The Missouri State University

ROV Team

Presents

Ice Box

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Mentor: Dr. Pawan Kahol — Physics, Astronomy, Materials Science

Abstract

This year the Missouri State University ROV Team designed a very powerful, versatile, and modifiable ROV to be used in this year's MATE competition as well as research and exploration of our local large lakes for our universities biology department. It is possible that the ROV may also be improved significantly throughout the next year to be used in the 2008 MATE competition. This year's ROV is built with an increase in resources since last year, as well as an increase in ROV design experience, but the price tag for the project was kept relatively low.

Design Rationale

When designing this year's ROV the team took what we learned from last year's ROV project and competition experience, and attempted to apply those lessons learned to the new design. This year we decided to continue to explore new ideas and test new concepts, but put emphasis into reliability and overall ROV performance. What we created was an ROV full of new ideas and concepts that where designed to expand the ROV's capabilities and improve its reliability in extreme conditions such as freezing water.

Propulsion Concept

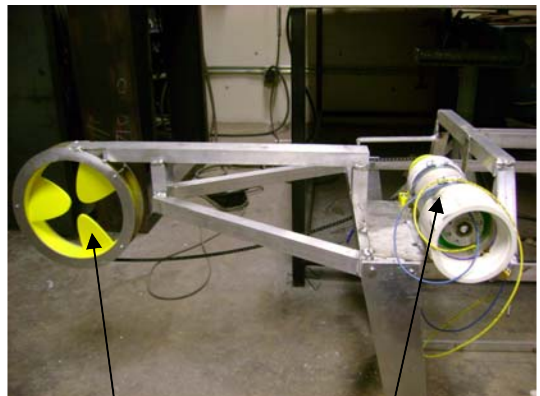
The 2007 ROV propulsion system concept uses several unique ideas that test possible improvements to conventional methods of controlling direction and motion of an underwater ROV.

The conventional thinking of ROV propulsion utilizes several thrusters in fixed positions for mobility. Our team decided to try a new take on propulsion control that saves money and provides efficient operation. The additional weight of additional thrusters creates an overall heavier ROV that requires more energy to power, and the cost of the ROV increases significantly per added thruster. Our design uses a single powerful "variable position thruster," as opposed to several fixed position thrusters, to thrust the ROV in six directions, and an additional smaller thruster provides turning motion. In total the ROV uses only two DC motors to propel the vehicle in the necessary four degrees of freedom. The variable position thruster works by using two pneumatic cylinders to quickly position the thruster in either of three positions that provide the three degrees of movement. The main thruster is a 36 VDC Minn Kota 46 kg thrust waterproof motor. This large thruster was chosen to provide more than enough thrust to hold the ROV against a mild current, and to move around its large frame with ease.

Rear Rotor

The rear rotor is a unique thruster designed and positioned to provide the ROV with its turning- in-place motion. The thruster is mounted far beyond the center of mass of the ROV, and its mass and resistance against water is relatively smaller than the rest of the ROV. This causes the ROV to pivot about its center of mass when the rotor thrusts sideways. The goal was to turn the vehicle with only one thruster.

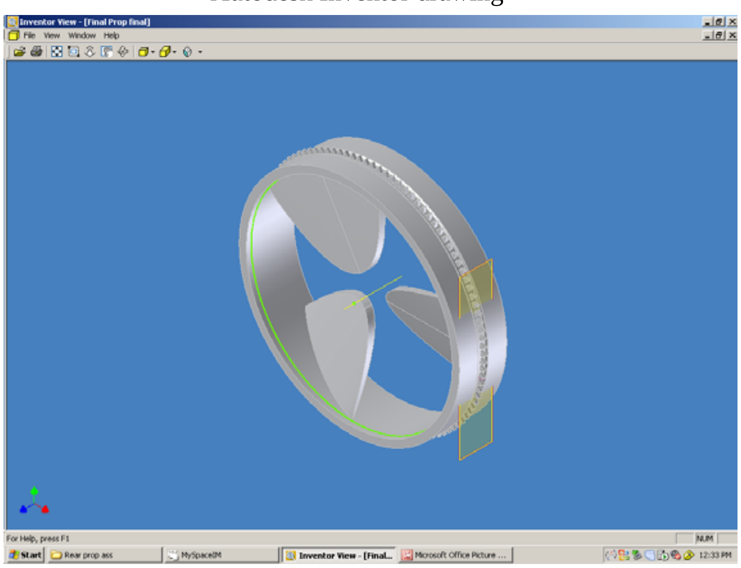
The propeller is an inverted blade design, in which the center remains open to the water, increasing water flow and efficiency. The chain drive places the motor closer to the center of the ROV, making the thruster lighter for easier pivoting of the ROV at its center of mass. The design also positions the drive motor away from the thrusters path of water flow into an area of less resistance to water flow.



Rotor Drive motor

The propeller was designed with Autodesk Inventor. Initially, the designed differed completely from the present result. After building 1/5 scale models in a rapid-prototyping machine, the 1/5 scale models were each tested in a small tank to observe the amount of water flow. The design was then changed to three blades and the pitch was adjusted for finer turning.

Autodesk Inventor drawing

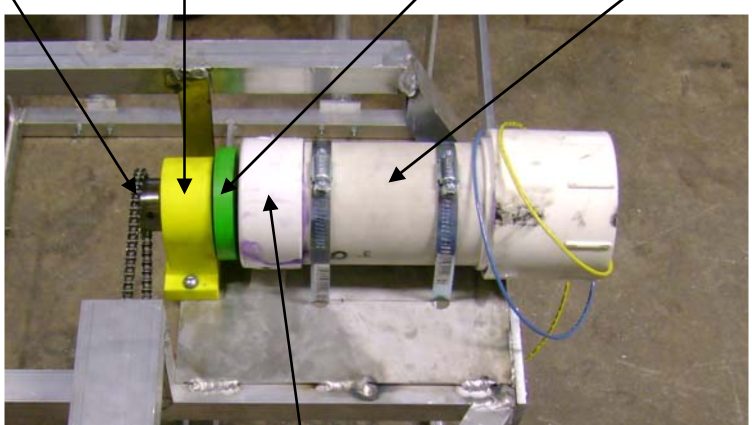


Surrounding the propeller ring are sprocket teeth designed to fit into a #25 roller chain, which transfers force from the drive motor and sprocket. The rotor's sprocket teeth fit into a groove which was designed to help keep the chain from slipping off the teeth. The propeller blades are equal in both directions of rotation to allow for equal thrusting in either direction of turning. The entire rotor and its sprocket teeth where designed as a single part to be constructed in a rapid proto-typing machine with ABS plastic. The team was initially concerned with using plastic parts in extreme low temperature conditions because they could become brittle and break as the expected forces are applied. We tested each part by freezing them and applying the necessary amount of force to the necessary areas, and if they broke they were redesigned, rebuilt, and re-tested.

Magnetic Coupler

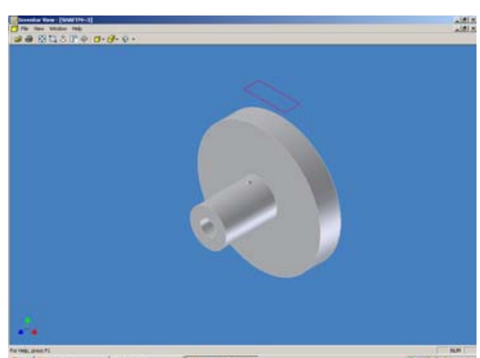
A major fundamental challenge is introduced when designing a machine to operate in extreme underwater environments. This challenge is keeping water out of the machine. Using conventional sealing methods, motor shafts, transferring force and motion from within a dry compartment, must pass through an opening in the compartment. This opening must reliably keep water out as well as let force from the motor transfer efficiently. This concept relies on the use of a “dynamic seal,” where methods of contact with the motor shaft keep water from entering. The team came to a consensus that this type of seal may fail in freezing water because the o-rings could crack when transitioning from freezing to warm temperatures. In designing a seal, the team opted on using a concept that does away with the use of a dynamic seal, and instead uses a static seal, removing the need for unreliable sealing methods. This static seal is achieved with the use of a simple system of rotating magnets. Two magnetic rotors, one attached to the motor shaft, and one connected to the load side, each separated by a static seal, transfer forces via magnetic pull. Our magnetic coupler uses a set of 36 kg holding force neodymium magnets on each rotor. In the center of each rotor is a small bearing ball, which keeps the rotors from contacting the container, and provides very little friction.

Sprocket **Bearing block** **Magnet rotor** **Sealed Motor tube**



Matching opposite facing magnet rotor inside motor tube

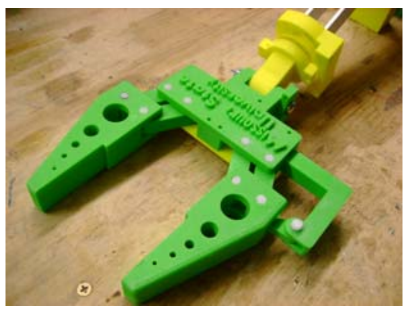
Magnet Rotor for Coupler in CAD



Parallel Manipulator

In designing a manipulator, the team decided on a very versatile but reliable and simple concept. The concept we envisioned was a parallel manipulator system powered only by human force from the operator. Our manipulators use a “Bowden cable” system in which several cables within incompressible housings transfer force and motion between the two manipulators. For the cables we used 13.6 kg test strength fishing line, and the cable housings are bicycle brake cable housings. We used fishing line because it’s thin enough to fit 4 lines in each single housing, which reduces the tether size, and it’s also very light weight, which reduces the overall tether weight. The identical manipulators each have 6 degrees of freedom; 3 degrees for moving the end arm in a 3-D area, 2 for the wrist, and 1 for the grasper open/close. As it was designed, the “slave” manipulator replicates the movement and force of the “master” manipulator provided by the human operator. The reason for a 6 DOF manipulator is for versatility. This manipulator system should be able to accomplish any light weight manipulation tasks. The gripper is the most mechanically complicated assembly of parts. It is made entirely of plastic parts each specifically designed to interlock with each other.

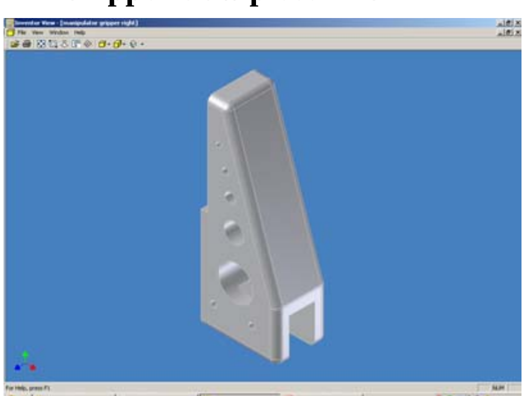
Gripper and Wrist



The manipulator system was first designed with pencil and paper sketches. The design was then refined with AutoCAD to work out the finer details of its movements and limitations. Then the final design was sketched to the figured specifications in Autodesk Inventor. The parts were then uploaded into and created by a rapid-prototyping machine.

Gripper fully open

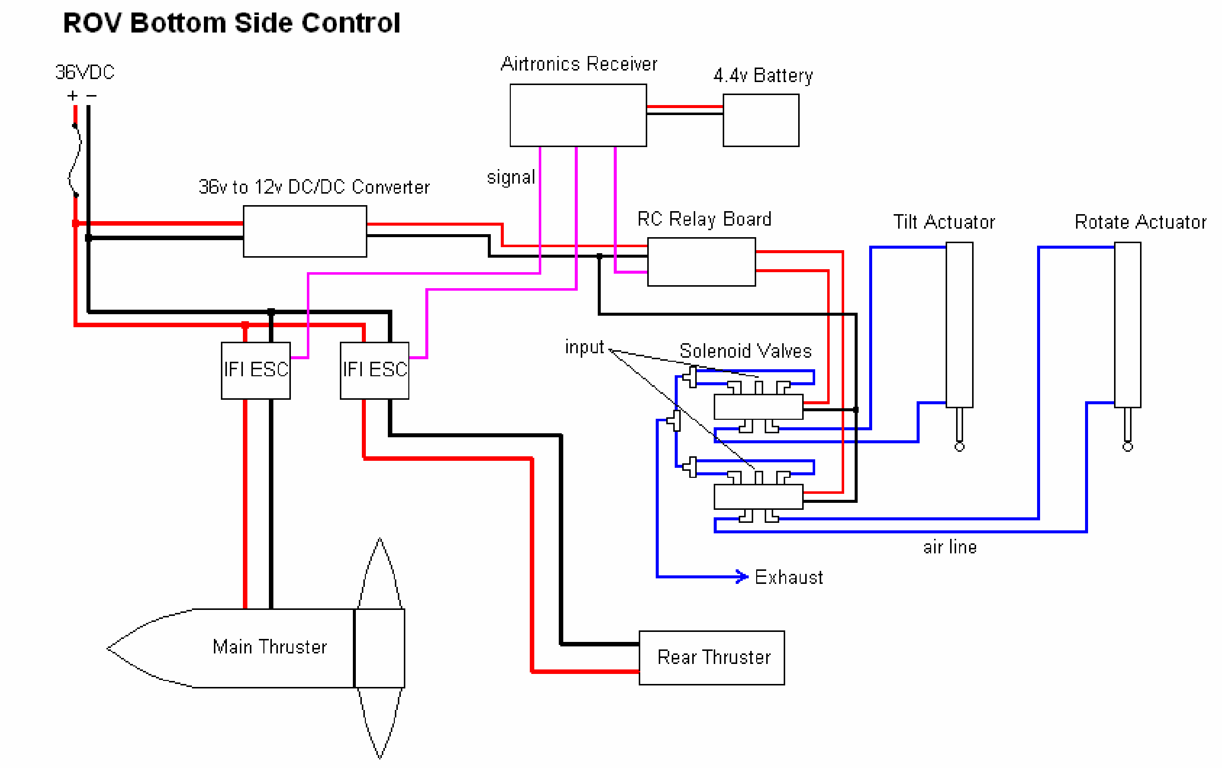
Gripper claw piece in CAD



Gripper fully closed

ROV Drive Control System

This year our team opted for a very simple and reliable control system. The ROV is controlled topside with an Airtronics RC transmitter. All signals are transmitted and received through a single shielded coaxial cable. This keeps the tether light at a fraction of the cost of using fiber optics for such a shallow-water ROV. Due to the number of products for radio controlled equipment, it is also very easy to integrate with other radio controlled devices. The system uses two IFI speed controllers to power the main thruster and the rear thruster. A radio controlled relay board switches the solenoid valves for the pneumatic actuators. The radio system uses frequencies in the 75 MHz range.

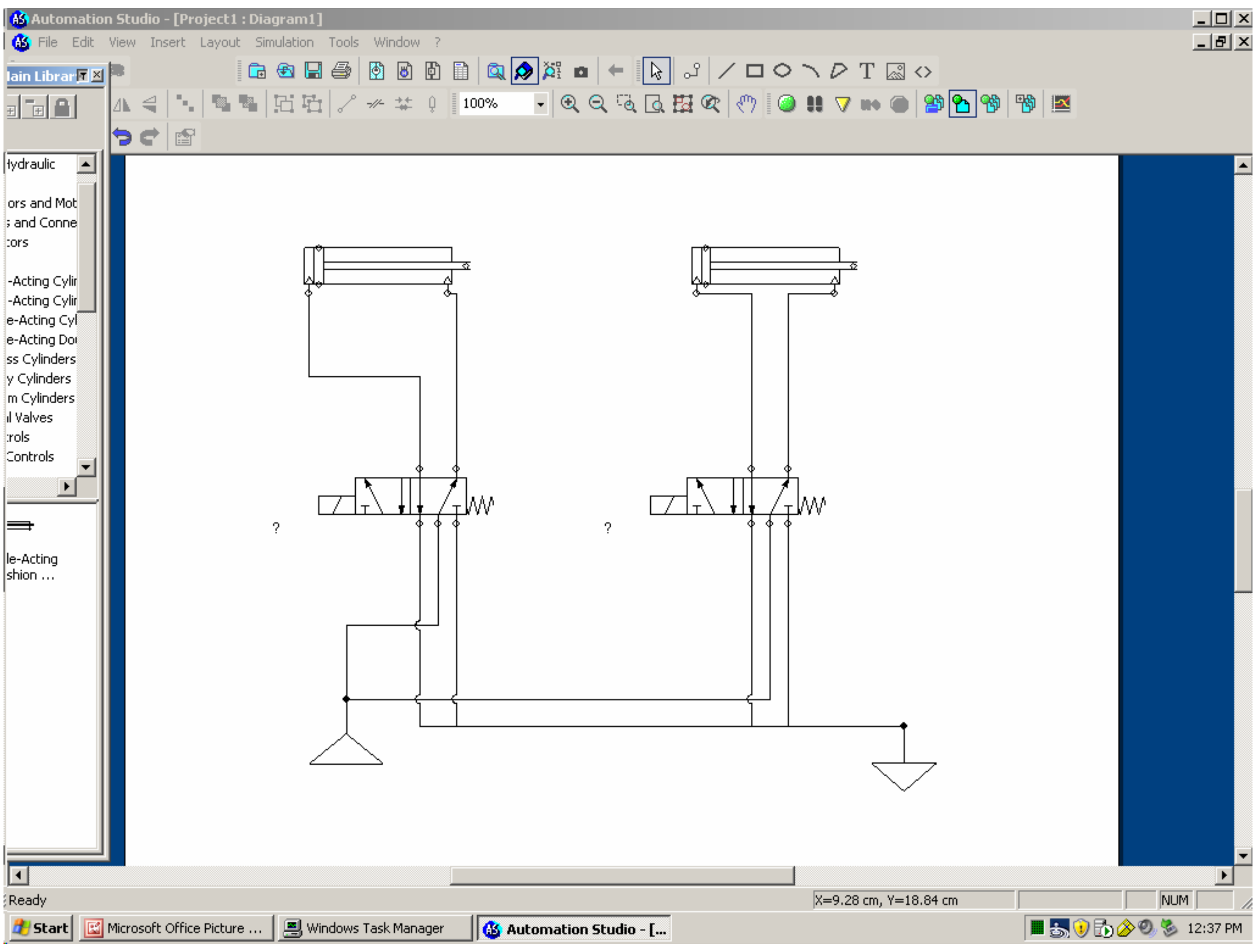


Camera System

The camera system consists of four wireless cameras and one high resolution wired camera. The high resolution camera is positioned straight forward and center for the pilot to use as the main navigational view. The other four cameras are adjustable auxiliary views to give multiple perspectives dependant on the mission. The signals for the wireless auxiliary cameras are sent through the same coax as the control signals, and use frequencies in the 2.4 GHz range, which are too high to interfere with the control signals.

Pneumatics System

The 2007 ROV uses a pneumatics system for a number of purposes. The pressurized dry air is used to keep the condensation from forming on the camera lenses and electronics when exposed to a low temperature environment by completely removing the humidity from within the ROV housings. The pressure of the air is used to keep the ROV housings watertight by remaining at a higher than ambient pressure. Most importantly for the operation of the ROV, the air pressure is used to power two pneumatic actuators responsible for changing the direction of the ROV’s movement. The pneumatic actuators are driven by two 4-way solenoid valves. These valves direct 20 to 40psi of dry air from within the ROV housings to the actuators. The solenoid valves are triggered with 12vdc. The 12vdc signal is provided by a radio controlled relay board that connects directly to the Airtronics receiver, and completes a circuit between the relay com output and the com input. The com input is wired directly to the output of a 36v to 12v DC/DC converter. The pneumatic linear actuators are used to rotate the main thruster up, and to the right. When no signal is sent to the relay board, and the ROV is pressurized, the main thruster’s normal position is straight forward.



Automation Studio Diagram

Budget and Expenses

Expenses

Minn Kota Rip Tide 101 trolling motor = $660.00

36 VDC Motor = $33.00

Fishing line = $15.74

DC/DC Converter = $160.00

Scooter drive belt = $31.95

Roller chain & Sprocket = $34.19

4 Neodymium magnets = $34.19

3 Brake cable housings = $29.85

Waterproof grease = $5.00

1 High-resolution camera, 4 camera kit, 1 color quad processor = $524.45

Rose Metal Material = $114.91

Electronic Goldmine order 04/02/07 = $21.98

Shamrock Bolt & Screw = $9.37

IBT = $58.52

Scuba Depth Gauge = $67.90

Radio Kit & Servo = $192.97

2 Solenoid valves = $100.00

Shipping = $1000.00

2 plane tickets = $1100.00

Home Depot = $300.00

Total = $4494.02

Project Budget

$4250.00

Donations

Missouri State University funding allocation council = $3000.00

MATE Rookie of the Year Award = $250 Home Depot Card

Missouri State University Industrial Management Dept. = Rapid-prototyping machine access and plastic

Rose Metal = 4 laser cut aluminum sheets

MATE Travel Stipend = $1000.00

Description of a Challenge

The main challenge for the project over all was the overwhelming amount of work to be done during an already overwhelming semester of school. As a result of the team's busy schedule, many sacrifices where made to everyone's free time so that we could get the project done… almost in time. It also didn't help that the design was particularly complicated. It was a great challenge to make efficient use of time and materials to get the best end-result we possibly could. The team worked many Saturdays, after having to get special permission to be in the building on the weekends. Because the project was very labor intensive, or maybe other reasons as well, many of the initial team members quit, leaving a dedicated four members. This created a somewhat hectic atmosphere toward the end of the school year, when we realized how much more we needed to accomplish, and how little time we had left. Toward the end of the project we made efficient use of our time by completing much of the project individually rather than waiting until everyone could meet at once. The drawback was the gap in communication when the team was not together. We relied on e-mails and text messages to communicate what each other had accomplished or needed to accomplish.

Troubleshooting Technique

While developing any new system, problems can and do arise, making for a time consuming challenge. One problem our team had in particular was with the valves used in our pneumatics system. We use two identical 4-way solenoid valves to route pressurized air from within the ROV housings to the actuators. When we initially connected our valves to pressure, they would constantly leak air from a small hole and would not trigger when power was applied. The fact that both of the valves did not trigger led us to believe that we were doing something wrong. We thought it could have been a number of things. The power may not be connected correctly, our battery may not contain a strong enough charge to trigger the solenoid, our pneumatic lines may not be correctly connected, or the valves may both be defective. We soon noticed that when the tiny leaking hole was plugged, the solenoid valves would work fine. This completely changed our initial thoughts of the problem. After consulting with an engineer from the company which we purchased the valves, we did not get any further, and were told that valves could be defective. We decided to open one of the valves and take a look at the mechanisms to see if we could see anything strange. We quickly noticed that a very small gasket could be removed, and placed in a new position, orientating the gasket in the opposite direction inside the valve. Just to see what would happen, we moved the gasket to the new position, and triggered the valves. They then worked perfectly with no leaks. The valves were obviously made to move the gasket, and the hole where the air was leaking was there by design, so we are still curious of what purpose that feature is used for. We're not that curious though, we're just glad our ROV works now.

Future Improvements

To improve the quality of our ROV, our performance at the competition, and our experiences during planning and building, we think that we should re-use the same ROV for the 2008 MATE competition. Some changes could be made to the ROV, but starting back from scratch will not be necessary next year. This will give us more than enough time to better prepare for the missions, and we will have more money to spend on travel expenses. As far as changes to the ROV, we think that many of the weaker plastic parts could be replaced with cast aluminum, or injection molded ABS plastic. Also, some mistakes where made during construction that were not planned. This caused us to improvise quick solutions to save time. If we used the next year to “upgrade” our ROV and modify it for the new missions, we would have the time to redo many of the small mistakes and restore the ROV to its original design. Many of our concepts were untested before we decide to use them, but after having put them into practice we now know what needs some improvement. Our manipulator in particular is not very accurate in transferring its force to the other manipulator. This is due to its soft plastic parts and the fishing line used to transfer force which stretches when too much force is applied. We plan to strengthen the manipulator to handle grasping of heavier objects.

Lessons Learned

As with any project, there are lessons learned. We feel that this project in particular had many lessons for us. At times these lessons came with frustration, and other times they came with relief. Each one of the team members learned how to weld aluminum for this project, and we each learned how to use a rapid-prototyping machine. Some of us learned how to use 3-D CAD software, and how to turn an idea into a physical product in a matter of hours. We learned how to build a magnetic coupler, and some of us where introduced to fluid power. Some members learned some basic electronics, and some learned basic machining skills. Most importantly to us though; we learned how our own designs fared, and how to make them better.

Short History of Arctic Exploration

Much of the Arctic exploration being pursued today is for purely scientific reasons, but this has not always been the case. The first explorers of the northern most region of the world are motivated by more political reasons. The arctic was initially discovered as a result of the search for an alternate trade route to the Orient from Europe. These expeditions took place over a number of centuries beginning in 1453 with the capture of Constantinople by the Turks. Later, Columbus explored a westerly passage to the Orient from Europe in 1492, then John Cabot in 1497 explored farther north, stopping in Newfoundland. Much later, Sir John Franklin set out to travel through the Northwest Passage in 1845 with two Royal Navy vessels, and never returned. No evidence was found of the vessels until 1857. The crew did not survive the extreme environments of the Arctic after abandoning, and the ships where found frozen in ice. To this day the history of Sir John Franklin's exploration is researched and evidence of the what happened to the vessels and crew is frequently collected. After Franklin's failed expedition, Britain shifted its attention to exploring the North Pole. The first person credited to reach the north pole is Robert Peary in 1909, though it is disputed whether or not he actually made it there.

Sources:

http://en.wikipedia.org/wiki/North_pole

http://geography.about.com/library/misc/ucarctic.htm

Reflections on the Experience

By Luke Waier

Once again the ROV project for the MATE competition has been a great learning experience. Just a rookie in last year's competition, I feel now as though I've gained a tremendous amount of general engineering knowledge and experience from this project. As the team captain, and president of the robotics organization, I have extended my learning from trying to hold the project and team together. Our design in particular incorporated so many individually designed components and used so many things I had not previously been familiar with, building them was quite an experience. Some of the skills I have learned, though some other members were already familiar with, were using 3-D CAD programs, using various machines such as the rapid-prototyping machine, mill, lathe, and arc welder, and designing and using pneumatics systems. Other things learned were from our own designs put into practice. I learned that a simple magnetic coupler does actually work great, and that the strength of a rapid-prototyped plastic part depends on how it is oriented when it is built. Overall, the ROV project has been a learning experience worth the amount of hard work put into it.

Acknowledgements

The MSU ROV Team would like to thank Rose Metal for donating their time and materials to laser cut some of our aluminum parts. We would also like to thank the Missouri State University Industrial Management Department for donating the ABS plastic used for the rapid-prototyping machine. We also appreciate the large donation from SOFAC (Student Organization Funding Allocation Council) at Missouri State. And we would like to thank MATE for their generous support with the travel stipends as well as their online support to answer questions.