Missouri State University
MSU Robotics Team

Presents

U D O
Unidentified Deep-sea Object

MSU ROV Team Members
Kirk Jones - Senior - Computer Science, Mathematics, Physics Timothy Burnell - Junior - Computer Science, Mathematics, Physics Luke Waier - Freshman - Mechanical Engineering Gerald Leenerts - Freshman - Graphic Design, Computer Science Mathew Landis - Senior - Computer Science, Mathematics Travis Washeck - Junior - Computer Science, Mathematics
Instructors - Dr. Pawan Kahol, Dr. Richard Belshoff

Abstract

During the initial design conceptions of an ROV, a team must address the main intention of the ROV and design accordingly to effectively complete the objectives. We proposed that the most important factor in designing an ROV for this year's mission tasks is maneuverability. Much maneuverability is needed in every mission task. It is need to orientate the ROV to precisely install the electronics module into the frame, insert the cable connector, and also to position the cable through each of the waypoints. Our other factor to consider was our budget, which relied completely on little sponsorship and our own money. With these parameters in mind, our team designed a highly maneuverable ROV with a cost well under our planned limit of $1000. We devised a radical streamlined design that implements what we are considering a new method of motor positioning for propulsion that gives the ROV a complete full range of motion. We present our efforts of creating this design in this document.

Introduction:

Since their first appearance decades ago, remotely operated underwater vehicles have played an important role in keeping divers out of the hazardous depths of the ocean. ROVs today are used in several industries inspecting underwater structures and even performing duties with large tools that would otherwise put a person at risk. ROVs even reduce the cost a company would need to pay to send a diver to the dangerous abyss by altogether eliminating that need. Modern industrial ROVs carry the latest technology, and some are as large as some manned submersibles, and have a similar price tag. Many other ROVs have created a low cost option revolution by providing a high performance small size platform for use on inspection and smaller scale manipulation of objects.

In this report, our team details our solutions to the given tasks of the 2006 MATE ROV competition, as well as the extra creative ideas that we couldn't help but implement into our design.

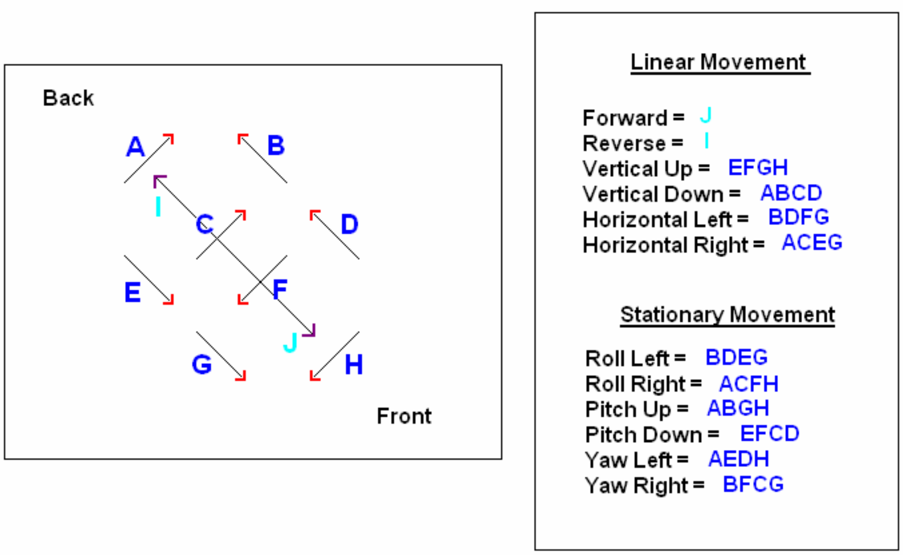
Design Rationale:

The Missouri State University Robotics Team held many meetings to discuss a design for the competition, and each member was given the assignment of researching ROV design and function as it applied to the sea industries. We quickly agreed that almost all ROVs have a box like shape. We discussed the many reasons for this, such as stability, simplicity, and adaptability. Although these are worthy reasons for the design, our team felt the consistently similar design is boring, and we wanted to bring something new to the competition, and to the world of ROV's. This design is achieved by our own devised methods that are outlined in this document. Everything from the fiberglass molding to the computer programming was 100% conceptualized and fabricated by the students of the MSU Robotics Team.

Propulsion Theory and System:

The U D O uses a seemingly complex system of small motors switched on and off by a computer program networked to a single joystick to orientate the vehicle as the operator needs.

The main idea for the placement of the motors is to utilize simplicity while achieving motion in three dimensions, as well as rotation pivoting at a center point of each of the x, y, z planes for unlimited mobility and maneuverability. All together, the motor setup has twelve different thrust combinations that provide a maximum of control needed to perform the demanding mission tasks.



U D O uses a total of nine motors to thrust itself in any desired direction, eight of which are 1000 GPH bilge pump cartridges, and one main motor with the most power. The main motor controls forward and reverse functions of movement, with a powerful 13.6 kg thrust rated Minn Kota Endura 30 trolling motor. This motor is rated for 4.3 meter boats and uses a max of 30 amps of the 40 amp limitation. The troll motor is 9.53 kg, so it is most efficient to use no more than one of these motors because of the amp limitations. Using two Endura 30 motors would give the ROV about the same thrust capacity at twice the weight. The other eight motors are placed in a way so that they control every direction of movement other than forward and reverse.

The eight 1000 GPH bilge pump cartridges are placed in a diamond formation around the thrust tube; a diamond of four pumps at the front of the tube, and a diamond of four pumps at the rear of the tube.

The multi-directional thrust works by turning on four pumps at a time for every direction of movement besides forward/reverse. Because the ROV uses four motors at a time, it jets 15,141 liters of water per hour for every movement, and even more for thrusting forward. The Minn Kota control is set up to run at either a low, medium or high speed in forward, and a single slow speed in reverse. We chose to use bilge pumps because they are cheap, easily replaceable, waterproof, and already provide a direction of thrust, eliminating the need for mounting propellers. The formation of the jets on the ROV eliminates the need for reverse thrust, which furthermore eliminates the need for propellers. Although there are a total of nine motors, which may seem like too many for an ROV, the pumps are a very cheap and simple way to provide thrust. All nine motors cost the team a total of only $129.00.

ROV Body Design and Fabrication

The shape or build up of U D O, as well as the methods used to attain the design, are probably the most unique aspect of our ROV. The curved "wings" of the craft serve as U D O's primary ballasts, and also function to house the bilge pump thrusters. A duct is cut through each wing to allow water flow into the pumps. To fabricate the wings, we originally discussed using plastic molding, but we opted for a lower cost option of laying fiberglass. The versatility of fiberglass allowed us to create virtually any shape, and provided for solid, very buoyant and very pretty ballasts. We formed wings into four sections from modeling clay, and then laid fiberglass directly over the clay molds. We allowed 24 hours for each fiberglass shell to dry, and then lifted the shells from their molds. To displace water, we poured 97% closed cell marine grade expanding foam into each wing section shell.

Buoyancy:

In order to achieve a maximum of efficiency by weight to power ratio, buoyancy must be calculated within the design before implementing displacement. Because of the compound curve design of U D O, it is obviously very difficult to accurately measure the volume of the ballast design before fabricating it.

We therefore devised a method to figure the amount of displacement needed to achieve near neutral buoyancy through design. We measured the dimensions of a block of clay to find its' volume. Once calculating the weight needed to be displaced, we found that we needed about the volume of 4 blocks of clay; knowing that, we used one block of clay to mold the wings into four sections that would later be placed together to form the ROV ballast. Here are our calculations:

Calculations of Buoyancy

We used 4 blocks of stoneware clay to make the molds for the ROV wings. We measured each block to be approximately 25.4 cm by 20.3 cm by 10.2 cm. Using the measured volume of one clay block, knowing we used four clay blocks, and using the known density of water, we can calculate the displacement of the wings formed from our four clay blocks. By weighing the components used on the ROV and measuring their displacement, we found that the ballasts would need to displace about 210 kilograms of water.

Density of water = 1 gram/cubic cm

Calculated volume of one block of clay =
25.4 cm x 20.3 cm x 10.2 cm = 52,593.24 cubic cm

Multiplied by 4 blocks of clay = 52,593.24 cubic cm x 4 = 210,372.96 cubic cm

$$210{,}372.96 \text{ cm}^3 \times \frac{1 \text{ gram}}{\text{cm}^3} = 210{,}372.96 \text{ grams}$$

$$\div\ 10 = 210.37 \text{ Kilograms of Displacement}$$

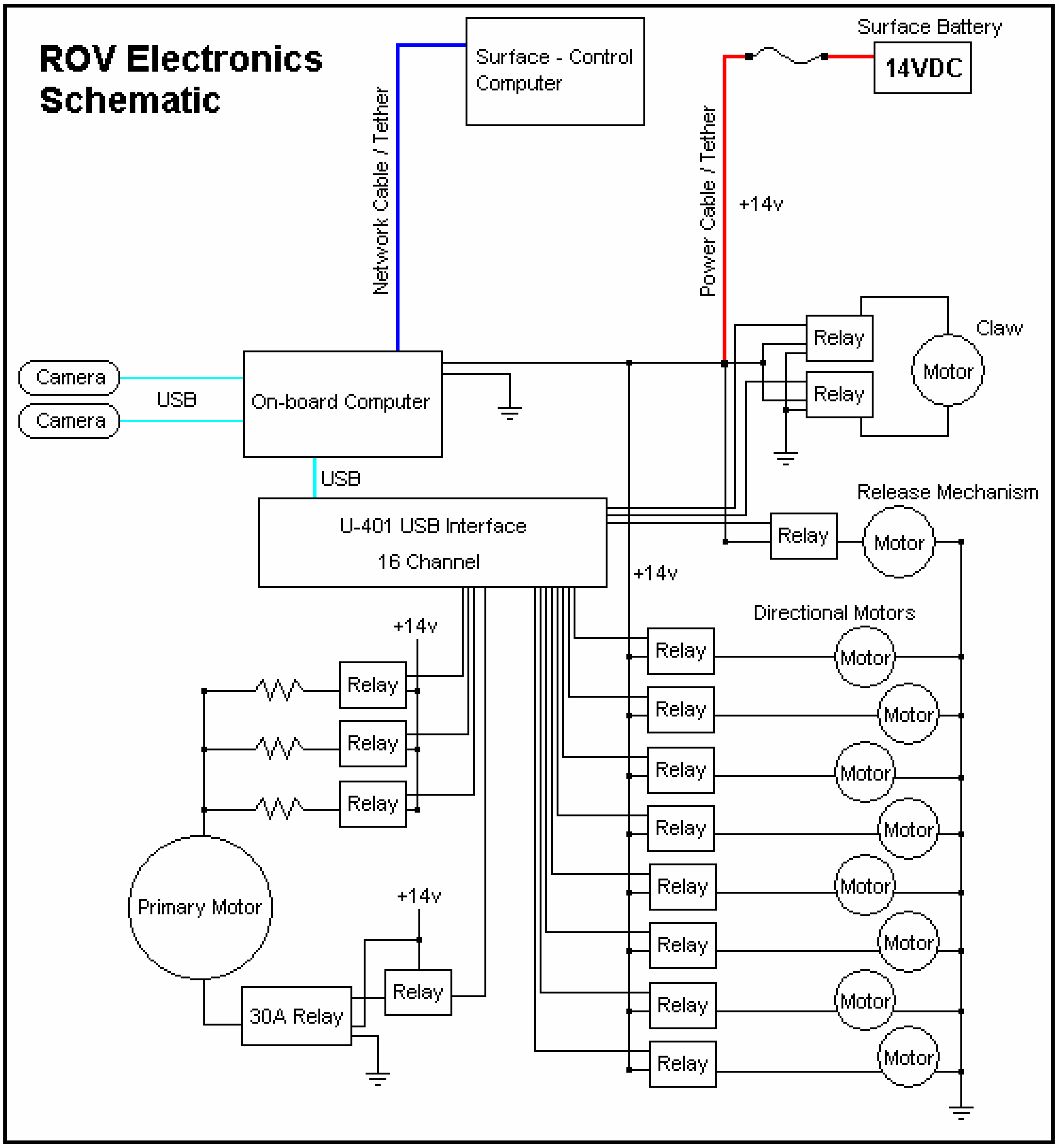
Control System and Interface:

Electronics

The electronics system on board is controlled by a USBMicro U401 USB interface controller (more information available at http://en.wikipedia.org/wiki/USB) operated by an on-board computer. The computer is a 1 Gigahertz Pentium III with 384MB RAM taken from a Dell Inspiron 8000 laptop which was donated by John F. Hodge High School for the purpose of this project. The motherboard was removed from the laptop, leaving only plugs for external devices and a hard drive. The remainder of the electronics consists of an array of low voltage triggered high powered electro-mechanical relays. The relays can handle 10 amps of current each and can be operated with a 5 volt switching signal drawing only 10 milli-amps. This was a necessary feature as the switching voltage provided by the computer is 5 volts with roughly 500mA total current capacity according to USB Specifications found at Wikipedia, http://en.wikipedia.org/wiki/USB.

The computer was chosen for flexibility. Using the laptop provides small and light weight size and low power consumption compared to other available platforms. The on-board computer also allows us to keep the tether at a minimum weight by operating everything over a single lightweight twisted pair Cat-5 network cable. We were also able to minimize the physical complexity of the vehicle and reduce the number of moving parts. Manually synchronizing the eight water jets as well as the primary thruster would be very complicated for a human to control unaided.

The computer also provides forward flexibility. In concept design we had discussed adding gyroscope stabilizers to maintain orientation. This feature proved too complex to implement in our short design and building phase, however for a production system or future events it may be added relatively easily due to the adaptable design of the computer architecture and the software. This too would be operated by the computer seamlessly without any interaction from the driver or interference to the driver's goal.



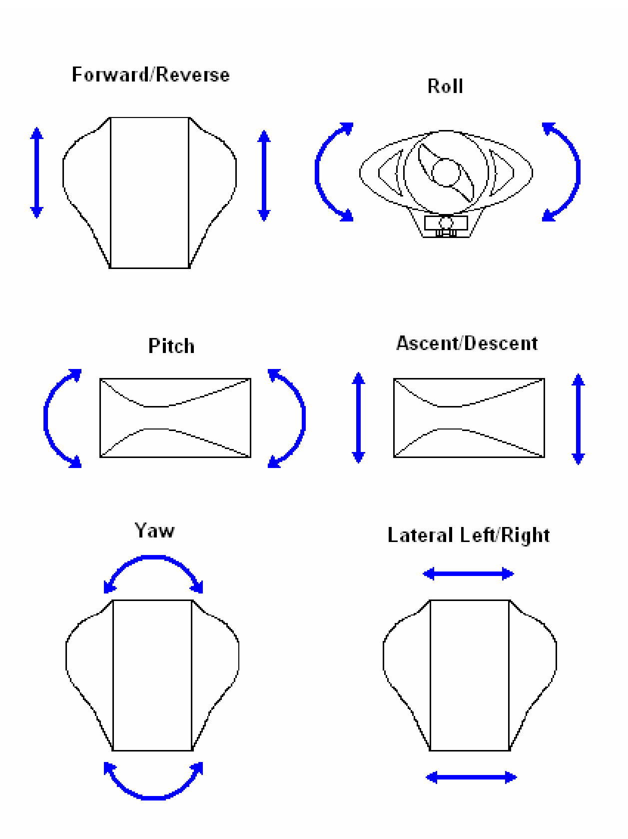
Software

The video is fed into the on-board computer and delivered to the surface monitors over TCP/IP through the open source VideoLAN software available at http://www.videolan.org. This software has the ability to handle video data from a command line system, allowing the on board computer to run with as little overhead as possible.

Due to the expandability of the computer, we can have as many cameras as we would like without adding significant power consumption, and adding no weight to the tether. The control software is custom designed and implemented in Java 5. This allows flexibility for operating systems on the on-board computer, as well as in the hardware architecture. The control software will feature a user interface on a surface computer connected over TCP/IP to the vehicle's client

Manual Stability Control:

U D O was designed to have a center of buoyancy at its' center of mass. This gives the operator the ability to manually control its' stability rather than having a low center of mass common on most ROVs to auto-stabilize the vehicle. With this manual control design, U D O can orient itself in anyway suspended in the water, and essentially remain in that position until a command is given through the joystick control to right itself. In still water such as a pool, this puts every bit of control at the will of the ROV operator. Below are the control capabilities of U D O:

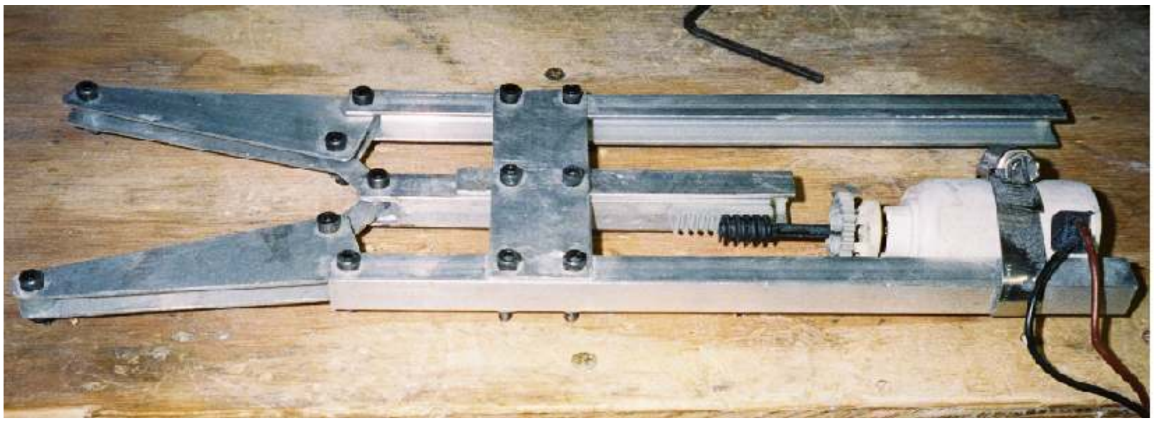


Because of the vehicle's ability to pitch and yaw, the pilot can also use the center thruster for linear movement in any direction. And because U D O is stabilized manually, the center thruster can be used for a quick ascent or descent by pitching vertically up or down and throttling forward the center thruster. This gives the pilot many possibilities for maneuvering.

Mission Tools:

Front claw/manipulator

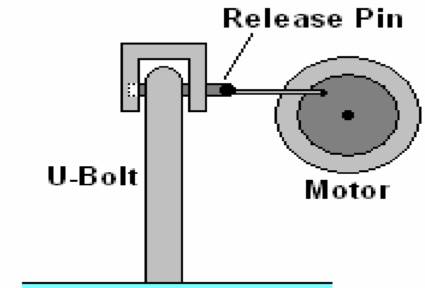
The front manipulator was constructed from three original pieces of aluminum that were cut into smaller pieces and bolted together. The mechanism was designed by team members to be constructed for as little money as possible while still operating effectively. The device also uses a very simple method to open and close.



Overall the mechanism cost the team about $35.00, and a few hours to build.

Release Mechanism

The release mechanism is a very simple method, using one bilge motor and some small pieces. During original discussion of a release mechanism for the electronics module, we had brainstormed various ideas of complex release methods including suction cups. We decided that suction cups may be too unreliable, and would also require purchasing a waterproof solenoid valve. The team eventually decided on a simple pull pin method that would attach only to the center u-bolt. The aluminum skids on the underside of U D O have attached rubber to grip the plexiglass which keeps the module from moving side to side and front to back. Then, a pin fits through the u-bolt, holding the module from moving downward.



2006 MSU ROV Team Budget ⁄ Expense Sheet			
Description	**Estimate Worth**	**Expense**	**Balance**
Minn Kota Endura 30 troll motor - previously owned by team member	$100.00	$0.00	$0.00
10 inch ID Industrial PVC tube	$20.00	$0.00	$0.00
U-401 USBmicro interface – sponsored a discount	$45.95	$20.00	-$20.00
US Composites - Fiberglass materials		$189.60	-$209.60
US Composites - Fiberglass Finish		$20.82	-$230.42
Dell Laptop - Donated By John F. Hodge High School	$1000.00	$0.00	-$230.42
8 Bilge Pumps - Johnson Pump sponsored a discount		$129.00	-$359.42
600 ft. 10AWG - Donated by Tucker Electric	$300.00	$0.00	-$359.42
Auluminum box - Hood's welding donated materials	$70.00	$50.00	-$409.42
Materials - Ace Hardware Store		$114.73	-$524.15
Materials - Home Depot		$47.55	-$571.70
100 ft. Cat-5 Cable - Donated by MSU CSC Department	$20.00	$0.00	-$571.70
15 x 5v SPDT Relays -Hobby Engineering		$50.00	-$621.70
Marine high-gloss Paint - 2 colors		$60.00	-$681.70
2 PC Cameras – provided by team member	$60.00	$0.00	-$681.70
Totals	**Estimate Worth** **$2225.65**		**Balance** **-$681.70**

Troubleshooting Techniques:

During the later construction of the ROV, we noticed that the path of thrust from the downward thrusters was partially blocked by the electronics box. In the design, the thrusters were farther from the box to allow for correct flow of water, but the box was built wider than originally planned to accommodate for additional hardware and wiring. To troubleshoot this problem, we decided to attach a hose to each downward thruster that changes the path of thrust to pass by the box unblocked.

Lessons and Skills Learned:

Each member of the MSU Robotics Team gained new knowledge and skills from this unique experience. As this is our first year competing we have acquired a tremendous amount of information from a wide range of areas. Some members learned how to create a fiberglass mold, lay fiberglass strips, and for the first time worked with various composite materials and hazardous chemicals. Every member has gained an in-depth understanding of ROVs. Every member has experienced working under pressure, and working with a team, to complete an objective within a small time frame. And some of us will continue our learning experience as we compete among top engineering schools at the 2006 MATE ROV competition.

Challenges Faced:

One of the most difficult challenges faced was balancing school with a very short deadline of one semester to design, build, and test an ROV. To overcome this challenge, we tried to manage our time efficiently by setting goals for each meeting, and assigned individual goals for the time between meetings to increase productivity.

Future Improvements:

There is always room for improvement, and in our case we expect a 500% improvement in every aspect of the quality of our team by next year. Our team first met to start this project late January of this year, and we almost did not have enough time to complete everything for the competition. As a huge improvement for next year, we will spend the entire school year on the project. The team will spend the first semester fund raising, designing, and testing and modeling design concepts. By the second semester, we will be ready to start building early. Another improvement is to get more students and faculty involved. This year there was little involvement and interest from students and faculty, but there was also little effort to advertise the robotics group. As for ROV design improvements, a huge draw back from our design is the complex curves. Because the molds were hand made with modeling clay, there are many inaccuracies in the construction. And because the design is curvy, it is extremely difficult to accurately measure points for drilling holes and mounting objects. As an improvement, we plan to design an ROV with

more angles and accurate distances. Another design improvement is to use an already made waterproof casing. This year we welded one from scratch. We also had many ideas to implement through software and electronics hardware, but we were too limited on time. All of our improvements are based on the experiences and knowledge gained from this one semester with 2006 MATE ROV.

Ocean Observing Systems:

IOOS, Integrated Ocean Observing System, provides continuous data of the oceans and Great Lakes. It provides information from the global scale of ocean basins to local scales of coastal ecosystems.

The IOOS system provides data in various forms and rates for a variety of users. The system links three subsystems that detect and predict changes in the state of marine systems. The observing subsystem employs both remote and *in situ* sensing. Remote sensing includes satellite-, aircraft- and land-based sensors, power sources and transmitters. *In situ* sensing includes platforms (ships, buoys, gliders, etc.), *in situ* sensors, power sources, sampling devices, laboratory-based measurements, and transmitters. The development of the observing and modeling subsystems must be closely linked with the data requirements of models driving future developments of the observing subsystem.

AOOS is an IOOS regional association that provides a centralized location for marine environmental and geographic data for the Alaskan area. AOOS goals are to improve the safety and efficiency of marine operations, reduce the effects of natural hazards, improve predictions of climate change and its effects on coastal populations, improve national security, reduce public health risks, and More effectively protect and restore healthy coastal marine ecosystems

References:

http://www.ocean.us/ioos_system, http://www.aoos.org/

Acknowledgements:

The MSU Robotics Team would like to thank the individuals and companies that made this project possible. We thank John F. Hodge High School for donating the laptop, which is the most expensive and important component to our ROV. We thank USBmicro for discounting our interfaces. We thank Johnson Pump for the great deal on the bilge pumps. We thank Hood's Welding for their provided welding services, Tucker Electric for the free wire, and the MSU CSC Department for the Ethernet cable.