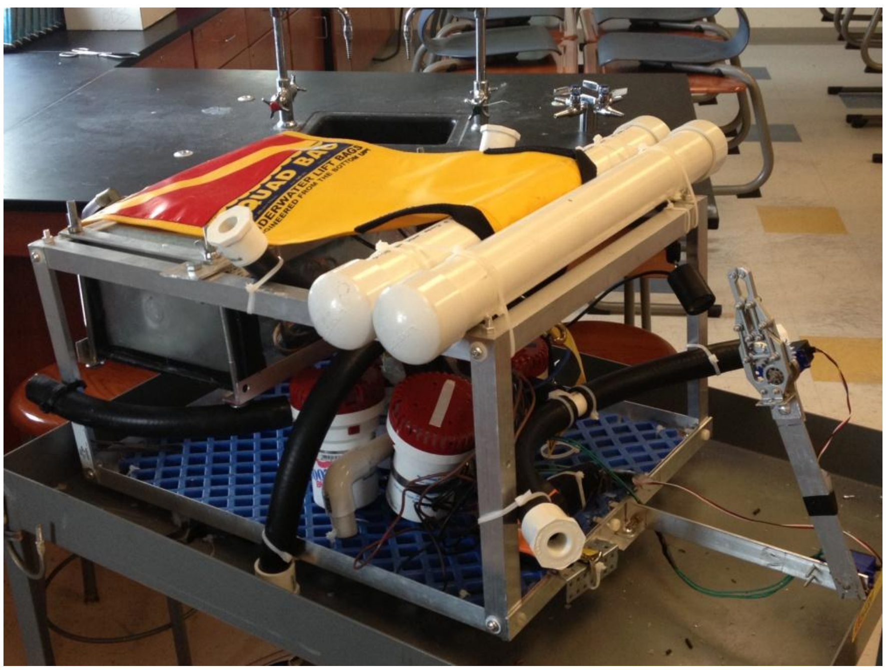
Mc. Jambey Robotics

Cape Henlopen High School

Lewes, Delaware



ROV THOR

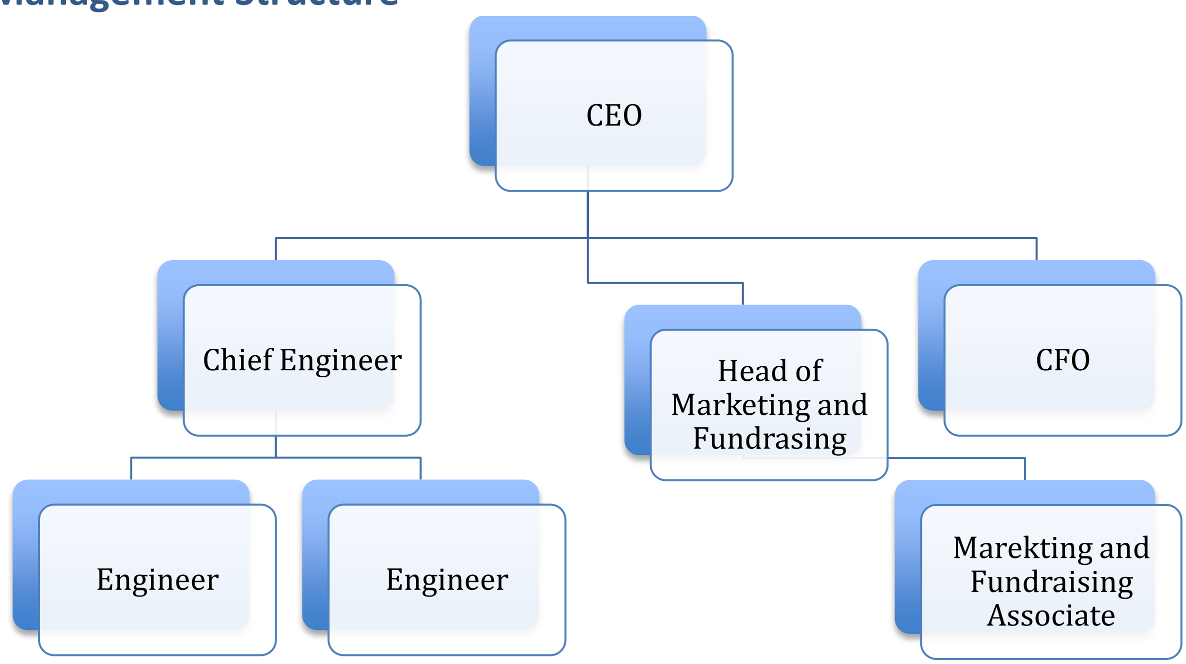
Matthew Spicer	*CEO, Co-pilot*	Esther Kung	*Head of Marketing and Fundraising*
Joel Tylecki	*Chief Engineer, Pilot*	Angela Carroll	*Marketing and Fundraising Associate*
Matthew Hurlock	*Engineer, Tether Operator*	Bobbie Wyatt	*Engineer*
Kevin Yang	*CFO*		
Mr. William Geppert	*Mentor*	Mr. John Proctor	*Mentor*

Table of Contents

Abstract

In a world where we know more about the surface of the moon than the depths of the oceans, Underwater Ocean Observing Systems are and will continue to be a central aspect of the marine technology field. As a company that produces ROVs, Mc. Jambey Robotics is excited about the opportunity to contribute to this field by producing an ROV that can, as requested, maintain and expand the University of Washington's Regional Scale Nodes observatory. The company is confident in ROV Thor's ability to perform the mission for a few key reasons. First, the ROV's innovative components, such as its propellerless jet-drive thrusters and fail-safe electronics housing, enable it to perform the mission tasks efficiently and effectively. Not only can Thor complete the mission tasks, but it can do so for a fraction of the cost of our competitors' ROVs. Finally, there is a diverse yet cohesive team behind our product committed to customer satisfaction. For all the reasons, Mc. Jambey Robotics is a leader in the field of Underwater Robotics and looks forward to both meeting and exceeding client expectations at the international competition in June.

Management Structure



Company Hierarchy

The team behind Mc. Jambey Robotics is a close-knit and cohesive group of people. As illustrated by Figure 1, our company has three main divisions: engineering, marketing and fundraising, and accounting. The Engineering department is responsible for designing, constructing, testing, and operating an ROV built around the requests of our client, the University of Washington. Although less conspicuous in their day-to-day operations, the other two branches of the company perform equally important functions. Our Marketing and Fundraising branch promotes a positive image of our team throughout the local community as well as to our client in order to raise the money that sustains our operation. Finally, our accounting division headed by the Chief Financial Officer keeps track of all transactions in order to ensure the financial health of the company.

Each of the three divisions of Mc. Jambey Robotics has its own leader who is ultimately answerable to the Chief Executive Officer. Dividing labor in this way gives each member of the company a chance to specialize in the area in which he/she is most talented. Through the leadership of the CEO, who facilitates communication between the three branches, the company produces capable, cost-effective ROVs.

Project Finances

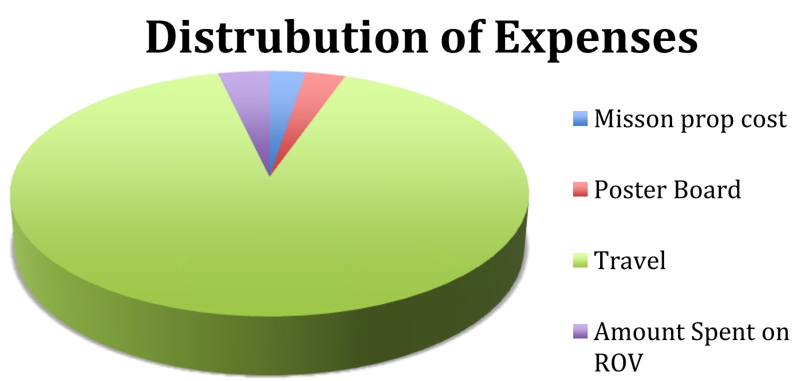
In the interest of conserving our limited funds, Mc. Jambey Robotics re-used many parts previously owned by the company. Consequently, the total value of the ROV is calculated by adding the market value of these parts to the value of both donated and bought items as illustrated in the table below.

ROV Part	Re-used	Donated	Cost
Cameras (x2)	$200.90		
Motors (x5)	766.24		191.56
16 gauge speaker wire (30.48meters)	96.58		
1in radiator hose (198 centimeters)			$84.43
Cat-5 cable (15.24meters)	17.25		
Vinyl hose (15.24meters)			14.00
Usb extender (7.62meters)	24.95		
usb cable (7.62meters)	17.95		
analog camera wire (60.96meters)	50.00		
aluminum (3.35meters)			8.90
Lead (9.1 kg)		$17.80	
PVC (30.5 cm 3/4 inch PVC & 2 34 inch90 degree joints)	0.78		
14 gauge speaker wire (1.2meters)	11.36		
Lift bag	47.00		
CPO Science Light and Optics kit Laser			1.99
Orange traffic cone			7.00
Parallax Board of education (x2)	200.00		

Otter box	40.00		
Nylon aluminum Nuts (x6)			10.62
Nylon aluminum bolts (x6)			7.60
Zinc bolts(x4)			3.36
Zinc nuts(x4)			7.04
Traxxas 2056 Waterproof Digital Servos (x2)			45.28
10 ohm resistor			2.49
Total ROV Value	**$1,875.08**		
Total Amount Spent on ROV	**$384.27**		

In addition to the expenses associated with constructing the ROV, additional costs were incurred over the course of the project. These are outlined below. The total breakdown of expenses is summarized in the pie chart below.

Other Expenses	**Amount**
Misson prop cost	$135.00
Plane tickets x6 (estimated)	3600.00
Hotels 2 rooms 3 nights (estimated)	1200.00
Poster board	150.00
Total Other Expenses	**$5,085.00**
Total Other Expenses plus Total Amount Spent on ROV	**$5,469.27**



Finally, due to the generosity of our local supporters, the team had several sources of income to offset the costs of building the ROV. These are catalogued below.

Contributors/ Fundraisers	Amount
Friendly's Restaurant	$92.00
Catcher's Restaurant	100.00
Moe's Restaurant	100.00
Rehobooth Beach Car Wash	500.00
Cape Henlopen School Board	5000.00
Total Contributions	**$5,792.00**

Subtracting our $5,469.27 in total expenses including costs related to the ROV from our $5,792.00 worth of contributions yields $322.73, our current account balance.

Design Rationale and Mission-Specific Applications of ROV Subsystems

General Component Orientation

Placing the components of the ROV was as much objective as it was subjective. The design needed to make sense functionally and to be convenient. While placing internal components, the Engineering Team chose to consider ease of connections and buoyancy. Placing the jet-drive motors in the center of the ROV gives the machine an evenly distributed weight. It also optimizes connections by fixing them to a central point and by minimizing stray wires within the structure. This is made possible by the 1-inch radiator hose lines that extend from the jet-drive motors. These lines allow thrust to be generated anywhere on the ROV. The electrical components are housed in a double waterproof box arrangement. Naturally, the boxes contain air which significantly affects buoyancy. The Engineering Team found that placing the box at the rear of the ROV is the optimal position. This imbalance is easily adjusted with ballast. Likewise, a slight angle in position downward of the ROV provides a better ability to see the apparatus being studied or manipulated. The robotic arm and modified measuring tape are placed in the anterior ROV to maximize usage. This position also minimizes the blind spots to the cameras created by the frame. Finally, the cameras are placed to give the pilot and co-pilot the different underwater perspectives they need to complete the mission. One is placed solely for arm movement. This camera can view the entire range-of-motion of the robotic arm as well as the measuring tape. The second camera is centered just above the jet-drive motors. The purpose of this camera is to provide the main view for the operation of the ROV. This creates a wider angle of sight while providing for accurate depth perception.

Frame

The Engineering Team decided to use the conventional structure of an ROV frame. It is an elongated rectangle with dimensions of 60x45x30 cm. The design maintains a relatively compact shape and a sound structure that provides maximum space for internal components. The question of material was answered with great consideration to cost as well as effectiveness of materials. Based on these two factors, the possible materials were quickly narrowed down to a choice between PVC piping and aluminum angle stock. PVC is an easily accessible material that is equally cost effective. Its buoyancy is also easily controlled. However, PVC is less structurally sound than the aluminum angle stock. Aluminum also has a low corrosion rate due to the protective layer of aluminum oxide that forms on its surface in the presence of oxygen and also serves as ballast for the machine. On the other hand, it is much less cost effective when compared to PVC. Ultimately, the team decided that functionality outweighed cost in this situation. Therefore, the ROV was constructed with solid aluminum angle stock. The ROV is held together with aluminum washers and finished zinc bolts. Finished Zinc bolts were chosen because of their low cost, availability, and negligible tendency to react with aluminum.

The rectangular frame has no closed sides. The base of the ROV is outfitted with a payload tool platform made of plastic grating cut from a bread tray. This provides a solid base for internal components to rest on while making vertical water flow through the ROV possible. Vertical movement is necessary for achieving thrust due to the nature of the ROV THOR's jet propulsion system. The jet drive motors pull water from the top of their housings. In order to maintain an open flow of this water, the other sides of the ROV need to be open. Additionally, open sides reduce drag as the ROV moves through the water.

Buoyancy

The ROV THOR's Buoyancy Control system is relatively simple. By trial and error, the Engineering Team placed a combination of two PVC cylinders and lead weights about the ROV so as to achieve both stability and neutral buoyancy. One notable addition to this simple design is the dive bag attached to the top of the ROV. Connected via a vinyl cable to a hand-operated bilge pump motor on the surface, this bag can be inflated or deflated to vary the buoyancy of the ROV to balance the extra weight added when the ROV has to carry heavy components like the SIA, secondary node, and ADCP to and from the surface.

Cameras

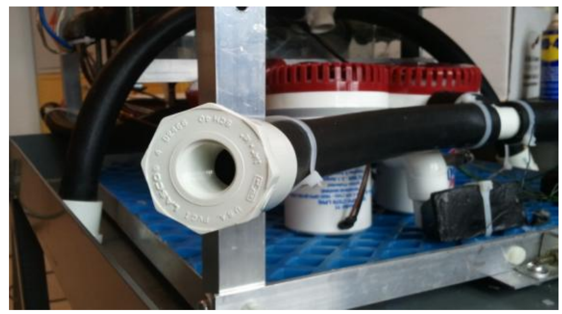
As in years passed, Mc. Jambey Robotics has opted to use waterproof Speco Systems brand surveillance cameras. These cameras have, however, been slightly adapted for use on Thor. The power plug has been snipped off and the power wires stripped and soldered to the ROV control board. The two video signal wires running to and from the surface are soldered within the electronics housing to the video signal wires that connect to the cameras. For an explanation of camera placement, see "General Component Orientation".

Jet-Drive Thrusters

In the initial stages of thruster design, our engineers struggled to answer the question of how to satisfy the 48 volt Explorer Class power requirement. Using an expensive dc to dc converter to step down the voltage to a level appropriate for 12 volt bilge pump motors was considered, however this solution was ruled out because of a lack of funds. Our engineers also considered using large resistors to drop the voltage but abandoned this idea in favor of a more elegant solution.

Ultimately, the team decided to adapt Rule 2000 32 Volt Bilge Pump motors to purpose of providing thrust for the ROV. There were a couple obvious advantages to this design choice. First, it was a cost-effective solution because four out of five of the 32 volt motors had already been purchased for a past competition. Additionally, they could be run directly on 48 volts of power which eliminated the need to use additional components to drop the voltage. Finally, using larger motors translates to greater thrust which is especially necessary for mission tasks that require heavy-lifting such as installing the SIA, removing and placing the Secondary Node, and Replacing the ADCP. Despite these benefits, however, the 32 volt motors presented some serious design challenges.

The main issue with using larger motors centered on their thicker ⅝ inch shafts. None of our drive dog suppliers carried a drive dog that fit that size. Consequently, it would have been necessary to pay for custom-machined drive dogs in order to affix propellers to the motors. Even if we had the money to purchase these drive dogs, opening the casing to expose the shaft compromised the built-in waterproof seal protecting the metal motor inside the casing. Rather than confront these messy problems the team decided to adapt the 32 volt motors as propellerless jet-drive motors.



Front view of one of the front thruster's nozzles

The ROV's jet-drive motors are essentially 32 volt bilge pump motors that have been outfitted with one-inch radiator hoses. The open ends of these hoses are zip-tied to the positions on the ROV where traditional propeller thrusters would be found. With this design, the motors can be located in a central location on the ROV which optimizes buoyancy (see "Buoyancy"). Two motors with single hoses run to the back sides of the ROV to provide thrust for going forward, left, and right. Because water-jets can only pump water in one direction, our ROV requires three separate motors to go forward, up, and down. To provide symmetrical thrust, split hoses are attached to these motors. Although this initially results in a 50% decrease in thrust, the velocity of the water coming out of these jets can be adjusted using constricting nozzles as demonstrated by the Continuity equation below:

$$A_1V_1 = A_2V_2$$

Those motors whose flow is split in two have a PVC bushing attached to the end of their radiator hoses that reduces the area out which water flows from one inch to half an inch. By the continuity equation, this doubles the rate of water flow which adequately compensates for the loss of thrust that results from splitting the hose.

Waterproof Electronics Box (WEB)

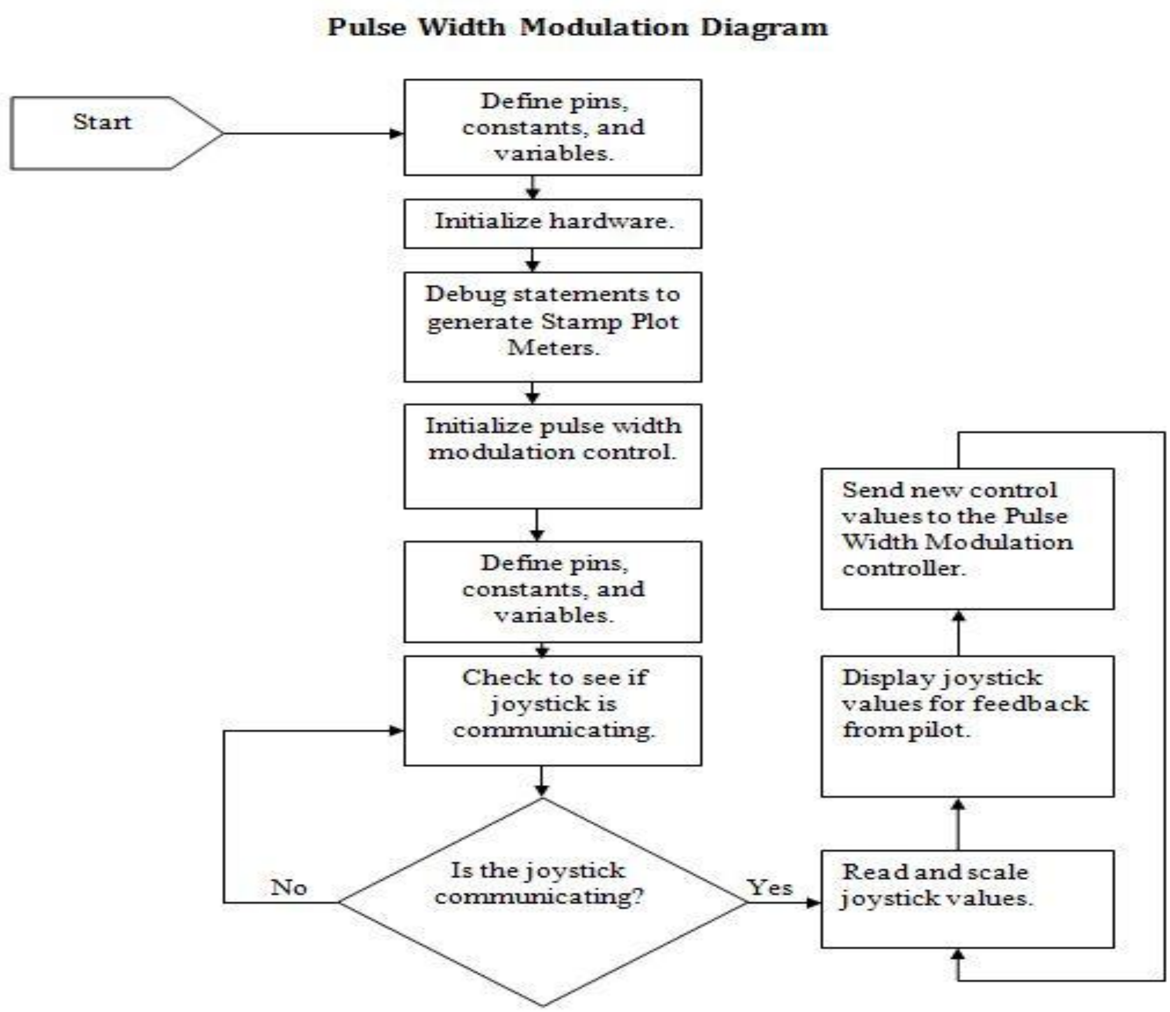
To comply with the rule that the electronics must be housed underwater the Engineering Team proposed many ideas including making a housing out of PVC tubing, using a modified Otterbox, and dipping the board in plastic. Ultimately the Engineering Team chose to use the modified Otterbox with a second failsafe rectangular prism housing constructed out of clear acrylic in anticipation of small leaks.

The failsafe is a 36x30x25 cm clear acrylic box with a removable lid to for easy access to the electronics. This material was chosen due to its strength, durability, and transparency. Acrylic plastic was also used because it is also readably available, cheap, easy to shape, and easy to seal. A watertight seal is maintained by a strip of weather seal compressed between the lid and upper edges of the box. The compression is the result of a small aluminum frame that clamps down on the outer box to hold the seal in place.

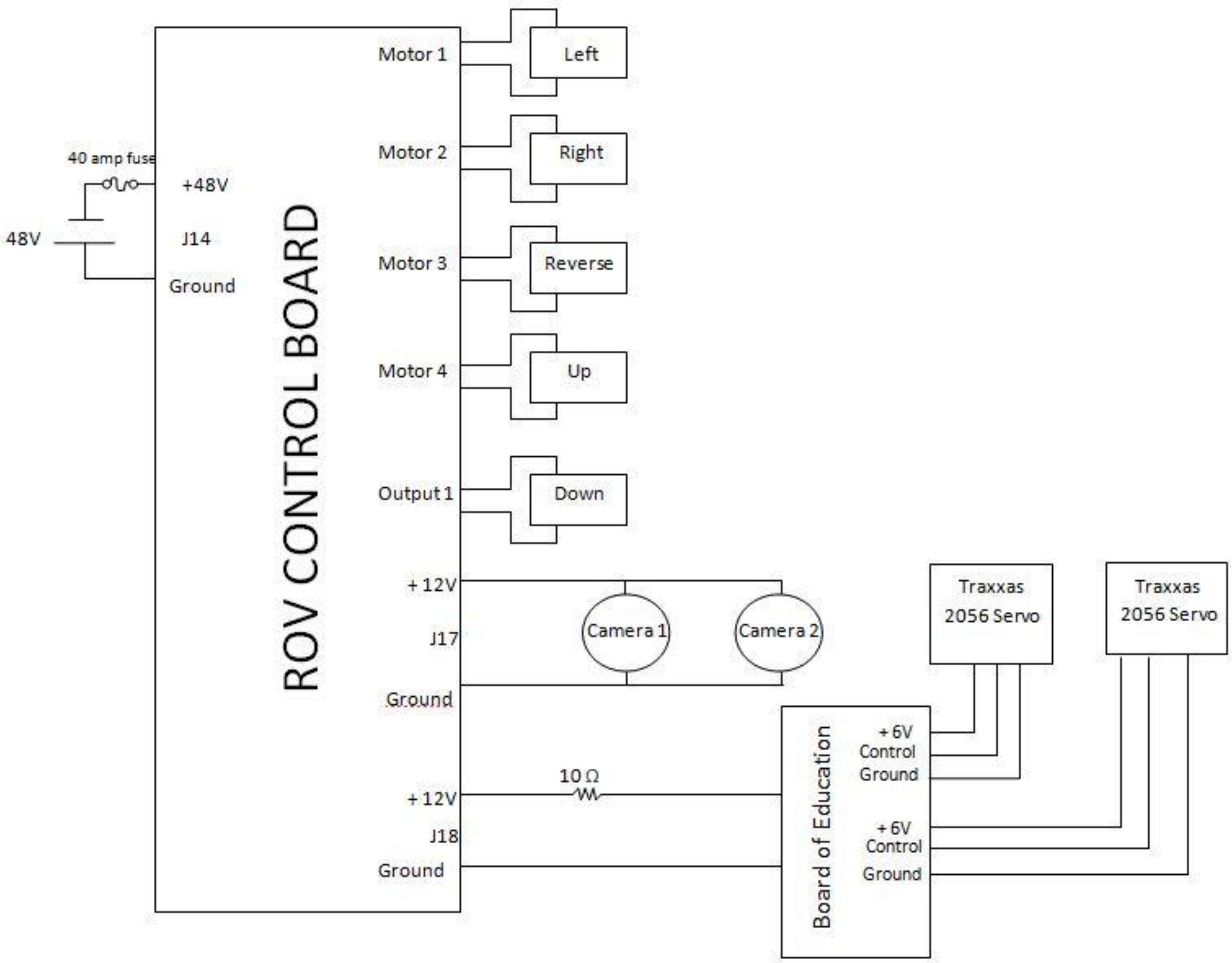
Electronic Control System

The two major components of the ROV's electronic control system are the MATE Center's ROV control board and a Parallax Board of Education. Each has been customized to meet the particular needs of the ROV.

The MATE center's ROV control board, selected for its demonstrated reliability and familiarity to our team, is the primary electronics component of the system because it drives our thrusters while also powering both our cameras and the Board of Education we use to drive the servos. To drive four out of five of the motors, the MATE ROV control board uses a BASIC Stamp microcontroller programmed for pulse width modulation joystick control facilitated by a Stamp Plot Pro Interface as illustrated by the PWM program diagram below.

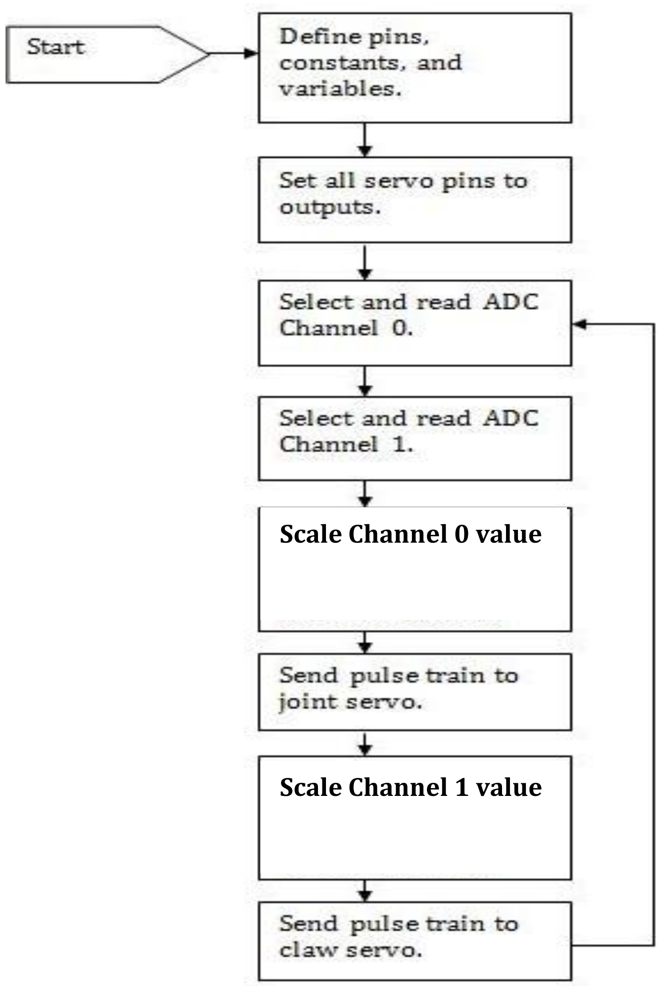


This system affords the pilot the precise control he needs over the ROV to perform mission tasks such as releasing the pin from the elevator and removing biofouling—both tasks that require fine adjustments in motion. Another task for which this precision is needed is adjusting the legs of the secondary node. To complete this task, the pilot uses a delicate combination of the front thrusters and right and left thrusters to rotate the machine around each leg as the robotic arm grips the corresponding PVC T-joint. The fifth motor, required this year due to the one-way capability of the ROV's jet-drive thrusters, is connected to the control board's J15 output switch. As this fifth motor is simply used to make a quick descent in the water column, the precision of PWM is not needed to control it. Consequently, a single joystick button is all that is needed to send power to the motor attached to this output. The other components connected to the board, as mentioned above, are the cameras and the Board of education. Soldered to the J17 and J18 12 volt outputs, these components are simply powered but not regulated in any way by the ROV control board's microcontroller. The whole system is depicted in the schematic below.

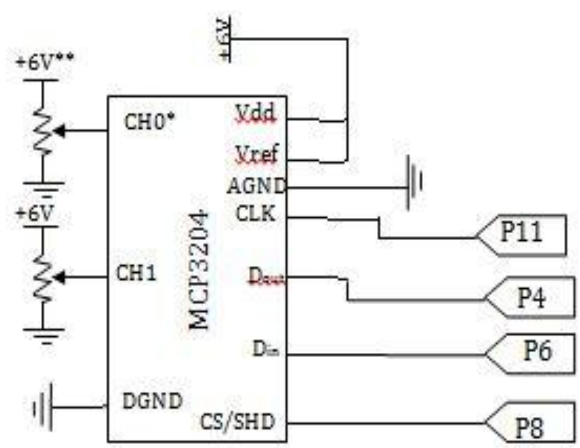


The second major component of the ROV's control system is a Parallax Board of Education whose breadboard has been wired with an MCP3204 A/D converter. Two potentiometers connect to two channels of the converter. Turning them varies the voltage and, therefore, the digital value produced from the voltage by the converter. This value is then scaled to within the pulse range of the Traxxas 2056 waterproof servos to send the pulse train that holds the servos in a given position. The program diagram for the arm board's microcontroller as well as the schematic of the A/D converter configured with two potentiometers are shown below. For the mission-specific applications of the arm, see "Robotic Arm".

Arm Control Diagram



A/D Converter Diagram



*The MCP3204 A/D Converter has four channels, however only the two used ones are shown.
**This is the voltage value of the Board of Education's Vdd Output.

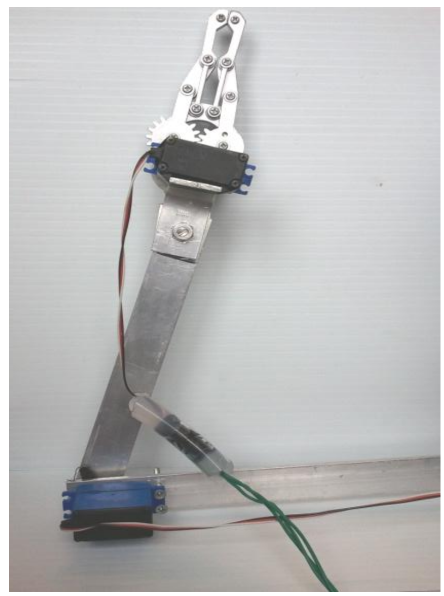
Tether

The Engineering team's primary goal when designing the tether was to achieve a balance between keeping the tether lightweight and maneuverable while minimizing voltage drop.

Through practice and experimentation the team determined that the optimal type of wire for our two power cables was 16 gauge speaker wire. To connect the potentiometers to the surface, the team used two of the wires within a cat5 data cable. Although the voltage drop of these 24 gauge wires is significantly greater than that of 16 gauge wire, it was determined through trial and error that control of the arm did not suffer enough from this voltage drop to justify wiring the corresponding components with bulkier 16 gauge wire. To facilitate the interface between the laptop and ROV control board, our engineers used an extended USB cable as opposed to the nine-pin cable used by our teams in the past because the head of a USB cable is much smaller and therefore easier to wire through the WEB's access points than the relatively large head of a nine-pin cable. Finally, the tether also contains a 3/8 inch clear vinyl hose connected at the surface to a two-way pump which inflates or deflates the lift bag on the ROV to regulate buoyancy as well as two camera wires.

Sensors and Payload tools

Robotic Arm


Side-view of the robotic arm

From the very beginning of the design process, the Mc. Jambey engineers knew that a robotic arm would be required to complete all four missions because each heavily involves moving objects around the seafloor as well as opening and closing hatches and pulling pins. Considering these tasks involve both heavy lifting of objects like the SIA, turbidity sensor, and ADCP as well as fine, dexterous movements like those needed to handle the Cable Termination Assemblies, pluck biofouling from the various structures, or open and close the BIA and mooring platform hatches, the Engineering Team aimed for a design that would strike a balance between strength and control.

The initial structural material choice between PVC and aluminum was a difficult one. As with the frame, we ultimately decided on aluminum as our primary material for its more favorable strength-to-weight ratio. Two aluminum segments are attached to form the elbow of the arm which allows it to move in the vertical direction. At the end of the second segment, a prefabricated geared aluminum claw is bolted. This commercially-sourced part was incorporated because its finely machined gears provided the level of precision we needed to complete the mission tasks.

Attached to the arm's elbow and claw are two Traxxas 2056 Digital High-Torque waterproof servos. There are a number of advantages to using these servos to drive our arm. Obviously one of their most favorable characteristics is that their casings were already sealed to keep out water. Another reason for using them was that their maximum torque exceeds the 10 Newton weight of the heaviest component that the ROV has to lift. Finally, the Traxxas 2056 servos could be programmed for finely-tuned control using a "What's a Microcontroller" Board from Parallax (see Electronic Control System Section).

Modified Measuring Tape

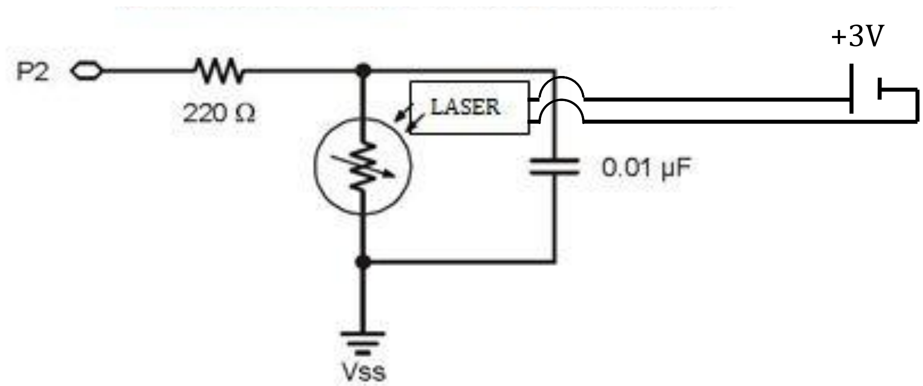
In task 1, teams are required to measure a distance from the BIA to one of the secondary node locations. Our team took a relatively straightforward approach to this task. We simply extended the tab of a tape measure to grip the edge of the BIA. The pilot has only to grip the PVC with the extended tape measure tab and engage the backward thrusters. Using the payload tools camera he can then quickly easily determine when he has reached the correct area.

Transmissometer

Task 2 requires the team to measure the turbidity of water near the seafloor platform. This task is simulated by measuring the relative difference in opacity of a rotating disk. To accomplish this goal, our engineers planned from the outset of the design phase to measure relative opacity by measuring the change in the intensity of a laser beam as it passed through the disk. Although we considered using a commercially-sourced light sensor, we ultimately decided to make use of materials we already had available to us in the classroom in order to save money.

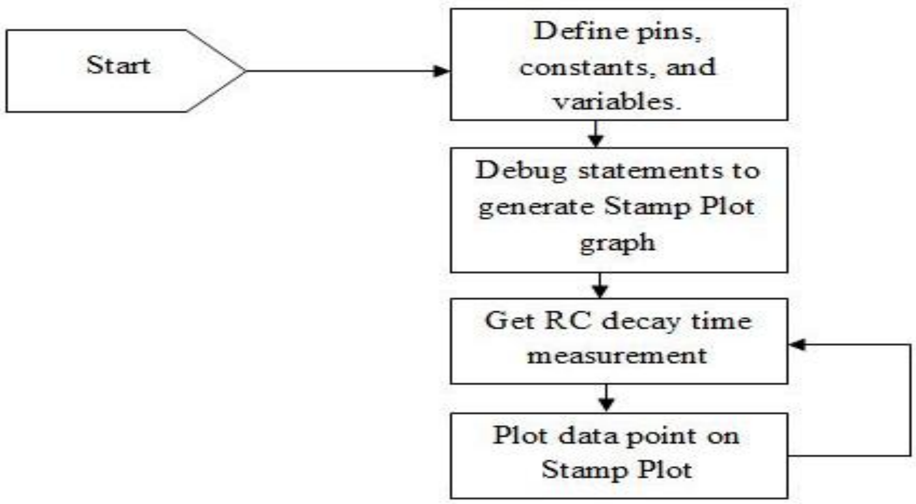
To measure the changing intensity of the laser beam as it passes through the rotating disk, our transmissometer uses a photoresistor connected to an RC time decay circuit as diagramed below.

Transmissometer RC Time Decay Circuit



("What's a Microcontroller?", 2004)

This circuit itself is wired onto the breadboard of a plastic-dipped Parallax Board of Education connected to surface battery packs as well as a laptop. Embedded in an orange traffic cone, the laser shoots a beam that hits the head of the photoresistor. To maintain proper alignment, the board with the photoresistor is fixed to a PVC rod jutting out of the cone. The traffic cone forms the core of the apparatus because it is easily placed and aligned on the seafloor platform owning to its square base and U-bolt attachment. The BASIC Stamp microcontroller on the board measures the decay times as they change based on the intensity of the light detected by the photoresistor. These changing values are then plotted on a laptop screen using Stamp Plot Pro to illustrate the changing opacity as the disk rotates according the logic depicted by the following program flowchart.



Safety Features

While functionality and cost-effectiveness were always guiding principles in the design process, safety was, of course, the top priority. In light of this, a solution to a given engineering issue was only ever approved if deemed safe by the standards of the MATE center. As a result of our safety-comes-first philosophy, our ROV has the following safety features:

- All exposed connections are thoroughly coated in silicone and wrapped in either electrical tape or clear vinyl tubing,
- Sharp edges of the aluminum frame have been filed and finished so as to prevent them from cutting anyone who is trying to handle the ROV.
- A 40 amp circuit breaker is always used when operating the ROV.
- Jet-drives produce thrust rather than propellers which eliminates the safety risk associated with working around sharp moving propeller blades.
- As stipulated by the MATE center, our laser is equipped with a shield to prevent the beam from causing any arm when the transmissometer is out of water.

Throughout the construction and operation of the ROV, the following procedures have always been observed to ensure the safety of all personnel.

- Protective glasses or goggles are worn whenever power tools or the laser is in use.
- Gloves and masks were always worn when handling noxious chemicals such as the spray-rubber used to plastic dip the board or PVC cement.
- The safety officer supervised practices to ensure the general safety of the team.

See Appendix C for a Safety Checklist outlining steps taken to ensure safety during pool practices.

Challenges Faced

Technical

Besides the technical challenges described in the above sections, one of the most vexing challenges our team confronted throughout the duration of the project centered around developing a program to drive the arm servos. Initially, we were only able to produce a program that gave us half the advertised range of motion of the servos with the added problem of very shaky movement. To address this problem, we carried out a series of tests under the supervision of one of our advisors, Mr. John Proctor. The team developed a test program that allowed us to send varying pulse trains to the servos to translate the true limits of their motion into code. Next, we worked to achieve smoother control of the arm. With the aid of an oscilloscope, we were able to see that it was taking longer than the 20 millisecond maximum time window to deliver the signals needed to hold the servo in a given position. Based on this information, we were able to fine-tune the timing of our control loops to ensure that the servos rotated smoothly.

Financial

Perhaps our greatest challenge throughout the duration of the project was our financial situation. Although our school board did allocate a significant portion of its discretionary funds to our team this year, this money came only in the middle of May of 2013. During the previous months, we struggled to raise enough money to offset our expenses.

There were a couple of ways in which we met our financial challenges. First and foremost, we always made cost a central factor in all engineering decisions. Consequently, we recycled a lot of parts that had been purchased and used in previous years or that we simply already had available to us in the classroom. The team also attempted to improve its financial situation with aggressive fundraising. In the resort town where Mc. Jambey Robotics is based, there is a wealth of restaurants. Our aggressive fundraising and marketing department reached out to a multitude of these to set up and promote fundraising nights as well as a carwash at the local firehouse. These funds, in addition to those the school board granted us, ultimately amounted to enough to keep the company fiscally solvent.

Troubleshooting Techniques

Over the course of the project, the team's main approach to troubleshooting was to use the trial and error method to solve problems. In other words, as problems emerged during either the design process or sea trials, the team attempted to solve them with a list of different solutions brainstormed by the team until one option solved the problem. For example, after some of our early practice sections, an excessive amount of water was observed in the outer part of the WEB. Upon closer observation, it became apparent that there was a leak at the opening where the tether wires entered the housing. This area had only been waterproofed with clear silicone gel that apparently did not provide an adequate seal. To strengthen the seal, the Engineering Team considered adding both plumber's putty and automotive brand silicone to the leaking areas. After trying each in practice it was determined that a combination of both types of silicone along with plumber's putty produced the most effective seal. Although trial-and-error problem solving lacks elegance, it ultimately proved to be the most realistic and effective troubleshooting method for our team.

Lessons Learned

While our team, as evidenced by the problem solving described in the sections above, learned many technical skills (especially programming skills, see "Challenges Faced"), some of the greatest lessons we learned were interpersonal in nature. For example, some of the greatest learning experiences took place in the context of logistics. As busy high-school-soon-to-be-college students, the team members did not always have flexible schedules. This made planning necessary out of school practice times and fundraisers particularly difficult. Ultimately, the team members collectively solved this problem by honing their time management skills. At the beginning of each week, there would be a team meeting led by the CEO to outline what goals the company needed to accomplish by Friday. Each team member could then make a specific time commitment that the other members would hold him/her responsible for. In this way, Mc. Jambey Robotics was able to steadily make progress on fulfilling the client's order.

Future Improvements

Overall, two areas where Mc. Jambey Robotics could stand to improve its operations include its fundraising efforts and the efficiency of its design process. As mentioned above, uncertain finances plagued the team for many months. Not knowing whether we would have enough money to reimburse a member of the team who fronted cash to buy a part often led us to reuse old parts. In many cases, this simply made the ROV more cost-effective. However, more elegant designs could be possible in the future if our engineers were liberated from having to reuse the same parts year after year. To widen our access to new components, future teams may want to consider an all-year-round fundraising schedule. Moreover, in the construction of all components of the ROV whether from old or new parts, future team members should not lean so heavily on trial-and-error problem solving. Although this method is adequate, it is often quite inefficient because it can result in a multitude of wasted parts.

Reflections

Embarking on a project as involved as building an ROV for the MATE competition is always intimidating. Add to that the pressure of competing with colleges and universities at the Explorer level, and there were times when the team was not sure that it could take the project to completion. Luckily, with the encouragement and guidance of our advisors, we overcame our own doubts to produce an ROV that we are proud of. Although the team believes it will be successful at the competition, each member will always take pride in having been a part of designing, testing, and competing with ROV Thor.

Acknowledgements

Mc. Jambey Robotics would like to thank the following organizations and individuals for the various roles they played in affording us the opportunity to compete in this year's competition:

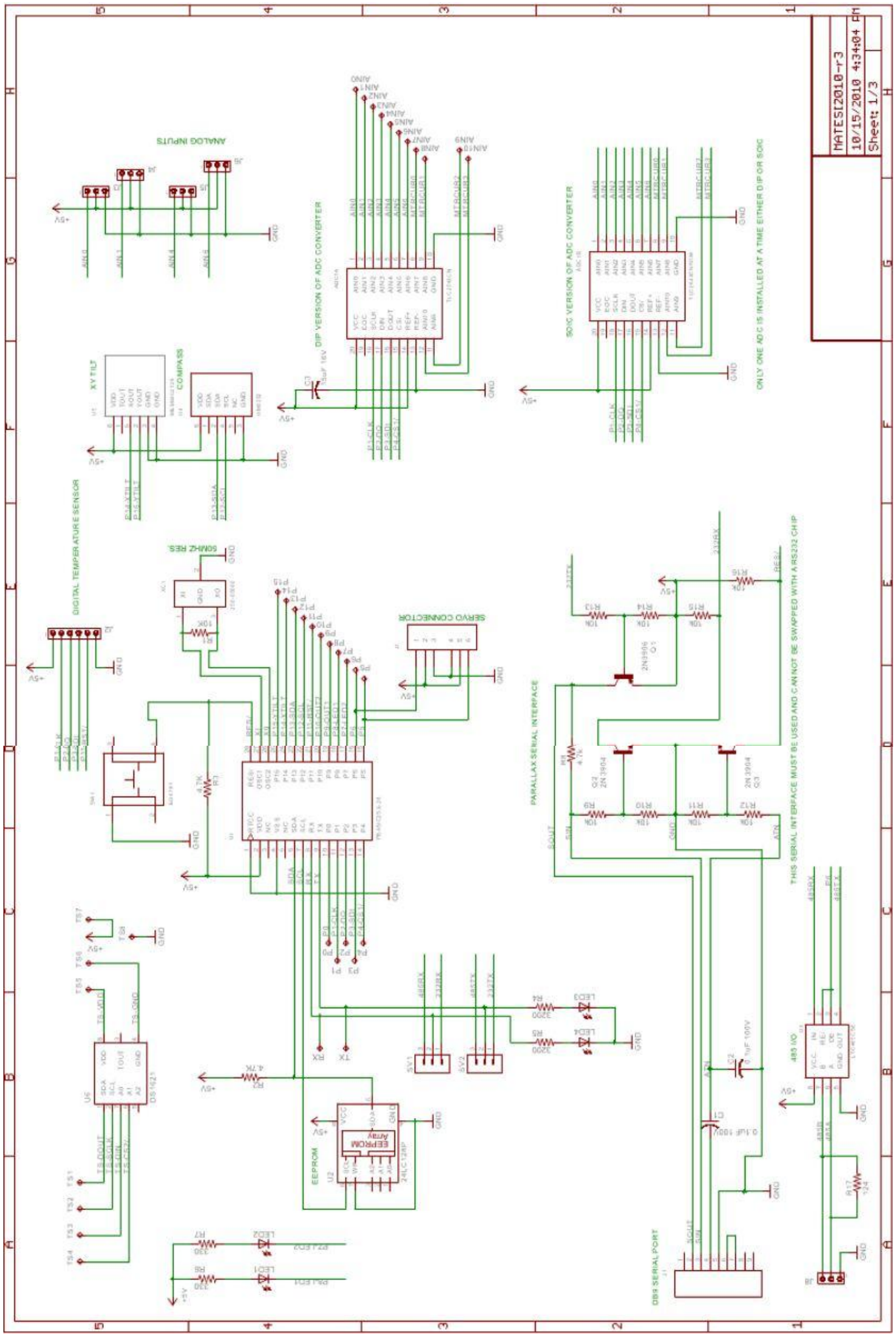
- The MATE Center,
- MATE's Mid-Atlantic Regional Coordinators,
- All of the contributors mentioned in "Project Costs" especially the Cape Henlopen District School Board,
- Our incredible mentors Mr. William Geppert and Mr. John Proctor for their boundless knowledge and patience.

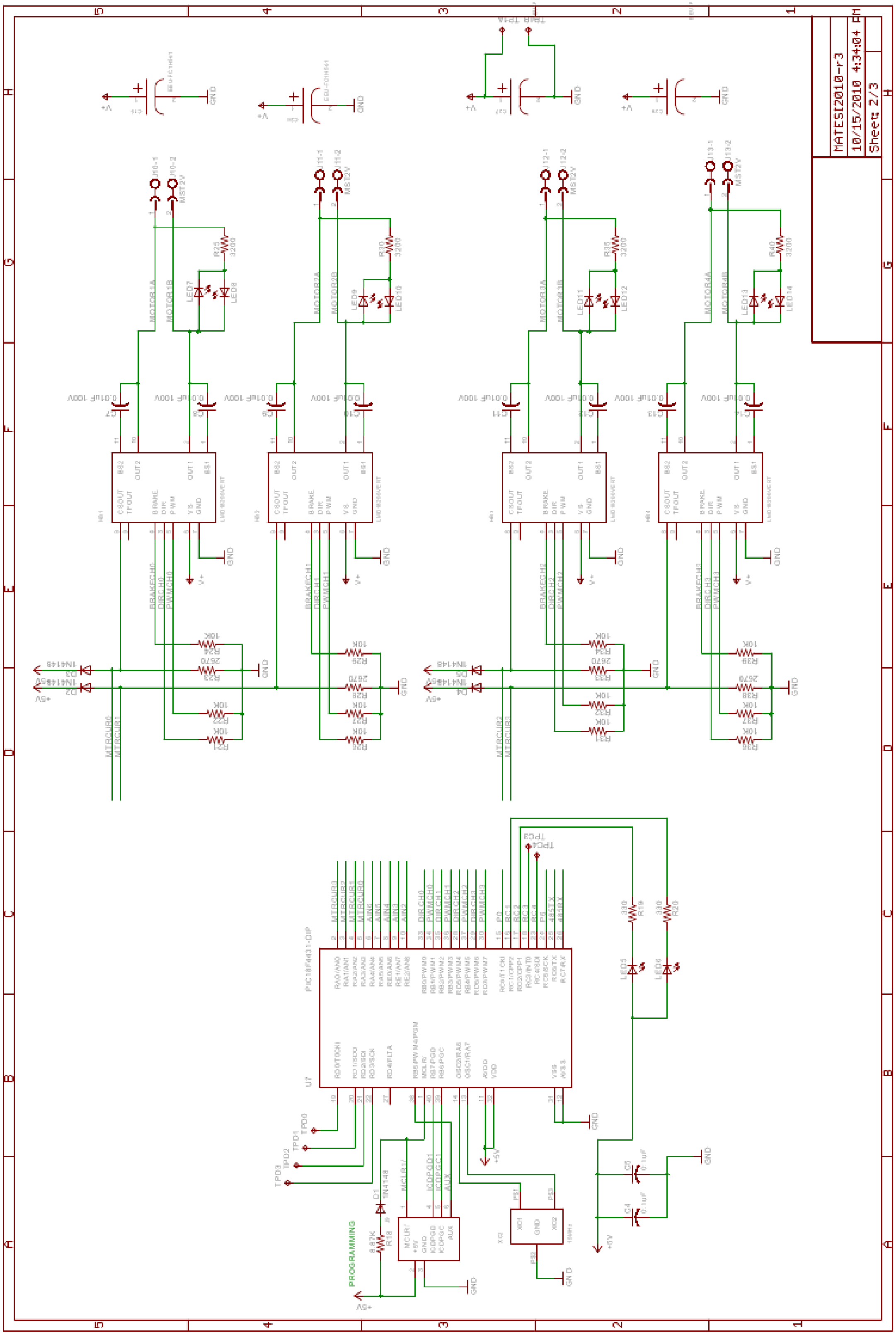
References

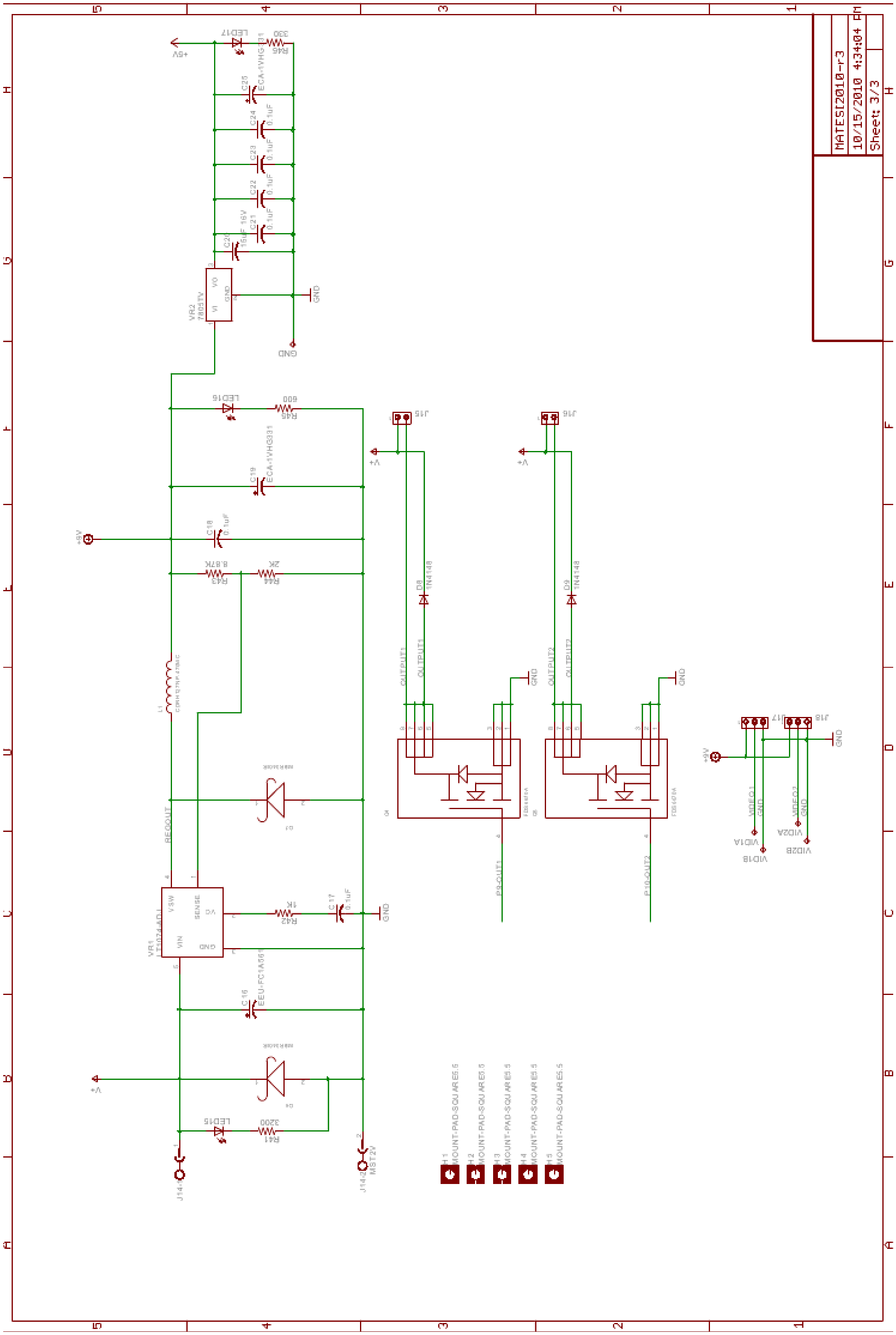
2013 Explorer Missions [PDF]. (2012, December). Retrieved from http://www.marinetech.org/files/marine/files/ROV%20Competition/Missions%20and%20Specs/2013%20EXPLORER%20Mission%20Tasks5a.pdf

What's a Microcontroller? (2003-2004). Parallax, Inc.

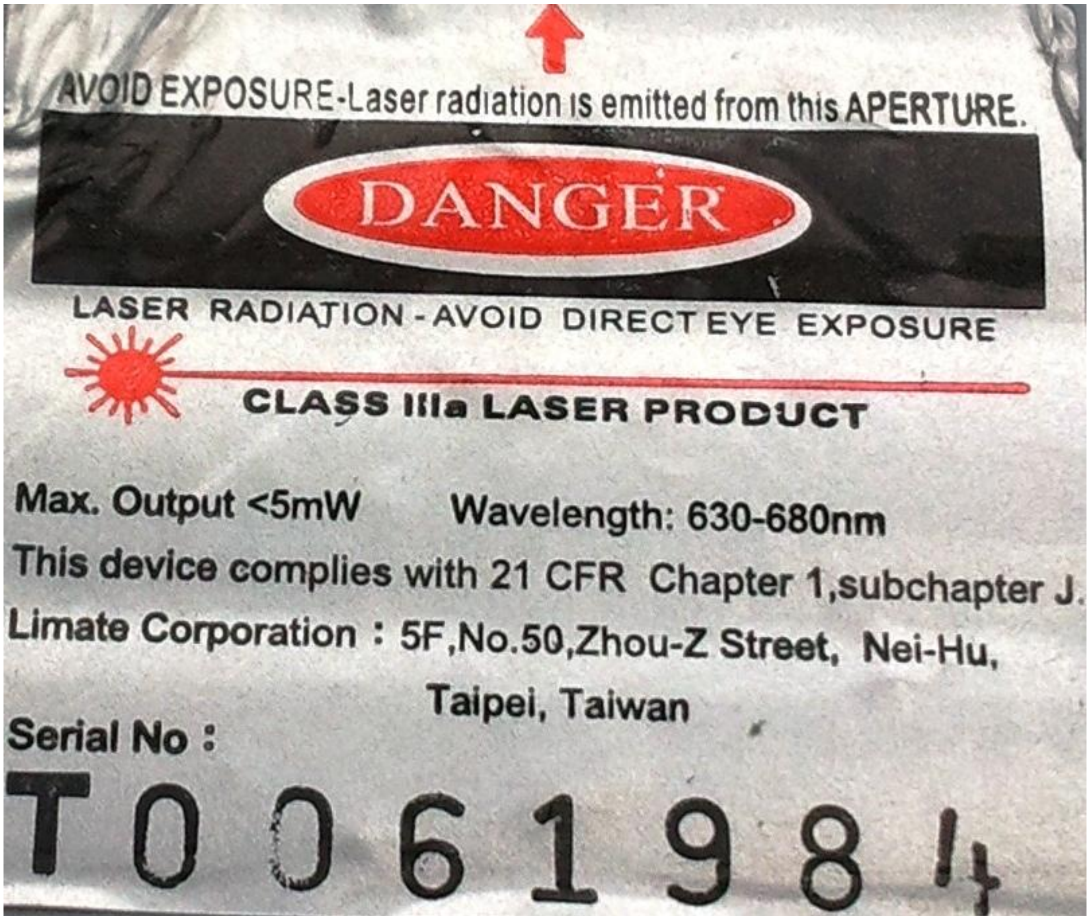
Appendix A: MATE ROV Control Board Schematics




MATESI2010-r3
10/15/2010 4:34:04 PM
Sheet: 2/3
PIC18F4431-DIP
PROGRAMMING


MATESI2010-r3
10/15/2010 4:34:04 PM
Sheet: 3/3

Appendix B: Laser Specifications



The above specifications are taken from a label attached to the laser used to construct the transmissometer. Note that the maximum output power of less than 5 mW and the wavelength range of 630-680 nm both meet the requirements set forth by the MATE center in the Explorer Class "Design and Building Specifications and Competition Rules" document.

Appendix C: Safety Checklist

The following is a checklist of additional questions asked before each practice session to ensure the safety of all team members:

1. Is the circuit breaker or fuse hooked up the circuit as shown in the schematic on page 10?
2. Are all weights and other possible loose items fastened securely to the ROV?
3. Has any silicone worn off of connections leaving exposed wire?
4. Is the beam shield over the laser?
5. Do prevailing weather conditions (thunderstorms, for example) create an unsafe environment in the pool?
6. If using a variable voltage power source (known to our team to give an unreliable voltage level), has the voltage been checked to ensure that it is not too high?
7. Are all wires plugged into laptops and monitors fastened to the pool deck so that they are not accidently pulled out or so they do not accidently pull any command and control equipment into the water or onto the deck?
8. Are the potentiometers that control the arm connected and set to a position such that the arm does not make a violent flailing motion when power is connected?
9. Are all electronics outside the water clear of both standing water and the splash zone?
10. Is there anyone swimming in the pool besides practice divers?