Final Report – Interim Design Report

Design and Development of an Autonomous Underwater Vehicle

Team 23

AUVSI RoboSub

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Abstract

The goal of Team 23 is to represent the FAMU/FSU College of Engineering in the 19th annual AUVSI RoboSub competition, which occurs from July 25th to July 31st of 2016. This will be accomplished through the design, development, and extensive testing of a modular sub which will meet all of the competition requirements provided by the AUVSI RoboSub competition. The particular aspects of design that the mechanical team will endeavor are a redesign of the hull to make it less buoyant, torpedo design and actuation, and finally the gripper mechanism, which are all normally required to perform tasks in the AUV RoboSub competition.

Team 23 is also not the only team to be working on the RoboSub this year, team 4 of the ECE teams will also be working to achieve the goal of reaching the competition this year. While the two teams will be assisting each other in the development of various subsystems required for the AUV, team 4 will be focusing more on the navigation and vision systems for the sub while team 23 focuses more on the mechanical subsystems for the sub. This collaboration of work will give the teams the best chance at sending a sub to compete in competition.

1. Introduction

The FAMU-FSU College of Engineering 2015 Senior Design Team 23 (ME) is a multidisciplinary group comprised of two electrical and four mechanical engineers who were asked to design and build an autonomous underwater vehicle (AUV) as a competition-based project. The design team was initially allocated $2,000 of available funds, and the previous teams sub from the year before. Each team member was assigned a vital role in the project, including the following responsibilities:

John Nicholson- Torpedo Design
Corey Cavalli- Hull Redesign
Max Austin- Hull Redesign
Ross Richardson-Hull Redesign
Erik Olson- Gripper Design, Kill Switch Analysis
Jordan Clein- Electrical, Gripper and Torpedo Design

The AUV is battery powered and operates using a Zotac mini computer and Arduino microcontrollers, which interpret all data collected by the sensors to control the six Seabotix SBT-150 motors and directional heading of the vehicle. It is designed to be as small as possible to save on weight and spatial dimension so that any last minute changes can be made without worry of disqualification due to the physical constraints. Two cameras are used for color and shape recognition, which allow the AUV to complete most of the objectives found in the competition rules. A hydrophone will be utilized to identify and locate an acoustic pinger at the bottom of the pool, which marks the rescue object. A mechanical grabber attached to the AUV provides a means to bring the rescue object to the surface while constraining the object in 3 degrees of freedom. The six Seabotix SBT-150 motors will provide propulsion and control for the sub. The programming language for the sub is C++ while it operates off an operating system known as Ubuntu.

2. Problem Statement and Project Scope

4.1 Problem Statement

The Association for Unmanned Vehicle Systems International (AUVSI) Foundation and the U.S. Office of Naval Research (ONR) has designed a competition to advance the development of Autonomous Underwater Vehicles (AUVs) by challenging a new generation of engineers to perform realistic missions in an underwater environment.[1] The competition requires the design of a vehicle that operates autonomously in a self-contained unit. The AUV will be deployed in a large salt-water pool. The rules and competition objectives are not yet released but based on past patterns it can be assumed that they will be similar to the 2015 AUVSI competition and can be found online at www.auvsifoundation.org. The competition has several objectives to complete, which require an optical sensor, for color and shape recognition, and an acoustic sensor for the identification and location of an acoustic pinger.

4.2 Competition Course

The AUV will be operating at the SSC SD TRANSDEC Facility, which houses an anechoic saltwater pool. The facility is located in San Diego, CA, and the water is obtained directly from the Pacific Ocean. The underwater obstacle course will be arranged in a region with a maximum depth of 16 ft. The practice facility that will be utilized for testing the AUV is the FSU Morcom Aquatics Center. This pool has the closest specifications to the competition pool and the design team has been granted permission to set up a replicated obstacle course environment to test the AUV at depths up to 17 feet. Figure 1 is a schematic of the competition pool layout. It shows how different tasks and obstacles would be set up in the competition.

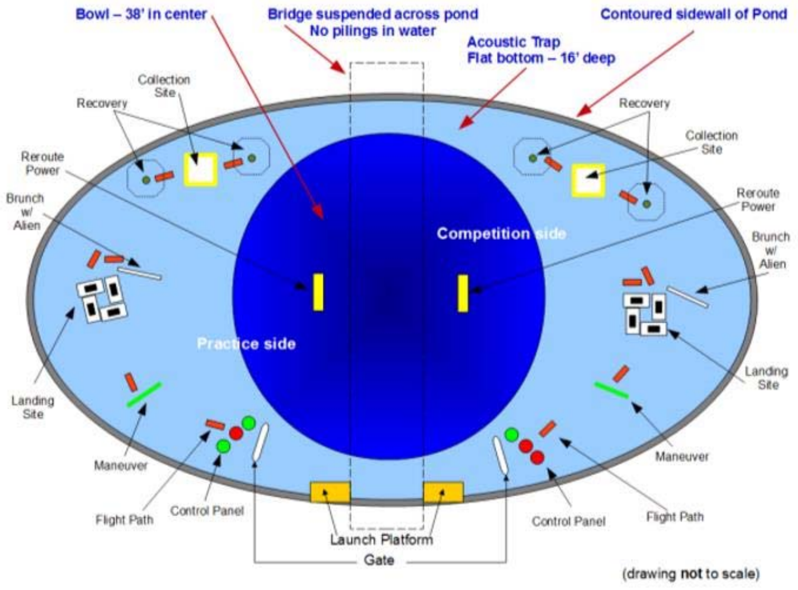


Figure 1: Competition Pool Layout

4.3 Project Scope

The sub has to be designed with the abilities capable of performing these tasks (these are rules from a previous competition):

[1] Pass through the center of a PVC gate

[2] Path Navigate from task to task by following a segmented orange PVC path

[3] Strike two of three buoys in a designated order prior to advancing to the next task—each buoy will be a different color (i.e. green, red, yellow)

[4] Obstacle Course Traverse through a PVC window at a particular height

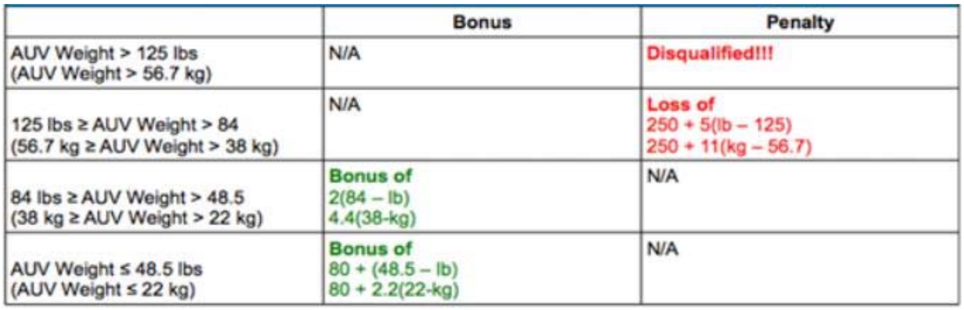
[5] Drop two markers into two of four explicit bins (black with white borders), designated by color forming a shape created by the competition.

[6] Independently launch a torpedo through two of four explicit PVC cutouts designated by size and color

[7] Navigate to the location of an acoustic pinger (operating at a designated frequency between 22 kHz and 30 kHz), secure a PVC laurel wreath object, surface within a designated octagonal region, and submerge to return and release the object either to its original location, or to a secondary location designated by an alternate pinger.

4.4 Constraints

Table 1: Size and weight constrain on AUV's entered in the competition

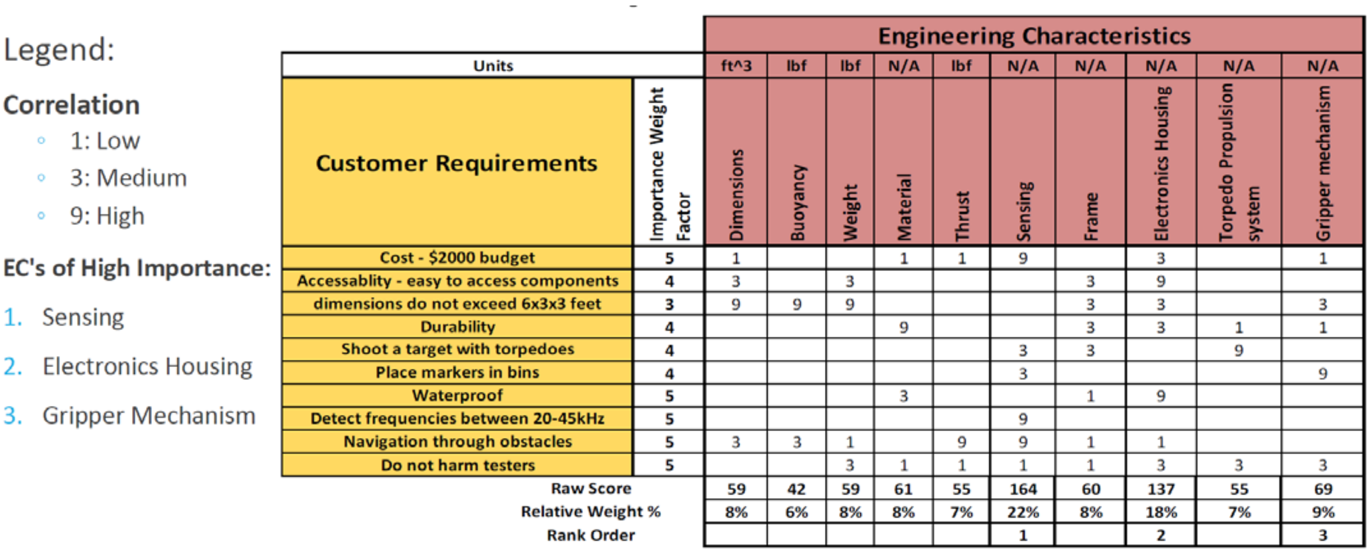


	Bonus	Penalty
AUV Weight > 125 lbs (AUV Weight > 56.7 kg)	N/A	Disqualified!!!
125 lbs ≥ AUV Weight > 84 (56.7 kg ≥ AUV Weight > 38 kg)	N/A	Loss of 250 + 5(lb – 125) 250 + 11(kg – 56.7)
84 lbs ≥ AUV Weight > 48.5 (38 kg ≥ AUV Weight > 22 kg)	Bonus of 2(84 – lb) 4.4(38-kg)	N/A
AUV Weight ≤ 48.5 lbs (AUV Weight ≤ 22 kg)	Bonus of 80 + (48.5 – lb) 80 + 2.2(22-kg)	N/A

- The AUV weight must not exceed 125 pounds in air
- The AUV must be able to fit in a 6 feet by 3 feet by 3 feet box
- Torpedoes and markers must have a dry weight of no more than 2 pounds
- Torpedoes and markers must be able to fit into a 2 inch by 6 inch space
- Torpedoes must travel at a "safe" speed, or a speed that will not cause bruises when it strikes a person
- The vehicle must be battery powered and the battery must not have an open circuit voltage that exceeds 60V
- The vehicle must have a kill switch that can be easily accessible
- All propellers must have shrouds that surround them and have at least a 2 inch distance between the spinning disk and the edge of the prop
- The AUV needs to be buoyant by at least 0.5% of the sub's mass when it has been shut off through the kill switch

3. Design and Analysis

The constraints set forth by the AUVSI competition define what would traditionally be customer requirements. These requirements have been entered into the design house of quality seen below in Figure 2. This figure compares the competition requirements with the engineering characteristics. The competition requirements are given an importance factor and a correlation of the engineering characteristics to the competition requirements is assigned.



Legend:

Correlation

- 1: Low
- 3: Medium
- 9: High

EC's of High Importance:

1. Sensing
2. Electronics Housing
3. Gripper Mechanism

		Engineering Characteristics									
Units		ft^3	lbf	lbf	N/A	lbf	N/A	N/A	N/A	N/A	N/A
Customer Requirements	Importance Weight Factor	Dimensions	Buoyancy	Weight	Material	Thrust	Sensing	Frame	Electronics Housing	Torpedo Propulsion system	Gripper mechanism
Cost - $2000 budget	5	1			1	1	9		3		1
Accessablity - easy to access components	4	3		3				3	9		
dimensions do not exceed 6x3x3 feet	3	9	9	9				3	3		3
Durability	4				9			3	3	1	1
Shoot a target with torpedoes	4						3	3		9	
Place markers in bins	4						3				9
Waterproof	5				3			1	9		
Detect frequencies between 20-45kHz	5						9				
Navigation through obstacles	5	3	3	1		9	9	1	1		
Do not harm testers	5			3	1	1	1	1	3	3	3
Raw Score		59	42	59	61	55	164	60	137	55	69
Relative Weight %		8%	6%	8%	8%	7%	22%	8%	18%	7%	9%
Rank Order							1		2		3

Figure 2: House of quality for the design and development of an autonomous underwater vehicle

5.1 Mechanical Design

5.1.1 Hull

The current hull is made out of 0.5" thick aluminum 6061, with an approximate volume of 1.55 cubic feet, weighing about 83.5 pounds. The buoyancy force was calculated using Equation (1) below.[2]

$$\mathbf{F_{buoyancy} = \rho_{water} * V_{sub} * g} \tag{1}$$

Using the equation above the buoyancy was calculated to be about 100 pounds of force. To confirm our calculations and make sure the hull was waterproof we removed all the electronic and took the sub to Morcom Aquatic Center for leak and buoyancy testing.

Figure 3: Buoyancy and leak testing at Morcom Aquatic Center 10/16/15

The sub floated when we set it in the water at the pool. Upon adding an addition 15 pounds, the sub barely floated. Once we stepped up to a total of 18 pounds, the sub slowly started to sink. This confirmed that our calculations were on point, having calculated the sub was 16.5 pounds over buoyant and the test showing the point of neutral buoyancy being between 15 and 18 pounds. At this point, we took the liberty of throwing on a few more weights and tying a yellow rope to the sub so we could sink it deep into the pool to make sure the lid was water tight at greater depths. Figure 3 shows the test in action. We marked on the rope the point when it reached its maximum depth, which ended up being about 13 feet, and when we opened the hull after taking it out of the pool, it was water free. The purpose of this test was to confirm the buoyancy of the sub and to make sure we could use the current hull for testing which was confirmed since it passed the leak test.

The pool test also gave us an idea of how much force the vertical thrusters would have to apply just to submerge the sub. Taking into account the addition weight of the electronics, being about 5 pounds, the thrusters would have to output around 3 pounds of force each just to submerge the current sub. With this in mind, it was decided that a new hull that was much closer to neutral buoyancy need to be designed.

Although adding additional weight to the sub would be the simplest way to achieve neutral buoyancy, that is not an option due to the weight constraints of the competition. The competition specifies that if your design exceeds a dry weight of 84 pounds, points will be deducted from your score. So the only option is to decrease the volume. In order to continue testing with the current hull the design of a new hull with similar geometry but less volume was done.

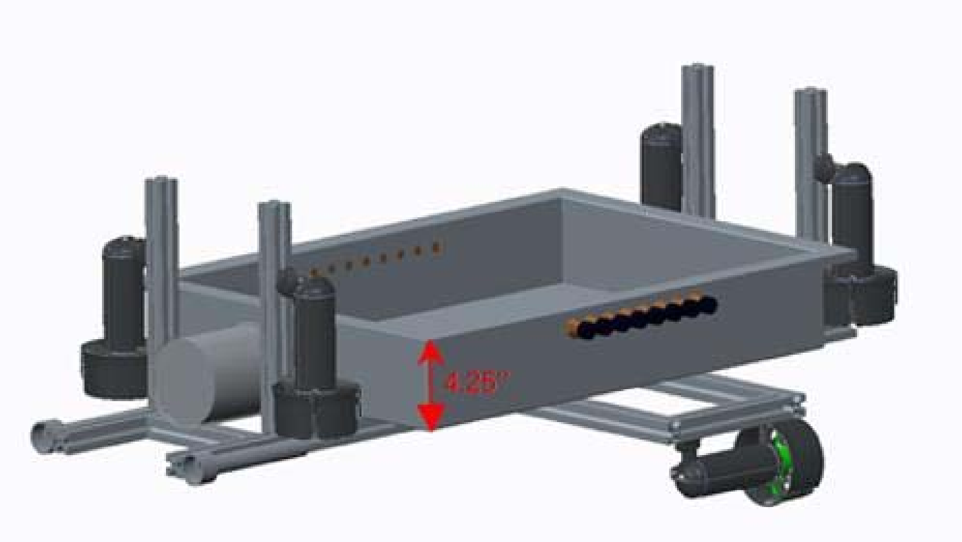


Figure 4: CAD of the hull redesign

The redesign of the hull seen in Figure 4 was made by simply taking 1.4 inches off the height of the hull. This would make it neutrally buoyant, and also improve its mobility since not as much force from the thruster would be required to submerge the sub. The same geometry was kept so the placement of electronic would not have to change. Actual completion of the redesigned hull is expected to take place early next semester.

5.1.2 Thrusters

The sub currently has six SeaBotix BTD 150 motors. Four motors are positioned vertically at each corner of the sub and two are positioned on either side of the sub facing forward. The BTD 150's are waterproof brushless DC motors capable of about 5 lbs of thrust at max capacity. However, they are wired with a 16 volt battery which limits the thrust to about 4 lbs of force each. Figure 5 shows power and force outputs for the thruster for a given voltage.[3]

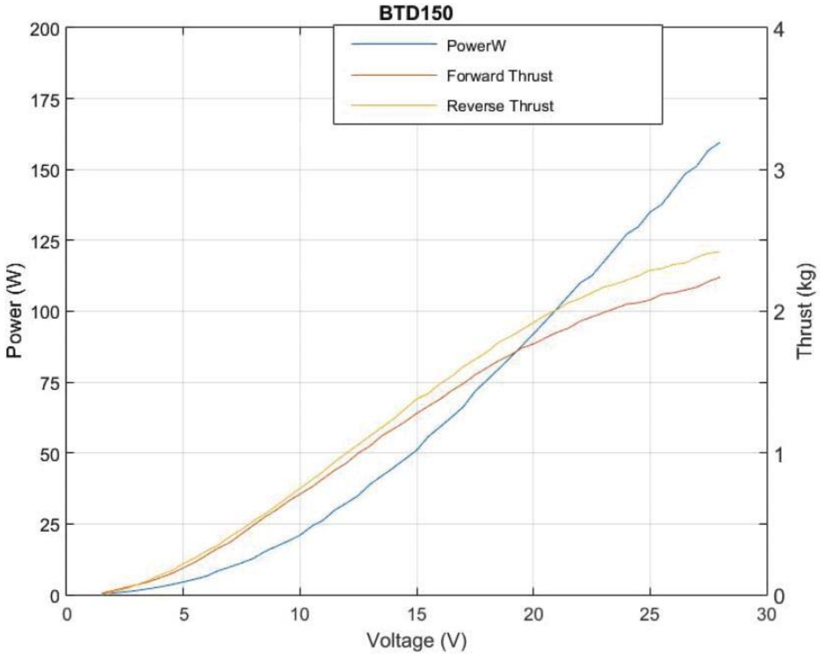


Figure 5: Output power and force of one SeabotixBTD150 for a supplied voltage

5.1.3 Gripper

The gripper mechanism must be able to grasp and continuously apply pressure to a variety of small objects that will be disclosed by the competition rules at a later date. The gripper must constrain at least 3 degrees of freedom of the object throughout movement in all directions. The gripper must be controlled effectively by the microcontroller while interfacing with the downward facing camera to ensure accuracy in securing a target.

Figure 6 shows the actuator the team has decided to go with for the gripping mechanism. This model runs off compressed air. The camera would detect an object on the bottom of the pool and would activate an air compressor, which would close the claw and keep the object inside of its grip. This subsystem will be improved upon this year by redesigning the physical gripper but keeping the same principles intact. Ideally, the gripper will hang 17 inches below the hull so that it clears the bottom camera. The arms will also be interchangeable so they can be switched out depending on the size and shape of the object it has to pick up.

Figure 6: Gripper Mechanism

5.1.4 Torpedo

The torpedo system must launch two projectiles through two separate openings of smaller than 1.5 feet in diameter. These projectiles must reach a large square target 4ft away directly behind the hole. Ideally, the projectile will be neutrally buoyant so it can remain on target until it reaches its destination.
The system must be successfully integrated with the navigation system, as target identification is paramount.

From the work of the senior design team two years' prior, there is framework of a torpedo system that is powered by compressed air and controlled with an electronically actuated value. Based on a video uncovered from the team's research, the system did work separately form the sub's body. However, the torpedo when launched only traveled a short distance before quickly rising to the surface. Based on this the team has chosen to rebuild and keep the launching system from this previous year. Currently the entire system is able to be mounted on the frame with the exception of the air tank supply which has rusted and requires replacement.

The portion of this system that the team is focused on redesigning is the physical projectile. The problem of the torpedoes buoyancy will invariably effect scoring during the competition. Upon investigation of an old torpedo, it was found that the object is made out of either cast or machined ABS plastic that contains a metal rod in its center and a magnet to attach to the projectile system. The use of a metal rod gave structure and assisted in the attempt to correct buoyancy. With the knowledge that this had less than optimal buoyancy but the system is designed for these particular projectiles to fit into, the team chose to look at a manufacturing change. Figure 7 shows a remade CAD design that mimics the previous design. The manufacturing methods that will be used to replicate this is 3D printing. Using 3D printed ABS rapid inexpensive prototyping is available to change buoyancy based on core size and infill. This will also allow the altering of core materials with ease to produce the ideal weight addition to the sub. Additionally the rapid prototyping will allow for slight changes in shape to optimize trajectory in the water.

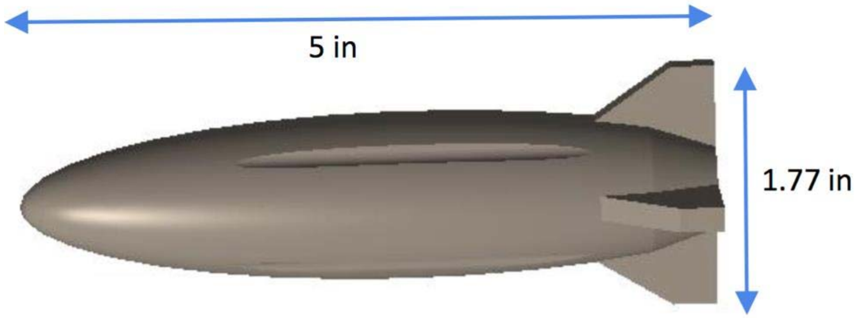


Figure 7: Torpedo Design

5.1.5 Marker Dropper

The design used for the marker dropper came from a design adopted from a previous FAMU-FSU RoboSub team. The decision to continue with this design came down to its simplicity and effectiveness. The mechanical subsystem is made out of aluminum 6061 and contains a parabolic track where two steel balls will be in place. The parabolic track is bound on both sides by aluminum walls in order to prevent the markers from accidentally falling off the device. There is a servo motor that is oriented vertically downward, located directly between each of the two markers. When the camera sees the desired object the servomotor will rotate right or left to a desired angle releasing one of the two balls. After the ball is released, after a given delay, the motor will rotate back to its starting position. When the cameras see the other desired object, the motor can rotate to the same angle in the opposite direction in order to allow the second steel ball to drop into the desired bin. The servomotor will be controlled by one of the microcontrollers. The wires from the microcontroller will run to one of the seacon ports that will run the rest of the connection to the waterproof servo.

5.2 Electrical Design Specifications

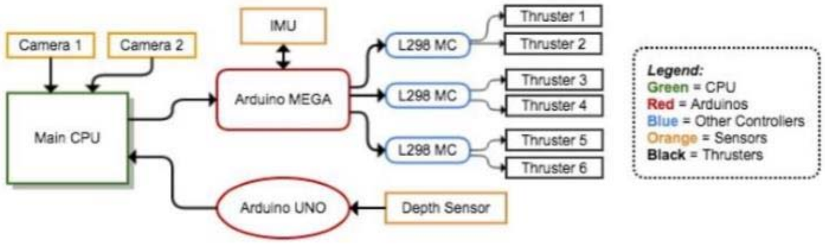


Figure 8: Electronic Components Diagram

<u>Main Components</u>

- Two microcontrollers: Arduino UNO and Arduino MEGA. Arduino UNO interacts and operates the depth sensor.
- Arduino MEGA is the primary control, interacting and operating thrusters and the inertial measurement unit
- Cameras that directly interact and operate with the main CPU
- Zotac is main CPU: Controls image processing and communicates between the microcontrollers
- Third microcontroller being implemented which will control the torpedoes and gripper

The electrical system is broken down into multiple main areas. These are the CPU, the cameras, the battery source, and the controllers. Since this is an autonomous submersible, the main way it operates is through vision. This is why there are two cameras on the sub. The front facing camera is used to identify some of the obstacles such as the target for the torpedoes and the gates to pass through. The bottom camera is used to trace the path on the ground that the sub has to follow. The images from the cameras are processed through the Zotac, which is the main CPU of the sub. It interprets the color, shape, and size of the images and then outputs the appropriate response to the microcontrollers. The Arduino Mega is responsible for telling which thrusters to power on, which allows the sub to move in the right direction. The Arduino Uno is in charge of the depth sensor and the proposed second Arduino Uno would control the torpedoes and gripper.

Figure 8 above shows the connections between some of the important electronics. This is the current layout of the sub without any of the new ideas implemented. Currently, the setup inside the hull of the sub is very disorganized. The wires were crossed and not organized in a way that allowed easy debugging of issues that arose. The decision to create a new will allow the electronics to be organized better. The other challenge related to the electronics is heat. Heat is a very common issue with anything that needs power to operate. Powering the electronics creates heat and if this heat is not dissipated efficiently then they run the risk of overheating. The designs above also help to combat this issue. It allows the air inside to flow easily so that the electronics have no issues operating.

5.2.1 Main CPU

In order to integrate all of the subs functions to communicate with one another a main processing unit is need. The Zotac computer acts as the main processing unit for the AUV and can be seen in Figure 9. As the MPU, the Zotac is essentially the sub's "brain" and is responsible for most of the high-level communication. The Zotac is where the image processing takes place, which then communicates to other peripherals of the sub. The MPU interfaces with one Arduino Mega and two Arduino UNO microcontrollers. The Zotac makes use of its USB ports to establish bidirectional UART serial communication links with the microcontrollers. The information is sent to the Arduinos to control various hardware such as the thrusters, and depth sensor. The Arduinos also regularly update the MPU with necessary mapping and control data such as current latitude readings, acceleration readings, as well as relative depth readings, which helps process the instructions and commands. The serial communication links are opened at a baud rate of 19,200 bits/s and zero parity. The Zotac computer also utilizes two Logitech webcams connected via USB for vision information. The MPU receives power from an external 19V/ 4mA universal laptop battery. The Zotac also acts as a power source to the microcontrollers and IMU.

- CPU Intel Core i32330M Processor (2.2 GHz, dual Core)
- Chipset Intel HM65 Express
- Memory: 2 X 204pin DDR31333 SODIMM Slots, Max Capacity of 16GB
- Hard Drive: Supports 1 X 2.5Inch SATA 6.0 GB/s Hard Drive
- Ports:4XUSB2.0Ports(1front,2rear,1top);2XUSB3.0Ports;1X

- WiFi Antenna Connector; 1 X DVI Port; 1 X HDMI Port; 1xOptical S/PDIF Out; 1 X RJ45 LAN Port; Audio I/O Jacks

- Card Reader: 6In1 Card Reader, Supports MMC/ SD/ SDHC/ MS/ MS Pro/ xD
- LAN: Integrated Gigabit
  Ethernet Controller;
  802.11n/g/b Wireless LAN; Bluetooth 3.0

Figure 9: Zotac Mini Computer

5.2.2 Microcontrollers

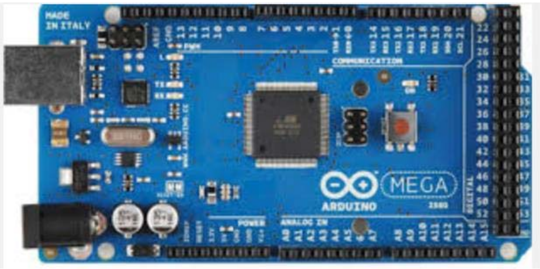


Figure 10: Arduino Mega

The Arduino Mega microcontroller is the main control for the thrusters. It is responsible for interfacing with the motor controllers that control the thrusters, which are connected to the Zotac. The Arduino Mega microcontroller communicates with the Zotac computer through a UART serial link, which is channeled through the USB ports of both devices. The serial communication link sports an effective baud rate of 19200 bit/s to ensure data is transmitted quickly, yet effectively. Each of the motor controllers supply voltage to two thrusters. These motor controllers therefore require the use of six pins on the Mega, two of which must be analog (PWM) pins in order to have variable control of the speed the thruster propellers are rotating. The Arduino Mega receives power from the MPU through the USB connection. Each of the three motor controllers are supplied with a maximum input of 14.8V from the thruster and motor controller power system.

Figure 11: Arduino UNO

The Arduino UNOs are useful in controlling parts of the sub that have to deal with each task to perform. One of the UNOs acts as the main microcontroller for the Depth Sensor. The microcontroller interfaces with the MPU via a UART serial communication link channeled through the USB port. The Arduino UNOs receive power from the USB connection to the MPU. The microcontroller is supplied with 12 V. The Arduino Uno then reads an analog voltage output for the depth sensor. It communicates the data from the sensor to the Zotac.

The other UNO controls the actuation valves for the air tank, which is important for torpedo and gripper tasks. The UNO receives the image processing from the Zotac, which then activates one of the pins on the microcontroller. The signal sends the necessary voltage to open the desired valve, releasing the air pressure, which will either fire a torpedo or open and close the gripper.

5.2.3 IMU

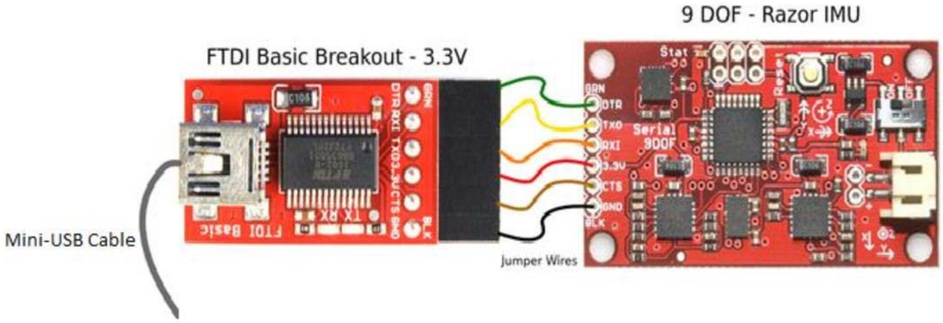


Figure 12: Sparkfun Razor IMU

The Sparkfun Razor IMU is a sensor that is used to determine current angular velocity data and acceleration, which is valuable in describing the AUV's current state of balance and movement. The sensor utilizes a triple axis gyro, accelerometer, and magnetometer. The current IMU used in the sub can be seen in Figure 12. The IMU directly interfaces with the Zotac PC via the FTDI Breakout Board, which is connected through a mini USB connection. The RazorIMU is therefore supplied with the ideal voltage and current flow to operate by connecting the 3.3V and GND pins from the Breakout Board to the respective 3.3V and GND pins on the IMU.

5.2.4 Motor Controllers

There were brands of the L298 H-Bridge motor controller, seen in Figure 13, that were used in the AUV. Both of which were very similar. This year the team purchased a new motor controller to replace the older model which made all of the controllers the same. The motor controller used is the CanaKit driver, has the following specifications:

- Motor supply: 6 to 35 VDC
- Output Power: Up to 2 A each or 4 A if bridged together
- Onboard Power Resistors Provided for Current Limit
- Enable and Direction Control Pins
- Power-On LED indicator
- 4 Direction LED indicators

Figure 13: L298 H-Bridge motor controller

5.2.5 Battery System

There are three batteries that power the sub. These are the depth sensor battery, thruster battery, and MPU battery. The depth sensor and thruster battery were reused from the previous year but the MPU battery was missing. A new battery was purchased to replace the missing battery so that the MPU could be powered in the water, which powers the microcontrollers. The battery can be seen in Figure 14 and its specifications are listed.

- Capacity: 4000 mAh
- Run time: 2-3 hours
- Output: 19V DC
- Max Discharge Current: 3A
- Dimensions: 155x100x23 mm

Figure 14: MPU Battery

5.2.6 Cameras

The camera system was adopted from the previous year's team. The vision system will use two C615 webcams, seen in Figure 15. One webcam will be positioned horizontally in the front of the AUV. The other webcam will be placed on the underside of the AUV. The horizontal webcam will handle detecting the Gate and maneuvering the structure. The bottom webcam will detect the path segments on the floor of the pool. Each webcam is powered by USB so no external power adapter will be necessary. The following are the camera specifications that they provided.

- Full HD 1080p video capture (up to 1920 x 1080 pixels) with recommended system
  HD video calling (1280 x 720 pixels) with recommended system
- Logitech Fluid CrystalTM Technology Autofocus
  Photos: Up to 8 megapixels (software enhanced)

- Hi Speed USB 2.0 certified (recommended)

Figure 15: Logitech Webcam

4. Project Management

As previously stated the project team has been subdivided into two groups the mechanical engineering led team and the electrical/computer engineering led team. Funds from each of the teams' respective departments have been allocated to the groups for the project. The mechanical team has been provided two thousand dollars and the computer team was provided seven hundred and fifty dollars. With such a small budget for a large project, resource allocation and efficient utilization of these funds for purchasing of resources is paramount. Thus far in the project funds have been primarily restricted to the replacement of non-functioning components. The first of these replacement costs were covered by the ECE led team upon the discovery that one of the motors was unable to function due to a broken motor driver. The driver was replaced with a CanaKit driver that was found to fit the same purposes with a higher current output than the previous model. After reconstructing the old air pressure pneumatic system, it was found that the air supply was unusable due to rust in the tank and valves. A new air supply has been purchased by the ME team. The third large purchase made was of the aluminum for the new submersible hull that will be altered to conserve on buoyancy. This choice was made so that the team has freedom to edit a hull without potentially damaging the older model. The final purchase made was for the first new hardware component to be developed: the pneumatic gripping mechanism.

With the preceding items purchased the final task of the semester is principally debugging and finalizing designs so that physical builds can be rapidly made upon the start of the spring semester

Apart from financial management a lot of planning and management goes into the design of the project, especially for a project involving many smaller systems and component integration like this one. A summary of how time was managed for the major subsystems worked on during the Fall 2015 semester for the entire RoboSub team can be seen in the Gantt chart in Figure 16.

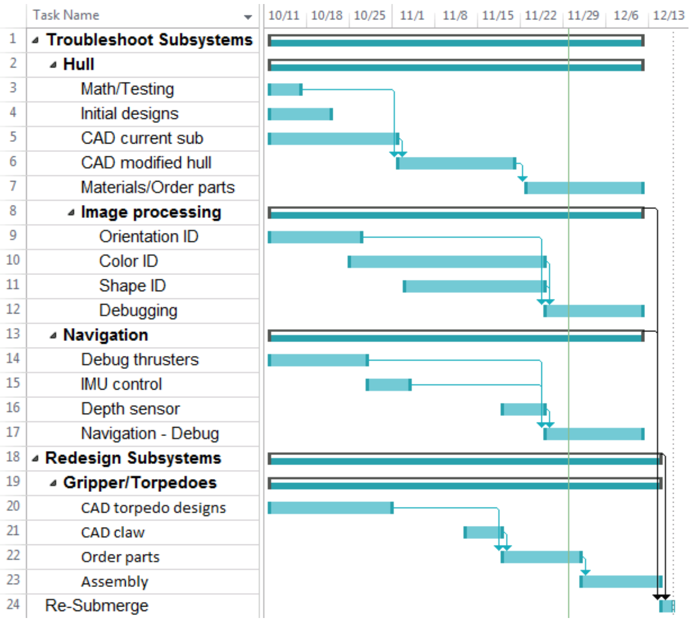


Figure 16: Gantt chart of the Fall 2015 semester

5. Environmental and Safety Issues and Ethics

When conducting experiments with the submersible autonomous vehicle, it is important to evaluate the environmental and safety hazards regarding all possibilities while testing. The environmental issues are minimal and almost nonexistent, considering the testing is performed within a controlled environment. However, a potential environmental hazard of the submersible would be the malfunction and detachment of components within a large body of water. Also, if the submersible is not waterproof, the electronics will malfunction and could leak battery acid within the water, causing damage to the environment. The safety issues regarding the sub are minimal as well. If the sub is not waterproof, the components could potentially shock and injure individuals within the sub's vicinity. Furthermore, when testing with compressed air, it is imperative to use caution within its testing vicinity. When launching projectiles such as torpedoes, there is a possibility that one of the projectiles could impact and injure an individual. With all these risks in mind the submersible is tested to be waterproof before electronics are inserted to ensure that the sub is both environmentally friendly and safe to test.

6. Results

When testing the various systems of the submersible there are two different stages. One stage of testing is the dry testing. This is testing done on land with the sub sitting on a stand. This type of testing can serve to determine basic functionality for each component system. The second type of testing is water testing. This testing serves to confirm functionality of the previously dry tested systems and to prove that any in water code algorithm for the robots motion works correctly. This is the testing phase where most of the debugging and troubleshooting occurs. Due to this and to the limited pool time that can be allotted to the group for testing, these tests are critically important and must be put to the best use. The following are the various systems that have been or need to be tested. With the exception of the hull all of the tests have been given a passing or failing grade based on dry tests alone. Due to the critical failure that the battery caused the other ready subsystems were unable to be testing in the water and have therefore been noted as such. The summary of tests performed in the Fall 2015 semester can be seen in Table 2.

Table 2: Summary and results of tests performed during Fall 2015 semester

Test	Date Completed	Pass/Fail	Reason Failed
Water Proof Hull	10/16/2015	Pass	
Thrusters	10/27/2015	Pass	
Camera Vision	11/01/2015	Pass	
Battery Power	11/16/2015	Fail	Voltage regulator malfunctioned due to faulty battery
Marker Dropper	Scheduled for early next semester		
Air Actuation	Scheduled for early next semester		

The in water tests for the hull also served to determine the accuracy of our buoyancy calculations for the hull. The calculated value for buoyancy we determined was 16.5 lb of positive force causing the sub to float. During testing we found this value to be accurate as the weight that was added to the sub to achieve neutral buoyancy was between 15 and 20 lb. Though it took 20 lb to sink it is important to note that the reason for using this weight rather than the 16.5 found in simulation is simply due to the increments of weights available to the team during testing.

7. Conclusion

Through the testing and research of the three subsystems that the mechanical engineering led group is responsible for the next steps have been made clear. The testing revealed that the current hull is functional but not optimized for the design. However, the upfront cost, both financially and time wise are too great if the group were to scrap the design completely. Therefore, the decision was made to generate alterations to the current hull to improve its performance in testing. Ideas may be taken from the other designs in this process however at its core the hull will maintain the same overall geometry due to its proven effectiveness. The old gripping mechanism however will be redesigned and built from scratch due to the poor quality of the existing design. In order to reduce strain on the electronics and to easily apply a continual force the choice was made to make the mechanism air actuated. The competition officials have yet to release the specific tasks that the gripper should accomplish therefore a holding mechanism has yet to be fully designed. Because of this delay from the competition organizers the design has been slightly delayed. The torpedo system has yet to be tested by this year's team due to rusted parts however based on old video it was at one point functional in previous years. For this reason, the air compression system will remain largely unchanged and simply reconstructed with replacement parts. The torpedoes themselves on the other hand will need to be updated. Based on the video evidence the projectile is too buoyant to meet competition task standards therefore a new design is needed. The process of this new design will be iterative using 3D printing for the purpose of rapid prototyping. This in hand with buoyancy testing will allow the team to produce several options that will best achieve performance standards. Overall the current sub is making good progress but falling just short of competition standards. For this reason, our work is focused on small but critical updates to the submersible to bring it to the level it needs to be at to compete successfully. In the future the team plans to focus on Further design of the hull as well as creating a functional torpedo system.

8. References

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9. Biography

Max Austin:

A Mechanical Engineering senior working in STRIDE Lab, TA's for Dynamics System's 2, planning on going to Graduate School after graduation.

Corey Cavalli:

A Mechanical Engineering senior interned with United Launch Alliance as a strength analyst during summer of 2015. After graduation he will return to United Launch Alliance in Cape Canaveral as a test engineer.

John Nicholson:

A Mechanical Engineering senior worked in the STRIDE Lab under Dr. Clark as an undergraduate research assistant during the summer of 2015. Also has been a teaching assistant for Mechatronic 1 since spring 2015.

Ross Richardson:

A Mechanical Engineering senior who work as an undergraduate research assistant at the Applied Superconductivity Center under Dr. Hellstrom since summer 2014. Interested in going to graduate school upon graduation.

Erik Olson:

An Electrical Engineering senior who's interested in interning and working in the power systems industry after graduation.

Jordan Clein:

An Electrical Engineering senior who interned at Nextera Energy summer 2015 and will be returning to Nextera for a job after graduation.