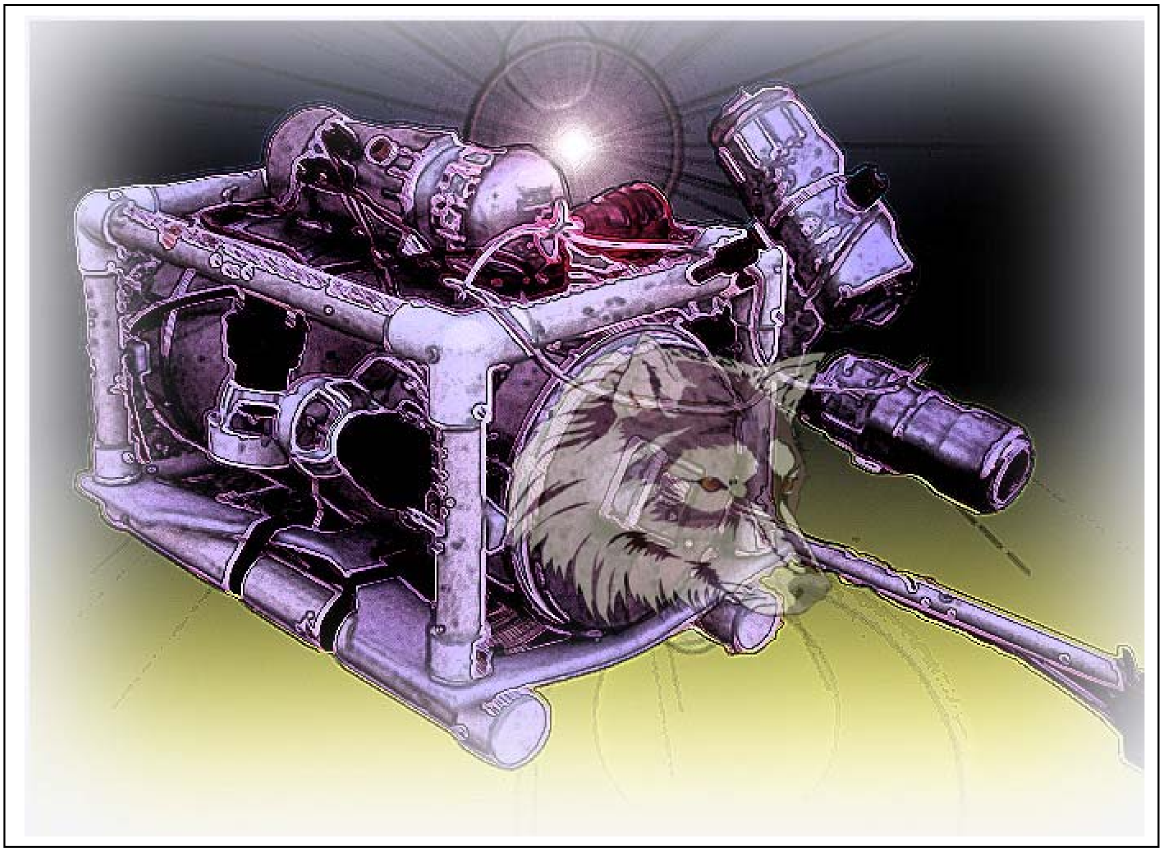
TECHNICAL REPORT
SEAWOLF ROV



Submitted by the

Lochiel U-Connect ROV Team

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Submitted to the Marine Advanced Technology Education Center

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Abstract

Essential information concerning the Remote Operated Vehicle (ROV), the *Seawolf*, can be found in this technical report. The ROV was designed and built by the robotics team of Lochiel U-Connect, an alternate education program for home learners in Langley, British Columbia, Canada.

The ROV has been specifically designed to participate in the Marine Advanced Technology Education Center (MATE) 2005 ROV Design Competition. The primary objective of the *Seawolf* is to complete the three Ranger mission objectives within a cumulative time of 15 minutes. The ROV is equipped with a laptop computer activated topside control system that communicates with the *Seawolf* using 802.11 wireless technology, running two specialized mission tools, five thrusters and two Logitech USB cameras.

Some of the design innovations of the *Seawolf* include the following:

- tetherless communication system between a poolside laptop computer and a floating antenna.
- a software controlled switching system between the front and horizontal mounted cameras.
- a control system and optics that are activated by a laptop keyboard, which allow for rapid and accurate changes in vehicle positioning.
- a Microsoft Access controlled keyboard-to-motor mapping system that allows any combination of motors to be triggered by specific hotkeys. This feature allows us to use the five thrusters in a wide variety of directional configurations.

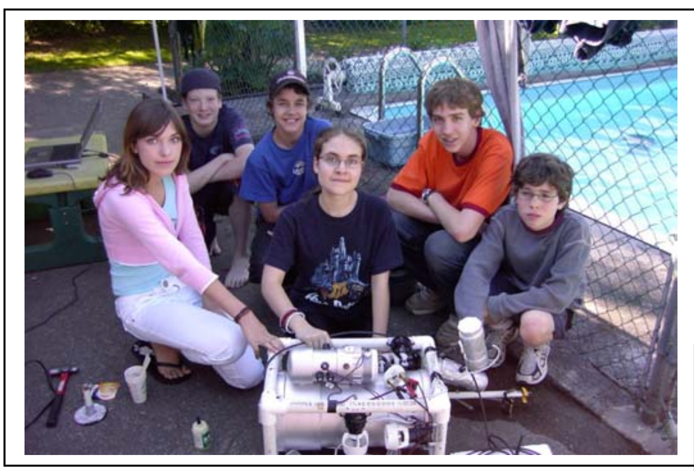
This technical paper will also not only discuss the design rationale for the *Seawolf*, and specific design challenges, but will also give an overview of the technology used for the Hubble Space Telescope's cameras.

Acknowledgements

The Lochiel U-Connect *ROV team* would like to express their gratitude to the many people, companies, and organizations that have been supportive in this ROV project. We acknowledge their assistance in making the *Murdoch* a reality:

- Jim English, Peter Helland, OceanWorks
- Allan Sanders, SMI Industrial Electronics
- International Submarine Engineering
- Master Airscrew, Dumas, RP Plastics, Pacific Fasteners, Rona, Home Depot
- Harry Bohm (the mentor's mentor), WET Technologies
- Jill Zande, Marine Advanced Technology Education Center (MATE)
- Jean-Yves Rochon, Industry Canada School Net
- Ron Hurtig,
- Our incredible parents
- Beckie-Anne and Sarah Thain
- Barry Friesen and Kelly Klassen at Friesen Electric

We also thank Peter Thain, our mentor, who has been afflicted with the "disease" of infinite patience and generosity



"Our Team"

From left to right: Braden Janson, Chris Friesen, Garrett Wutzke, Josh Stephenson, Caleb Ward,
Lisa Woykin, Jadon Dick, Meredith Franger.

Description of ROV

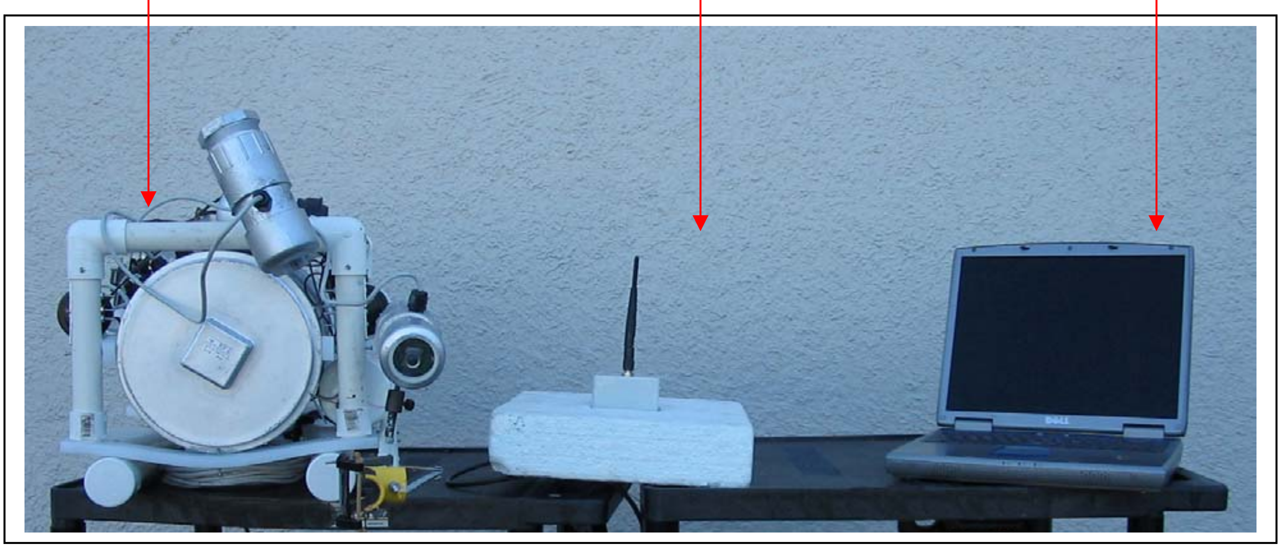
The ROV, *Seawolf,* is 55 CM X 42 CM X 42 cm wide. The polypropylene (PP) base supports a superstructure made from 2.6 cm polyvinylchloride (PVC) pipe. A large 20 cm X 51 cm PVC pipe not only acts as a termination can to house the P4 processor, the networking components, three sealed 12 volt gel cell batteries and USB interfaces, but also acts as a floatation device to maximize the differential between a lower center of gravity and a higher buoyancy center for greater operational stability. Two thrusters in a dual configuration move the ROV on the XZ planes. Two vertical (Y axis) thrusters are mounted midway on either side and one thruster, mounted at the front is used for tracking the ROV sideways. The ROV possesses a dry weight of 23 KG and is ballasted for neutral buoyancy in pool water. The "tool bay" is located at the front bottom left of the ROV where one of two tools can be attached. The *Seawolf* is connected by RG-174U coaxial cable to a floating antenna which transmits and receives wireless signals to a poolside laptop.

"No Strings Attached"

1. Laptop controller sends 802.11 wireless signal to floating antenna

2. Floating antenna relays data to onboard computer.

3. USB relay devices connected to submerged computer to activate thrusters, cameras and control arm.



1. Frame

We used 2.5 cm PVC pipe for the top, horizontal and vertical cross members of the ROV frame. PVC joints, rustproof galvanized steel set screws, four trim posts and two aluminum camera mounts are also included in the frame. The sheet PP base provides stability and tool support. Two 2.5 cm tubes are screwed underneath the pp base and are filled with 10 - 100 gram metal objects for fine tuning buoyancy.

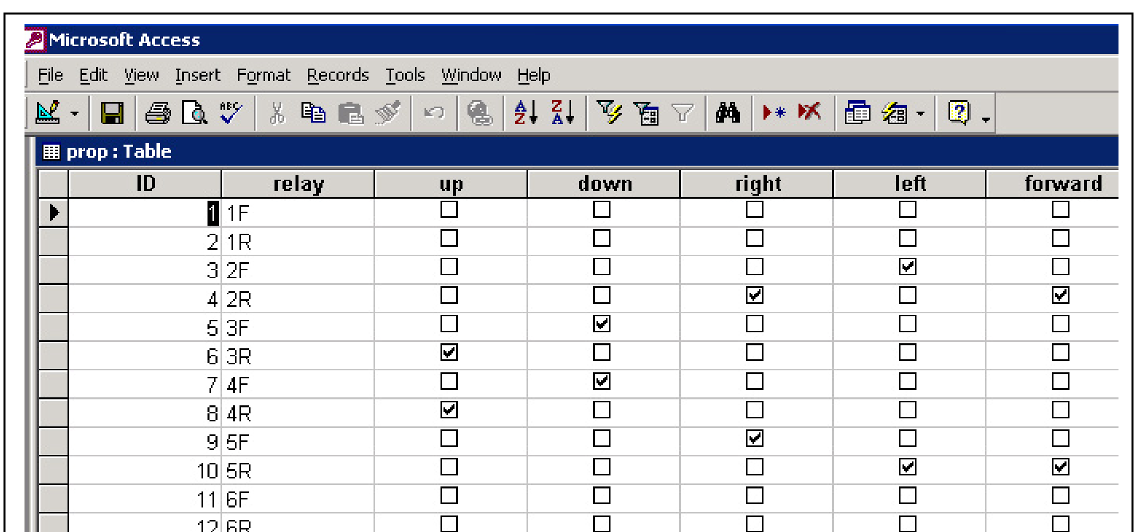
2. Control System

The first step in the control system is a Visual Basic executable written to control five motors and one or two servo connections. Control telemetry is activated by keyboard control and is generated by a D-Link DWL-G132 Wireless USB Adapter. Powered by D-Link 108G Technology, this 802.11g compatible device is capable of delivering maximum wireless signal rates of up to 108Mbps. The D-Link transmitter provides input to the onboard CPU - a 1GHZ VIA Eden-N Nehemiah with 512 MB Ram . The signal is then routed out through USB connected devices; a NAIS 5 amp relay for the motors and a Friesen electric dedicated servo controller.

Control instructions are mapped to the poolside laptop keyboard, with separate keys controlling bidirectional movements on the XYZ planes as well as fast and slow speeds.

3. Video Cameras & Monitors

The *Seawolf* is equipped with two Logitech Pro 4000 wide angle color video cameras that have been made submersible by placing them in 17 cm X 5 cm PVC tubes with a clear lens at one end and a threaded PVC end cap at the other end for easier access. The top camera is mounted on the top front of the frame to provide clear unobstructed views for navigation and tool use. A second bottom camera is mounted horizontally on the control arm for a close view of the tool bay. Video telemetry is monitored through the poolside laptop monitor's graphics as 802.11 data is transmitted by a D-Link DWL-G132 Wireless USB Adapter.



ID	relay	up	down	right	left	forward
1	1F	☐	☐	☐	☐	☐
2	1R	☐	☐	☐	☐	☐
3	2F	☐	☐	☐	☑	☐
4	2R	☐	☐	☑	☐	☑
5	3F	☐	☑	☐	☐	☐
6	3R	☑	☐	☐	☐	☐
7	4F	☐	☑	☐	☐	☐
8	4R	☑	☐	☐	☐	☐
9	5F	☐	☐	☑	☐	☐
10	5R	☐	☐	☐	☑	☑
11	6F	☐	☐	☐	☐	☐
12	6R	☐	☐	☐	☐	☐

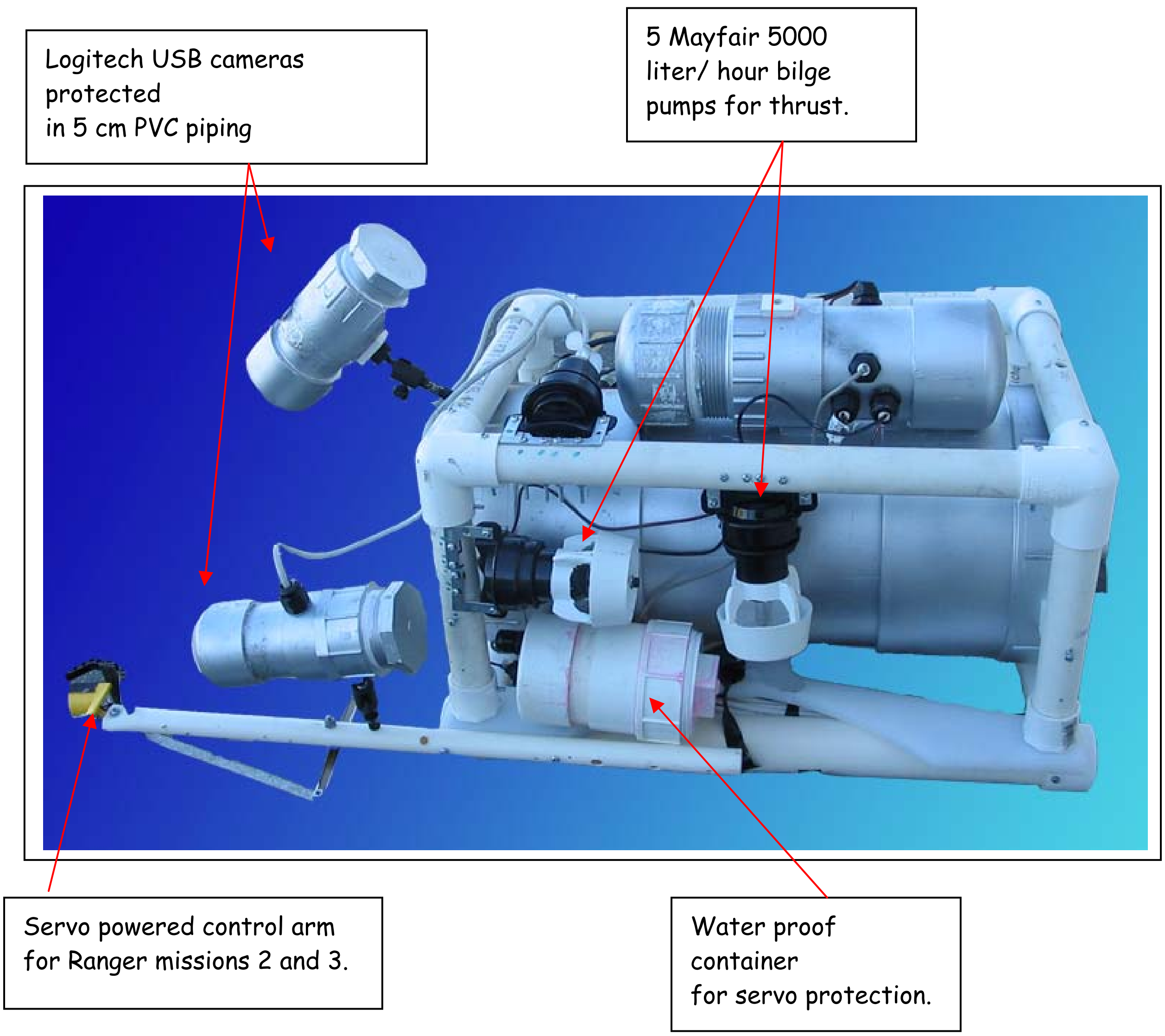
Customizable Motor Assignment Interface

4. Retrieval Mechanisms

The ROV is equipped with one powered "grabber" tool and one non-powered "push" tool for performing the different underwater tasks.

The *Grabber* is made from 1.3 cm PVC with a plastic and steel claw attached to the front end that rotates on one pivot point. It is 30 cm long and is slightly negatively buoyant. The claw is tightened and loosened by a servo that is installed in 7.5 cm X 15 cm threaded PVC for waterproofing. The controlling wire penetrates the PVC through an adjustable rubber boot. The claw is activated through a Visual Basic interface operating though D-Link 802.11 transmission devices and is opened and closed by adjusting a software slider bar with the poolside laptop's mouse. It is attached to the bottom left side of the frame for easy attachment, adjustment and removal.

The non-powered "push" tool is made from plastic and has a "C" shaped mouth which will capture and push the "valve bar" for the first mission. It is slightly negatively buoyant and is easily attached to and removed from the "grabber" with two 3.5 mm bolts.



5. Thrusters

The *Seawolf* uses 5 thrusters fabricated from Mayfair bilge pumps with a discharge capacity of 5000 litres per hour (LPH), Master Airscrew prop adaptors, machined for greater efficiency, and 3.8 cm Dumas props. The kort nozzles were fabricated from 6.3/4 cm PVC adaptors. The thrusters are attached to the frame with 6 cm L clamps to allow for 90 degree vector adjustment. The thrusters are 12 volt motors and have a 4.5 current draw with a 6 amp spike.

Design Rationale

The ROV was designed and built within the following constraints:

- ➔ The 2005 MATE ROV Competition rules
- ➔ Able to fulfill the three mission tasks
- ➔ Able to fit through into competition size restrictions
- ➔ A maximum DC voltage of 13.5 volts
- ➔ A time budget of 7 months and a overall construction budget of
- ➔ Diving capability of 5 m without leaking or imploding

1. Frame

The first iteration of the *Seawolf's* frame design called for a length and width of approximately 0.8 cm. The major factor that necessitated this larger size was the substantial dimensions of a termination can that must house 3 12 volt gel cells for the power supply as well as the Pentium 4 processor and the various USB relay devices. However, the competition constraints necessitated a size reduction for the craft to a width of under 0.6 m. In the end we were able to reduce the size to our current size of 53 cm X 40 cm X 40 cm by using smaller components and by the realization that compressing the control into a smaller area would not cause excessive heating. We considered using a transparent lexan frame, but found that this material's extra weight would make it more difficult to stretch the distance between a lower center of gravity and higher buoyancy center, thus imperiling the craft's stability. Also, as the initial estimates for the size of the termination can varied widely, it was important to choose materials that would be relatively simple to modify, with PVC proving more flexible to resize than lexan. In the final analysis, the design was inspired by the competition constraints and by both our own ideas and several other ROV's we researched on the Internet. Upon completion, we have found that its relatively simple, yet sturdy design – fabricated mainly from of 2.5 cm PVC piping - is robust and responsive.

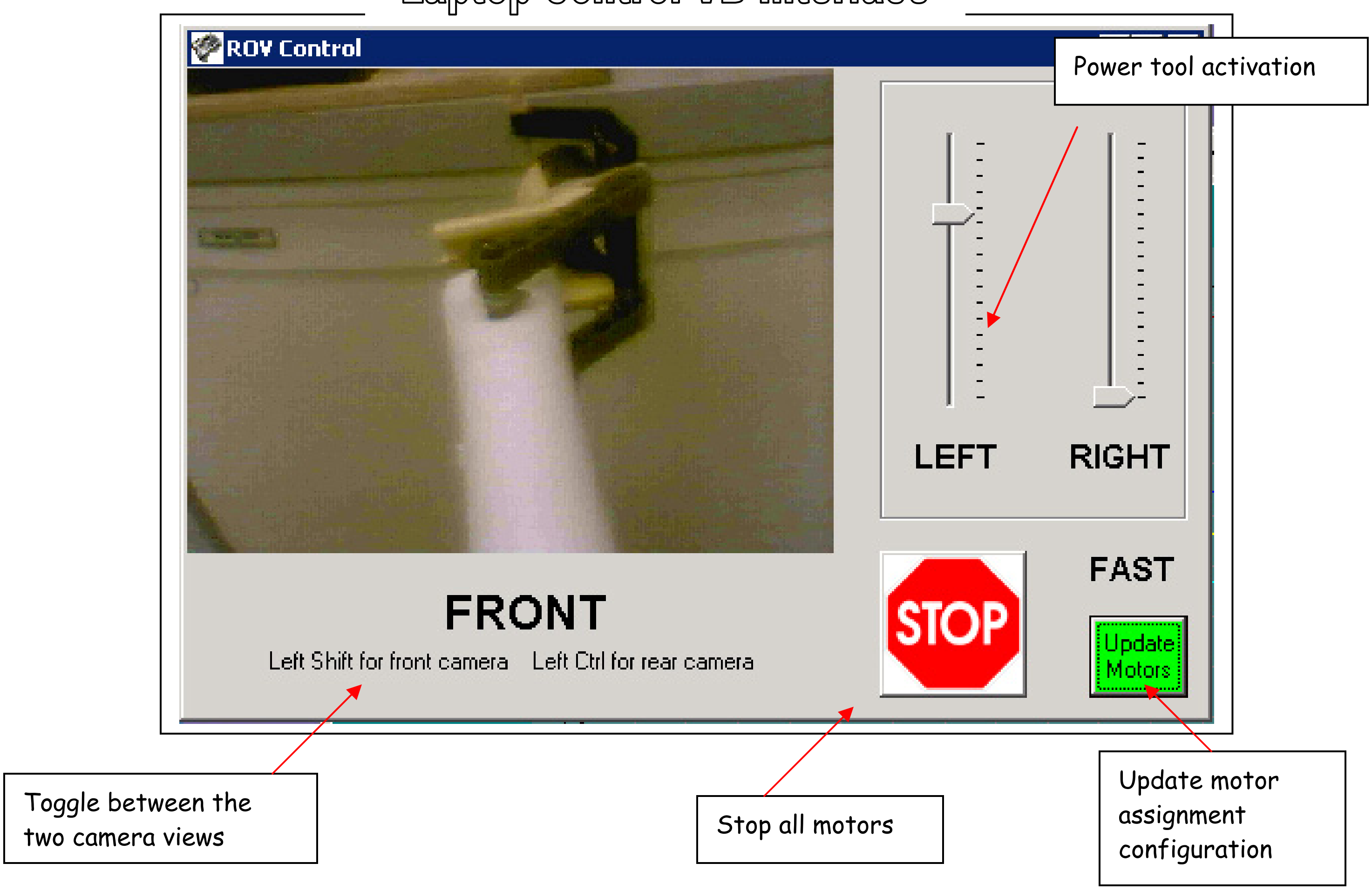
2. Control System

For the control system we considered the strengths and limitations of three basic options:

a. DPDT Switches
b. RC radio control systems
c. PC interface

DPDT switching has the advantages of being affordable and relatively simple to implement but it could not accommodate our objective to include wireless components to eliminate the need for a direct tether connection from the ROV to the poolside. Early in the planning process, we decided that a wireless control system feeding telemetry to a floating antenna could more efficiently facilitate the mission objectives. For example, thin coaxial cable attached vertically to a floating antenna would be less likely to tangle with submerged objects than a much thicker tether protruding at a wide variety of angles. Also, while a radio control system could facilitate our objective to eliminate the tether, our research suggested that a PC interface not only allows the collection of wider ranges of data through many commercial sensors created for the ubiquitous PC market, but that it also allows for faster data transfer speeds which are crucial for the instantaneous uploading of video information.

"Laptop Control VB Interface"



Once we chose a PC based wireless control system, the next major decision involved the choice of the most effective wireless protocol and hardware. Four widely used options include IEEE 802.11, IrDA, Bluetooth and HomeRF. Both the 802.11 and the HomeRF both have the furthest range of the four options. While the IrDa has the lowest cost, the 802.11 and the HomeRF are not substantially more expensive and they are both compatible TCP/IP data network support. However, we ended up choosing the 802.11 system for not only because it scored well on the above criterion, but also because it has the best peak data rate of the four. Wide bandwidth data transfer is crucial for the effective streaming of the *Seawolf's* two Logitech USB cameras, and thus 802.11 was the logical choice.

The hardware we chose to send and receive the 802.11 signals was the D-LINK AirPlus Xtreme GDWL – G132. We selected this solution because these networking components can are capable of delivering maximum wireless signal rates of up to 108Mbps when connected to other D-Link AirPlus Xtreme G products. Also, the DWL-G132 USB Adapter is a convenient as it is portable - only 2 cm x 6 cm x 1 cm in size – and easily fits into the USB port of our PC control laptop. These attributes naturally mesh with the competition's required rapid poolside setup and mission deployment. Furthermore, our testing demonstrated that the DWL-G132 can be effectively used in peer-to-peer mode to connect directly to the USB ports in the *Seawolf's* termination can.

External magnetic switch to start the onboard computer after the termination can has been sealed.

The control system and optics are activated by a laptop keyboard, which allows for rapid and accurate changes in vehicle positioning with conveniently positioned keyboard commands. To facilitate rapid changes in motor configurations, we created a Microsoft Access controlled "keyboard-to-motor" mapping system that allows any combination of motors to be triggered by specific hotkeys. This feature allows us to use five thrusters in a wide variety of configurations. An application written in Visual Basic not only executes the keyboard generated thruster commands, but also controls the "grabber" and displays streaming video data.

Last, we chose the VIA Eden-N Nehemiah for our onboard processing as this model has ultra low power consumption, which will help to extend battery life.

3. Video Cameras

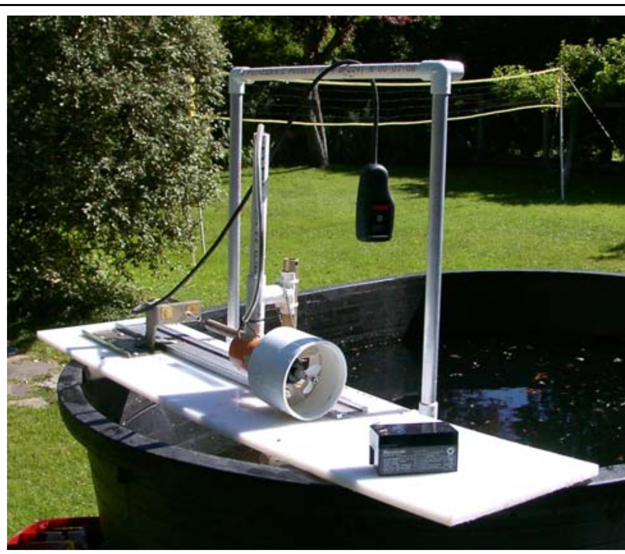
We chose the Logitech Pro 4000 as our cameras for the following reasons:

- This model can capture up to 640 x 480 pixels. We ended up using a resolution of 480 X 360 as this size on a screen provided a good balance between clarity and efficient data transfer. We found that if the image was too large, (e.g. 640 x 480) the increased transfer rate requirements caused delays that impede accurate navigation. On the other hand, if we increased video responsiveness by lessening the resolution, (e.g. 340 x 240) too much visual detail was lost to efficiently accomplish the missions.
- This model handles up to 30 frames per second
- We found that the LP 4000 performed very well in a variety of lighting conditions, with quick automatic brightness adjustments.
- Our research found that this model was consistently recommended by multiple reviewers as providing a good balance between quality and affordability. (see, for example, http://www.consumersearch.com/www/computers/webcams/reviews.html)

4. Thrusters

We chose to use Mayfair 5000 (litres per hour) bilge pump cartridges, which generate 4 to 4.5 pounds of thrust when tested on our thruster jig. We used bilge pumps because they did not require sealing. They were also powerful, easy to mount and economical. We considered using Shur-Flo pumps but due to a lack of availability and a higher cost outlay we decided against them. Also, in our depth testing the SF pumps revealed problems with sealing consistency that led to motor unevenness and in some cases, motor failure.

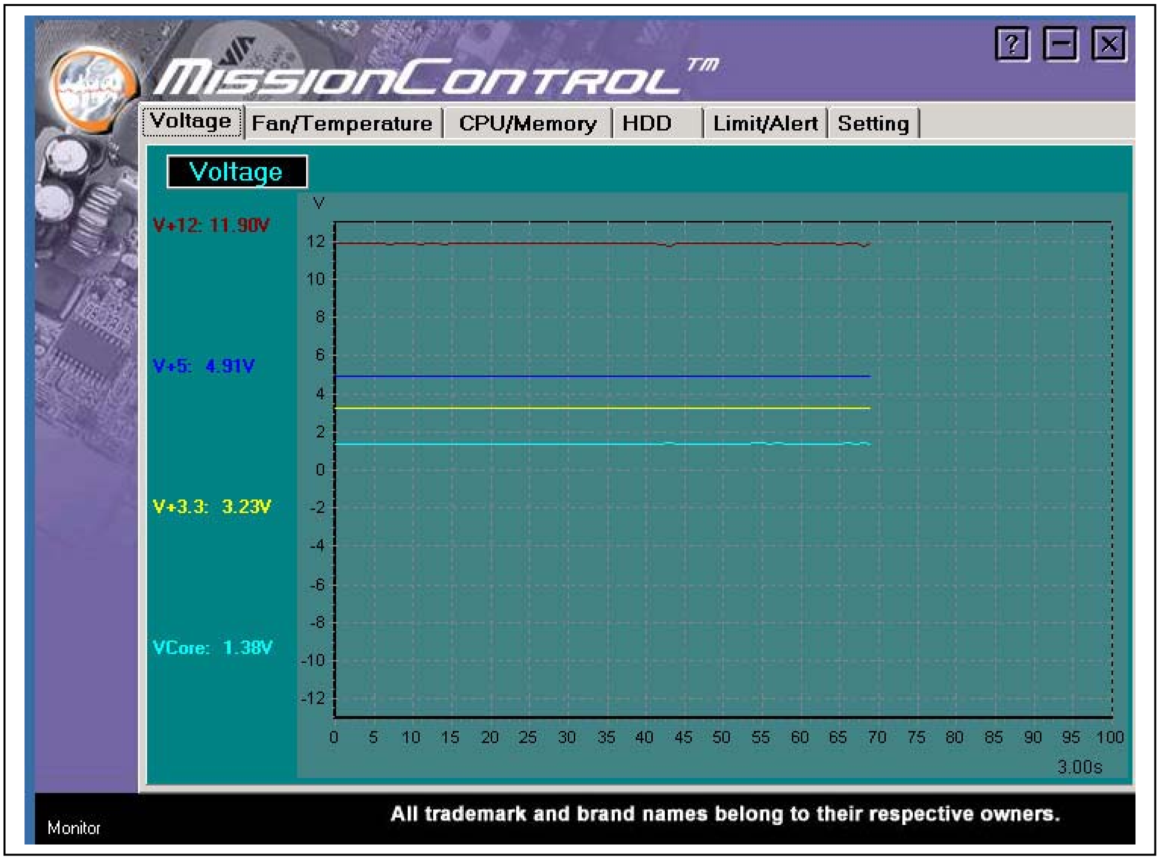
We tested several two and three-bladed props and chose the 3.8 cm Dumas props since they produced the most thrust for the least current. They also required smaller nozzles than the larger aircraft props.



Thruster jig used to measure thruster force.

5. Power

For our onboard power we connected two 12 V Panasonic LCR127R2P and one Portalac - PE12v4.5A batteries. We chose to use gel cell batteries because this kind of lead-acid battery is the valve-regulated type (sometimes called "sealed" or maintenance-free), which fixes the acid electrolyte in a gel or in an absorptive fiberglass mat. The advantage of this design is that the battery needs no water additions, can be operated in any position, and can be used in close proximity to people and sensitive equipment. This model also is a sealed no leak design and displays great vibration resistance.



Remote monitoring software for onboard submerged computer.

Challenges

After the first prototype was built, the first trials indicated that the large termination can was causing the *Seawolf* to be excessively positively buoyant. We solved this problem by attaching two 5 cm PVC tubes under the polypropylene base that could hold assorted metal weights.

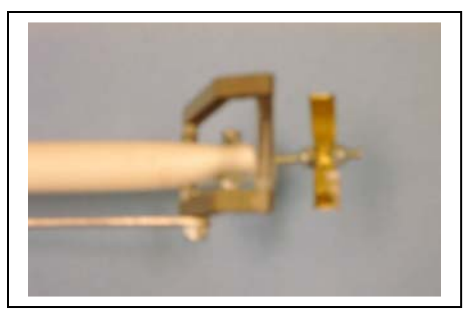
A second major problem involved leakage into our termination can. We consulted a hydraulics engineer and he cautioned that the threaded end caps would expand and contract with temperature changes at different rates than the 20 cm PVC tubing, which would reduce the sealing effectiveness of the PVC glue we were using. We solved this problem by using a cold epoxy glue on the joints. We also installed a moisture sensor inside the termination can.

A team-related challenge that we encountered was related to the size of our group. We realized mid-way through that the team was probably too large for maximum efficiency. It was sometimes difficult to communicate effectively and much time was spent just listening to everyone's ideas. This was frustrating at times when allocating responsibilities, setting meetings and making any final decisions. Another large group challenge is the tendency to assume that "someone else" is "taking care of business." As the competition date loomed and the workload intensified, it was crucial that we developed better work strategies and a greater collective focus. We divided into specialized teams that were responsible for four broad areas:

- propulsion - Josh Stephenson
- tools - Caleb Ward, Jadon Dick, Braden Janson
- Wireless – Chris Friesen
- Frame – Garrett Wutzke, Lisa Woykin, Meredith Franger

However, there were inherent advantages working in a large group; considering the wide range of opinions and ideas helped us to develop our patience, leadership abilities, time management and conflict resolutions skills.

"Control Arm Iterations"



Future Refinements

We believe that the application of 802.11 technology to ROV design has great potential. We are planning on experimenting with a wide variety of sensors in future iterations of the *Seawolf*. We would particularly like to explore the possibilities of adding different types of rotation, force and pressure sensors that could be used to execute code that would, in turn, send thruster instructions for object avoidance or be used for sophisticated target retrieval missions that require a extremely precise navigation.

Another exciting development could see the installation of a cell phone internet connection card in our onboard computer so data could automatically be uploaded to our website as our mission progresses. Perhaps next year our classes at home can watch our mission live through our ROV cameras from streaming video!

Applications: The Hubble Space Telescope

For 15 years NASA's Hubble Space Telescope has orbited the Earth traveling at an estimated 8 km per second (5 miles per second). It promised the world a revolution in the understanding of the origin and evolution of the universe and the answers to many other astronomical and cosmological questions. These expectations have been partially realized in the over 700, 000 astonishing images it has taken since its deployment in the spring of 1990.

Though no less could be expected from a craft that has taken longer to build and launch than any other of NASA's spacecrafts at a cost greater than most other space missions. Part of the cost has accrued from the many servicing missions it has needed, which underscores the practical relevance of the third Ranger mission. Hubble's visionary, modular design requires regular upgrades to aging equipment. For example, due to the electrical power requirements of the Hubble Space Telescope's many instruments, two solar panels measuring 40 feet (12.2 m) were installed on the spacecraft. The solar panels provide the craft with 2,400 watts of electricity, which is the same amount of electricity used by sixty 40-watt light bulbs. When the Hubble is positioned in the Earth's shadow, electrical power is supplied by six nickel-hydrogen batteries, which provides the same storage as 20 car batteries. Efficiently, the batteries are re-charged by the solar panels when the spacecraft reaches sunlight.

During the course of Hubble's 20-year mission, new and improved instruments are regularly installed to bring the most advanced instrument technologies to this observatory. The Wide Field Planetary Camera 2 (WFPC2), located along the radial bay, is the spacecraft's main eye. Like the retina of a human eye, the WFPC2 contains four CCD chips which catch the light, three low resolution wide-field CCD chips and one high resolution planetary camera. Upon finding a suitable target, the four CCD chips are exposed to the target at the same time, and the target is centered on the desired CCD chip, either high or low resolution. The photos this camera is capable of taking, such as the Eagle nebula, bare an uncanny resemblance to viewing them firsthand.

Another of the Hubble’s many cameras is known as the NICMOS (Near Infared Camera and Multi-Object Spectrometer). Often interstellar gas and dust can block our vision of the visible light from various celestial objects; however, it is possible to see the infra-red light, or heat, from the objects hidden in the dust and gas. To see this infra-red light, Hubble has three sensitive cameras which make up NICMOS. It can see through interstellar gas and dust that blocks visible light.

Important to the functioning of the telescope are the Fine Guidance Sensors (FGS). The FGS are used to point the telescope and to make precise measurements of the positions of stars. There are three FGS aboard the Hubble; two are used to point the telescope and keep it fixed on its target, while searching for a guide in the stars. When each FGS finds a guide star, it locks on to it and feeds information back to the Hubble steering system to keep that guide star in its field. While two FGS are steering the telescope, one is free to make measurements or star positions, these are very important for detecting planets, because orbiting planets cause the parent stars to wobble in their motion across the sky.

While the Hubble telescope is reaching the end of its 20-year lifespan, the advances it has made in science and in astronomy will certainly last decades longer.

References:

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Freudenrich. Craig (N.D.) How Hubble Space Telescope Works. Retrieved May 26 from http://science.howstuffworks.com/hubble4.htm

Financial Overview: Expense Sheet For Lochiel Seawolf ROV Project

Quantity	**Item**	**Cost – Rounded to Nearest Dollar**
2	12 V Panasonic LCR127R2P battery	$88.00
1	Portalac - PE12v4.5A battery	$44.00
63’	cat5e network cable with ends	$52.00
2	DWL-G132 Dlink usb wireless adapters	$82.00
1	Dlink 4 port usb hub	$52.00
1	Via mb & cpu	$398.00
1	hard drive	$92.00
2	Logitech usb web cams	$88.00
4	4 relay boards	$124.00
1	4 servo driver board	$58.00
20’	Coaxial cable	$23.00
1	wireless antenna connector	$19.00
	Assorted Wire	$31.00
1	Polypropylene sheet	$23.00
1	toggle switch	$8.00
	bolts, nuts washers	$43.00
6	watertight connectors	$66.00
	Velcro	$12.00
1	512mb ddr ram	$126.00
	misc cable end connectors	$92.00
	winxp pro OS	$178.00
	Assorted PVC piping	$79.00
1	Rubber boot for controller arm	$6.00
5	Mayfair bilge pumps	$250.00
	Total	**$2034.00**

Schematic Diagram