The Manipulators
COSI Academy
Columbus, Ohio
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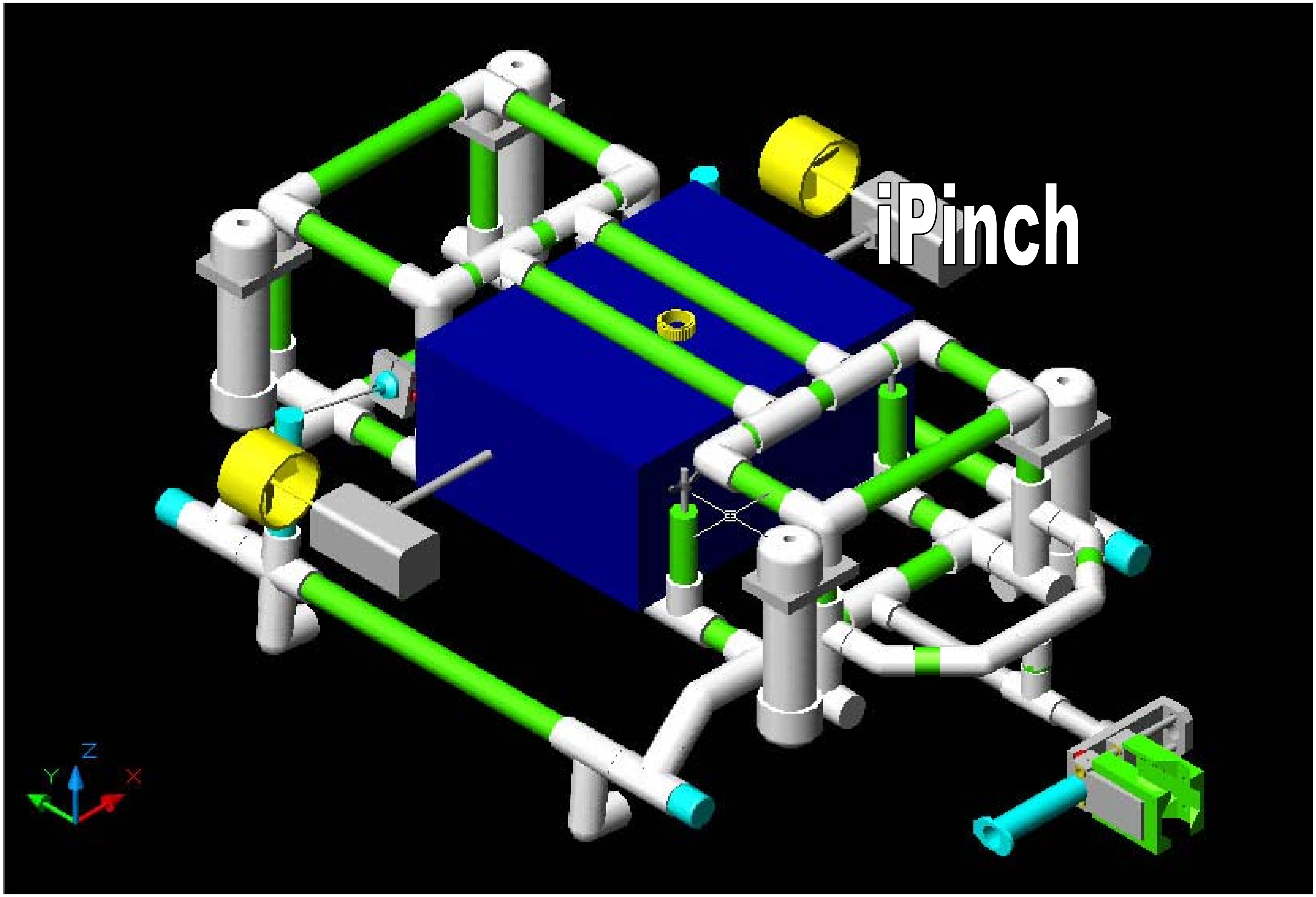
Present:

iPinch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Abstract

The iPinch is a remotely operated submersible specifically designed to complete the tasks set forth in MATE Center's ROV Challenge. It is designed to accomplish these tasks as quickly and simply as possible, from an engineering and operation standpoint. Certain exceptions to this rule were made, such as the vectored thrust system; however, these exceptions were allowed only when the benefit outweighed the difficulty of implementation.

The primary building material for the iPinch is PVC tubing, which forms the majority of the frame. Mounted within the frame is a Pelican case, which has been modified to hold the ROV's electrical and vectoring components.

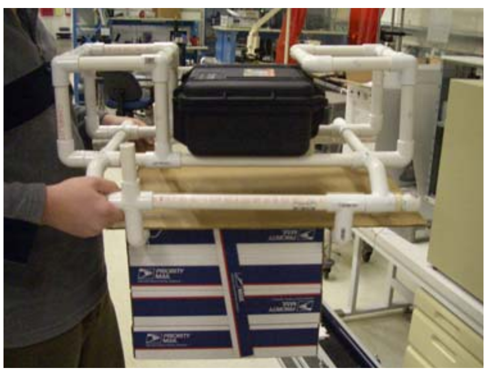
The iPinch utilizes fabricated pneumatic rams to power its manipulators. An RF control system adapted from a remote control helicopter provides control input. The loam tether of the ROV allows for maximum flexibility and minimum submerged weight, while still providing a durable, protective coating.

Our original budget was set not to exceed five hundred dollars for the entire ROV – a number based on current funding at the time. This changed as new information about the challenge emerged. The increase in size, power, and manipulating ability contributed to the elevated price of the ROV. Fortunately, we were able to find companies willing to donate or loan us the components necessary to realize our new vision of the ROV.

Pictures

Giacomo modifies the remote control

Remote motor test conclusion: IT LIVES!



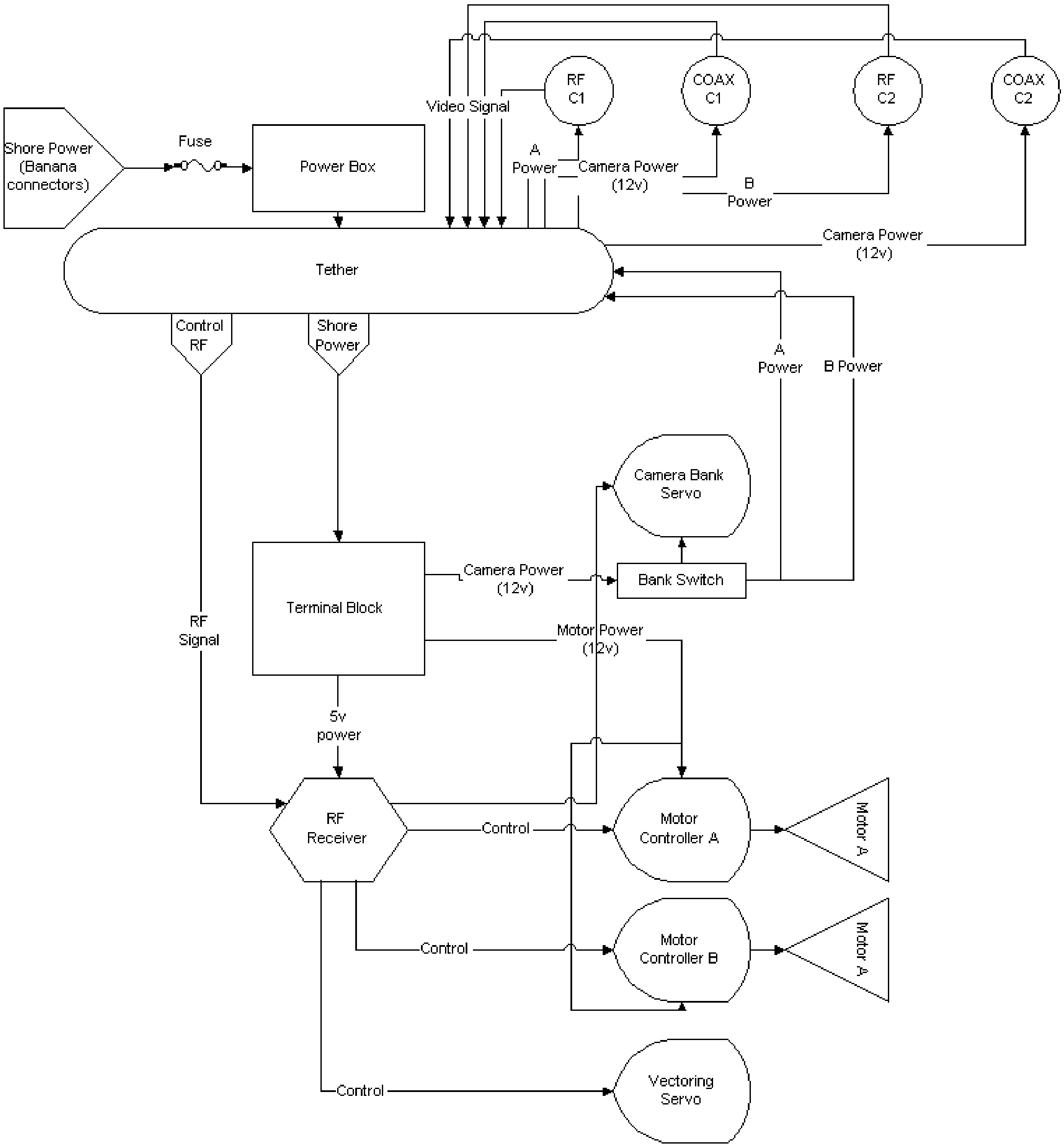
Payload clamp test with watertight box.

The motor mounts with motors.

Lauren and Angelica purchase frame supplies.

Clayton fits the cylinders into their clamps.

Electrical Schematic



Design Rationale

Frame

The frame of the ROV is assembled from 1.905 cm (¾") PVC tubing. Its design provides a structurally rigid platform for various ROV subsystem components, while remaining modular and simple to service. The design was modeled in AutoCAD prior to its construction, and has been extensively tweaked in order to ensure optimal performance. All construction was done using sheet metal screws until the design was entirely finalized, at which point plastic welder was injected into the most critical seams, saving the time and risk involved in disassembling the craft for gluing.

The points at which the watertight module is mounted include a pair of machined, free-floating 1.905 cm (¾") T-fittings, which lock onto the lip of the rear hinge of the box. These are secured with stainless clevis pins. The forward locks consist of a pair of machined upright 1.905 cm (¾") fittings, fitted with ¼-20 (metric dies were unavailable) threaded rod which fits through the padlock holes in the case's front lip and are tightened with wing nuts.

The stabilizing bars at the top of the frame are designed to increase the rigidity of the platform while still facilitating easy removal of serviceable parts. The two bars are constructed from PVC and hinge vertically to the back of the frame, allowing the tether to pass between them. When closed, stainless clevis pins secure them. The watertight module can be easily removed from the frame for any sort of necessary service.

Optical Components

Four video cameras are attached to the frame, two forward for maneuvering and viewing the front manipulator, and two angled down to assist in nesting the electronics module. All are positioned to offer a wide view so that the various tasks can be completed effectively.

Two watertight, battery powered external LED lights were modified and integrated into the frame, to enhance visibility of mission props, should this be necessary.

Payload Clamps

In order to manipulate the electronics module, we integrated a set of payload clamping bars into the runners of the ROV. Actuated by pneumatic cylinders of our own design, these facilitate gripping the lip of the box rather than the central u-bolt, thereby preventing the module from swinging or slipping while underwater, preserving the ROV's center of gravity. The clamping force of these bars is sufficient to prevent the box from sliding. The cylinder itself is locked into a pivoting Lexan mount preventing the system from binding and damaging itself.

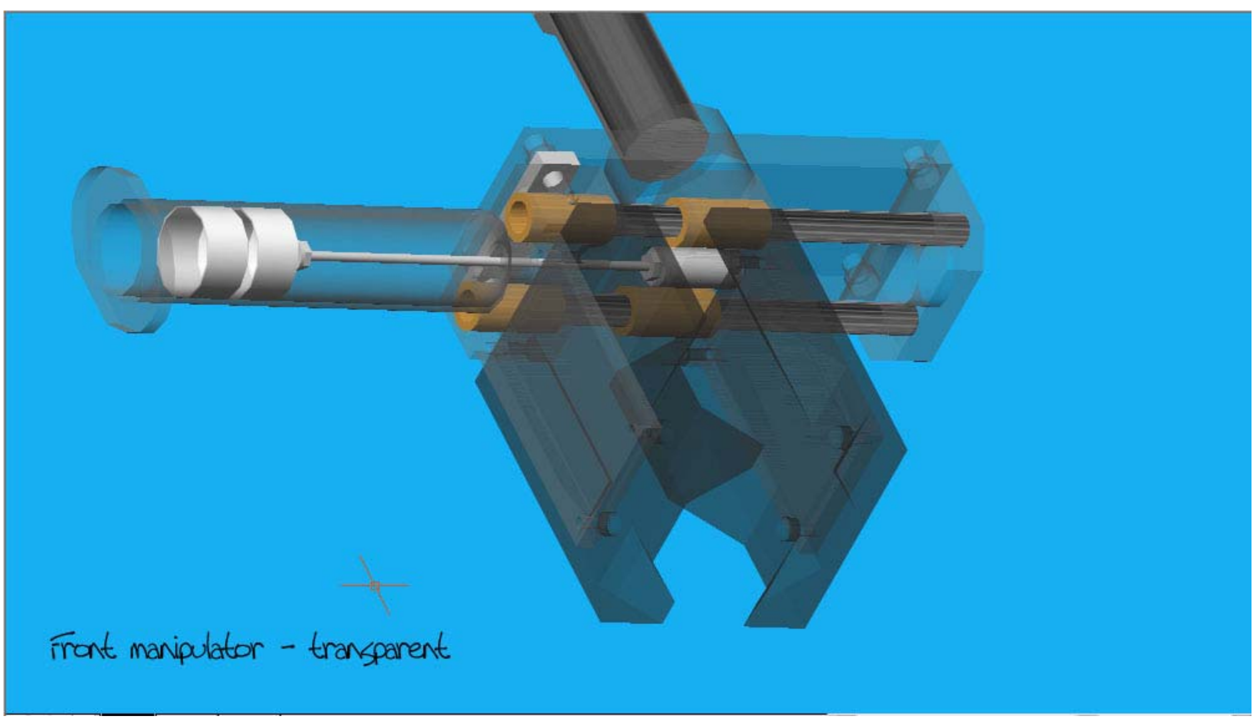
The pneumatic cylinders are made from 30cc EFD cylinders. The front end has been modified with several vent holes, allowing the inflow and exhaust of water from the cylinder itself. Each cylinder has been outfitted with stainless drill rod tapped into the first puck and bolted in place, followed by a second unmodified puck, which provides the necessary airtight seal.

Forward Manipulator

The forward manipulator is the single most redesigned item on the ROV. It originated as an electrically powered system that was moved with a threaded brass rod. We chose to drill out the immobile brass rod, replacing it on one jaw with a steel lug to fit the cylinder shaft. The cylinder is mounted to the other jaw, machined directly into the jaw with three setscrews to retain it.

The jaws ride on ground rods with a thin coating of waterproof silicone grease to prevent any binding. The rods are secured in the immobile jaw with assembly screws, while the other side fits into an aluminum block that serves to keep them aligned and retain the return springs. The rods are jacketed with steel springs, which provide more than 5.4 kg of clamping force to the jaws, which are machined from Delrin. An aluminum lug has been fitted to the stationary jaw, to protect the cylinder.

The jaw assembly is mounted to an aluminum fitting, which secures the immobile jaw and the rod guide at a fixed length, and provides a fitting for the 1.27 cm (½”) stainless tube that anchors the manipulator to the frame. The entire manipulator can be disconnected for re-tooling if needed.



Vehicle Maneuvering / Watertight Compartment

A modified Pelican case was used as the watertight compartment for the ROV. It contains the majority of the ROV's electrical systems and houses the hardware for the thrust vectoring,.

The lid of the module is the penetration point for the control tether. Two water tight external drive motor / propeller pods are attached to the vectoring control shaft, rotated using a servo and a belt drive. The Delrin is glued into the bottom of the box, providing an entirely stable platform for the electronics, while also displacing a large amount of air from the case, moving the box closer to neutral buoyancy. The platform also serves to isolate the electronics from any slow leak that may develop, keeping these systems 3.8 cm from the case floor.

Early design of vectoring system and motors.

Ballast System

Four ballast tanks are attached to the ROV, one located outboard at each corner of the frame. These serve to augment the buoyancy of the ROV, allowing limited vertical maneuverability and compensation for changes in ROV system weight in-mission. This system is controlled from shore by a Tygon line running through the tether. By adjusting the air volume in the tanks, very fine adjustment in vertical position can be achieved. While we do not foresee a problem with the ballast, the system was designed as modular: the tanks can be removed and replaced with a single tool.

Tether

Our design has streamlined our tether to only contain power wires, thin antenna/coax wires, and air lines. As an alternative to a pair of heavy-gauge power wires, two pairs of thinner wire were chosen to minimize tether stiffness. One coaxial antenna wire carries a signal from both radio cameras, while another coaxial wire carries the signal from whichever wired camera is on at the time. Since only one wired camera can transmit on the wire at any given moment, a system made of a servo tripping a three-way switch was constructed allowing easy control from the shore transmitter.

Challenges, Troubleshooting and Skills Learned

Overcoming challenges is one of the best indicators of a well-balanced team. Throughout the design phase, our team has encountered and successfully solved many potential problems. Some of the major issues are outlined here, as well as our approach to problem solving.

One of the first decisions was to use a thrust vectoring system: a decision, which brought many challenges. Placing the shaft through the watertight module required high quality rotary seals, which proved difficult to integrate, requiring specialized glue to bond to the polyethylene. We also experienced inconsistencies in the materials we had chosen for our vector shaft.

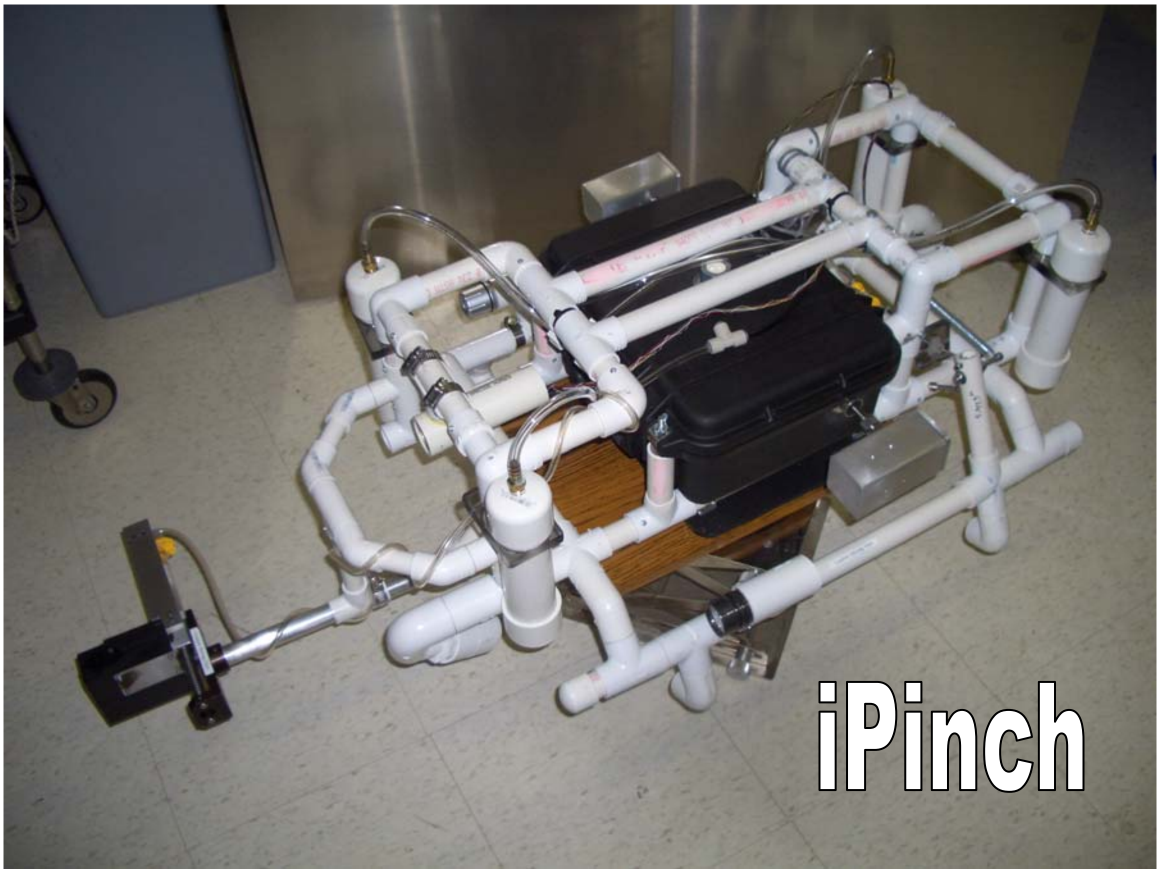
For minor problems, the person working on the part had the initiative to do as he chose, most often consulting a nearby mentor or teammate to gain fresh insight from someone who was not involved with the part in question.

When the need surfaced, we learned how to perform CCD machining via a computer, which we successfully used to create a number of custom parts for our ROV. Although not implemented for this year's ROV, we also learned how to design and fabricate printed circuit boards.

Future Improvements

While we believe our ROV to be sufficiently finalized to properly execute the tasks outlined in the competition manual, we believe there is always room for improvement. During the construction of the ROV, we experienced considerable difficulty finding adhesives and sealants that would bond to the polyethylene surface of the Pelican control box. A future design would replace this type of enclosure with another type that would be easier to bond to.

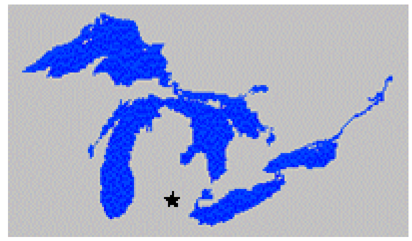
A custom designed and built controller for the ROV would be an item we would like to add; however, time constraints and cost eliminated this choice for this year's challenge.


iPinch

Great Lakes Environmental Research Laboratory

The Great Lakes Environmental Research Laboratory is one of seven Federal research laboratories, within the Office of Oceanic and Atmospheric Research. It was formed in 1974 by the merger of the Limnology and Computer Divisions of the Lake Survey Center of NOAA's National Ocean Service with the staff of the International Field Year for the Great Lakes Office to provide a federal research laboratory dedicated to research on the Great Lakes, the United State's fourth coast.

GLERL



As a NOAA research station, the GLERL conducts research into all manner of environmental phenomena that affect the Great Lakes and surrounding coastal areas, in conjunction with their counterparts at the Canadian Hydrographic Service. This research includes studies of invasive aquatic species, the physics of the lake's processes, and the overall effect on the great lakes ecology. In doing so, they rely on data recorded by various ocean observing systems.

Based at the Lake Michigan Field Station, the R/V Laurentian and the R/V Shenehon are the GLERL's current Research Vessels. At 80 feet and 65 feet, respectively, they allow GLERL researchers to gather water, chemical and biological samples from the lakes. They can both deploy a number of instruments for more direct observations, including remotely operated vehicles, as well as various sampling equipment to obtain specialized samples.

The researcher at the GLERL's Lake Michigan Field Station also support and operate a set of instruments permanently moored to the bottom of Lake Michigan, including instruments to measure the lake conditions before, during, and after storms and other episodic events. Additional instrument packages are planned to study the outflows of the Muskegon and Grand Rivers and to determine the effect of these outflows on the Lake Michigan ecology. The researchers also support the study and comparison of the food chains of the five lakes, as well as the comparison of the present state of the lakes with earlier states.

The Great Lakes Environmental Research Laboratory studies the Great Lakes in amazing detail, attempting to improve our understanding of the these inland seas. To study such a large area, largely inaccessible by humans, in exhaustive detail over a long period of time requires the use of well-engineered machines, such as the ocean observing systems that the GLERL uses. The information generated by these systems will prove invaluable for many generations of researchers.

References:

NOAA Great Lakes Environmental Research Laboratory (2006, May 16th) Retrieved May 22nd, 2006 from NOAA Website:
http://www.glerl.noaa.gov and sub pages

NOAA's Underwater Research Program (2004, May 28th) Retrieved May 22nd, 2006 from NURP's Web Site:
http://www.nurp.noaa.gov/Spotlight/Webcast_ThunderBay.htm

Budget

This was our original budget for the ROV. Unfortunately, reality set in with the release of the challenges, and cost climbed dramatically with the new, revised plans.

Part	Quantity	Price	Total
1/2" PVC Pipe	10	$0.50	$5.00
1/2" PVC 45 Degree Elbows	5	$0.45	$2.25
1/2" PVC T Joints	4	$0.65	$2.60
3/4" PVC Pipe	15	$0.19	$2.85
3/4" PVC T Joints	16	$0.27	$4.32
3/4" PVC Cross Joints	5	$1.22	$6.10
3/4" PVC 45 Degree Elbows	5	$0.79	$3.95
3/4" PVC 90 Degree Elbows	6	$0.23	$1.38
3/4" to 1/2" PVC T Joints	3	$1.00	$3.00
3/4" PVC End Caps	4	$0.24	$0.96
3/4" to 1/2" Thread PVC T Joints	6	$0.43	$2.58
3/4" to 1/2" Thread PVC Connectors	6	$1.29	$7.74
1" PVC Pipe	4	$0.50	$2.00
1" PVC End Caps	8	$1.00	$8.00
1" to 1/2" PVC Couplers	6	$1.25	$7.50
1" PVC Couplers	3	$1.25	$3.75
Hardware (Various)	1	$70.00	$70.00
PVC Glue	1	$1.94	$1.94
Servos	2	$80.00	$160.00
Motors	2	$30.00	$60.00
RF Cameras	2	$70.00	$140.00
		Total	$500

These are our final costs. Though the actual cost of the ROV climbed significantly, our mentors were very good at helping us find parts through sources that would be willing to donate or loan them, making the cash cost of the ROV quite low, while the value of the parts is quite high.

Part	Quantity	Price	Total	Donated/Loaned?	Value Donated
1/2" PVC Pipe	10	$0.50	$5.00	0	$0.00
1/2" PVC 45 Degree Elbows	5	$0.45	$2.25	0	$0.00
1/2" PVC T Joints	4	$0.65	$2.60	0	$0.00
3/4" PVC Pipe	15	$0.19	$2.85	0	$0.00
3/4" PVC T Joints	16	$0.27	$4.32	0	$0.00
3/4" PVC Cross Joints	5	$1.22	$6.10	0	$0.00
3/4" PVC 45 Degree Elbows	5	$0.79	$3.95	0	$0.00
3/4" PVC 90 Degree Elbows	6	$0.23	$1.38	0	$0.00
3/4" to 1/2" PVC T Joints	3	$1.00	$3.00	0	$0.00
3/4" PVC End Caps	4	$0.24	$0.96	0	$0.00
3/4" to 1/2" Thread PVC T Joints	6	$0.43	$2.58	0	$0.00
3/4" to 1/2" Thread PVC Connectors	6	$1.29	$7.74	0	$0.00
1" PVC Pipe	4	$0.50	$2.00	0	$0.00

1" PVC End Caps	8	$1.00	$8.00	0	$0.00
1" to 1/2" PVC Couplers	6	$1.25	$7.50	0	$0.00
1" PVC Couplers	3	$1.25	$3.75	0	$0.00
Camera Mount Windows	3	$0.75	$2.25	1	$2.25
1/2" Aluminum Pipe	1	$2.00	$2.00	1	$2.00
1/8" Steel Plate	1	$4.00	$4.00	1	$4.00
Delrin	1	$160.00	$160.00	1	$160.00
30cc Cylinders + Fittings	3	$20.00	$60.00	1	$60.00
RF Cameras	2	$70.00	$140.00	1	$140.00
PVC Glue	1	$1.94	$1.94	0	$0.00
Welding Clamp	1	$2.00	$2.00	1	$2.00
Pelican Case	1	$87.25	$87.25	1	$87.25
Stainless Steel Tubing	1	$2.56	$2.56	1	$2.56
Stainless Steel Fittings Valves	4	$400.00	$1,600.00	1	$1,600.00
1/8" Aluminum Plate	1	$12.00	$12.00	1	$12.00
Aluminum Motor Mounts	2	$100.00	$200.00	1	$200.00
Shaft Seals	2	$13.47	$26.94	1	$26.94
Oil-Light Bushings	5	$0.97	$4.87	1	$4.87
Servos	2	$80.00	$160.00	1	$160.00
Motor Controllers	2	$105.00	$210.00	1	$210.00
Motors	2	$30.00	$60.00	1	$60.00
Props	2	$69.00	$138.00	1	$138.00
Poly-Carbonate Tubing	2	$5.00	$10.00	1	$10.00
Tygon Tubing	100	$0.77	$77.00	1	$77.00
Loam	130	$1.46	$189.80	1	$189.80
Co-Axial Wire	140	$0.12	$16.80	1	$16.80
Co-Axial Cameras	2	$50.00	$100.00	1	$100.00
Cylinder Mounts	2	$5.00	$10.00	1	$10.00
Ballast Tank Mounts	4	$6.00	$24.00	1	$24.00
RF Recievers (Camera)	2	$40.00	$80.00	1	$80.00
Radio Controller	1	$80.00	$80.00	1	$80.00
Gears and Belt	1	$26.57	$26.57	0	$0.00
RTV	1	$5.00	$5.00	1	$5.00
Epoxy	2	$19.81	$39.62	1	$39.62
Vector Shaft	1	$15.00	$15.00	1	$15.00
RF Controller Recevier	1	$45.00	$45.00	1	$45.00
Motor Seals	2	$25.00	$50.00	1	$50.00
Hardware	1	$70.00	$70.00	0	$0.00
	Total		$3,776.58		$3,614.09
	Donated		$3,614.09	**Donated: 1 =Yes**	
	Total Cost		$162.49	**0 = No**	

Acknowledgements

The Manipulators of **COSI Academy 2005 / 2006** would like to acknowledge:

- **COSI**, for creating and maintaining the **COSI Academy Program** that has allowed us to do and experience things that we never would have without them.
- **Dave Briley** and **Emily Rhodes**, whose tireless efforts keep COSI Academy operating and our team alive.
- **Jim Bergner**, for his generous donation of time material and experience, and his role as a returning mentor for the COSI Academy program.
- **Brad Chapman** for donations of time and material, as well as advice and training in a number of the tools used in the creation of our ROV.
- **Battelle**, for its continued involvement in the success of the **COSI Academy Program**.
- **Our families and friends**, for their acceptance of the long hours we spent on the ROV, as well as for tolerating the occasional grumpy, sleepless morning.
- **PointSource, Mickes Quality Machining, PLC Services, M.A. O'Brian, PLC Connections** and **Schumacher Engineering Services** for their hospitality in welcoming us into their lab to work on the ROV throughout the year.
- **SubRon6**, for his help and advice in the selection of propulsion systems.
- **Mike's Sub Works**, for providing materials as well as assisting us in locating parts necessary to complete this project.

As a final acknowledgement, The Manipulators would like to thank Jill Zande and the MATE ROV Center for allowing us the opportunity to participate in the competition. We have all had a wonderful learning experience that would not have been possible with out Jill and MATE.