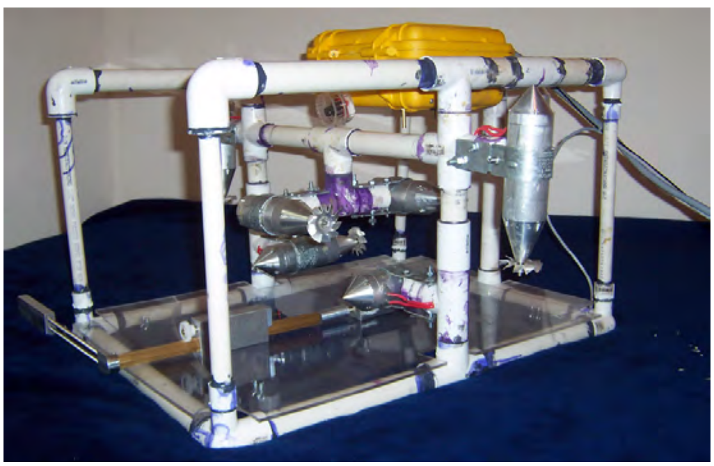
underwater..............
Remote Operated Vehicle Challenge

Built for use in the
2006 MATE Center/MTS ROV Committee ROV Competition

ROV1



Calvin

ROV2

Hobbes

Design and Manufacturing by Team Powerfish

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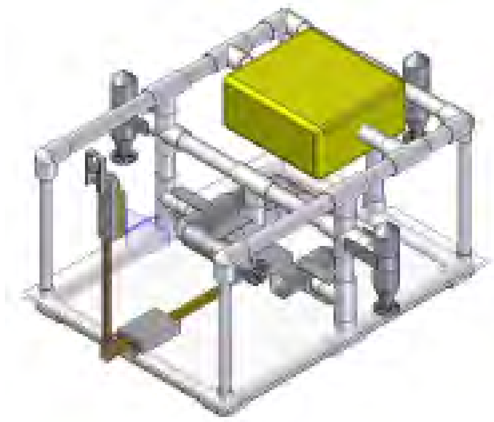
ABSTRACT

Whether navigating the currents of a human blood vessel, traversing the aftermath of nuclear destruction, or exploring the furthest limits of deep sea, or deep space, today's Remote Operated Vehicles have given humans the ability to experience matters previously unattainable because of our own innate inabilities and imperfections. From nanobots to orbital satellites, ROVs of all shapes and sizes allow perception well beyond the limitations of our given five senses, all while protecting the relative frailty of the human body. In order to promote ingenuity and understanding within the architects of the next generation of ROV technology, the MATE Center and the Marine Technology Society's ROV Committee have partnered with Ocean.US and the Ocean Research Interactive Observatory Networks (ORION) Program to hold the 2006 Underwater Remote Operated Vehicle challenge. The competition, meant to familiarize engineering students with ROVs tailored towards oceanographic observing, challenges teams to manufacture vehicles that conform to preset design criteria in order to operate at a submerged depth of 13m while performing a varying array of predetermined tasks. To meet this challenge the UC Davis Team Powerfish has developed two ROVs meant to complement each other as they work in conjunction to complete the assigned missions.

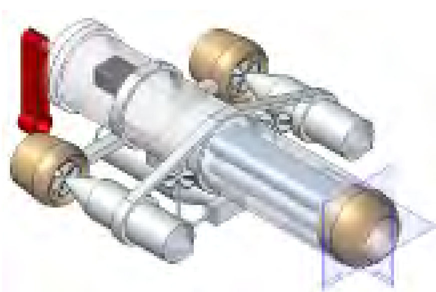
DESIGN RATIONALE

In order to meet the challenges set forth by the competition committee, it was decided that two vehicles working in conjunction would create the best opportunity to successfully complete required exercises and resurface before the expiration of the 20 minute time limit. The first of the ROVs, designated Calvin, is designed with the intention of being a bulkier vehicle responsible for transporting the electronics module as well as ROV2 to the pool floor. Equipped



with a robotic arm, ROV1 is also capable of opening the trawl resistant frame door and subsequently plugging the cable connectors into the electronics module. What the vehicle lacks in overall top speed, it gains in maneuverability, which will be necessary in order to accurately position the electronics module within the constricting dimensions of the trawl resistant frame on the pool floor.

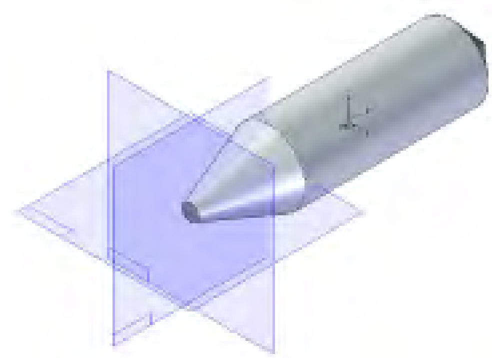
The sole responsibility of ROV2, Hobbes, is to bring the cable connectors to the arm of ROV1 in a timely manner, after having run the nylon cable through the positioned waypoints. Designed to attain high horizontal speeds just above the pool floor, ROV2 is not equipped with the means to generate a great deal of vertical thrust and must therefore return to, and dock with ROV1 so that the two vehicles may resurface as a tandem after successfully completing the missions.



When original design configurations for the pair of vehicles were considered, a great deal of attention was focused on the competition's 20-minute time restriction. It soon became apparent that an additional goal of the team should be to develop vehicles capable of being the fastest in the competition to complete the entire mission. In accordance with this goal a great deal of time was put into the research and development of strong and efficient propulsion systems.

Propulsion System Details

In order to save time as well as resources, one thruster design was modeled and then implemented on both vehicles. The goal of the propulsion design calculations were to obtain an optimal performance while staying within the specified power restrictions laid out in the competition guidelines. A motor and gearbox were first selected to operate within this range. The chosen output shaft can operate at 195 radians/second (1862 RPM) with .08 Nm of torque while staying within the electrical power constraints. Rough calculations were then used to estimate the drag on each ROV by modeling each vehicle as combination of cylinders, elliptical cylinders, flat plates and other geometric shapes of varying sizes. Each component's drag was calculated by summing its surface drag and its pressure drag and a rough estimate of the drag force was calculated for each vehicle. Using the speed that gave a drag force which met the power requirements, an appropriate prop blade was designed.

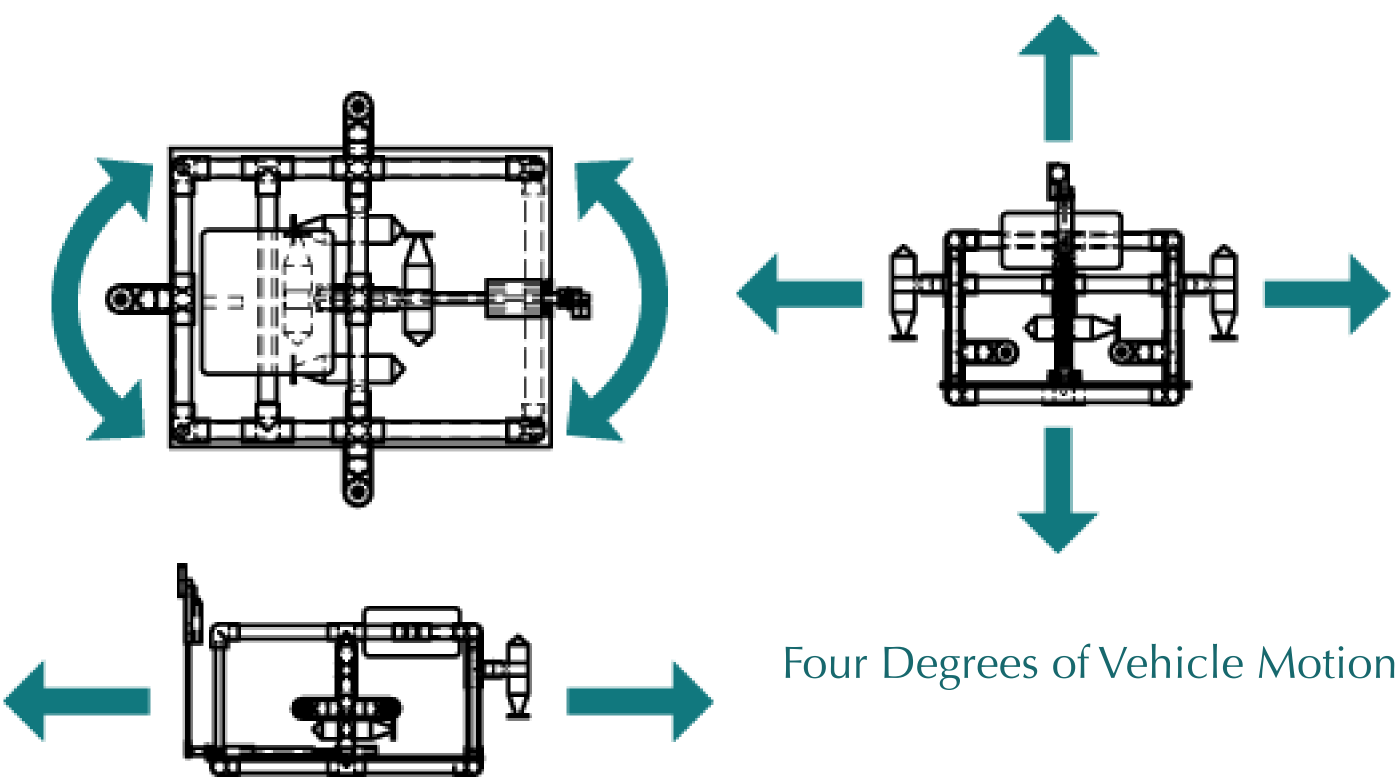


In order for the thrusters to operate underwater, aluminum casings were meticulously machined to house the motor and gearbox assembly. The housings caps are waterproofed by the use of two o-rings, each with a 15 percent compression. The shaft is waterproofed by a lip and spring seal that can withstand pressures well beyond the 13 meters of water that is required. The design allows for easy access to the motor and gearbox for any necessary maintenance, while still retaining its waterproof capabilities. Aluminum casings are not only easy to machine but also provide excellent thermal properties which help prevent overheating and possible burnout of the motors.

ROV1 Design Details

The design of Calvin (ROV1) centered about the completion of four tasks: (1) delivery and release of the electronics module payload, (2) opening of the trawl resistant frame door, (3) receiving the cable connectors from Hobbes (ROV2), and (4) plugging the cable connectors into the electronics module. In order to fulfill these requirements, Calvin was designed to be a large transport vehicle, capable of delivering the electronics module to the trawl resistant frame. Once atop the frame, Calvin is meant to actually remain sitting in place while completing the three remaining tasks. A robotic arm was developed and mounted to a side of Calvin to aid in the completion of these tasks.

Calvin has seven mounted thrusters for full motion in three dimensions: two for "x: left-right," two for "y: front-back," and three for "z: up-down." At least two thrusters were added in each direction around the center of mass to allow for greater stability and control, which will be necessary to accurately deliver the electronics module. Three thrusters were added in the z-direction to account for asymmetry across the "fore-aft" centerline.



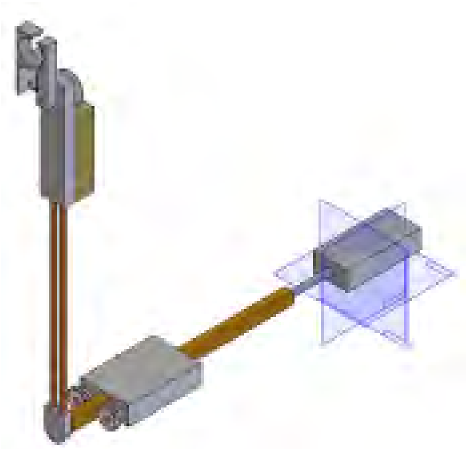
Four Degrees of Vehicle Motion

The electronics module will be held underneath the vehicle. Four pins will connect the corner U-bolts of the module to the base of the ROV. Each pin connection consists of two screw eyes that are attached to the base of the ROV, and a U-bolt, which is attached to the module. The U-bolt is inserted between the screws, and a pin slides through the eyes (Figure X). In order to release the pins, a motor inside the ROV control box pulls a rod that is connected to four thin steel wires. A series of pulleys feed each wire down to its corresponding pin.

ROV1 has three cameras to guide its movement through the water. The first camera looks below the vehicle, allowing the remote pilot to guide the ROV into the trawl resistant frame. The second camera is mounted in the middle of the vehicle in order to observe and control the arm. A third camera is mounted on the head of the arm to determine the location of the plugs.

In order to facilitate the delivery of the cable connectors from Hobbes, one side of Calvin was left relatively open. Consequently, the vehicle was asymmetric about the fore-aft centerline, and weights had to be added to the back to stabilize the vehicle. On the open side of the vehicle, the arm is mounted.

The arm for ROV1 has been through many different design considerations. The original plan called for a fully articulated humanoid arm with six degrees of freedom. As the design for



the two ROVs improved, so did the arm's. The final manufactured part has three degrees of freedom. Two Swiss-made Escap-22 gear motors are capable of rotating a geared rod, which forms the upper arm. A third Escap-22 gear motor turns a threaded rod to move the arm forward and backwards in a direction perpendicular to the open face of ROV1. A fourth Escap-22 with a pair of bevel gears opens and closes a claw mounted on the forearm. The length of the forearm is adjustable, but will specifically set before the competition so that as the arm rotates about its fixed axis of rotation, a cable connector grasped in the claw can be plugged into either of the ports on the electronics module.

Opening the door to the electronics module is the first objective of Calvin's arm. To accomplish this, ROV1 will use a wedge mounted on the side of the arm to open the door partway, and finish by simply pushing outward. Once the door is open, the arm must plug in the two cable connectors. It will grasp one of the cable connectors directly from an accompanying arm on ROV2, then swing down and lineup the connector to the appropriate port and insert. It will then repeat this process once Hobbes has finished running the instrument cable through the waypoints and returns the connector to Calvin. Once the mission is accomplished, the arm will return to a vertical position for the trip back to the surface.

In order to effectively operate the arm, the pin connections and the thrusters, a sophisticated control module for ROV1 was developed by one of the electrical engineers on the team.

ROV1 Control Module in Greater Detail

The control module for Calvin consists of transmitter and receiver. The transmitter reads data form a single analog joystick, encodes the data and sends it via Rs485 to ROV1. The receiver gets data from the transmitter, decodes the data and runs selected motors at a desired speed. Both transmitter and receiver have a PIC877A processor on board. There were three main reasons that microcontrollers were chosen for the control module. The first reason was the availability of serial communication (RS232) on these processors. The RS232 communication allows the sending of data with just two wires, so that a thinner wire may be used to control the ROV. The second reason is that it allows the thrusters, arm and release system to be controlled with a single joystick, all while a user can monitor state of the motors on an incorporated display. The last reason is that it is easy to reprogram the controller without changing the physical circuit boards. These processors add a great deal performance efficiency as well as future design flexibility.

The main board of Rov1 has following features: 20 MHz processor speed, 9 bridges on board, 2 channels PWM, half Duplex Asynchronous communication (RS485), current limiter, and a security system for water leakage inside the control Module. These processors are programmable/reprogrammable. Two available PWM channels of the PIC processor can change the speed of the bridges, running at 1.2 Khz. These two PWM channels are multiplexed with nine bridges on the main board. From nine bridges, three of them are used for arm control. The other six are used for thrusters. With a single keystroke on the Joystick, a user can easily choose to control the arm, thruster or the release mechanism. The transmitter for the ROV1 is also equipped with a 16x2 line display that shows the user information about the thrusters, the arm, vehicle direction, and motor speeds.

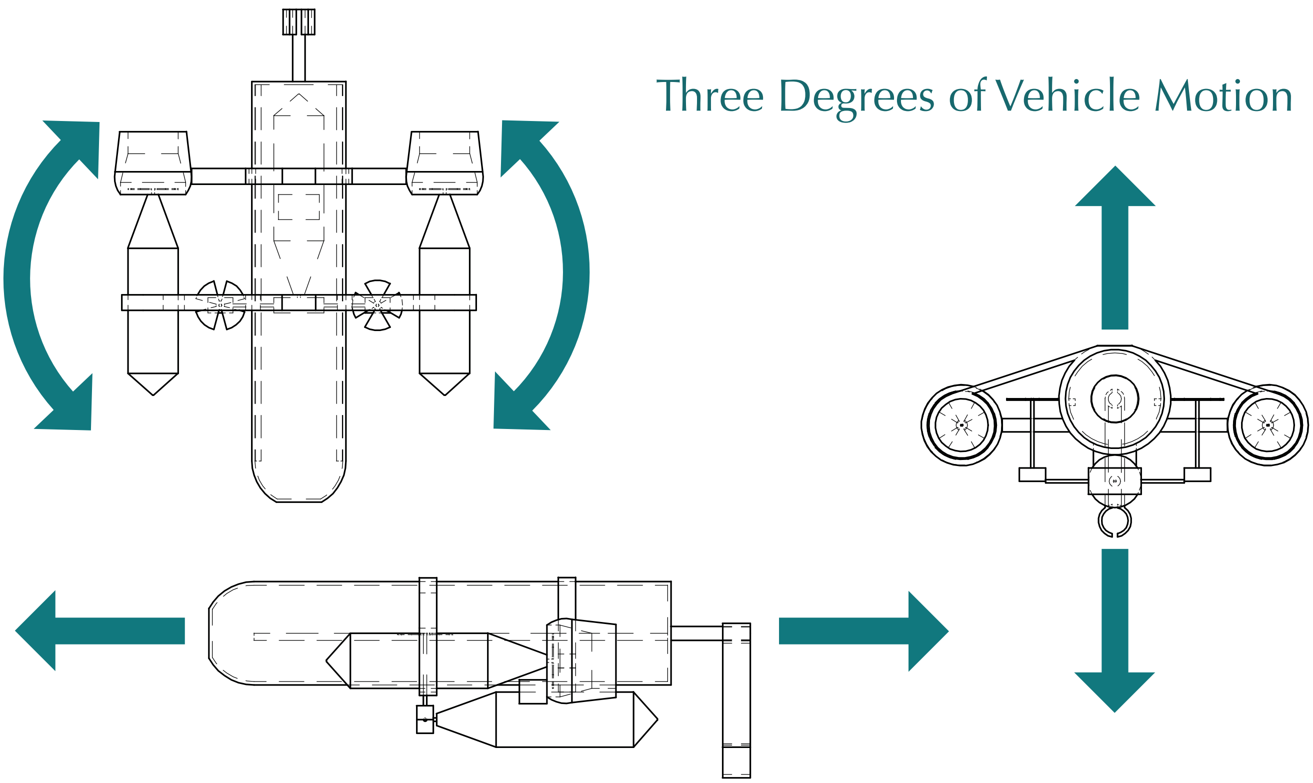
A complete electrical schematic of ROV1's control module, may be found in Appendix A.

ROV2 Design Details

The challenge in the design of a complement to ROV1 was to manufacture a compact vehicle capable of attaining relatively high speeds while remaining mobile enough to reliably navigate the waypoints on the pool floor. It was decided that since ROV2 was not charged with plugging in the actual cable connectors to the electronics module, that some amount of maneuverability could be sacrificed in order to acquire a higher top speed. Much concern was also taken over the very real threat that any tether used to power ROV2 had much the same chance of getting caught on the waypoint's vertical PVC posts, as the actual instrument cable. To negate the possibility of this potentially mission-ending circumstance, ROV2 has been freed from any sort of control tether and designed to operate completely wirelessly.

A linear body type was chosen for Hobbes in order to minimize drag and allow the vehicle to remain in control at speeds around 1m/s. The main fuselage is simply a ¼" (0.635cm) thick clear acrylic tube 8.25cm in diameter and 45cm in length. The fuselage is kept clear for both aesthetic appeal, and because it allows for easy detection of water leakage during testing.

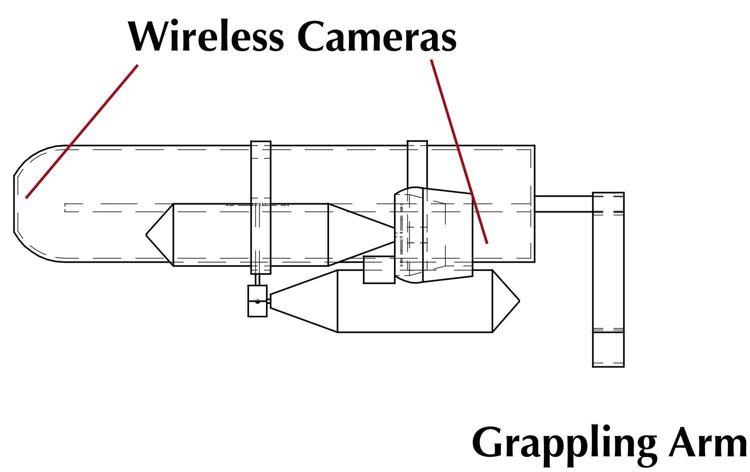
The strength of ¼" thick acrylic combined with the circular shape of the fuselage were chosen to assure that the vehicle could maintain an air-tight seal within the main cabin, since this would be the only source of positive buoyancy within the vehicle. The front end of the fuselage is fitted with a milled hemisphere PVC cap.



Two of the aforementioned aluminum cased propulors are mounted to the left and right of the fuselage, providing the vehicle's sole source of horizontal thrust. These independently controlled thrusters are capable of driving the vehicle both forward and reverse, however the PVC shrouds mounted around the two propeller blades are designed to attain maximum thrust efficiency in the forward direction. By giving independent speed control to each of the horizontal thrusters the vehicle has the ability to turn about its z-axis (vertical-axis).

One more propeller-less thruster mounted to the underbelly of the fuselage drives a shaft system which in turn rotates two vertically directed propellers. These propellers are protected between the fuselage and the horizontal thrusters and are positioned along both the center of mass and center of volume to assure complete vertical motion without induced pitch. The vertical thrust system of ROV2 is meant only for fine-tuning the vertical position of the vehicle while in the water**.** While Hobbes is designed to be as neutrally buoyant as possible, the vertical propellers do give the vehicle the ability to overcome tension and drag from the instrument cable. A certain degree of vertical motion will also be necessary when running the cable over the waypoints and when docking with ROV1 in order to return to the surface.

The arm mounted on back-end of the fuselage is driven by a housed aluminum shaft which is rotated along its main axis by a 180° motion capable servomotor. One arm protruding from the shaft is allowed to rotate with the shaft, while another is fixed in place. When picking up the connection cable, the stationary arm on Hobbes will be positioned in line and as close to the PVC connector as possible. A signal will then be sent instructing ROV2 to rotate its movable arm, effectively pinching the connector in place. Both arm extensions on the ROV will be equipped with fitted rubber grips to ensure enough traction so that the cable connector cannot fall out during the mission.



Hobbes "eyes" are two wireless cameras positioned strategically within the body to provide optimal viewing of necessary angles. One mounted within the vehicle's nose cone allow the vehicle controller to see forward. A second camera placed toward the end of the vehicle will keep a fixed lock on Hobbes' arm and the cable connectors it will pick up during the mission.

These two cameras have proven to be one of the greatest challenges of the entire design process, as well as place for possible future improvement. The range of wireless signals capable of handling video data is severely retarded underwater due to limited propagation of certain frequencies of light through fluid bodies.

So far testing has shown that a typical 900mHz wireless camera signal is incapable of being received in any useable fashion if it must travel more than 35cm underwater. Efforts are being taken on both the transmitting and receiving ends of the process in order to boost the video signal. However, as a contingency plan, a thin coaxial might have to be floated up to the surface so that a clear signal may be sent. While such a tether was hoped to be avoided on ROV2, it would only be a thing wire and would float directly upwards, greatly decreasing the possibility of its getting caught along one of the vertical waypoint posts.

Hobbes is powered by two 9.6 Volt 5 Amp-hour battery packs, each composed of eight 1.2V 5000mAh C-cell NiMH batteries soldered in series. Mainly meant to drive the two horizontal thrusters, these packs also continuously provide power to the two onboard wireless cameras along with an occasional burst to the vertical propeller assembly. These battery packs are capable of being drained at a rate of 10A constantly over 15 minutes, which should provide an ample amount of time to pick up each cable connector, run the instrument cable, and return each connector to ROV1 for final insertion into the electronics module.

Description of a Technology that Supports Ocean Observing Systems

In recent years, the interest and willingness to learn more about ocean observing systems has spread across the country. More companies and organizations have been reaching out to lower and higher education and extending their programs to inform the public about the importance of ocean research and new technology.

Since the devastating effects of Hurricane Katrina, research concerning the activity of storms has become a huge priority. Recently, the National Oceanic and Atmospheric Administration (NOAA) enforced new enhancements in the current technology of 23 National Water Level Observation Network (NWLON) stations that are located along the Gulf Coast. With these upgrades, NMLON will be able to send information about the storm tide to the public within a six minute interval due to real-time communication. This new technology (which is similar to that of OASIS) will ensure up-to-date predictions and allow more time to make decisions that are in the best interests of the environment, the economy, and the nation's safety.[1]

In order for ocean related issues to be understood and fully resolved, the public must be more knowledgeable in the field of science to allow them to explore the possibilities that can come from it. Organizations such as the Consortium for Oceanographic Research and Education (CORE)[2] and the Marine Advanced Technology Education Center (MATE)[3] offer programs that encourage students to participate in research concerning ocean observing systems and gives them the chance to experience hands-on learning, which would not be taught in the class room. With this knowledge and understanding, students are able to enter the workforce knowing that they have the capability to express their ideas and further the advancement of oceanographic research.

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[1] "NOAA Improves Storm Tide Information Along the Gulf Coast," PRNewswire, May 24 2006. http://sev.prnewswire.com/environmental-services/20060524/DCW07224052006-1.html

[2] Consortium for Oceanographic Research and Education. http://www.coreocean.org/?anchor=core_about.

[3] Marine Advanced Technology Education Center. http://www.marinetech.org/.

Description of a Learned Skill

An significant challenge in the construction of the two ROV's was the manufacturing of parts that were not available to the public for purchase. The ability to efficiently prototype models and construct parts that are fit for the vehicles can save both time and money. However, the level of efficiency in these said processes is purely a product of practical experience.

There are three aspects of vehicles' designs that required intensive manufacturing. On both Calvin and Hobbes, each casing for the thrusters was designed and machined to mesh with each particular function. With thin sidewalls and crucial seal issues, these casings proved to be difficult to construct. The front cap on Hobbes was a difficult piece to assemble. Originally, the assumption was made that hemispheric pieces of PVC would be available at a bulk plastic store, there are, however, no such standard parts. This meant that the piece would have to be created by the team's own means. The piece was difficult to construct because it curved in three dimensions. Standard milling and lathing operations cannot create such three-dimensional curves. A new sophisticated program was needed to create the three dimensional surface. In fact, this was one of the first five pieces that was constructed using this program, in the machine workshop at UC Davis where the vehicles were being manufactured. The use of such a program for manufacture greatly increases the possible components that can be assembled for any project. Learning this new technique is valuable for many design applications.

The final and most taxing aspect of component manufacturing was the arm for Calvin. The basic design of the arm calls for two degrees of freedom: rotation and extension. This meant that a geared shaft must be used to integrate the arm into the system. This was a difficult task to complete. The arm shaft had to be well supported in order to freely rotate and move laterally. As an added difficulty, the motors used to provide this motion needed to be in a waterproof housing. A unique aluminum case, with bored holes that fit the geared rod parallel to the motor, was created to serve this purpose. It was necessary that these holes were kept separate in order to keep the water out , yet close enough to maintain the correct the gear ratio. These two criteria caused this component to be the most precisely manufactured part for either vehicle. Two cylinders were bored out of a block of aluminum, and the wall separating the holes was only a few hundredths of an inch thick.

A design project such as this one is an excellent catalyst in improving workshop skills. The overall design is useless if there is no practical use for the system. The experience gained from manufacturing these two vehicles puts into perspective some of the design choices that were made. The team inherited valuable understanding of both the design process, as well as the mechanized skills.

Acknowledgments

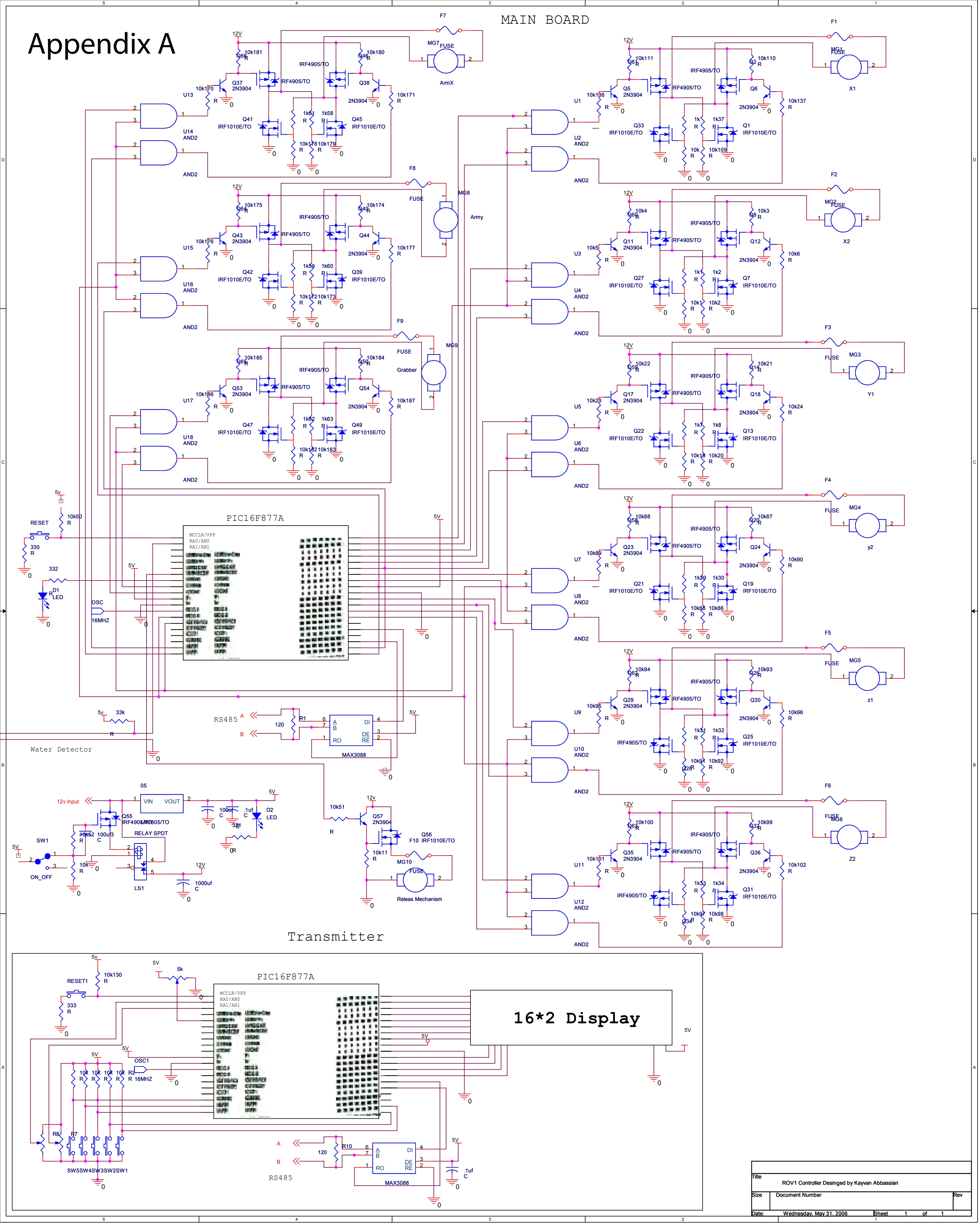
The team would like to acknowledge a handful of organizations and people who have given their time, support, and advice in the design of the vehicles.

First to Professor Roger Davis, our faculty advisor and friendly mentor, without him there would quite literally be no team. His efforts in organizing Team Powerfish at UC Davis, has provided us all with the opportunity to learn what it means to design and build.

Second to Mike and Leo, the tireless managers of the student workshop at UC Davis, building the vehicles would have been a shot in the dark.

Third and finally, to the University of California, Davis, College of Engineering, for their monetary contributions, and the education they have provided us which is why our design works.

Appendix A



MAIN BOARD
PIC16F877A
ArmX
Army
Grabber
Releas Mechanism
RESET
OSC
16MHZ
RS485
MAX3088
Water Detector
RELAY SPDT
ON_OFF
12v input
Transmitter
PIC16F877A
16*2 Display
RESET1
OSC1
RS485
MAX3088
SW5SW4SW3SW2SW1
Title
ROV1 Controller Desinged by Kayvan Abbassian
Size
Document Number
Rev
Date:
Wednesday, May 31, 2006
Sheet 1 of 1

BUDGET

$123.00	**pipeframe**
$130.00	**controls**
$493.06	**Thrusters**
$46.00	**reciever**
$32.31	**charger**
$12.55	**Alluminum**
$7.70	**Acryllic**
$26.94	**gearmotors**
$13.47	**gearmotor**
$13.45	**jb weld**
$10.24	**ss screws**
$49.47	**camera/w**
$71.67	**camera/w**
$254.67	**contollers**
$97.23	**gear/arm**
$65.00	**batteries**
$17.24	**wire**
$12.09	**props**
$75.41	**Video/laptop**
$16.81	**solder parts**
$4.51	**solder parts**
$15.23	**rods**
$8.48	**12" drill bit**
$23.17	**props**
$23.09	**rods screws**
$11.99	**12" drill bit**
$60.34	**camera**
$39.38	**bevel gears**
$1,754.50	**TOTAL**