three jaw grabber from Seabotix was chosen. Brandon Hunt at PADT was a major help on sketching and construction the arm. This grabber was chosen due to its water tightness and its ability to handle the temperature changes it would encounter while underwater. The arm has a two pin interface which consists of power, a common interface, and the three jaw grabber which has a gripping force of 6.5kgf using a motor with a voltage of 24VDC. It is made of anodized aluminum and stainless steel. The three jaw grabber weighs 500 grams and is 360mm long. A linear actuator in the arm opens and closes the jaw by means of a lead screw. Once the jaw has been opened, the polarity is reversed to close it. The reversal of the polarity is completed by means of a double switch that is connected to the power and common interface. One switch is used to open the jaw and, once open, the remaining switch is used to close the jaw. The three jaw grabber was attached to the front of the ROV using two connection points made out of ABS, which is thermoplastic. Once the arm was attached a counter weight was placed on the back of the ROV to prevent tipping due to unequal loading.



Figure #2: Original robotic arm design
*assisted by: Brandon Hunt, PADT

Ballast System

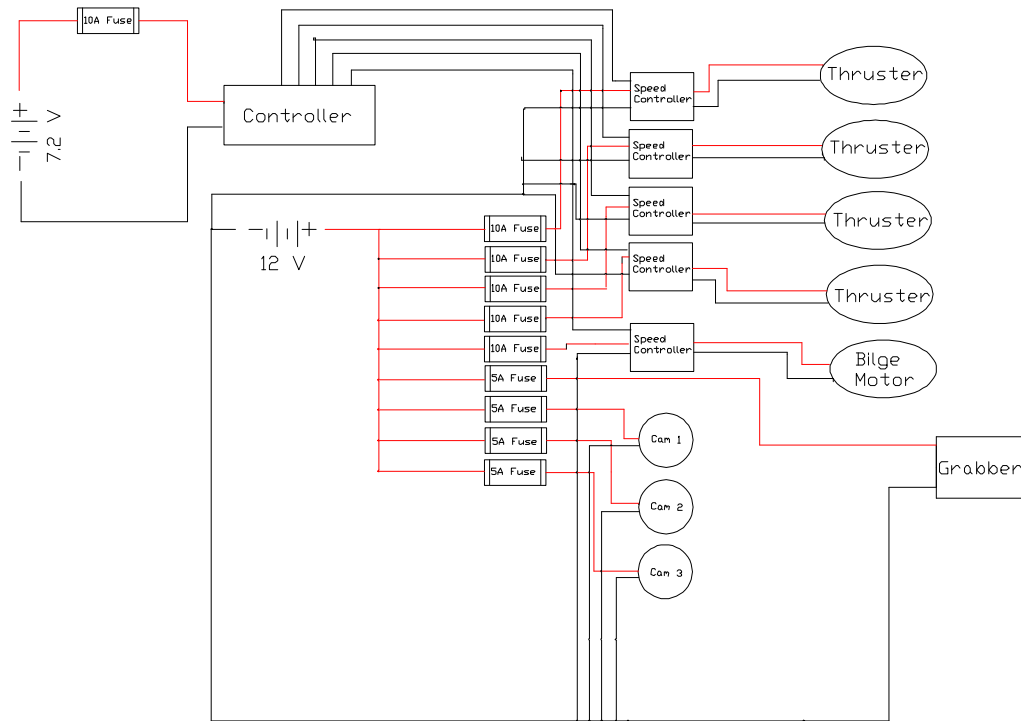
Throughout the course of the project, the overall design of the robot evolved. In accommodating each new design idea, the ballast system also evolved and has been considered to be one of the most important design aspects. Initially, air bladders attached to the ROV were considered however, several issues arose in trying to inflate each bladder and bring the ROV to the surface. Another system that was considered and eventually implemented was utilizing air already present in the PVC frame when sealed. Air present in the PVC helps to regulate buoyancy to create a positive effect on the ROV. Counterweights are added to balance the ROV and ensure neutrally buoyant conditions. Lightweight foam blocks are attached to the frame in various locations to also balance the weight of the ROV and its components. A centralized bilge motor was mounted to the frame to control both ascending and descending directional control as well as to assist with neutral buoyancy. This ballast system was determined to be optimal for the finalized ROV design and was the most simplistic for our purposes. Lead shot was considered as a backup system to counterweight or to control any positive effects from individual aquatic environments. This extra weight can be added by pouring lead shot into the bottom portion of the PVC frame before it is sealed.

Cameras

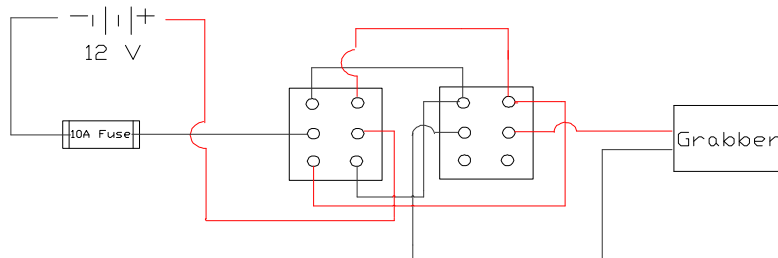
Individual underwater cameras were purchased as a set with monitors, 10V batteries, and cables. These cameras transmit black and white images and have led lights situated around the facing. Since the cameras were already watertight, we did not have to face leakage or malfunction issues. Each camera monitor has input and output connectors on the back side. Two cameras can be connected to one monitor through the ports and each camera image can be switched to be viewed on a single monitor. This give ease in viewing from different perspectives from a single monitor. This was an advantage on several occasions when testing, due to the unavailability of batteries. Each camera was attached by hinges to allow viewing from multiple angles. Advantages include viewing objects located in front and give depth perception. That way, better viewing was achieved for peripheral objects located in blind spots.

II. Schematics

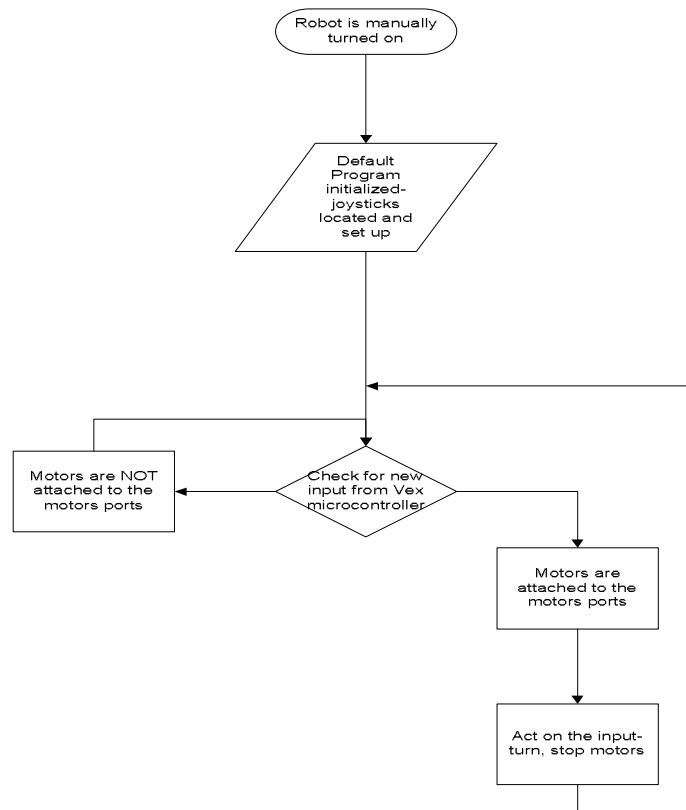
Electrical Component Diagram



Robotic Arm Switch



Programming Flow-Chart



III. Troubleshooting and Challenges

Troubleshooting has been a concern throughout the entire building process. In order to avoid complex problems after the ROV was completed, individual components were tested for functionality before assembly. Preventative measures were taken by connecting fuses to prevent destruction of the motors and robotic arm. When problems were narrowed to a particular component, it was further analyzed. The typical troubleshooting procedure consisted of checking for loose wires and using a multi-meter to test each connection, assuring the correct amount of voltage is reaching the component. Each connection of the particular troublesome component was tested and analyzed until the problem was realized and a solution was implemented.

One challenge that was faced throughout the project was communication. Trying to organize schedules for eight team members was difficult however, we overcame these challenges through setting individual team meetings and regular times/days. Email was the main communication medium that everyone was able to keep in contact, even through everyone was involved in rigorous academic and personal activities. Project delegation was a challenge due to the inexperience of the team members and foresight for certain issues that did arise. Group decisions were made through a course of action that included voting and executive decision-making.

IV. Skills Gained

From the beginning of this project, there were multiple problems that required creative solutions. Through this, we have gained many skills. The team is now better acquainted with electrical components and soldering. We understand how important it is to make sure that all wiring is water proofed and connected to the right components. We learned to program and operate a VEX Control System and how to use it to maneuver A.U.R.O.R.A. Through this process, we were able to network with industry and had resources from several professional engineers including, Anna Haywood (PADT), Brandon Hunt (PADT), other PADT engineers, and Fredi Lejvardi from Carl Hayden High School. They have been very generous with helping us through our challenges and guiding our progress. We are grateful to have such a support system to complete this project. The most important skill learned was to understand the value of working in a team. Unlike class group projects, where students depend upon a grade, this project has allowed for an intrinsic motivation from each member to complete and participate in this endeavor. Each team member possessed certain strengths and we were able to overcome obstacles that were faced when team issues arose. This experience not only aided us in understanding how teams may work in industry, it also helped to better prepare team members for working on future projects together and as professional engineers.

V. Expenditures

WISE ROV Budget

Spring 2007

Industry Funding

Intel	\$5,000
ATK	\$3,000
WISE/Fulton	\$1,000
PADT (in-kind donation)	\$2,500
Adventure Hobbies (in-kind)	\$146
Soroptimist International, Phx.	\$12,000

Total Funding Support \$23,646.00

ROV Expenses (as of 4/17/07)

Date	Business	Items	Cost
11/16/2006	Hammer Schlemmer	RF Shark	\$136.85
11/29/2006	ASU Bookstore	Batteries, etc..	\$21.05
12/14/2006	Harbor Freight Tools	Underwater Cameras x3 w/ warranty	\$384.24
12/19/2006	Tres Aquas	dive light	\$37.84
12/22/2006	Cabela's	4 Bilge-pump Motors	\$101.71
12/31/2006	Si Se Puede	Competition Fees NURC	\$500.00
1/3/2007	Home Depot	PVC pipe, Epoxy, Tape, Adapter	\$50.09
2/22/2007	Seabotix	Thrusters	\$1,570.00
2/28/2007	Home Depot	Supplies - cement block rubber coating	\$16.17
2/28/2007	Innovation First, Inc.	VEX Controller	\$258.74
3/9/2007	Nventivity	Instruction Manual	\$57.95

3/13/2007	Home Depot	PVC;hooks;3Xdual sPG	\$13.63
3/13/2007	Petco	Aquatic Net	\$5.39
3/13/2007	WHAT SHE BUYS.com		\$7.99
3/15/2007	Lowe's		\$0.48
3/26/2007	Innovation First, Inc.	Y Cable, Transmitter, Battery Pack, etc..	\$534.05
3/31/2007	Radioshack	7.2V battery	\$27.01
4/4/2007	El Mar Diving Center	Pelican box	\$110.15
4/4/2007	Ace Hardware	plexiglass;epoxy;silicone grease;elbows;tee;etc...	\$55.33
4/4/2007	Radioshack	video cables; rca connector	\$67.00
4/4/2007	Ace Hardware	fasteners;epoxy, etc..	\$18.36
4/5/2007	Hobby Bench		\$12.49
4/13/2007	ACE Hardware	pvc; adapters; elbows, etc.	\$28.73
4/14/2007	ACE Hardware	misc. item	\$2.00
4/15/2007	ACE Hardware	plug; tee; etc.	\$8.62
4/16/2007	Home Depot	pvc, level; 1/2 pvc, etc..	\$11.27
4/30/2007	Blimpies		\$46.48
4/29/2007	Checker Auto Parts	fuses	\$33.36
4/29/2007	Radioshack	led lights	\$25.77
4/27/2007	Home Depot	gauge pliers & plasti coat spray scotchcast & self-vulcanizing	\$14.47
4/28/2007	Lights, Camera, Action	tape	\$52.25
4/27/2007	Innovation First, Inc.	speed controls	\$263.42
5/9/2007	Bookstore	supplies	\$11.79
4/17/2007	Security Camera		\$56.21
4/27/2007	Waytek Wire		\$18.51
5/15/2007	Fry's	wire	\$32.43
5/4/2007	Home Depot	tubing supplies	\$5.80
5/9/2007	Lowe's	paint & supplies	\$12.68
5/16/2007	Grainger	camera part	\$5.62
5/17/2007	Staples	Fulton Shirts	\$314.81
5/19/2007	Fry's		\$15.12
Total Cost			\$4,945.86

WISE ROV Donated Items - Adventure Hobbies

Item	Cost		
12 V Battery			
Charger		10.95	\$10.95
Servo Motor	13.97 (x2)		\$27.94
Propeller 4.75 x 5.5	2.13 (x2)		\$4.26
Propeller 4.75 x 5.25	2.13 (x3)		\$6.39
Epoxy		6.99	\$6.99
RC Airplane Beacon	2.95 (x6)		\$17.70
Nite Brite Lights		3.95	\$3.95
MP Jet Adapters	6.99 (x4)		\$27.96
12 V 7Ah Battery	19.??		\$20.00
Ballast System			
Bouancy Items	???		\$20.00
Total (in-kind)			\$146.14

VI. Acknowledgements

Soroptimist International, Phoenix

Robyn Romano, member

Stacey Haggart, member

Phoenix Analysis & Design Technologies (PADT)

Eric Miller, principal director

Rey Chu, director and engineer

Brandon Hunt, engineer

Anna Haywood, engineer

INTEL Corporation, Inc.

Alliant Techsystems, Inc. (ATK)

Shawna Johnson, HR Manager

Scott, owner, Adventure Hobbies

Karen Suhm, owner and engineer, Inventivity

ASU WISE Program

Fredi Lejvardi & Allan Cameron, educators, Carl Hayden High School

Terry Carey, Tres Aquas Adventures

Fred Pena, ASU Chemical Lab Manager

Dierde Meldrum, Dean, Ira A. Fulton School of Engineering