SeaCow 1.0
Technical Report

The Aquanauts

5/28/2015

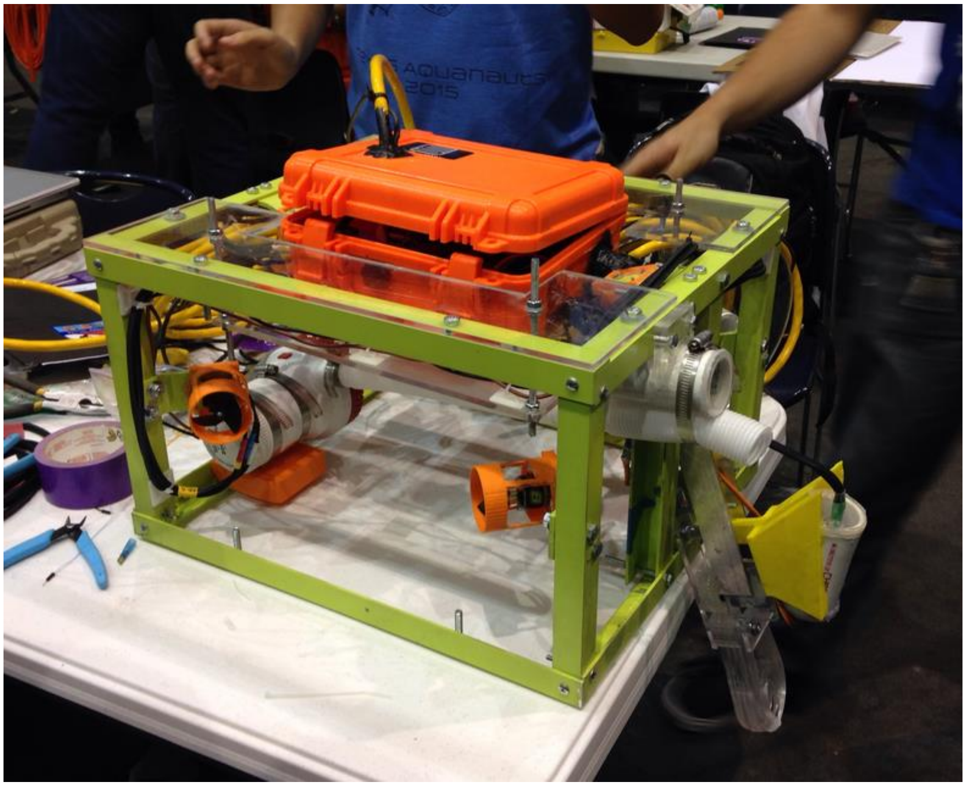

Figure 1: SeaCow

Aquanauts

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Figure 2: Team Photo

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ABSTRACT:

The Aquanauts at the University of Texas at Austin is a newly founded student organization seeking to apply technical knowledge to compete in the regional MATE competition. Encompassing students from mechanical, electrical, and petroleum engineering disciplines, the combined knowledge of the organization built an exceptionally capable ROV and overcame several challenges and obstacles. As a new organization, the ROV design follows a conventional design, allowing for ample room for the members to grow and develop the automation over time. The final ROV consists of an aluminum frame, six thrusters, two cameras, a bilge pump, and one manipulator. Most components were built in-house, utilizing advanced manufacturing machines such as 3D printers, laser cutters, end mills, lathes, cirqoid machinery, and CNC machinery.

MISSION:

The Aquanauts at the University of Texas at Austin improves the technical education of student members by pursuing challenges that members would not normally encounter in their curriculum. Through these obstacles, the company develops lifelong engineering and teamwork skills that will aid them throughout their future careers.

The Aquanauts 2014-2015 MATE R.O.V. Budget

Chassis	**Description**	**Cost**	**Quantit y**	**Total**
Aluminum	L-Brackets, Tubing, Sheets	$85.52	1	$86
Acrylic	Acrylic Sheets for laser cutting	$4	6	$24
Syntactic Foam	Syntactic Foam Block	Donated	1	-
PVC	PVC Pipes for camera mounts, props	$44.00	1	$44
Nuts, Bolts	Package of bolts and nuts	$3.68	1	$4
Consumables				
Epoxy	Epoxy, epoxy putty	$7	6	$42
Spray paint, Primer	ROV Aesthetics	$15	1	$15
Rubber Seal	Sealant	$14	1	$14

Electronics

E-chassis	S3 T5000 Dry Box	$40.63	1	$41
Motors	Propulsion system	$15	6	$90
Servos	Manipulator Arm	$8.00	3	$24
LED PCB	LED rings for the cameras	$6.85	1	$7
Cameras	HD Webcams	$30	2	$60
USB Hub	E-chassis USB hub	$19.00	2	$38
Arduino	Arduino Mega Microcontroller	$46	1	$46
Tether	Tether donated, shipping cost	$127.38	1	$127
Joystick Controller	Logitech 3D controller	$35	1	$35
Resistors	470 Ohm Resistors	$0.05	38	$2
LEDs	0603 White LEDs	$0.34	38	$13
Fuses, Banana Plugs		$14.48	1	$14
Bilge Pump	Bilge Pump and hose	$43.06	1	$43

Travelling Expenses and Other

Houston, Regional	Gasoline, food	$220	1	$220
Canada, International	Plane tickets, lodging, food	$7,000	1	$7,000
T-Shirts	Team T-Shirts	$289.86	1	$290
Registration	Regional Competition Fee	$100	1	$100
Miscellaneous		$400	1	$400

Grand Total **$8,778.28**

SID:

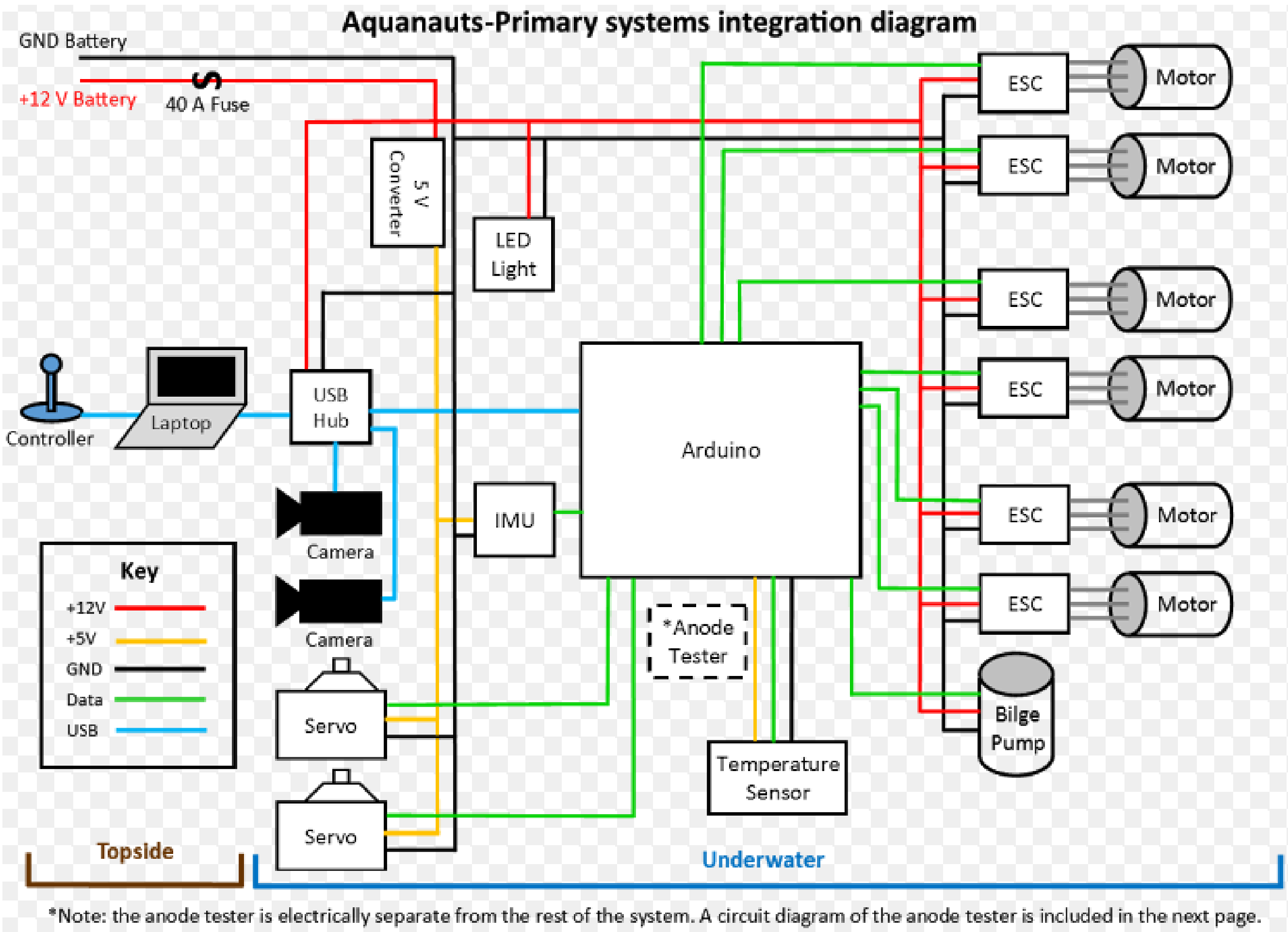

Figure 3: SID

Anode Tester:

Below is a circuit diagram of the anode tester. The anode tester is placed on an anode. One copper pad contacts positive voltage, and the other copper pad contacts ground, illuminating one LED. For example, if copper pad 1 contacts positive voltage, and copper pad 2 contacts ground, LED 2 will light up. Note that resistors 1 and 2 represent the resistance of the copper pads 1 and 2, respectively.

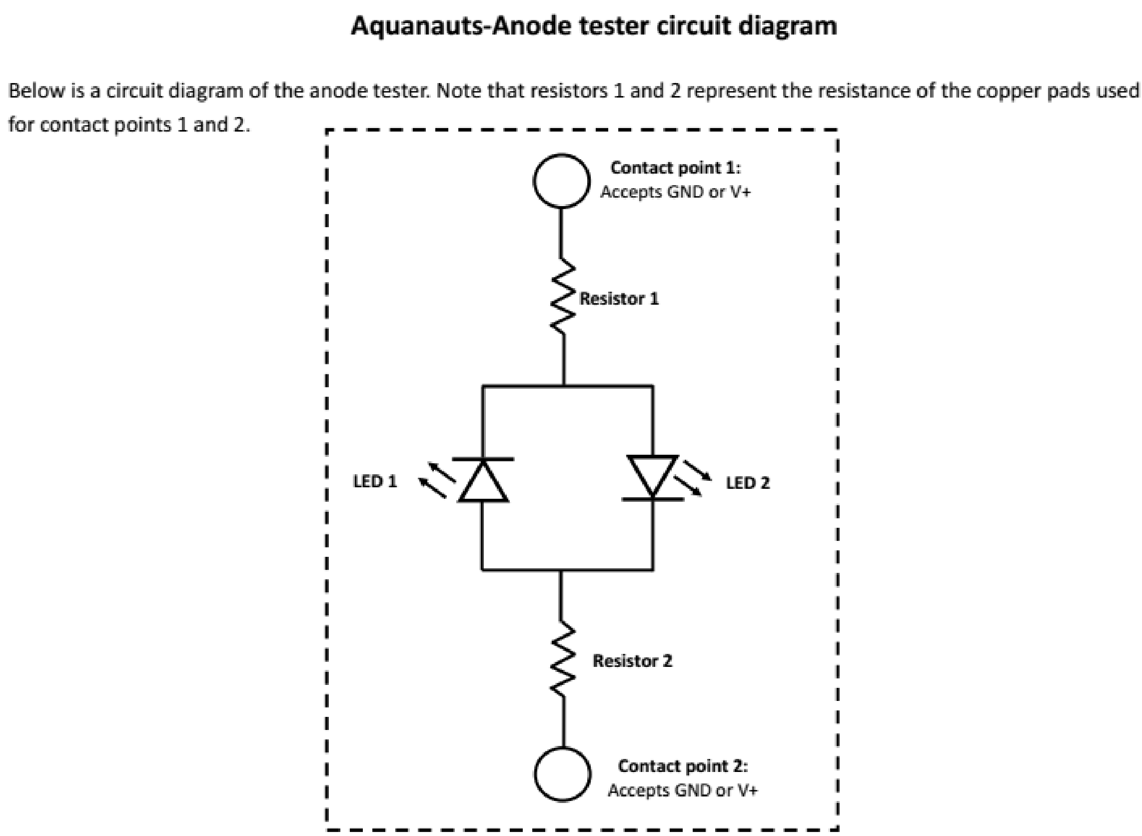

Figure 4: Anode Tester

Block Flowchart of Software:

ROV main:
Inputs: Controller serial data string, physical orientation of inertial measurement unit (IMU)
Outputs: 6 pulse width modulation signals (PWM) to control motor electronic speed controllers (ESCs), visual display of the ROV’s position
Description: The main() function of the ROV runs on the Arduino. main() processes controller serial data sent by the Python program running on the laptop, and controls each motor by sending a PWM signal to each motor’s ESC. Additionally, main() processes data from the IMU and displays the orientation of the ROV to the user.

Python program:
Inputs: controller button presses

Output: Controller button presses encoded in serial data string
Description: The python program runs on the laptop. The program reads button presses from the Pygame drivers. Next, the program concatenates the Pygame data into a string, and sends it as a string to the Arduino.

Pygame

Input: controller button presses

Outputs: digital values for each potentiometer and button on controller

Description: Pygame takes in controller inputs. Potentiometer voltages are converted to float values between -1 and 1, and buttons are represented by 0 for off or 1 for on.

Servo.h

Input: integer value between 0 and 180.

Outputs: PWM on Arduino pins.

Description: Servo.h is a library provided by Arduino. It maps an integer value to a PWM output. Servo.h is used to control servos and also motor ESCs.

Adafruit IMU driver

Input: physical position of ROV

Output: float values describing the ROVs position on each axis

Description: The IMU measures the physical position of the ROV, and the driver converts these values into float values that describe the ROVs position on each axis (x, y, z).

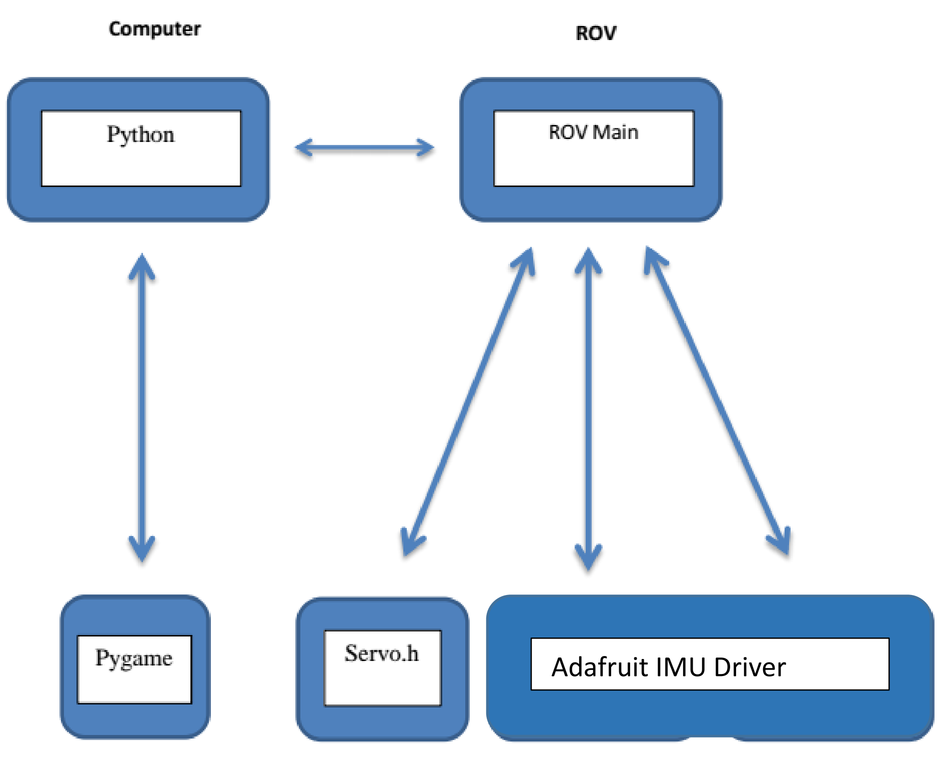

Figure 5: Software

DESIGN RATIONALE:

While each component requires unique considerations, the company maintained an overarching design philosophy throughout the ROV's formulation. Simply stated, mechanical components should last through improvements in electronic technology. So as available electrical components change, the modular design of the SeaCow allows easy integration into a mechanically sound design.

-Chassis:

The first consideration when designing the chassis, was to decide upon a proper material, because it restricted our fabrication techniques. After much debate, the company settled upon aluminum because of its strength per unit mass, cost, density, and ease of machining. Next, the general shape was taken into consideration, as it had to be balanced against multiple constraints. One such constraint was maneuverability, as symmetry is necessary to reduce buoyancy and thrust issues. It also had to follow the mission goals such as staying under the maximum size of 75cm x 75cm, housing thrusters, and containing a manipulator. As a result, the company chose a box shape for its ease of fabrication and maximization of internal volume. An open design was elected to allow easy access to components and simple assembly.

Angle bars were chosen to provide the necessary support at minimum material in order to reduce the weight. In addition, all angle bars and tubing were purchased as a 6061 alloy to avoid galvanic corrosion. Zinc plated bolts were used to mount the assembly to also prevent galvanic corrosion between the bars and bolts. Tubing was chosen to complement the assembly by giving each angle bar two unique mounting surfaces.

Figure 6: ROV Bare Frame

When choosing the material to support the manipulator, the company encountered a challenge. While C-channels would protect the servos without restricting access or movement, and its cross-sectional moment of inertia best reduced shear and bending stresses, no alloys of 6061 with the proper dimensions were available from the supplier. 6063 was the only alloy available, but the use of such an alloy could possibly corrupt the integrity of the chassis due to galvanic corrosion. Due to similarity nature 6061 and 6063 alloys, it was deemed more necessary to use the 6063 C-channels.

-Manipulator:

The company selected aluminum 6063 and Poly(methyl methacrylate), also known as acrylic glass, as the materials for the manipulator. The arm consists of aluminum, while the manipulators and brackets are manufactured with acrylic. Acrylic was chosen because of the easy accessibility to laser cutting equipment, allowing for rapid manufacturing and a highly precise fabrication of the claw and bracket. The arm serves multiple purposes as it supports the camera housing, the hose for the bilge pump, and allows the ROV to interact with the environment. The claw aspect of the sub-system took a meticulous design process, because the company had established that the claw was the most vital part of the ROV.

-Electronics Housing:

We modified a water tight Otter Box and used Velcro to attach the electronics to its base as opposed to a more permanent method of attachment it. The Otter Box allowed for easy access to the electronic components while also doubling as the main source of buoyancy for the SeaCow. Additionally, each component within the box was strapped in place to prevent any unwanted movement within the electronic housing.

In order to connect exterior electronic components such as the propulsion system and cameras, the necessary wiring was bundled and epoxied together. Then, three separate holes were cut into the Otter Box. Each hole was filled with camera and servo wiring, propulsion wiring, and finally tether and data wiring. Each hole was further epoxied and hot glued shut to prevent any water from leaking into the electronic housing.

-Propulsion:

For thrust, six brushless DC motors (BLDC) were used to propel and pitch the SeaCow. Four of the motors were positioned 45 degrees from the cardinal directions to provide full planar movement. The following top-down diagram of the ROV demonstrates how the motors were positioned:

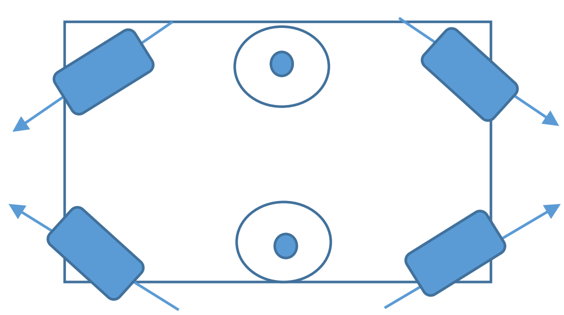

Figure 7: Thrust Vector

As the diagram shows, any form of planar movement can be achieved by firing a specific pair of motors. Additionally, two motors were placed 15 degrees from the horizontal on the top of the SeaCow to provide downward thrust while also allowing for pitch of the SeaCow. The following diagram presents a side view of the SeaCow to demonstrate this effect:

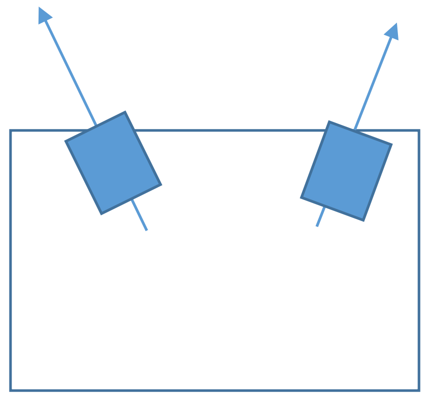

Figure 8: Side View Thruster

-Power Supply:

Most of the electronics operate at a 12V rating, however the servo motors and Arduinos operate at 5V. The power supply provides 12V for the SeaCow, but in order to provide the proper electrical supply to servos and Arduinos a 5V regulator was used to step down the voltage supply.

-Electronics/Sensors:

The purpose of the electronics is to enable control of the SeaCow, provide sensory feedback to pilot, and ensure the safety of the ROV components.

The pilot controls the SeaCow using a Logitech Extreme 3D Pro. The controller allows for multiple inputs, including an analog joystick and digital buttons. This system also uses a closed-loop PID control to maintain position without requiring constant human control.

An Arduino MEGA 20460 R3 microcontroller is used to implement all controls and sensor feedback on the ROV. The Arduino issues commands to the DC and servo motors from the controller, maintains sensor control over the humidity and temperature sensors, and powers the bilge pump.

-Bilge Pump:

In order to push water through the pipeline, the company decided to mount a Seaflo 2000 GPH bilge pump onto the frame of the ROV. There was previous discussion between this choice and a pump of lower GPH level. However, after acknowledging fluid mechanic calculations and minor head losses through the two valves and multiple bends and couples, it was found that the lower GPH pump wouldn’t provide sufficient power. In order to mount the pump on the ROV, a custom 3D printed part was designed so that hose clamps could be used to attach the bilge pump to the chassis.

-Tether:

The 50 feet of company tether was provided by Sound Ocean Systems International and consists of 8 conductors. An additional USB cable was attached to the SOSi tether to provide camera and Arduino feedback. Excess, the original 50 feet, tether cable length was purchased in order to provide enough slack to prevent a disconnection from the ROV. In order to provide this length, a USB extension cable was used to match the tether length. The connection was then wrapped in a PVC tubing and sealed with a thermal plastic adhesive.

-Waterproofing Connections:

In order to protect the electronics, the company had to ensure water would not come into contact with any live wires. Any water contact with live wires would not only corrupt the electrical components, but also create a large safety hazard. To prevent this, any openings to E-Chassis and camera housing were sealed with epoxy and hot glue.

The servo motors were another challenge. The motor shaft from the servos creates a leak point into the electronics. Therefore, the servos were disassembled and all electronic boards, wires, mechanical gears were coated with a non-conductive marine grease which protects the components from water contact. The marine grease also has a much higher viscosity than water and increases the internal pressure of the servo such that the pressure differential was not as high. The validity of the waterproof seal was tested using as custom pressure tester.

SAFETY:

The first step in promoting safety was to ensure all company members had proper training for the necessary fabrication techniques. The chassis team was fully machine shop certified and all members were trained with laser cutters, CNC machinery, and plasma cutters. In addition, safety goggles and appropriate clothing were worn at all times during build sessions.

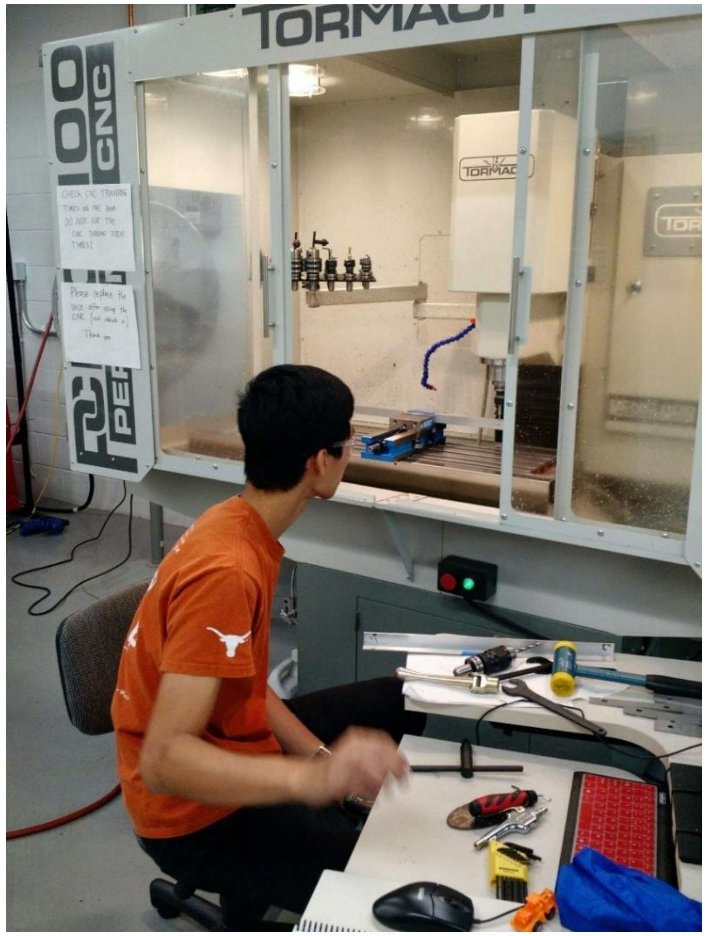

Figure 9: Darren is using CNC Machine

The ROV is equipped with the basic safety features such as fuses, waterproofed connections, and motor shrouds. All servo motors and housings were pressure tested to ensure they operated at design capabilities while at underwater pressure. The color of the ROV was chosen to make it clearly visible underwater, using paint that would not affect the aquatic ecosystem.

- The first identified safety hazard was having electrical components underwater. This issue was addressed by properly sealing the connections against water using epoxy.
- Safety labels are included inside the electrical housing to facilitate identification of wires when troubleshooting.
- Safety Checklist
    a. Mechanical Inspection
        - Are bolts attached
        - Are arms warped
        - Check for cracks
        - Look for obstructions in shrouds

b. Electronics Inspection
   - Look for cracks in electronic housing
   - Check for frayed wires
   - Check for exposed wires
c. Functional Inspection
   - Dry Run Motors
   - Verify Cameras
   - Servo Test Fire
d. Environment
   - Make sure weather is safe for operation
   - Double check stability of launch platform
   - Check for any extraneous hazards

MATEPAL:

As an aid to the mission tasks, in-house software was created using QT Creator, an open source GUI development platform. The software details the mission tasks specific to each day, provides a timer for the pilot, and calculates points as they are collected throughout the mission. Following the end of the mission, MATEPal creates a report sheet that details what tasks were accomplished, applies a time stamp to each accomplished task, and totals the score and time taken to complete the mission.

In use, the co-pilot uses and monitors MATEPal while the pilot controls the ROV. The co-pilot dictates the amount of time left to complete the mission and indicates the pace at which the pilot relays back the next task. If an error occurs during the mission, the pilot and co-pilot can decide which tasks can be performed to maximize the score. When the tasks are complete and the ROV surfaces, the co-pilot stops the timer.

Following the end of the mission MATEPal, creates a report sheet that details what tasks were accomplished, applies a time stamp to each accomplished task, and totals the score and time taken to complete the mission. This report sheet is generated in a clearly formatted text file that serves as a template for mission debriefing and documentation.

The report sheet will provide excellent data for future ROV improvements. It serves as a documentation program that allows the company understand which tasks consumed the most time or were unable to be accomplished. The company will then use this data to plan and design adjustments necessary to improve the ROV's capabilities and fine tune procedural processes.

MANUFACTURING:

The company manufactured and designed all parts utilizing SolidWorks ™ as well as the student machine shop and Makerspace. The Makerspace is a student run workshop consisting of laser cutters, CNC machinery, cirqoid machinery, and 3D printers. In the machine shop, the company made efficient use of mills, lathes, bandsaws, and a sheet metal bending brake. Additional manufacturing and adjustments were made using hand tools.

Figure 10: Andres is using the laser cutter

DESCRIPTION OF CHALLENGE:

The biggest challenge that the company faced was the limited budget. As a result, cost constrained all design choices. Operations were affected heavily as there was no room for superfluous expenses. For example, the thruster motor testing was completed later than expected due to purchasing errors. To overcome these challenges, we had to spend extra time performing calculations and running cost return scenarios before purchasing anything. In the future, we will have a more complete budget, because we will focus a sizeable amount of effort on getting corporate sponsorships and funding through the University.

SKILLS GAINED:

The greatest skill that the company learned throughout the build process was prototyping. More specifically, rapid prototyping. Team members were able to refine their skills using laser cutter, CNC mills, and plasma cutter fabrication techniques. With these tools at the company's disposal, it was possible to design a part and have a full, workable prototype in the same day. This skill allowed the build teams to see how parts would fit together in a more comprehensive way than pure computer animated design.

FUTURE IMPROVEMENTS:

For future years, we will improve the company's finances to allow a budget with more flexibility. The team would focus on getting corporate sponsorships early, allowing more spending money upfront, saving time. For improvements on the ROV, we would redesign the arm and claw system to have more degrees of freedom. Currently the arm only has two degrees, limiting the maneuverability of the arm and making the task of picking up small objects more difficult. Another area of improvement would be the waterproofing of electrical components. Modularity was sacrificed for a stronger seal in this year's design, but in the future this problem will be addressed.

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- Student Engineering Council for helping us in fundraising
- Scott Allen for mentoring the company and facilitating its growth