Midterm 1 Report

Design and Development of an Autonomous Underwater Vehicle

Team 23

AUVSI RoboSub

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1. Abstract

The goal of Team 23 is to be the first team 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 meets 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, torpedoes design and actuation, and finally the gripper mechanism, which are all normally tasks required of the AUV in the 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 reach 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 more focused 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 becoming the first FAMU/FSU College of Engineering to compete in competition.

2. Introduction

The Association for Unmanned Vehicles Systems International (AUVSI) Foundation is a nonprofit organization that intends to generate interest in STEM fields through various activities involving robotics[1]. One of these activities is the RoboSub competition, which involves students designing and building an autonomous submarine to perform a series of tasks. The AUVSI RoboSub competition is a yearly event held in San Diego California amongst teams from around the world. The Autonomous Underwater Vehicle (AUV) should be capable of performing a variety of tasks in a given time period. Tasks that are generally required by the competition are to be able to pass through a gate, locate colored buoys, launch a torpedo through a target, drop a marker at a specified location, detect frequencies emitted by pingers located in the water, and pick up an object. The FAMU/FSU college of Engineering has had teams looking to enter the competition since 2010, but has yet to send a team to actually compete in this competition. Team 23 has been tasked to take on this project and looks to redesign current subsystems to further improve them to be ready for the competition. This report will looks to give insight into the background in regards to the competition and project, the scope of the project, designs and analysis behind each subsystem.

3. Problem Statement and Project Scope

3.1 Problem Statement

The AUVSI RoboSub competition is held yearly amongst schools from around the world. The competition rules stay mostly the same from year to year. In the past these rules have included picking up an object from the bottom of the pool, shooting a torpedo at a target, and following a designated path. The figure below (Figure 1) shows the layout of the pool and the different tasks to be completed. The tasks involved for the competition include interacting with colored buoys located in the water, locating and passing over an obstacle, drop markers at a desired location, fire torpedoes through a target, grab and move an object, and travel toward a pinger emitting frequencies in the water. All of these tasks have to be completed autonomously meaning that once the sub is placed in the water it is on its own to complete the course.

To interact with the colored buoys the sub will have to utilize cameras mounted on the sub to process images. Depending on what the color of the buoy is the AUV will need to recognize an make a decision on whether to interact with or avoid the buoy. The colors of the buoys and more details about the rules will be released sometime in November. In order to complete the marker drop task, the sub will have to use its bottom facing camera to identify drop zones and then release a marble shaped object in hopes that it will land in the zone. The firing torpedo task involves identifying a target and then propelling a torpedo through a small hole in the target. The AUV is allowed to go up to the hole as long as the torpedo can go through it. The gripper task is similar to the marker drop. Using the bottom facing camera, the sub will identify an object and then use the thrusters and air compression to pick up the object and hold onto it until it arrives at a desired drop zone. The pinger task consists of detecting a frequency underwater and then tracking where the frequency is coming from. The sub will then travel in that direction. This task is generally completed using a hydrophone as it is the easiest and most efficient way to monitor frequencies in the water.

The competition specifications and rules talked about above were for the 2015 AUVSI Competition. The rules for next year's competition will not be released until November of 2015. As of now the sub is being prepared to complete the same tasks as last year, but once the rules are released the subsystems can be adjusted.

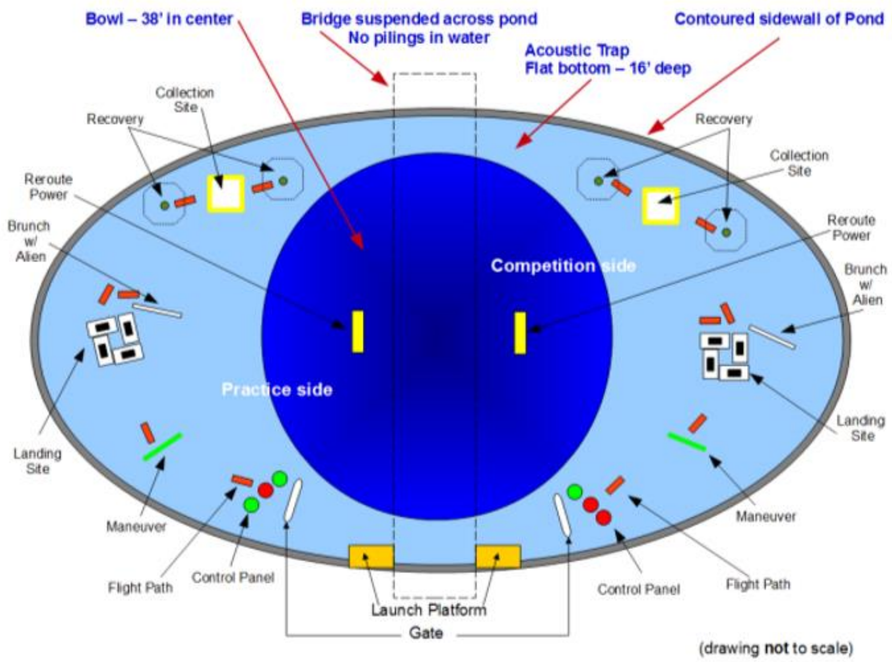

Figure 1: Competition Layout and Tasks

Even though previous senior design teams from the FAMU/FSU College of Engineering have attempted to compete for previous years, the FAMU/FSU College of Engineering has yet to make an appearance at the competition. The most recent iteration of the sub design had several problems related to both the hull and the software. However, after testing both the hull and the electronics, it's been discovered that the hull is watertight, and certain subsystems, such as the thrusters and cameras, are operational. The previous sub can be seen in figure 2.

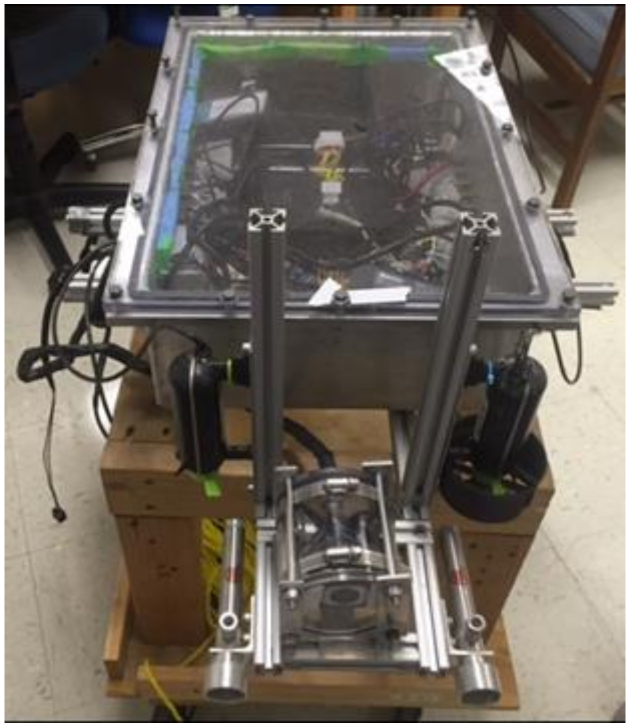

Figure 2: Current Sub Design

Even with these operational subsystems, many aspects of the sub require further integration. The code is incomplete and does not satisfy all the conditions set forth by the competition. Furthermore subsystems such as torpedoes and claws have also not been integrated with the AUV and tested as a complete system. Even though last year's design has provided successful subsystems and a watertight hub, these problems must be addressed before we can yield further successful results from last year's sub.

3.2 Project Scope

The scope of this project requires a redesign and improvement upon last year’s autonomous underwater robot, making it capable of navigating an underwater course and accomplishing a variety of tasks set forth by the AUVSI competition.

3.3 Constraints

Since the constraints of this year's competition are not yet accessible we are following the design constraints of last year. The 18th Annual International RoboSub Competition requirements and constraints for the design are listed below[2].

Table 1: Size and Weight Constraints on AUV's in 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

4. 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 3. 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 3: Design House of Quality

4.1 Hull/Frame:

Based on the competition requirements the hull must less than 125 lbs in weight and fit into a 3ft x 3ft x 6ft box to qualify. Additionally when the body enters the water with no control it must float just at the surface of the water. These are the minimum requirements needed, however there are several goals that the group has for the design. The hull must seal out water and ensure the safety of the electronics. The frame must support all external actuation and sensing components that are required to complete the competition tasks. The hull and frame combined should be less than 80 lbs to ensure a high scoring range for the competition. Thermal conductivity must be high enough to protect the electronics from damaging heat within the sealed hull container. All the electronics in the hull should be secured as to not cause errors in the competition.

With the aforementioned restrictions in mind two options were left to the team: to keep the current hull or to design a new hull. Based on testing, the current hull does perform the minimum objective of sealing out water from the electronics. However we have also found that the sub is overly buoyant, it takes a very long time to open to access the electronics, and water sits on top of the sub making it difficult to safely remove lid shortly after it is taken out of the water. Therefore three possible options have been posed for changes. One of the options is to edit the current hull design to fix the most outstanding issues. The other two options are possible new designs for the hull that will ideally address all of the design criteria.

If the hull redesign option is chosen the initial correction that will be made is with the buoyancy. Assuming the shape is maintained, a simple removal of material from the top of the sub would be able to both reduce the weight and reduce the buoyancy of the overall system. If material is removed from the top of the hull it also opens up options to revise the sealing mechanism between the lid and hull body. For this one possible option is pushing out the waterproofing material to the edges and increasing the amount of it to ensure a better seal. As well a reduction in the number of screws will greatly speed up assembly and disassembly. The final change made to this would be a new organization system to contain sub internal electrical components and prevent shifting during transit and operation. The securing of these devices will greatly assist with assembly and troubleshooting of errors in addition to preventing damage.

Figure 4 shows the CAD model of the first design option. This design incorporates a smaller body similar in shape and roughly twice the size of a standard mailbox. The purpose of this shape is to prevent water from remaining on lid of the sub after it is removed from the water and therefore serves to protect the electronics when rapidly debugging code during testing. Additionally it incorporates cooling fins that align with the direction of forward motion to increase the heat dissipation rate when moving. The purpose of this is to allow for the use of new lighter materials for the hulls body with high thermally conductive areas in place of the current aluminum to maintain heat transfer. This is designed to allow better freedom to adjust the weight and buoyancy at our own discretion as the design is implemented. This design also contains a ballast tank at its base to assist with buoyancy regulation. It can be filled with water for neutral buoyancy, Air for positive buoyancy, and sand if negative buoyancy is desired. A simple hand screwed seal will give the operators freedom to combine these as needed for testing throughout component addition.

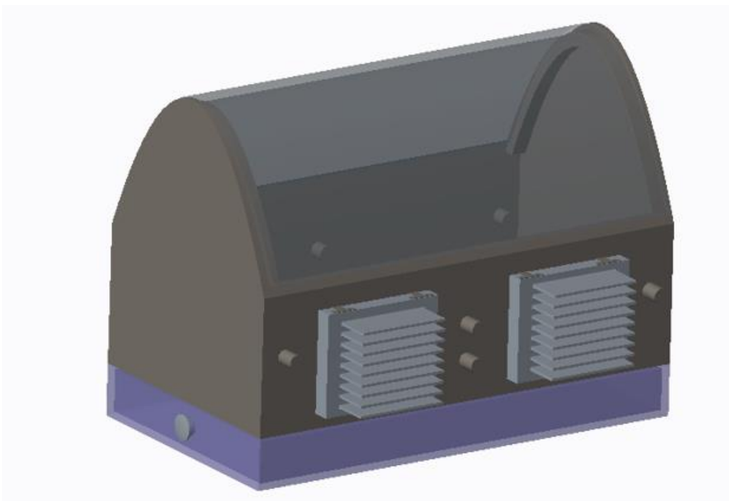

Figure 4: Hull Design Possibility 1

Figure 5 shows the other possible new design option. This is slightly smaller than the first design in Figure 4 above however maintaining a similar shape for the same reason of clearing the body of residual water when surfacing. The focus of this design is to overcome issues with rapid troubleshooting and water seal management. This body is designed to have a hollow cavity made of clear material, for the purpose of electronics observation, which will contain a shelf to hold internal components. When the end cap is removed this shelf will freely slide in and out of the containment unit for ease of access. The end cap, shown in silver in Figure 5, will screw into the containment unit with a small number of fasteners and it will allow the waterproof electronics ports attached to the shelf pass through it. The benefit to this end cap is that it has a significantly smaller area to secure than the current design which is what allows there to be fewer fasteners to seal it. However because it is not necessary to see through the end cap, as it is on the current sub, there can be a much greater surface area of waterproofing material used on it to ensure component safety.

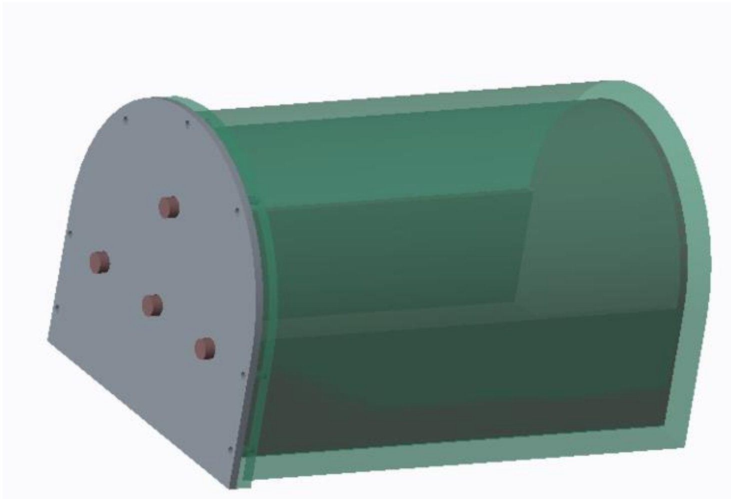

Figure 5: Hull Design Possibility 2

4.2 DECISION MATRIX

In order for the team to evaluate which approach should be taken moving forward the team created a decision matrix. The decision matrix compares the four approaches the team might take, keeping the current hull, redesigning the current hull, or going with design possibilities 1 or 2. The selection criteria felt were important were the cost to manufacture, time to manufacture, weight of the sub, volume and buoyancy of the sub, heat transfer within the sub, and ease of access to the electronics within the sub. The decision matrix generated can be seen in table 2 below. The cost and time of manufacturing were both important aspects to the team because the Hull is crucial to the sub, so the team wants to be able to upgrade it as quickly and efficiently as possible while still leaving a large amount of the budget. Any excess time lost because of setbacks while acquiring the new components for the new designs would be a significant blow to Team 23. Due to the over-buoyant nature of the current sub the team felt the reduction of the volume and buoyant forces was more important than reducing the weight, as such the scaling factor used in the decision matrix was adjusted accordingly. While the heat transfer of any heat given off by the electronics is an important aspect for the design, because the current design do not see any significant problems with heat transfer it was given a low priority in the decision. Lastly Team 23 wanted to incorporate an easier way to access the electronics, and while not an important aspect in the design it was given a low priority.

Table 2: Decision Matrix for Hull

Selection Criteria	Weight	Original design (datum)	Redesign Hull	Conceptual Design 1	Conceptual Design 2
Cost	0.2	0	0	-1	-1
Manufacturing Time	0.2	0	0	-1	-1
Weight	0.15	0	1	1	1
Volume/ Buoyancy	0.2	0	1	2	1
Heat Transfer	0.1	0	0	1	0
Ease of Access	0.15	0	1	0	1
Totals	**1**	**0**	**0.5**	**0.25**	**0.1**

4.3 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 grip 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 and interface with the downward facing camera to ensure accuracy in securing a target.

Figure 6 below shows the current gripper for the sub. This older model runs off of 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 it inside of its grip. This model will be improved upon this year by redesigning the physical gripper but keeping the same principles intact. Ideally, the gripper will hang 17" below the hull so that it clears the bottom camera. The head will also be interchangeable so that it can be switched out depending on the size and shape of the object it has to pick up.

Figure 6: Old Gripper Design

4.4 Torpedoes

The torpedo system must launch two projectiles through two separate small openings of smaller than 1.5ft 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 a team from two years prior there is framework for 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 all of this 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 floating torpedoes 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 still designed for these to particular projectiles to fit into it the team chose to look at a manufacturing change. Figure 7 shows a remade CAD design made to mimic 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 shape changes to optimize trajectory in water.

Figure 7: Mock Torpedo Design

4.5 Electrical Design Specifications

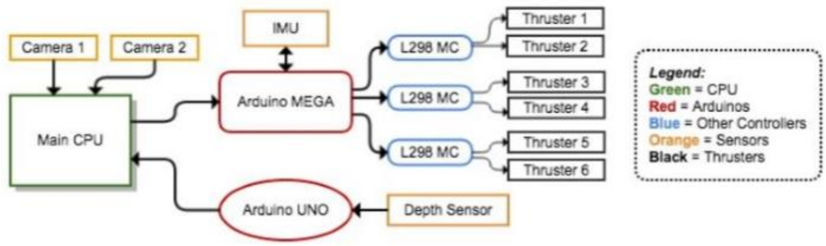

Figure 8: Electrical Components Diagram

<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
- Objective is to implement a third microcontroller which will control the torpedoes and gripper

The electrical system is broken down into three main areas. These are the CPU, the cameras, and the controllers. Since this is an autonomous submersible, the main way that 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 torpedo 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. 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. Some of the new hull designs showed above would allow easier access to the electronics. 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 causes heat to be created 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. Scheduling and Resource Allocation

Working with a large team management of time and allocation of resources becomes essential. Having a 10 member multidisciplinary senior design team split between the ME and ECE departments this becomes crucial. With any project scheduling of events and completion of events is not cut and dry. For the most part things rarely get started early and almost always get finished later than planned. This is why the scheduling of project tasks and allocation of time is a very organic process. Figure 9 below shows how our entire senior design team, both ME and ECE teams, plans on managing the rest of our time for the duration of the Fall 2015 semester.

	Task Name	Duratio	Start	Finish
1	**Troubleshoot Subsystems**	**26 days**	**Mon 10/12/15**	**Fri 11/13/15**
2	**Image processing**	**5.2 wks**	**Mon 10/12/15**	**Fri 11/13/15**
3	Orientation ID	1 wk	Mon 10/12/15	Fri 10/16/15
4	Shape ID	2 wks	Mon 10/19/15	Thu 10/29/15
5	Color ID	1 wk	Fri 10/30/15	Thu 11/5/15
6	Debugging	1 wk	Fri 11/6/15	Thu 11/12/15
7	**Hull**	**5.2 wks**	**Mon 10/12/15**	**Fri 11/13/15**
8	CAD current sub	3 days	Mon 10/12/15	Wed 10/14/15
9	Math/Testing	1 wk	Thu 10/15/15	Wed 10/21/15
10	Initial designs	8 days	Mon 10/12/15	Wed 10/21/15
11	CAD design choice	1 wk	Thu 10/22/15	Tue 10/27/15
12	Materials/Order parts	3 days	Wed 10/28/15	Fri 10/30/15
13	Procurement	1 wk	Mon 11/2/15	Fri 11/6/15
14	Assembly	5 days	Mon 11/9/15	Fri 11/13/15
15	**Navigation**	**5.2 wks**	**Mon 10/12/15**	**Fri 11/13/15**
16	Debug thrusters	2.6 wks	Mon 10/12/15	Tue 10/27/15
17	IMU control	1 wk	Wed 10/28/15	Tue 11/3/15
18	Depth sensor	1 wk	Wed 11/4/15	Tue 11/10/15
19	Navigation - Debug	0.6 wks	Wed 11/11/15	Fri 11/13/15
20	Submerge the AUV	3 days	Sat 11/14/15	Mon 11/16/15
21	**Redesign Subsystems**	**39 days**	**Mon 10/12/15**	**Mon 11/30/15**
22	**Gripper/Torpedoes**	**39 days**	**Mon 10/12/15**	**Mon 11/30/15**
23	CAD new/old designs	17 days	Mon 10/12/15	Sat 10/31/15
24	Claw-order parts	7 days	Mon 11/2/15	Tue 11/10/15
25	Claw-Assembly	8 days	Wed 11/11/15	Wed 11/18/15
26	Claw-Attach and Integrate	8 days	Thu 11/19/15	Mon 11/30/15
27	Re-Submerge	3 days	Tue 12/1/15	Thu 12/3/15
28	Debug Errors	5 days	Fri 12/4/15	Wed 12/9/15
29	Final Submersion	3 days	Thu 12/10/15	Mon 12/14/15

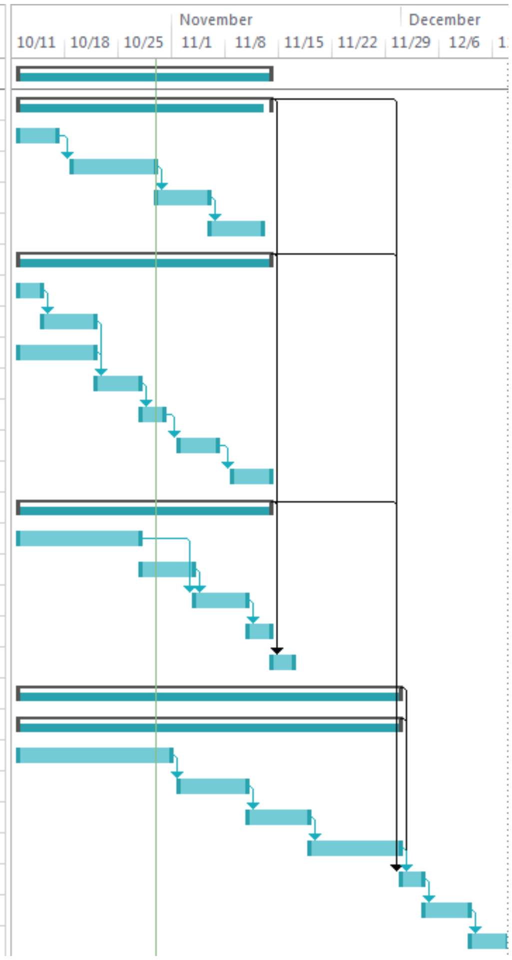

Figure 9: Gantt Chart displaying projected time management for senior design project Fall 2015

The way both the ME and ECE's time will be managed referring to the Gantt chart in Figure 9 above is prioritized by which subsystems are required to get the sub working at the bare minimum. For example to get this sub underwater and moving requires a functional hull, working thrusters, and operational cameras. For this reason the subsystems of top priority are the hull, image processing, and navigation. The beauty of having a ten member team allows us to focus on all the subsystems at once including the gripper mechanism and torpedoes. Due to the need of a redesign of the gripper and torpedoes they will require more time to implement after the essential subsystems are completed.

Designing and developing an autonomous underwater vehicle to compete in the International RoboSub Competition is a very involved project due to the design requirements of the competition. The multi-functionality required of these underwater vehicles (i.e. image processing, navigation, hull, gripper mechanism, torpedoes) breaks the project into multiple subsystems. A project with multiple subsystems requiring different disciplines, and such a large team can either help or hinder the process. For this reason we've broken the team into multiple 2 member groups that focus on a subsystem independently of the other members. The allocation of the ME team members to tasks can be seen in Table 10 below.

ME Task Allocation	
Subsystem	**Teammates**
Hull	Ross, Corey
Torpedoes	John, Jordan
Gripper	Erik, Jordan

Figure 10: Assignment of ME team members to subsystem

Of course when a decision that could possibly compromise another group's subsystem needs to be made, the members of the subsystems involved decided the best way to proceed. This requires members to take individual responsibility for their subsystem knowing the completion of this project and success of our team relies on each one of us. If a team member is not or cannot make progress on a particular subsystem it is their responsibility to let the team know so we can do what needs to be done and move on to the next challenge.

6. Results

Due to the complexity of autonomous robots compounded with the challenges of operating underwater several risks are associated with the design and development of an autonomous underwater vehicle. One of the biggest risks in an autonomous sub is water breaching the hull and damaging the electronics. Should this happen it is possible that all electrical components could be lost. Therefore ensuring the complete seal of the hull is a crucial part of not only the competition but all pool testing. If electronics were lost to water damage the project could be set back several hundreds of dollars as well as several weeks in work.

With the risks of submerging an electronic sub mentioned above analysis can be completed to minimize risk before pool testing is done. The first analysis completed was a weight and buoyancy calculation for the hull and frame. Through this analysis it was found that the sub had a displacement of 4.44×10^{-2} cubic meters of in the water, a weight of 83.5 lbf without electronics, and a buoyancy force of 99.4 lbf. Equation 1 below was used to calculate the buoyancy force. This gives the buoyancy force of any object immersed in a fluid.

$$F_b = \rho_{fluid} * gravity * V_{displacment} \qquad \text{Eq. 1}$$

$V_{displacment}$ is the volume of fluid displaced by the object

This analysis provided crucial assurance that the sub would not sink when completing pool testing. After testing it was found that the buoyancy calculations were correct to within 2 lbf. In addition to buoyancy forces the first pool test proved that the hull was completely waterproof through 13 feet and displayed stability when moving underwater. One drawback of the current hull design however is that 16 bolts must be removed to access the interior of the hull. This not only takes a while to do but it also risks cracking the acrylic lid if the bolts are over tightened. Further testing was done on the sub to test the thrusters and their associated components. This testing was done in lab to avoid the risks of pool testing as well as to provide easy access to the microcontrollers for debugging. All motors worked properly when testing which gives way to pool testing in the future.

7. Conclusion

Given 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 economically and time wise, are great if the group were to scrap this design in favor of another, given our low budget and the rapidly approaching competition the these factors are critical. 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 be the same piece. The old gripping mechanism has been analyzed however since it was never functional the team will simply be starting from scratch with a new system. 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 and in order to prevent interference with the camera it will hag far below the sub. The competition has yet to release the specific tasks that the gripper should accomplish a holding mechanism has yet to be conceptualized fully because of this 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. 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 purposed 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 close 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 work successfully.

8. References

1. "Home - Foundation." *Home - Foundation*. N.p., n.d. Web. 30 Oct. 2015. <http://www.auvsifoundation.org/home>.
2. "RoboSub Competition Official Rules and Mission." *Auvsi Foundation*. Web. 26 May 2015.