MATE 2007

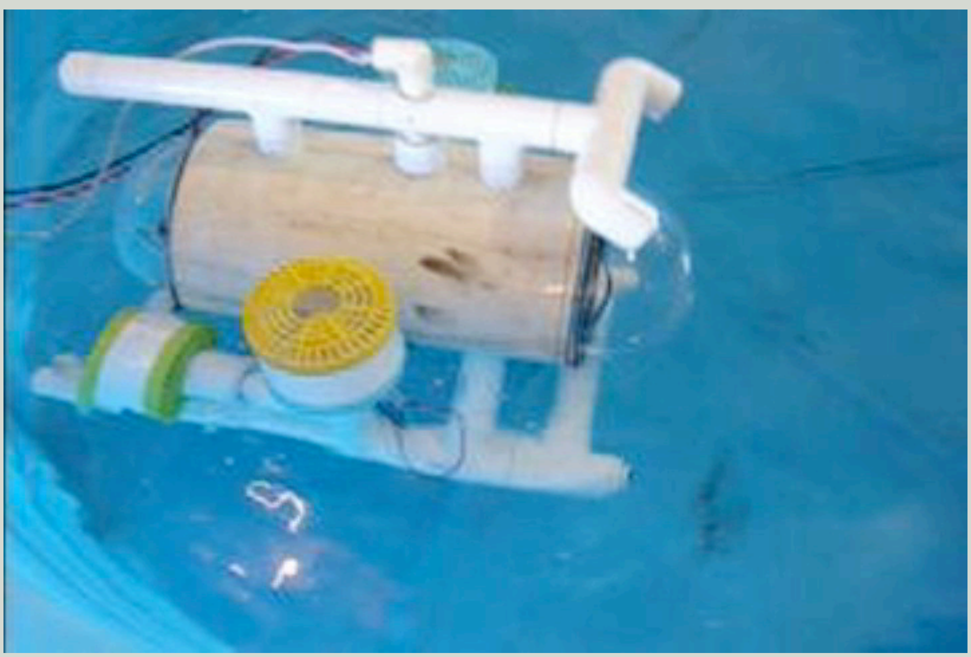
ROV Competition Saint Johns, Newfoundland

POLAR SUBMERSIBLES

Fairbanks, Alaska

Team members:
- Vincent L. Weibel,
- Logan Hanneman,
- Kluane D. Weibel

Mentors:
- Orion S. Lawlor
- Katherine I. M. Weibel



Project / ROV name: Polar Cub

ABSTRACT

Polar Submersibles Inc. is a robotics team made up of college and high school students from Fairbanks, Alaska.

Our ROV is constructed out of one main PVC tube and several smaller PVC pipe fittings. Thrust is provided by four custom built thrusters utilizing the vertrans set up. The onboard control system is custom built as well using PWM's (pulse width modulator) running to speed controllers and relays. Sight is provided through cameras on both the inside and outside of the main housing. The overall design is smooth and streamline in all directions permitting the least amount of drag. The tether and body will be able to slip through the water easily, as well as through water currents. Polar Submersibles continues to build robots with a good balance of aesthetics and function. Polar Submersibles takes great pride in the quality of construction and attention to detail.

The ROV will continue to be unitized outside of the competition through a robotics camp for Junior High and Senior High School students during the month of July 2007 at the University of Alaska Fairbanks.

DESIGN RATIONAL

Main Fuselage

The main housing is constructed out of a millimeter diameter tube mm long. The wall thickness is mm providing strength under pressure and a solid platform for mounting skids, motors and devices. Having one large tube provides maximum volume for electronics as well as central buoyancy without unsightly bulky foam mounted to the frame. On either end of the

tube are clear acrylic domes. Each dome has a camera for greater visual perspective. The domes also provide increased fluid dynamics for forward and reverse motion.

Skids

The skids are made of 25.4 mm PVC fittings, arranged in a helicopter foot print. At first our team was going to use aluminum, however it would have been more expensive to build. Aluminum is also a difficult material to build with. Lastly, aluminum has sharp edges and could damage pool tile and possibly injure swimmers. Whereas PVC plastic fittings slide together easily as well as cut easily. The assembly is similar to Legos making additions and construction efficient. The cost of PVC fittings are relatively inexpensive and replacement parts are easy to come by.

The skids house the wiring to the motors, lights and mission tools. The two main skids running the length of the ROV are outfitted in the center with threaded stainless steel rods. Threaded onto the rods are lead weights that can be spun forward and backward along the length of the skids for trim ballast. On top of the ROV is a single skid used both as a handle and mount for the lights. With the use of a modified hole saw the skids slide into the main housing snugly. PVC glue provides further strength and waterproofing. Five minute apoxy added to further seal the connections.

Propulsion

Propulsion is one of the most critical devices on the ROV. Our team decided to build thrusters from scratch. Our thrusters are made from bilge pumps cut and modified to fit within 114.3 mm PVC cowlings. Office fan blades were used for the propellers. The office fan blades produce almost equal thrust in both directions. The propellers are housed inside the cowlings to make channeling thrust as well as pull from the propellers.

Video/LIghts

Video consists of two cameras inside the main housing in each dome and one or two cameras outside the main housing. The cameras are pin hole micro cameras with high resolution of 520 lines for viewing on a computer. The cameras are low lux rating for viewing in low light conditions.

Six LED lights are grouped in two adjustable pods holding three LEDs' each. The LEDs are wired to switch on or off. To view the four cameras a toggle box on the surface can select between each of the cameras. A laptop computer connected to the EyeTV digital/anolog mpeg-4 encoder will view and record the video signal transmitted from the robot.

Tether and Connections

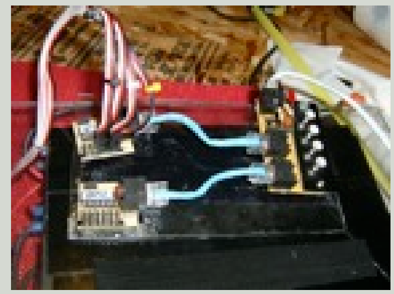
The physics behind the tether composition are crucial in the performance of a ROV. Streamline construction and flexibility all contribute to minimizing the effect of water drag, which allows for smooth unrestrained control of the ROV. Size, weight and flexibility are three important factors in designing a good tether.

We decided on a 12 meter tether utilizing 10 Awg power cables. The team's decision went back and forth on whether to use 10 Awg or 8 Awg cable. The 8 Awg would have less voltage drop and heat up less then 10 Awg. However, 10 Awg is a great deal smaller, causing less drag in the water. With only a 15% or so voltage drop. The 10 Awg wire was the prime and final choice for using a 12 volt system.

Our team used Arctic flex cable, which is a type of cable used in Alaska for plugging in winterized cars. The Arctic flex is specifically made to be flexible in extreme cold temperatures. In cold water the Arctic flex would stay nimble and manageable, whereas other cable would become stiff compromising the motion of the ROV.

For the communication we used CAT-5 cable. The cable is cheap, readily available in long lengths and has 8 lines within one casing. Four lines of the CAT-5 cable were used for controlling the ROV and the remaining lines allow four video signals.

PWM Chips



To distribute the commands to the speeds controllers and spikes our team built PWM chips that have the ability to run six victors or spikes. There are two chips mounted onboard the ROV. Software running on topside control computer:

\# C++ code, OpenGL user interface, USB joystick input, serial output.

The serial communication is all performed by a thread, that reads from the global 'robot_PWM' array.

Robot communication protocol:

Robot (chip A) sends one binary byte, with value 0xA2,
to indicate it's A-OK and ready to receive 12 PWM values.

CPU then sends a 14-byte command packet:

- fixed binary byte 0xEC (for synchronization)

- eight spike values, packed into the bits of one byte.

The low three bits (0x00-0x07) are chip A's three spike outputs.

The middle three bits (0x00-0x70) are chip B's three spike outputs.

- six PWM values for chip A's outputs.

- six PWM values for chip B's outputs.

Victors

The thruster output is controlled by voltage regulations sent from victor 883 speed controllers. They are simple to use and can be controlled using PWMs. The Victor 883's are robust and outfitted with fans to keep cool.

Spike Relay

PWM controlled spikes provide on/off switching of lights and cameras. Extra spikes are installed for expandability. Built in fuses provide protection to each isolated device.

Circuit Protection

All electronics on board the ROV are protected by a main fuse distribution block with auto reset fuses of varying amp sizes. The tether has an inline manual resettable breaker. To keep track of the amp draw an inline LCD display displays realtime amp draw, watts, and volt amp hours; therefore insuring the ROV does not reach the 25 amp limit. In the control program itself, a collective total of amps drawn from motors and other components are capped off and will keep the motors

from over drawing even if the driver applies full power to all motors. This is key, considering that each motor draws 8.1 amps, and there are four motors totaling 32.4 amps.

Surface Controls

To fly the ROV, our team uses a typical game controller. The game controller has two small joy sticks and several buttons for triggering the lights, cameras and trim settings. The controller is small, easy to use and will interface with a laptop computer.

Mission Tools

We believe in simplicity when building mission tools. Keeping the movements of the tools to a minimum and leaving the maneuvering up to the propulsion of the ROV thrusters. A simple pincher device, using a servo was built and will be used for most of the missions.

CHALLENGES

It was difficult to mount the thrusters, lights, cameras and other components and keep the look of the ROV aesthetically pleasing was a tough challenge. Of course, thrusters can be clamped or glued on anywhere and the performance will be sufficient. However, with a few placement changes and forethought, the function of the components working smoothly on the fuselage were addressed. Such as easy access for service or replacement and maximum performance.

Mounting the thrusters took the most planing and thought. The team did not want to drill holes in the main housing and risk increasing the chance of leakage. Because the team chose to use four thrusters, two in the vertans configuration each thruster needed to be as close to the center mass of the ROV as possible. This would keep the ROV stealth when making small or quick movements. Thrusters that are far from the center of mass would cause the ROV to oscillate or pitch in an undesirable fashion. The thrusters are also capable of adjusting to different angles. The ver-trans configurations will favor side ways shift or vertical movement depending on the angle of the thruster off vertical. The ability to detach and reattach damaged thrusters in a quick and efficient manner is also critical for competition where time during the mission is worth points.

We tried several different mounting options that used complicated and expensive parts. Our team overcame the challenge by using the KISS, “keep it simple stupid” process. The thrusters needed to be attached to supports, so we used the “T” PVC pipe fittings that were already being used as skids. The attachments can be mounted right into the skids without drilling or gluing. Another “T” piece was attached directly to the first “T” piece. This left two outlet holes which were fitted with threaded fittings. The thrusters were outfitted with matching thread pieces, making the replacement of thrus-

ters as easy as unscrewing a light bulb. Because the thruster mounts were “T”s the thrusters were pushing on the same point, one on each side of the ROV main housing. The configuration gave the best stability and performance. The cost of each mount was approximately five to seven dollars. Simplicity was the solution to our challenges.

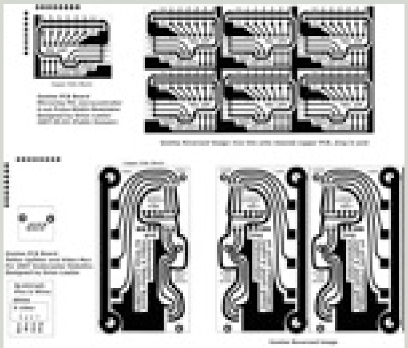
TROUBLE-SHOOTING

Tracking down electrical problems can be a tedious process. We had an electrical problem late in the project and the team was worried for a time. We decided to use computer power supplies as a power source tapping into 12 volt leads. A computer power supply gave unlimited power compared to using batteries witch required recharging. During a testing run the control system would shut down several times within a short time after the first start up. The team thought the victor speed controllers were causing the problem. So our trouble shooting method of systematically testing each victor connection was used. This method traced the problem to the power supplies. Apparently the computer power supplies are built to produce exact power output for computers that do not tax the power unit heavily. Unlike batteries that can take a great deal of abuse, the power supplies we used at first did not like what we were asking them to do. We found a heavy duty computer power supply that had high ratings and could handle the power requirements.

LESSONS LEARNED

Regardless of how good an ROV performs or what it is capable of doing, a good pilot is a must. Our team learned that having more time in the water is definitely an advantage. The pilot can practice maneuvers over and over until he or she becomes proficient at the task. Pool time or water access of any kind is key to building a successful underwater ROV. Because the number of pools in our area a small and the scheduling is a nightmare, we found a solution to accessing water. One of the team members bought a 1514 liter live stock watering tub. The tub is large enough to run maneuvering tests horizontally and deep enough to test small vertical movements. Additionally the pool is small enough to transport easily and store in a garage. Having this pool made it possible for on the spot testing, as well as round the clock accessibility.

A skill the team learned through our mentor, Orion S. Lawlor, was how to built printed circuit board hardware for the topside and underwater interface using the "Gootee" method. This uses a laser printout as the PCB mask, which means you can prepare the circuitry using any drawing program, print on a laser printer, iron the printout onto a copper-clad PCB, and drop the result in acid. This leaves only the copper traces where needed. Here's Tom Gootee's explanation of how to do this:



http://www.fullnet.com/u/tomg/gooteepc.htm

FUTURE IMPROVEMENTS

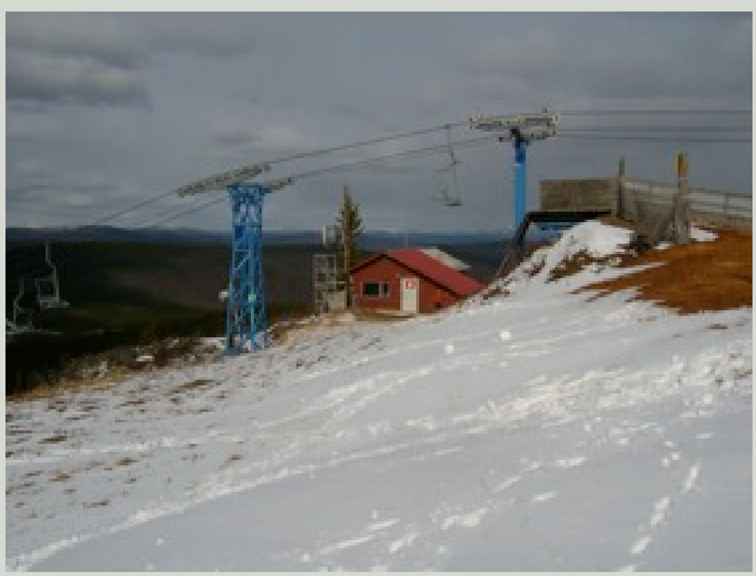
Decreasing the size of the ROV is on the top of the list for future improvements. The smaller the size the easier to manage and test. Fitting into tight areas and ease of transporting are additional benefits. Our team feels that the way to decrease the size of an ROV requires smaller electronics.

We custom built this years thruster almost from scratch, but we plan to build an even more custom thruster. A basic prototype is under construction for building a small powerful thruster with magnetic couplings eliminating drive shaft seals. The magnetic coupling would also let the motor run at full RPMs because there will be no friction from the shaft.

POLAR LIFE

Life at Earth's poles is dynamic and unique. Northern temperature fluctuations range from -45 to 30 degrees Celsius. At the Southern end temperatures reach -89 to -28 degrees Celsius. The arctic is in an area composed of a drifting ice cap, sea ice, surrounded by continents. Because of the Arctic ocean giving off latent heat, the arctic region is warmer in temperature. The antarctic region is located on a continent composed of a giant, slowly moving, ice sheet surrounded by sea ice; about 98% of Antarctica is snow and ice. All this ice causes the antarctic region to be very cold, the ice acts as a giant mirror reflecting light, energy/heat, from warming the area. Yet only the arctic region supports life; notably adaptive flora and fauna. What many people don't know is that the arctic and antarctic regions are desert like, receiving less than three centimeters of precipitation a year.

Being from Fairbanks, Alaska gives an interesting perspective of life's adaptability in extreme conditions, being only 200 kilometers away from the arctic circle. The bone chilling cold winter months are one of the first thoughts that pop into one's mind when thinking about the arctic region. Where there is little or no visible daylight and life is suspended, for nine long winter months, until spring arrives and life races to prevail before another winter season. Living with little daylight is manageable and easy for students in school, when it's -40 below staying indoors is easier. The arctic does have trade-offs; standing out in the bitter cold gives one a chance to gaze at the Aurora (Northern Lights) which are spectacular and breathtaking. One interesting connection



between the poles is that Aurora is simultaneously occurring.

To adapt to the arctic environment humans use technology to survive. For hundreds of years Eskimos have adapted by using animals as a means to survive: as a food source, fur clothing, and transportation, dog mushing. Animals that are well adapted for living in cold conditions: muskox, polar bears, penguins, seals, caribou, have thick blubber or hair to trap as much heat as possible. Societies are more closely knit together because there are fewer people and individuals need to rely on a community to overcome the difficulties of life at the poles. Humans bundle up in layers of warm clothing. Vehicles must be winterized and plugged in if the temperature is -7 Celsius or below, which is practically all winter long, nine months. Auto oil and grease can freeze or become too stiff to function.

Summer is short, about three months and therefore very precious. With 24 hours of daylight one can accomplish much in a day. Annual plants grow very large in a short amount of time due to continuous light. Wild, perennial flora's growth is stunted, due to harsh long winter seasons. Mosquitoes are abundant during the summer season, humorously they are referred to as Alaska's state bird. After enduring long winter months, summer is so enjoyable!

Societies continue to thrive in places that seem inhospitable, life at the ends of the Earth is challenging, but living there is uniquely amazing.

REFLECTIONS ON THE EXPERIENCE

It was difficult to find team members who could dedicate their time to an ROV project. Several people stated they would love to be on the team but because of financial obligations to save money for college, they had to choose working jobs over building an ROV.

Even though our team ended up being small, we all learned a lot from each other and plan to continue working together in the future.

Our youngest team member, 13-year-old Logan Hanneman was unable to renew his passport because of complications of required parental signatures. Therefore, Logan regretfully is unable to attend the Newfoundland international competition. He hopes to have the opportunity next year.

Co-captain Vincent Weibel has the opportunity to be an assistant instructor at the summer science camp for 130 kids to help inspire them with underwater ROVs and pique their interest in the field of science and technology. Building this ROV and attending the competition in Newfoundland will provide him with more experience to share with the summer science camp students.

Co-captain Kluane Weibel plans to use her experience in the future for architectural applications.

We all greatly appreciated Mentor, Orion Lawlor's expertise with computer programming and teaching experience.

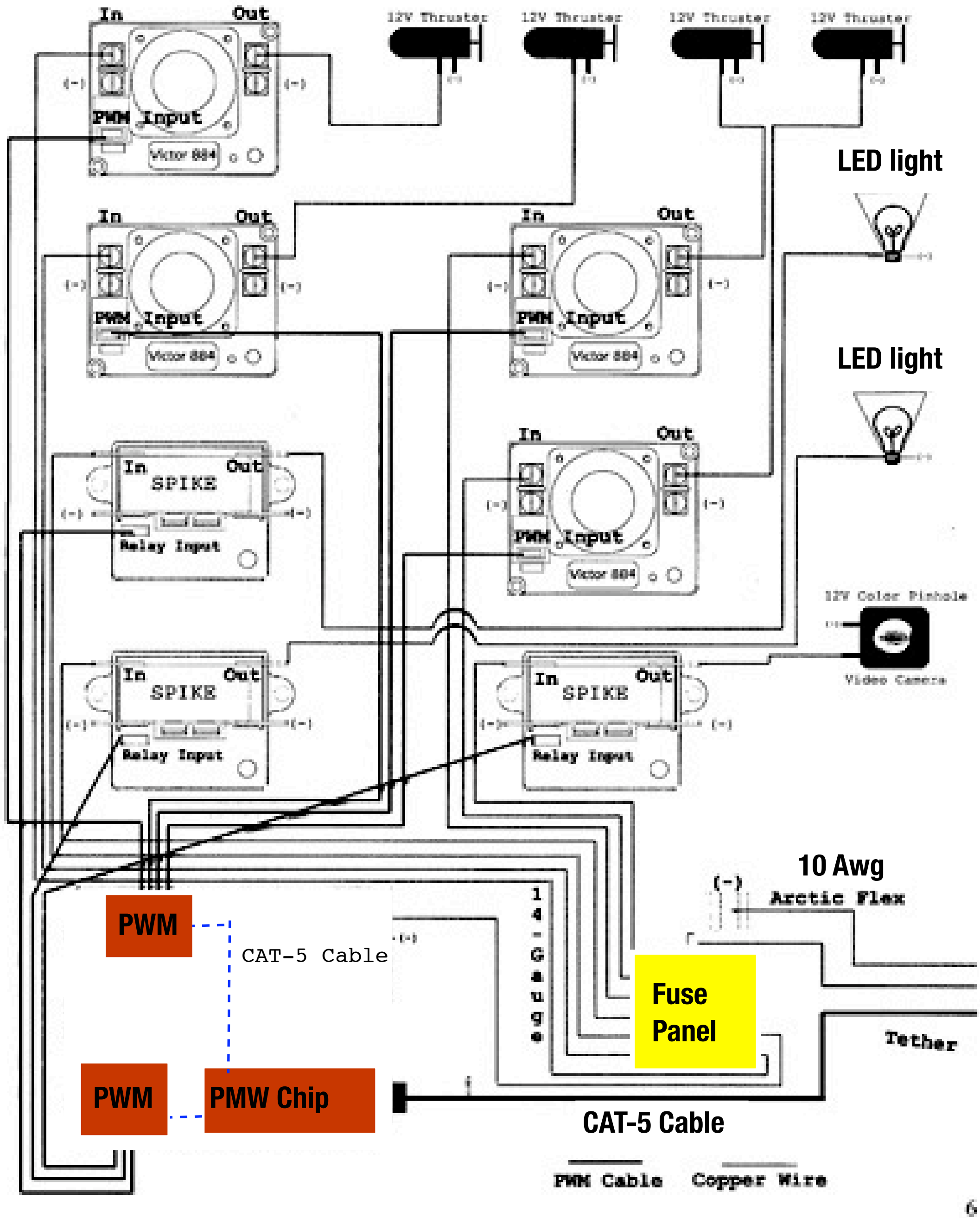
Overall our experience with the ROV was terrific!!!

BUDGET

ITEMS	COST
Chassis	80.00
Domes / Seals	90.00
Thrusters	250.00
Computers	1400.00
Electronics	200.00
Video	400.00
Test Tank	250.00
Shirts	236.00
Water tight connec-tions custom built	30.00
Fasteners	40.00
Plane tickets	3900.00
Total	6876.00

ITEM	COST	SPONSOR
Paint	100.00	College Collision
Speed controllers	500.00	Lathrop High School
Spikes Fuse panel	400.00	Lathrop High School
Total	1000.00	

ELECTRICAL SCHEMATIC



ACKNOWLEDGMENTS

Polar Submersibles would like to thank the following sponsors for their help and support.

COLLEGE COLLISION & REFINISH for the beautiful flame red paint job on the ROV.

KEIR DENTAL for their financial support.

Our mentors: Orion Lawlor and Katherine Weibel for their support and contributions.

All the other parents, friends and family for their encouragement, support and contributions.

And Psalm, the Yellow Labrador Retriever dog, who was interested in all the ROV activity and provided many opportunities for diversion which led to “brain clearing” and brainstorming.