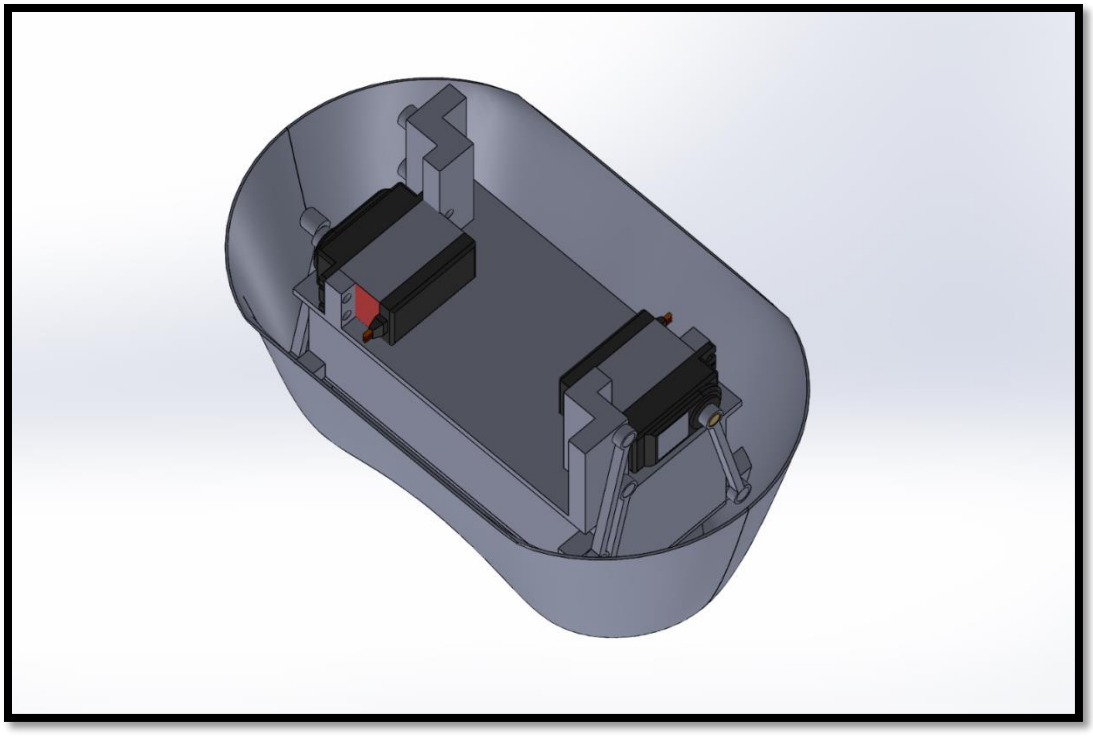
MECH 202 SUBMARINE PROJECT

Team 9



MAY 7, 2020

COLORADO STATE UNIVERSITY

MECH 202 SUBMARINE PROJECT

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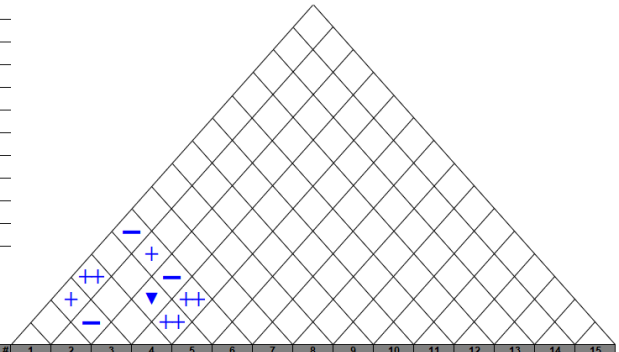
Design Problem Statement

The purpose of this design is to manufacture an autonomous watercraft or submarine that will compete in competition. The most generalized objective of the device is to travel 4.5 meters horizontally across a body of water and travel downward to a depth of 61 centimeters after starting out as buoyant, the order in which the watercraft achieves these objectives is unimportant. Additionally, only one starting action, or input may be provided to the watercraft, after that it must complete any remaining task on its own, fulfilling the autonomous function of the device. In theory the design will compete against similar devices from other teams, the first team to complete all the competition requirements listed above (in addition to more specific guidelines) is named the winner. Unfortunately, due to a global pandemic, the competition will not happen, but the device is designed as if we still plan on competing. These objectives represent the general problem statement behind our submarine, to ensure fairness and safety there are additional, more specific design restraints and rules, these are described in the following section.

Specifications Development

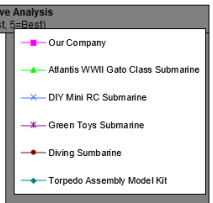
Title: Mech 202 Submarine Design Competition
Author: Team 9 Group members
Date: 3/3/2020
Notes:

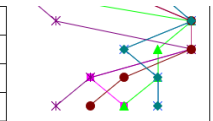


Legend

⊙	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	1 Exterior Dimensions	2 Water-proofing	3 Material Cost	4 Successful interactions of internal components	5 Power output	6 Hydrodynamics	Our Company	Atlantis WWII Gato Class Submarine	DIY Mini RC Submarine	Green Toys Submarine	Diving Sumbarine	Torpedo Assembly Model Kit
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▲	▼	x	▲	▲	Competitive Analysis (0=Worst, 5=Best)					
1	9	12.9	9.0	Buoyant on its own	⊙	⊙					5	5	5	5	2	4
2	3	12.9	9.0	Requires single action to start				O			5	5	0	5	5	5
3	9	12.9	9.0	Ability to travel horizontally through water		O				⊙	4	4	5	0	2	4
4	9	12.9	9.0	Ability to travel vertically through water		O				⊙	3	0	4	0	3	4
5	9	12.9	9.0	Dimensions fall within rules	⊙			O			5	5	5	1	5	5
6	9	12.9	9.0	Under $100			⊙		⊙		5	4	3	5	5	3
7	3	10.0	7.0	Looks cool	⊙		⊙		⊙	▲	2	4	4	2	3	4
8	9	12.9	9.0	Outperforms other submarines				⊙	⊙	⊙	3	3	4	1	2	4
9																
10																
				Target or Limit Value	< 9x6x5 in	Complete waterproofing	< $100	> 3 interactions	> 0.001 horsepower	< 0.1 N resistance						
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	4	5	3	7	9	7						
				Max Relationship Value in Column	9	9	9	3	9	9						
				Weight / Importance	184.3	192.9	145.7	115.7	261.4	357.1						
				Relative Weight	14.7	15.3	11.6	9.2	20.8	28.4						





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Who

Demanded Quality (a.k.a. "Customer Requirements" or "Whats")
Buoyant on its own
Requires single action to start
Ability to travel horizontally through water
Ability to travel vertically through water
Dimensions fall within rules
Under $100
Looks cool
Outperforms other submarines

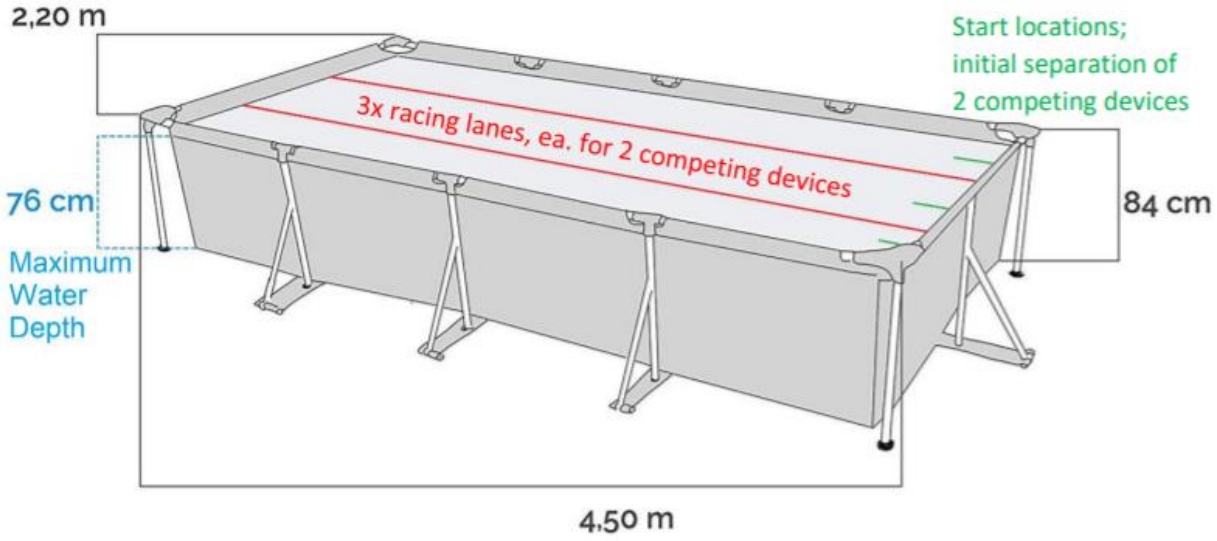
Dr. Roberts is our target audience because she will be grading our project against our competition, like how a customer would compare options from multiple brands to decide on what to buy.

To determine the customer requirements, we carefully read over the project description. The main objectives were separated and turned into the list of desired qualities below:

- **Buoyant on its own** – the submarine must be able to float on its own when placed into the water. The single action to start the submarine can change how it floats or sinks in the water
- **Requires single action to start** – only one action can be done to the submarine. This can be a button pushed, a switch flipped, or any other single simple action.
- **Ability to travel horizontally through water** – the submarine must travel 4.5 meters horizontally through the water. In order to win the competition our submarine must do this faster than the other group's submarines.
- **Ability to travel vertically through water** – the submarine must travel 61 centimeters downwards towards the bottom of the pool. In order to win the competition our submarine must do this faster than the other group's submarines.
- **Dimensions fall within rules** – the width of the submarine can be no more than 15.25 cm, the length cannot exceed 23 cm, and the height must be 12.5 cm or less.
- **Under $100** – the total cost to build the submarine must be below $100. These costs do not include the Arduino, which was provided by CSU. The cost also does not include the cost of parts found in CSU labs.
- **Looks cool** – to get full credit on the "wow" factor of the project our submarine must look better than the other submarines.

- **Outperforms other submarines** – our submarine must travel to the finish of the race faster than other group's submarines. It must also do so consistently, as it will have to race against multiple submarines in a tournament style competition in order to win.

The competition will be held in in a single pool with three subdivided lanes. Each submarine will start at the same end simultaneously. A diagram of the pool with the dimensions is shown below:



Seen below is the customer requirements template. This template was very useful for our team in determining the necessary qualities that our product must fulfill.

Customer Requirements

Design Organization: Flynn Yoder	**Date:** 5/7/2020
Product: Submarine	

Who:

1. Who are the primary users of the product? *The product will be used by our team and Dr Roberts, who will be judging the competition and grading reports.*

2. What skills or education will the primary users have? *In regards to the group members, they will all have taken some college classes related to physics, statics, dynamics, design and coding. I presume that Dr Roberts has taken all of these classes in addition to many others. Additionally she has experience working in the design field as well as teaching design classes.*

3. Describe any primary user physical conditions that affect the design of the product. *The user must only use one action to start the submarine.*

4. Who will purchase the product? *The product will be examined and reviewed by Dr Roberts and her team of Teaching Assistants*

5. Who else is a stakeholder in the design of the product? *The group is a stakeholder as their grade is dependent on the submarine and its performance. CSU students and teachers, both current and future, are stakeholders as a spectacular submarine design may result in additional recognition and funding towards CSU students and faculty.*

6. Describe any cultural practices or customs related to the product. *Submarines have been used by many different countries and cultures, mostly in times of war. However, in this situation the submarines are being used in a friendly competition instead of for aquiring intelligence or causing destruction.*

7. How much is the purchaser willing to pay for the product? *They should be willing to pay over $100 for the product as the submarine cost almost $100 to manufacture.*

8. How much is the user willing to pay to operate the product? *The user should be willing to pay small amounts towards batteries to power the submarine.*

9. How much is the user willing to pay to maintain the product? *The user should be willing to purchase extra wires and motors incase these components break and need replacing.*

How:

1. For what specific purposes will the product be used? *The product will be used in a competition to race against other student designed submarines to the far bottom corner of a swimming pool.*

2. What is the current process used? *Almost all of the parts were either 3D printed using ABS and HIPS as the working material. Those parts that were not manufactured this way were purchased already assembled from other companies and manufacturers.*

3. How often will it be used? *The submarine will only be used for one day, but hopefully used multiple times if it continues to beat other submarines in the competition.*

4. How long will it be used each time? *The submarine should take no more than 20 seconds to complete the race. After this it can be removed from the pool and let cool down before the next use.*

5. Describe the quality expected by the user. *The users should expect the submarine to travel very quickly, or at least faster than other submarines to the far side of the pool and downwards 61 centimeters.*

6. How far, how often and in what way will product be transported? *After being built the submarine will be transported only once to the competition, and once back to its final resting point. It will be carried by hand very carefully and set down in a car when being transported long distances.*

Where:

1. Describe the surroundings for normal use. *The product will be used in a swimming pool containing water of depths no more than 84 centimeters.*

2. Describe the noise, weather, temperature or other environmental factors that may affect the design of the product. *The environment of the pool was taken into account during the design process. The poll will likely not contain any large waves, and the wind will be negligible on the surface of the water.*

3. Describe any size or weight limitations. *The submarine cannot exceed 15.25 cm in width, 23 cm in length, and 12.5 cm in height. These dimensions can change after the submarine has been activated, but cannot change any more than 2.5 cm in any direction.*

4. Describe the aesthetics of the use surroundings. *The submarine will be used in a CSU swimming pool, and there will be a crowd of engineering students surrounding the pool, likely cheering for or against the submarine.*

5. Describe the energy available when the product is in use. *There will be energy stored in the battery of the submarine. Our group will have replacement batteries available incase one or more batteries die or are damaged. There will also be an energy in the crowd of engineering students cheering for one of the submarines in the competition.*

Customer Requirements (include how well the product fulfills each requirement):

1. Buoyant on its own
2. Requires single action to start
3. Ability to travel horizontally through water
4. Ability to travel vertically through water
5. Dimensions fall within rules
6. Costs under $100 to produce
7. Looks cool
8. Outperforms other submarines

Who Else (List other products that fulfill the requirements)**:**

1. Atlantis WWII Gato/Balao Class Submarine
2. DIY Mini RC Submarine
3. Green Toys Submarine
4. Diving Submarine

5. Electric RC Submarine Boat Torpedo Assembly 6. Other MECH 202 group's submarines	
Team member: Flynn Yoder	Team member: Noah Schenck
Team member: Nolan Sherrill	Prepared by: Flynn Yoder
Team member: Ryan Walkowicz	Checked by: Nolan Sherrill
Team member: Trevor Long	Approved by: Noah Schenck
The Mechanical Design Process Copyright 2018	Designed by Professor David G. Ullman Form # 16

How vs. How

We designed our product to maximize all the specified categories in order to exceed our competition. Our final design shows efficiency in design and function in order to accomplish all desired goals proficiency.

Who vs. What

It is important to Dr. Roberts (the customer) that all the project criteria are met and that the device is the best at what is does. We strive to perfect our product in the categories listed below:

- Buoyant on its own
- Requires single action to start
- Ability to travel horizontally through water
- Ability to travel vertically through water
- Dimensions fall within rules
- Costs under $100 to produce
- Looks cool
- Outperforms other submarines

What vs. How

Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Exterior Dimensions	Water-proofing	Material Cost	Successful interactions of internal components	Power output	Hydrodynamics
Buoyant on its own	O	⊖				
Requires single action to start				O		
Ability to travel horizontally through water		O				⊖
Ability to travel vertically through water		O				⊖
Dimensions fall within rules	⊖			O		
Under $100			⊖		⊖	
Looks cool	O		O		O	▲
Outperforms other submarines				O	⊖	⊖

This design does a good job meeting all the needs of the competition which is shown in the chart. The design has multiple strong relations between the demanded qualities and the quality characteristics, which means that each goal is well covered by multiple tasks. The characteristics that we chose in order to satisfy all the customer needs are listed below:

- Exterior dimensions
- Water-proofing
- Material cost
- Successful interactions of internal components
- Power output
- Hydrodynamics

Competition Analysis

At this point the designs of the competition are unknown and likely won't be known until competition day. Because of this we need our design to work well in anticipation that other submarines will work well.

However, we can compare our designed submarine to other existing products in order to get a sense of the level of performance of other products on the market. The products that we analyzed as our competition are:

- Atlantis WWII Gato/Balao Class Submarine
- DIY Mini RC Submarine
- Green Toys Submarine
- Diving Submarine
- Electric RC Submarine Boat Torpedo Assembly

These products as well as the companies that design and create them are all reviewed extensively later in this report, in the Competitive Analysis section.

How Much

Target or Limit Value	< 9x6x5 in	Complete waterproofing	< $100	> 3 interactions	> 0.001 horsepower	< 0.1 N resistance

Listed above are the target values for each of our quality characteristics. These targets have been designed to maximize the performance of our submarine, relating to cost, size and speed, while still staying withing reasonable limitations.

Through numerical analysis with the QFD diagram, we have determined the importance of each quality characteristics. These characteristics are ranked from most to least important below, with the top of the list being the most important.

Hydrodynamics: If the submarine is not hydrodynamic, it will be more difficult for the motor to move the submarine through the water which will result in a slower time across the pool. Poor hydrodynamics will also cause the submarine to have difficulty going straight which could lead to the device not finishing at all. Since getting to the far bottom corner of the pool is the main objective, the hydrodynamics enormous effect on this task makis it the most important quality.

Power output: The power delivered to the propeller of the submarine is very important as it has a direct correlation to how quickly the vessel travels through the water. As one of the main goals of the competition is beating the other group's submarines to the far bottom corner of the pool, the speed of travel of our submarine is extremely important.

Water-proofing: The water proofing is necessary for our craft to be able to function. If water gets into the hull of the ship before the hull opens, the ship will sink too quickly and wont make it to the far end of the pool. If water gets into the electronics pod, the servo motors and Arduino will break and our submarine will be rendered completely useless. This means that it won't be able to travel at all and will not complete the competition.

Exterior dimensions: The exterior dimensions are very important as a submarine that is too large would result in disqualification of our product. A submarine that is too small could result in less accuracy of direction of the ship, or a lower power output since a smaller battery and motor would be required.

Material cost: The material cost must be below $100. Anything higher than this and our submarine would be disqualified from the competition, rendering our project a complete failure.

Successful interactions of internal components: This quality is very important, but the threshold value is difficult to define. Because of this, this quality is our least important. Perhaps a better quality would be the amount of failures of internal components, and we would strive to minimize this as any failure could be detrimental to our submarine. Any failure could cause the submarine to not move in the direction we want, or to not be buoyant on its own.

Now vs. What

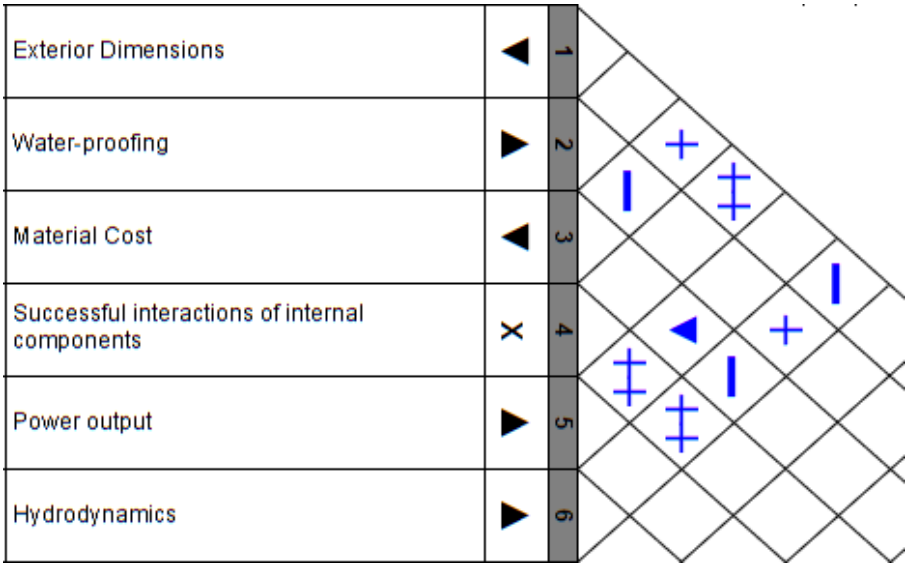
In the below table we have analyzed how we expect the other group's submarines to perform in each of our quality characteristics.

Buoyant on its own	The competition will likely have a buoyant device at the beginning, the customer will also expect the device to be buoyant at the start in order for it to be acceptable
Requires single action to start	All the competition will meet the requirement at a similar quality
Ability to travel horizontally through water	Most of our competition should be able to fulfill this requirement at a similar level of quality
Ability to travel vertically through water	Most of the competition will have a similar quality
Dimensions fall within rules	All of our competition will have similar quality
Under $100	Most of the competition will be similar in this respect

Looks cool	Our device should exceed the quality of most other devices in this category
Outperforms other submarines	Our device will likely perform better then at least half of the competition

Tradeoffs

While advancing the ability of our submarine to perform one specific function, other functions may suffer decreases in performance. Our group analyzed these tradeoffs in one section of the QFD, which is pictured below. Minus marks indicate a negative correlation between the two qualities, while a plus mark indicates a positive correlation, meaning that while one quality increases the other compared quality does the same. Two plus marks means a stronger correlation, and a downwards facing blue arrow indicates a strong negative correlation.



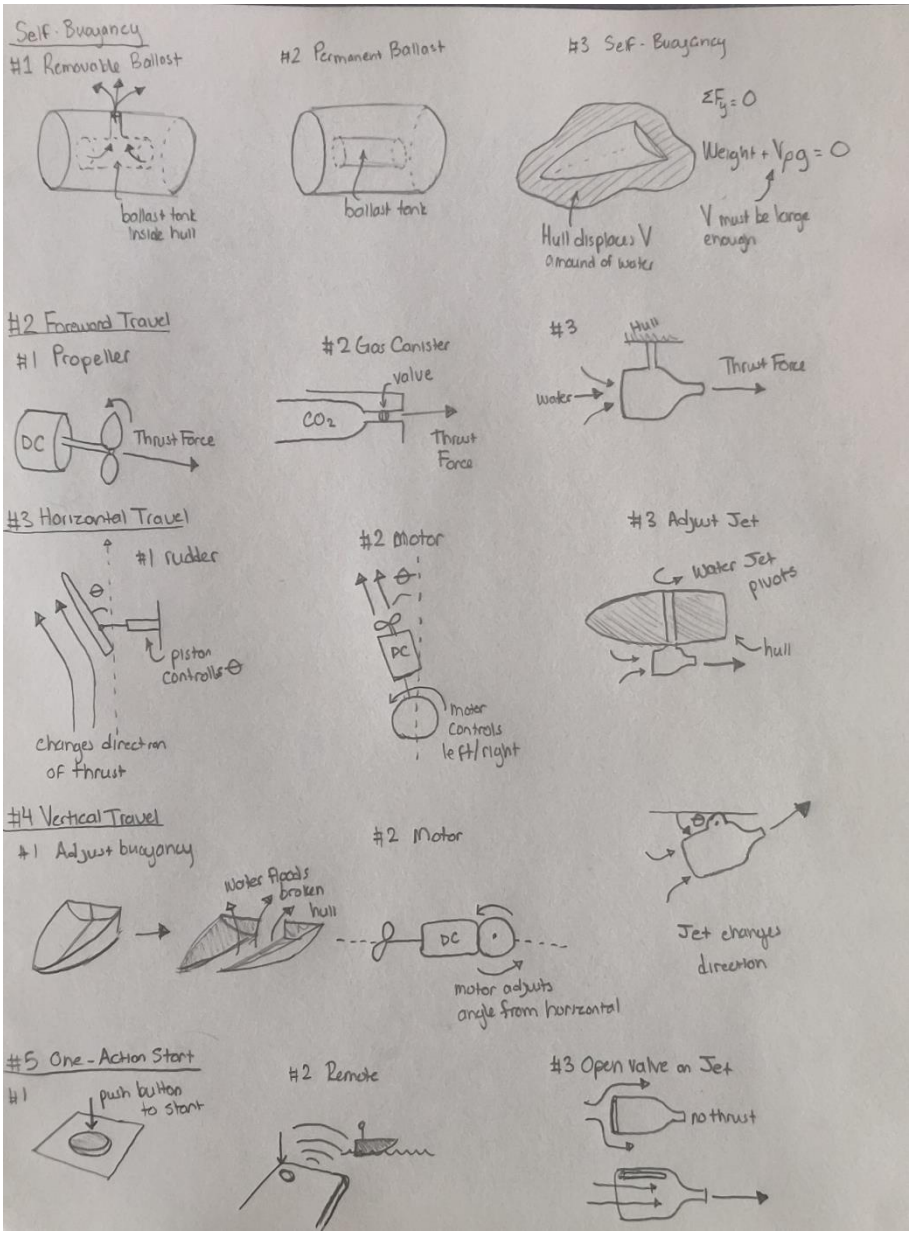
Concept Generation and Selection

Morphology						
Product: Submarine		Organization Name: Mech 202 Team 9				
Function	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Self-buoyancy	Use a removable ballast system that can control the amount of buoyancy	Use a permanent ballast to keep the submarine buoyant	The hull of the submarine is large enough to offset the weight and float			
Travel forwards through water	Add a motor attached to a propeller for forwards/backwards movement	Remote-activated CO_2 canister for forwards/backwards movement	Push water through a jet to create thrust to move through the water			
Travel horizontally through water	Add a piston attached to a fin for left/right movement	Add a system to tilt the motor left/right to propel system horizontally	Adjust direction of the jet to push submarine to the left or right			
Travel vertically through water	Adjust the buoyancy of the submarine to raise/lower it in the water	Add a system to tilt the motor up/down to propel system vertically	Adjust the jet to push submarine up/down in water			
Single action to start	A button that activates the device when pressed	A remote that activates the C02 canister	A valve that opens allowing the jet to start propelling the submarine			
Team member: Nolan	Team member: Noah	Prepared by: Noah Schenck				
Team member: Trevor	Team member: Flynn	Checked by: Ryan Walkowicz	Approved by: Ryan Walkowicz			
The Mechanical Design Process Copyright 2018		Form # 15	Designed by Professor David G. Ullman			

Concept Generation

The problem statement calls for some type of watercraft that can complete the necessary tasks, to begin concept generation, we looked at type of watercraft that were familiar to us, mainly submarines and boats. These are designs that already exist in our world, and need to perform very similar functions to our device. To generate concepts specific to our problem, a morphology template was chosen and is shown above. The template breaks down our design into 5 essential functions, and provides space to generate 3 unique designs. The objective in this step is to list as many concepts as possible, regardless of how practical or impractical they might seem. Our concepts came from previous knowledge in this area and applications of various engineering knowledge, this background is explained in detail in the Engineering Analysis section.

With the morphology template filled out, the concepts are sketched in order to provide another level of detail, our sketches are shown below:



Once the concepts are generated, we can move forward in evaluating them. To do so, one design from each function was chosen based on how well it falls within the design specifications, how complicated the design would be to create, and how likely the system would be to fail. Below is an in-depth analysis to show our thinking during this process, beginning with Function #1.

Function #1: Self-Buoyancy

Concepts #1 and #2 differ in that the ballast is permanent in concept #1 and the ballast will exit from the device at some point during the competition. Concept #3 requires a hull shape that is large enough to provide a buoyancy force, the equation used to determine this force is listed

below, where F represents Force, V represents Volume, ρ represents density, and g is acceleration due to gravity

$$F_{Buoyancy} = V_{object} * \rho_{fluid} * g \quad (1)$$

In order for concept #3 to be viable, the weight of the submarine must be less than or equal to this buoyancy force or the device will still sink. These concepts meet all of the specifications for our device as long as the removable ballast isn't toxic or dangerous if pursuing concept #1, and the hull size doesn't exceed 23cm x 15.25cm x 12.5cm if pursuing concept #3. Despite each concept meeting specifications, it was determined that a ballast system, especially one that changes over the course of the race, is slightly more complicated. The Self-Buoyancy function is perhaps the simplest of our device's functions, and it was determined best to keep this piece of the design simple as well, leading to the selection of Concept #3, a boat type hull that is able to stay afloat using Buoyancy Force alone.

Functions #2-3:

These functions relate to how the device will move back, forth, and horizontally if need be during the competition. The first decision made when evaluating these concepts was that functions 2 and 3 should be part of the same system. Function 2 is to propel the device forward, either through a propeller, cO2 canister, or a jet system. A burst of some pressurized gas such as cO2 in concept #2 would be very hard to control after the initial release, making it hard for any precise movement to made. Design specifications state that only water and air can be expelled from the device, however one can make an argument for whether or not cO2 can be considered air. Due to poor control and grey area in the specifications, we determined concept #2 to be impractical. Concept #3 employs a jet that accelerates water out the back, providing a thrust force to move forward, a similar action as concept #2, without the possibility of the design failing to meet specifications. However, it shares a similar problem that the thrust may be hard to control, and the jet system would be complicated to make and take up a large portion of the budget. Concept #1 that uses a DC motor attached to a propeller was determined to be the best design for Function #2, it falls within our specifications, and the system is simple, commonly used, and cost effective.

To move the submarine forward through the water, each concept provides a thrust force. It was determined the best way to achieve Function #3, left and right travel, was to adjust the direction of the thrust force, allowing the device to change direction. For concept #1, a simple piston would adjust the angle of the force, concept #2 involves a rudder to adjust the direction of the emitted fluid, or concept #3, a motor that would adjust the angle of our waterjet. The evaluation process for function #3 is partially determined by the decision made regarding function 2. With a propeller chosen to deliver thrust, the concepts of function #3 are evaluated based on how well they function in tandem with the propeller. Each concept achieves this with a simple system that interacts with the powertrain, and each fall within our specifications.

Function #4

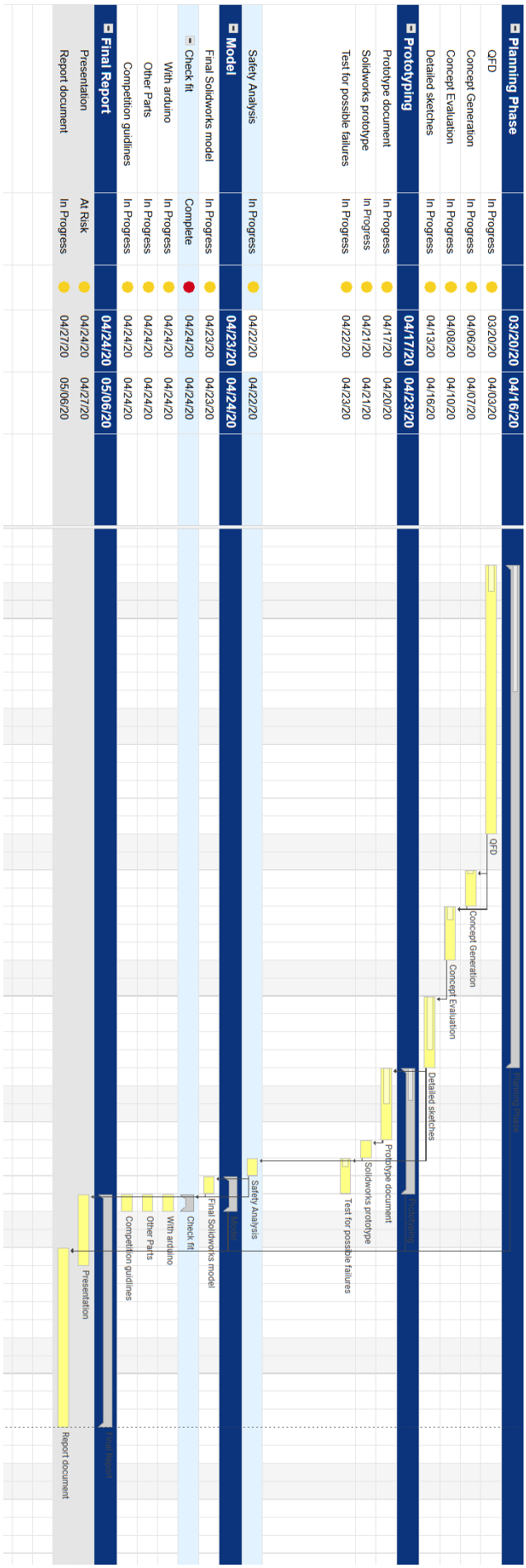
Function #4 of the device id to move up and down in the water column. Concepts 2 and 3 function on a similar principle to the concepts in Function 3, the thrust force is applied in a different direction to adjust the direction of movement, in this case downward. Once again, these concepts fall within specifications, but would mean creating a system to move the motor in 3 directions. The alternative concept is concept #1, changing the buoyancy. This is done by opening up the hull to allow water in, as long as the hull design follows specifications, and the shape doesn't change more than is allowed. In addition, this allows function 4 to be completed with one step, making the design much less complex. For these reasons concept #1 was chosen as the best.

Function #5

The final function of our device is the ability to start its process with a single action. The 3 concepts generated where a button, a remote, or a valve. Each of these would mark the beginning of the run and work with an Arduino to remain autonomous throughout the competition trials. In this case the specification is that there must be one action, and each concept achieves this. A button was determined as the best solution, because it provides a simplistic approach, and was determined to be the most water proof option. A button is also easy to integrate into an Arduino system.

This concept generation and evaluation process allowed us to brainstorm many design options, and ultimately determine concepts we thought to be best. From here a working prototype can be created, moving the design process one step closer to completion.

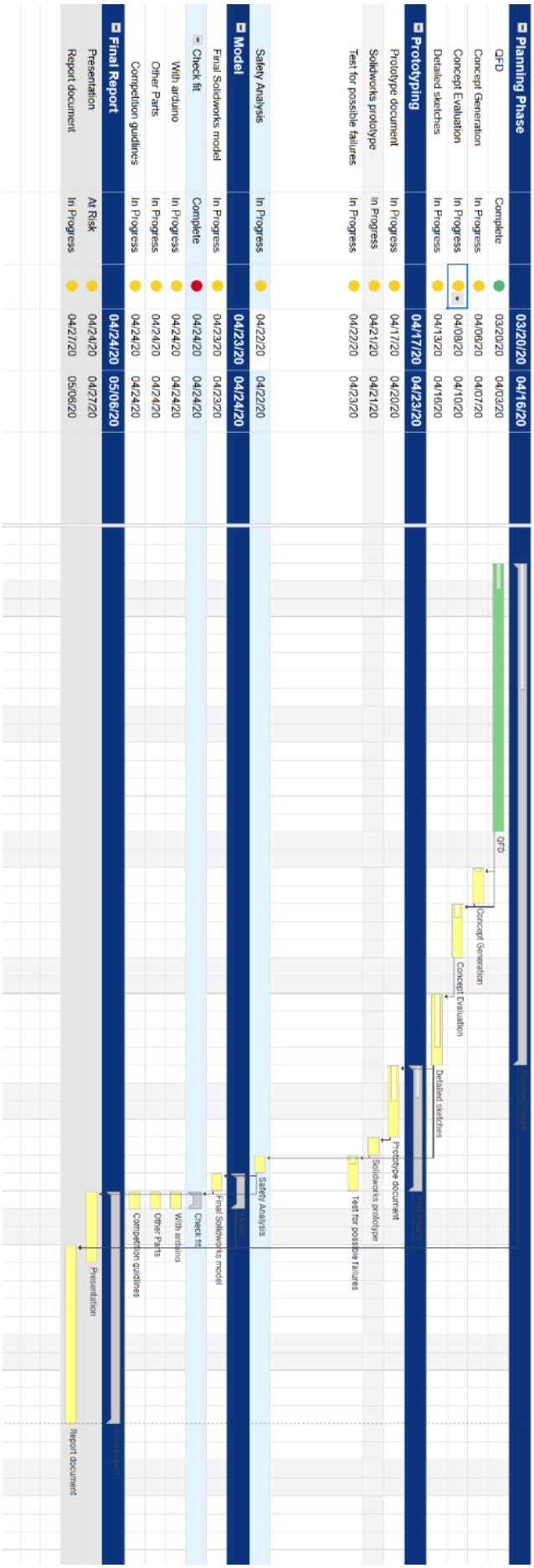
Gannt Chart Week 1-2



Week 1-2 Analysis

Everything was on schedule for weeks 1 & 2 as the project was started with the QFD & associated analysis

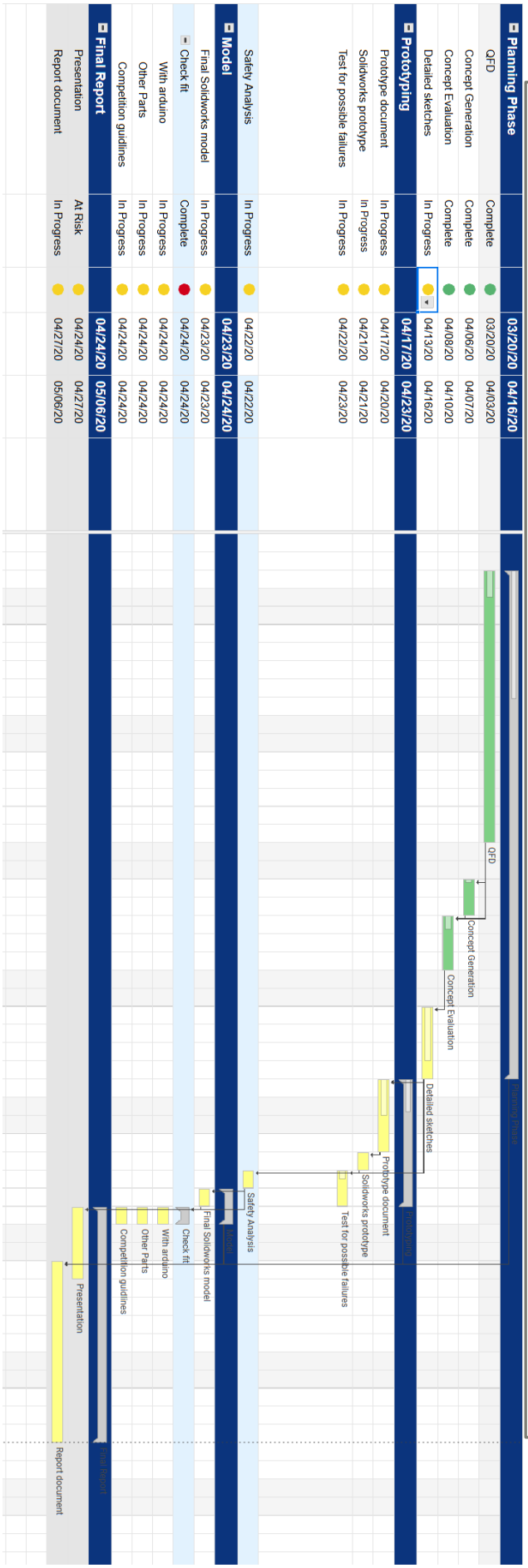
Gannt Chart Week 3



Week 3 Analysis

Everything was on schedule for week 3 as the QFD was completed and progress began on the Concept Generation & Evaluation

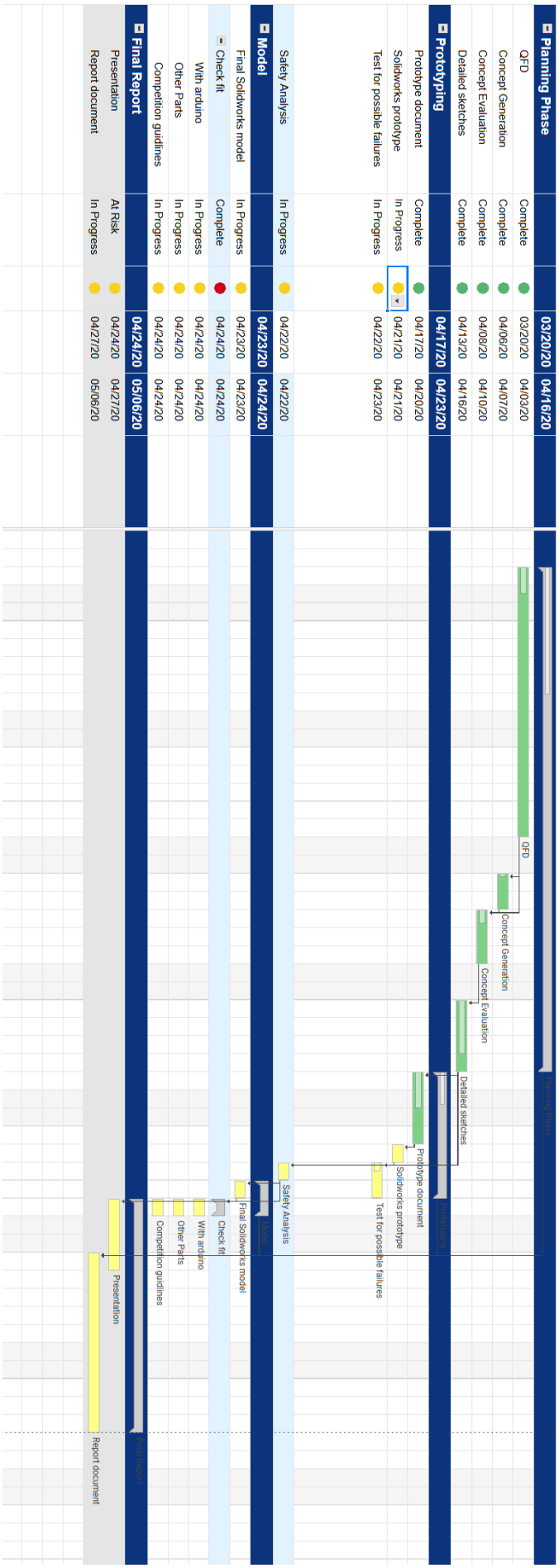
Gannt Chart Week 4



Week 4 Analysis

Everything was on schedule for week 4 as the Concept Generation & Evaluation was completed and progress began on the Detailed Analysis and Prototype Document

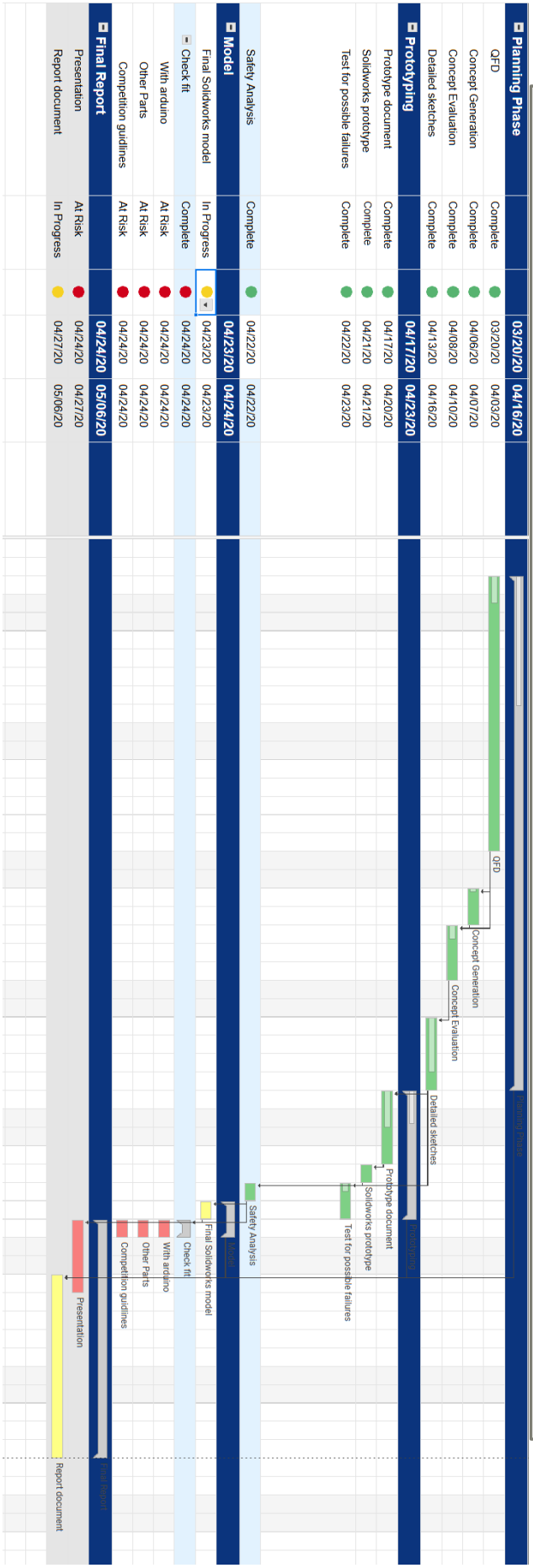
Gannt Chart Week 5



Week 5 Analysis

Everything was on schedule for week 5 as the Detailed Analysis and Prototype Document was completed and progress began on the first SOLIDWORKS model as well as its associated testing for function and safety.

Gannt Chart Week 6

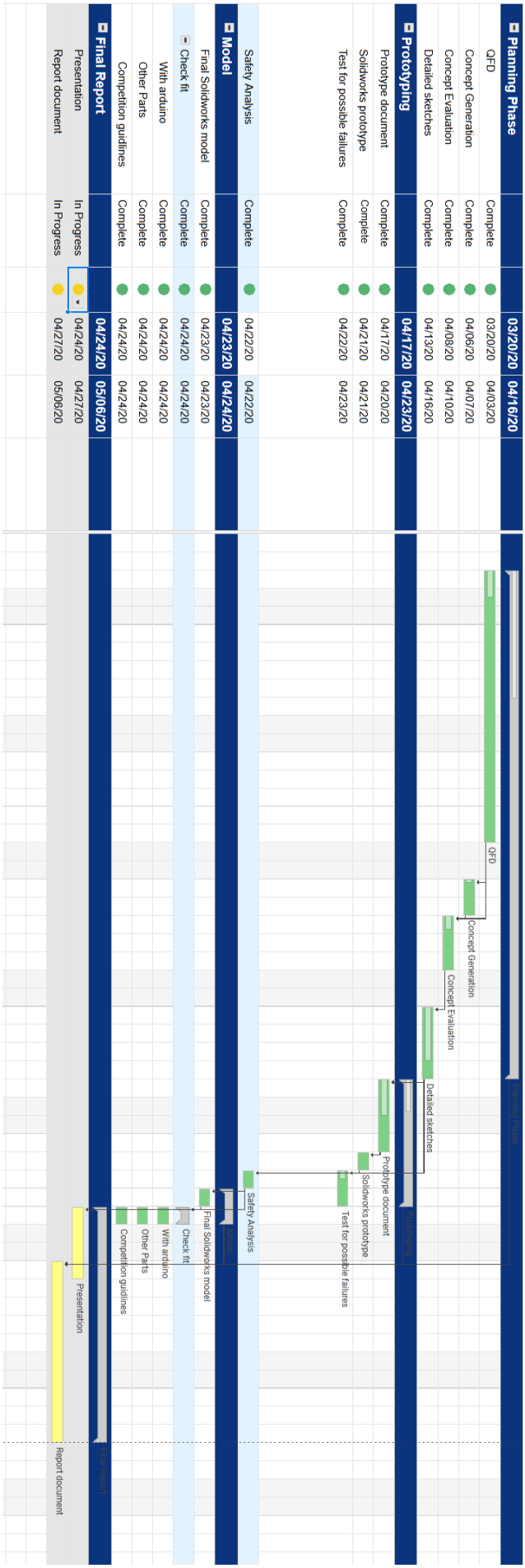


Planning Phase		03/20/20	04/16/20
QFD	Complete	03/20/20	04/03/20
Concept Generation	Complete	04/06/20	04/07/20
Concept Evaluation	Complete	04/08/20	04/10/20
Detailed sketches	Complete	04/13/20	04/16/20
Prototyping		04/17/20	04/23/20
Prototype document	Complete	04/17/20	04/20/20
Solidworks prototype	Complete	04/21/20	04/21/20
Test for possible failures	Complete	04/22/20	04/23/20
Safety Analysis	Complete	04/22/20	04/22/20
Model		04/23/20	04/24/20
Final Solidworks model	In Progress	04/23/20	04/23/20
Check fit	Complete	04/24/20	04/24/20
With arduino	At Risk	04/24/20	04/24/20
Other Parts	At Risk	04/24/20	04/24/20
Competition guidlines	At Risk	04/24/20	04/24/20
Final Report		04/24/20	05/06/20
Presentation	At Risk	04/24/20	04/27/20
Report document	In Progress	04/27/20	05/06/20

Week 6 Analysis

Week 6 was the first time that things fell slightly behind schedule with all the elements of the final SOLIDWORKS model. This added the potential that the assignment would not be completed on time, so extra effort had to be put in to ensure that did not happen.

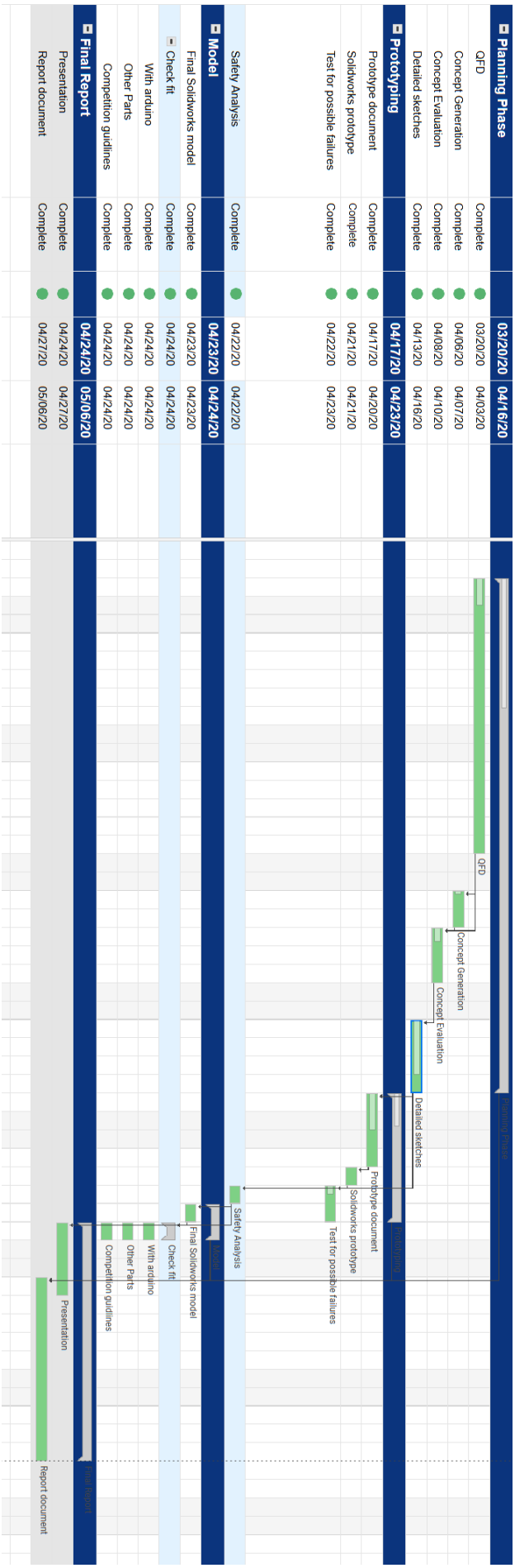
Gannt Chart Week 7



Week 7 Analysis

Week 7 was affected by the delay on the final SOLIDWORKS model, but with the team putting in extra time into the presentation to ensure that it was ready by the assignment due date.

Gannt Chart Week 8

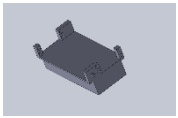
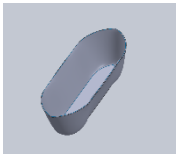
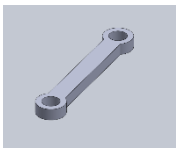
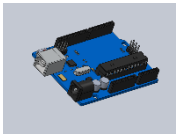
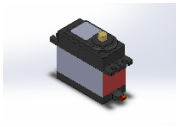
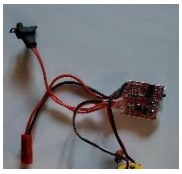


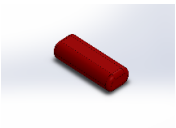
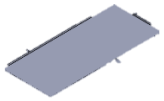
[redacted]

Week 8 Analysis

Everything got back on schedule to close out the project once the presentation and final SOLIDWORKS model was completed. Though the slight setbacks in prior weeks could have been detrimental, through extra efforts, the project was put back on schedule and completed on time.

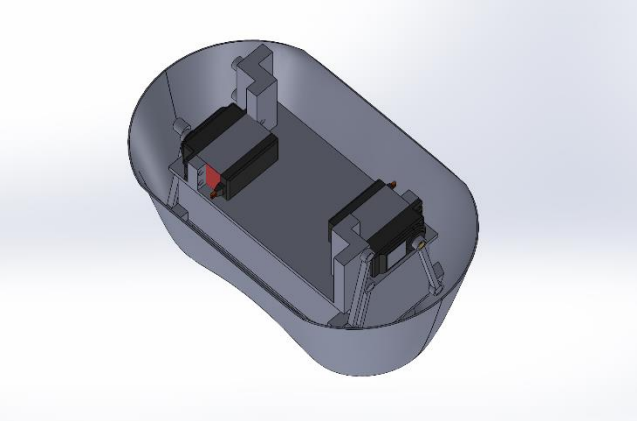
Bill of Materials:

Part #	Part Name	Qty	Material	Mfg Process	Image	Cost ($) (0 if provided)
1	Electronics Pod	1	ABS Plastic	3D Print		13.63
2	Hull	1	ABS Plastic	3D Print		10.98
3	Linkage	6	ABS Plastic	3D Print		1.44 (all)
4	Arduino Uno Microcontroller	1		Supplier		0
5	12 Gauge Wire	12”	Copper	Supplier		0
6	Servo Motor	2		Supplier		19.00 (x2)
7	DC Motor	1		Supplier		10.00
8	Electronic Speed Conrol	1		Supplier		7.00

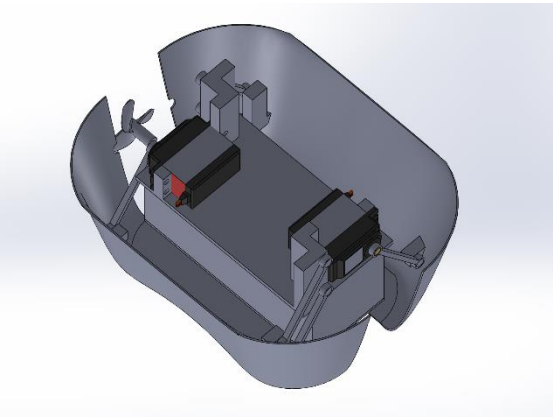
9	Battery	1		Supplier		10.00
10	Electronics Pod Cover	1	ABS Plastic	3D Print		1.40
11	Propellor	1	ABS Plastic	3D Print		1.20
12	Propellor Shaft	1	ABS Plastic	3D Print		1.19
13	Button	1		Supplier		1.00
14	Various attachment hardware	20	Stainless Steel	Supplier		0
15	Waterproofing Grease	1	Petroleum	Supplier		3.00
16	Rubber sealing gasket	2	Rubber	Supplier		1.00
Total Cost						99.84

Detailed Device Description

The submarine performs a few crucial actions in order to complete the task of getting to the end and to the bottom of the pool. Initially the button is pushed, which is the only action required by the operator of the submarine. The button activates the ESC and motor which connects to the propeller of the submarine. This motor propels the submarine to the opposite side of the pool, for a set amount of time depending on the distance desired. After a set period, the program tells hull to open, as the motor continues to spin and propel the boat further towards the end of the track. The servo motor powers the movement of the hull arms, which raise the two halves of the hull of the device. This moves the hull halves as shown from position 1 to position 2. The separation of the hull lets water flow around the submarine and lets in sink to the bottom of the pool. When the submarine reaches the bottom of the pool, the servos will close to reset the device to be used again. At this point the submarine has completed its required task and the submarine can be removed from the pool.

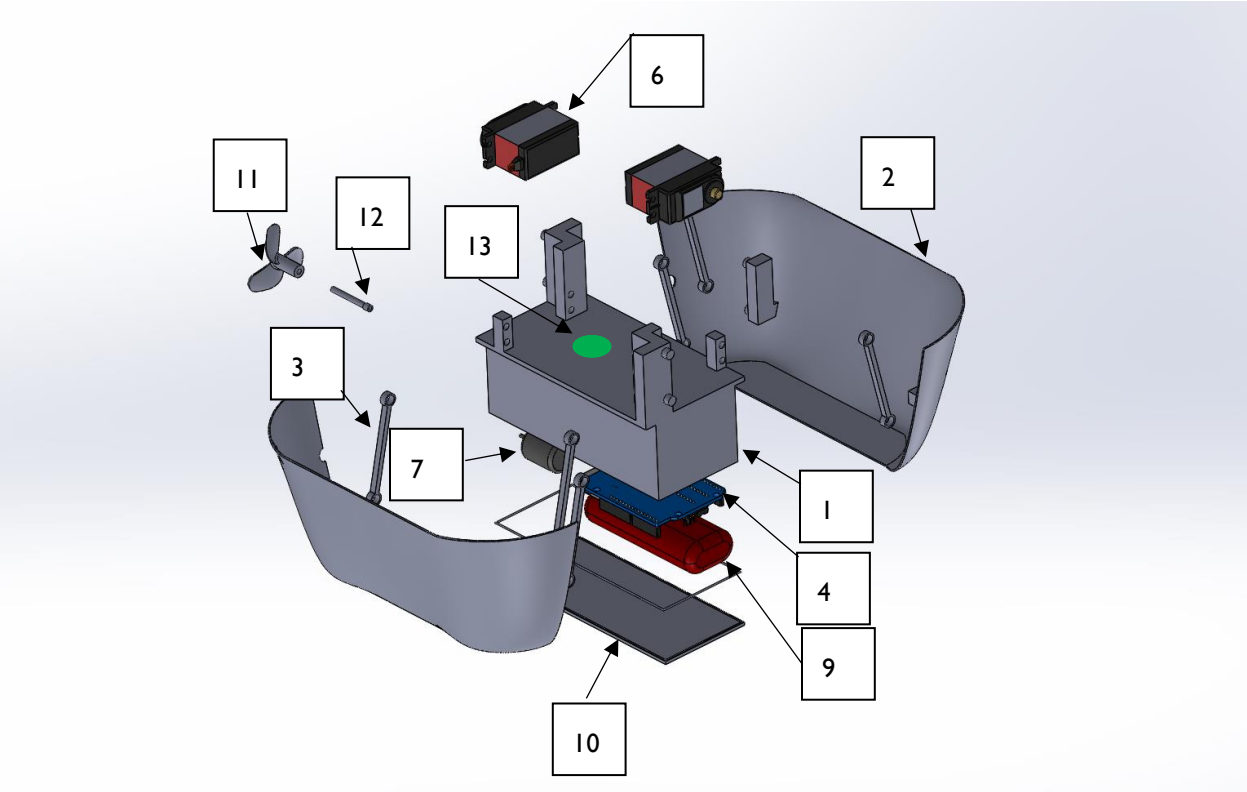


(Position 1)



(Position 2)

Exploded Assembly Diagram



This 3D exploded assembly assists our team and others visualize all the parts of the submarine as well as how they interact with one another. The parts are labeled, and any parts that are partially obscured by other parts are shown in their entirety in the other exploded assembly views. Not pictured are parts 5, 8, and 13-16. For parts 5, 8 and 13, the wires can be connected in many different positions and orientations, so modeling them would solely clutter up the assembly without adding to any understanding of the product. A diagram of the wiring for the Arduino is shown later in the report in the Detailed Device Description section under Arduino coding and wiring. Parts 14 and 16 would distract from the essential pieces of the assembly. These pieces are easy to picture without physically seeing them on the assembly. Part 15 is opaque grease, making it hard to see and model. Each labeled part correlates with a drawing and detailed description of the function of the part, seen in the engineering drawings portion of this report.

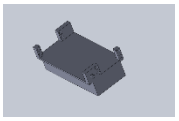
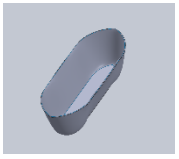
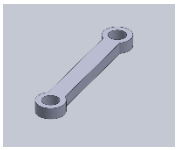
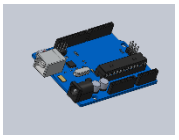
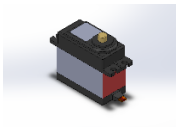
Product Decomposition & Reverse Engineering

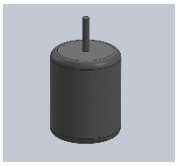
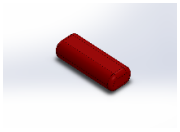
Design Organization: Mech 202 Winning Team	**Date:** 5/7/2020

Description (Brief) : This submarine is designed to operate with a single push of a button. Its purpose is to travel forward and downward in a pool of water, faster and more reliably than any other team's submarines.

How it Works: When the button is pushed a motor on the back of our submarine starts turning, propelling the submarine forward. Our submarine is equipped with two doors on the belly of the vessel. After a certain period of time the motor stops and these doors open, allowing water into the submarine and letting the vehicle submerge and descend.

Parts:

Part #	Part Name	Qty	Material	Mfg Process	Image
1	Electronics Pod	1	ABS Plastic	3D Print	
2	Hull	1	ABS Plastic	3D Print	
3	Linkage	2	ABS Plastic	3D Print	
4	Arduino Uno Microcontroller	1		Supplier	
5	12 Gauge Wire	12”	Copper	Supplier	
6	Servo Motor	1		Supplier	

7	DC Motor	1		Supplier	
8	Electronic Speed Conrol	1		Supplier	
9	Battery	1		Supplier	
10	Electronics Pod Cover	1	ABS Plastic	3D Print	
11	Propellor	1	ABS Plastic	3D Print	
12	Propellor Shaft	1	ABS Plastic	3D Print	
13	Button	1		Supplier	
14	Various attachment hardware	20	Stainless Steel	Supplier	
15	Waterproofing Grease	1	Petroleum	Supplier	
16	Rubber sealing gasket	2	Rubber	Supplier	

Disassembly:

Step #	Procedure	Part # Removed	Image
1	Remove linkage arms, attached with screws	3	See exploded view above
2	Port and starboard hull are no longer attached to the electronics pod	2	
3	Unscrew cover and take off cover	10	
4	Remove battery (not attached to anything)	9	
5	Remove propeller and shaft	11+12	

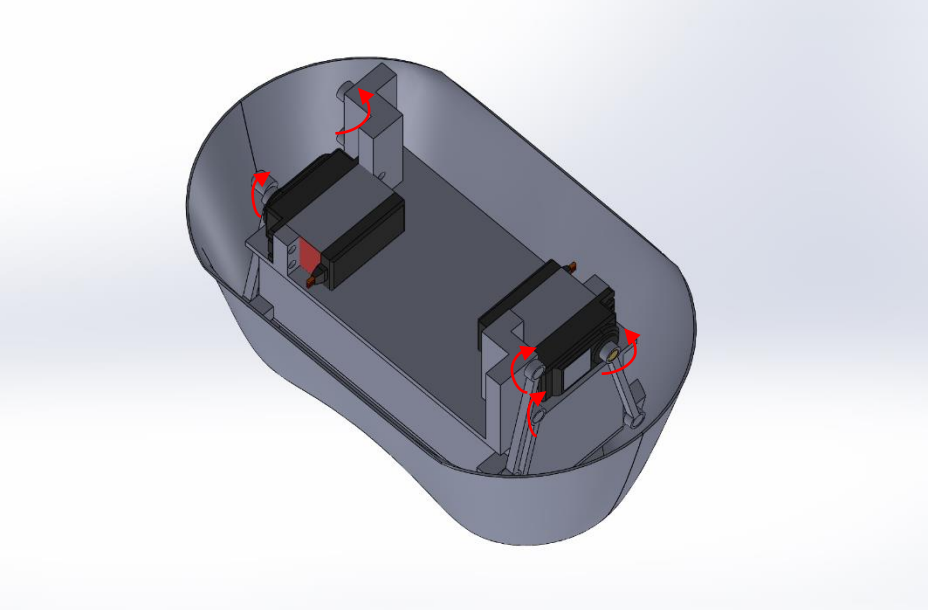
6	Unscrew and remove motor	7	
7	Unscrew and remove Arduino Uno	4	
8	Unscrew and remove servos	6	

Interfaces with Other Objects (Flows of Energy, Information, and/or Materials)**:**

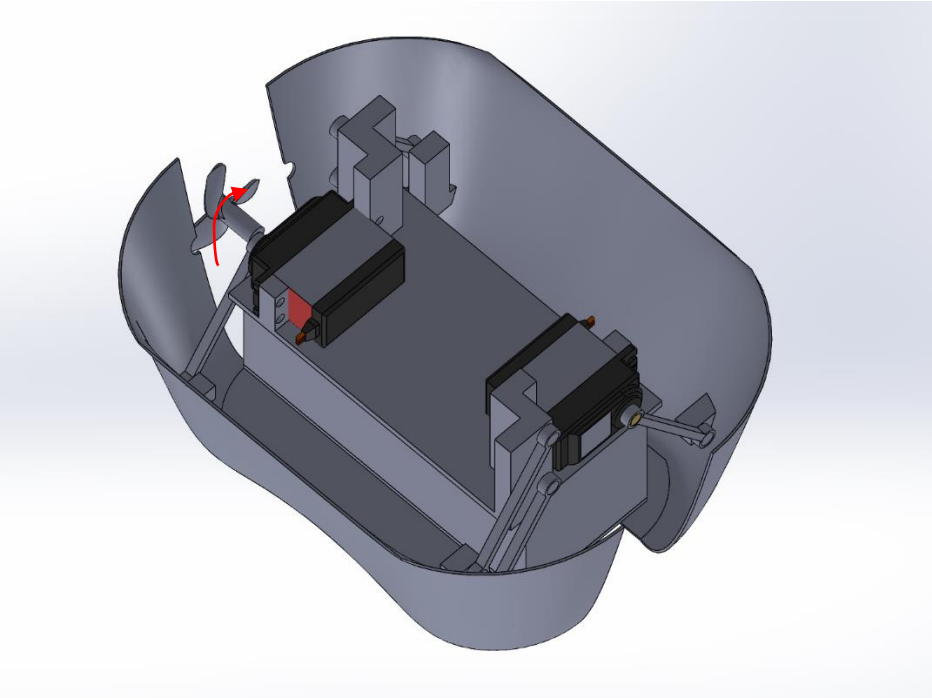
Part #	Interface Part #	Energy Flow	Information Flow	Material Flow	Image
1					See exploded view above
2	3	x			
3	3,6	x			
4	5,6,7		x		
5	6,7,9	x			
6	4,5,3,9	x	x	x	
7	4,5,3,9	x	x	x	
11	12	x			
12	7,11	x			
13	7	x	x		

Team member: Flynn Yoder	Team member: Noah Schenck
Team member: Nolan Sherrill	Prepared by: Flynn Yoder
Team member: Ryan Walkowicz	Checked by: Ryan Walkowicz
Team member: Trevor Long	Approved by: Noah Schenck

Device Movement Interactions



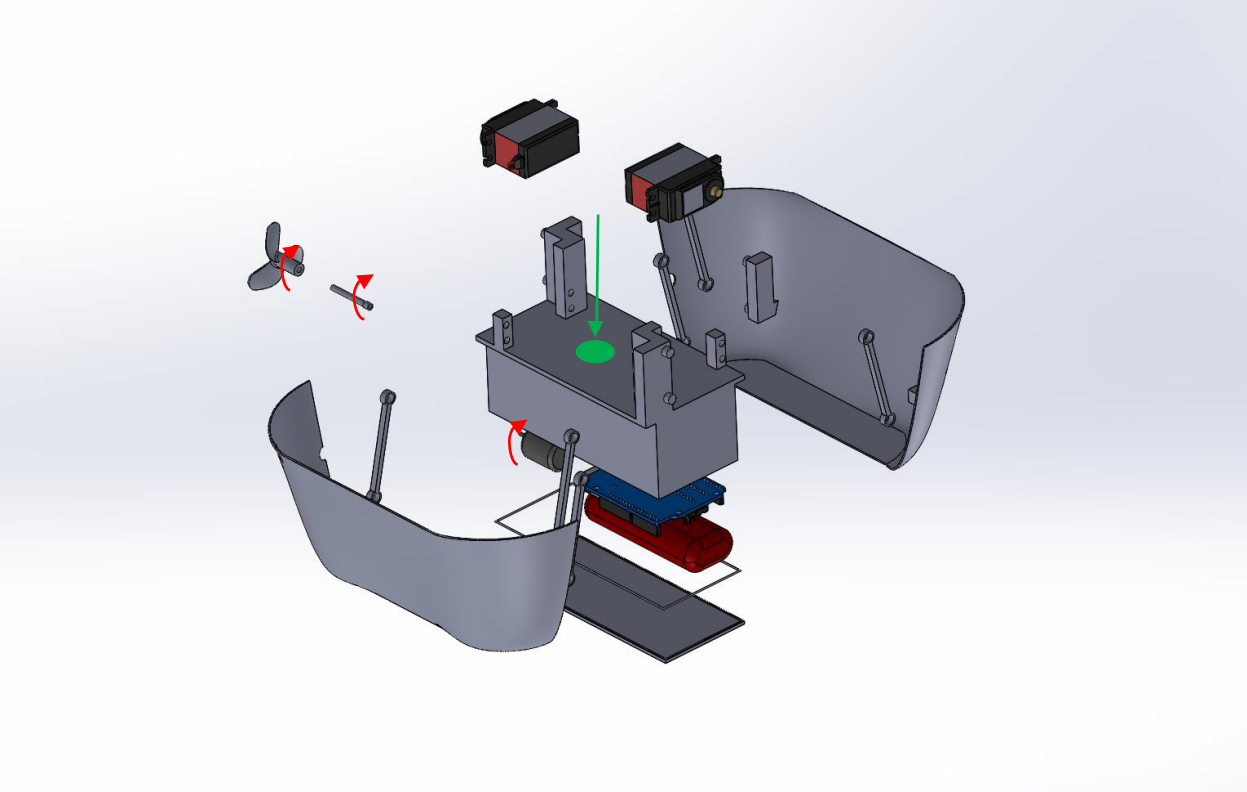
(Closed Position, Initial)



(Open Position, Final)

Movement Explanation:

From the closed position, the servos turn and apply torque to the arms, which then rotate and open the hull. The idler arms also rotate around their pivots, to keep the hull halves stable and provide support for the other side. Each servo opens one side of the hull.



(Motor Movement after Button Press)

Motor Movement Explanation:

When the button is pressed, the connection is bridged on the Arduino, sending an informative signal to start the device function. This starts the motor, allowing it to rotate the propeller shaft and the propeller, directly in line with the same angular velocity. The motor then runs for a set amount of time determined by the program, before the servo function starts and opens the hull as previously explained.

Design Structure Matrix

X when row depends on column.		1 Size	2 Speed to end of pool	3 Difficulty to reset	4 Ease of maintenance	5 Complexity	6 Speed to bottom of pool	7 Moving Parts	8 Cost	9 Programming	10 Material Availability	11 Reliability	12 Safety	13 Unique Design	14 Competitive
1	Size				x				x		x			x	x
2	Speed to end of pool	x				x	x	x	x		x	x	x		x
3	Difficulty to reset				x	x		x		x		x	x	x	
4	Ease of maintenance			x		x		x	x		x			x	
5	Complexity	x		x				x	x	x	x	x		x	x
6	Speed to bottom of pool	x				x		x	x	x		x		x	x
7	Moving Parts	x	x	x	x	x	x		x	x	x	x		x	x
8	Cost	x				x		x			x		x	x	x
9	Programming		x	x		x		x						x	
10	Material Availability	x				x		x					x		
11	Reliability	x	x	x	x	x	x	x		x				x	x
12	Safety		x	x											x
13	Unique Design		x		x			x	x		x				x
14	Competitive	x	x		x		x		x			x	x	x	

Design Process:

To design our submarine, we first started by identifying the most important attributes of our device in order to accomplish the end goal and beat all the other teams by having a superior design. We decided that if we wanted to reach the end of the pool the fastest, it would be best to stay above water for as long as possible to minimize the drag through the water and keep the average speed higher. We then needed the submarine to dive to the bottom of the pool, and this is accomplished by opening the bottom of the hull. We determined that this design would yield the fastest intake of water into the hull, making the submarine sink quickly, depending on the weight and ballast used. We also decided that instead of running our motor straight from the Arduino, using an electronic speed control (ESC) would allow for a bigger motor and a higher voltage battery to be used. The ESC also powers the 5v input of the Arduino as well as the 5v inputs of both servos, reducing the complexity and creating a higher amperage source to run the electronics. Waterproof electronics were used as well as a waterproof pod to keep the Arduino fully dry, ensuring that all the electronics function properly and reliably. A rubber bulb was also used to protect the button from the ingress of dirt and water that could stop the function of the device. Waterproofing grease was used as an added protective layer on the Arduino board and all wiring connections. All the wiring connections were soldered where applicable, and hot glued to the Arduino connection to keep the wire from coming. To keep the attachment screws from rusting, we used stainless steel fasteners so that the device is easily maintained and repaired after repeated exposure to water.

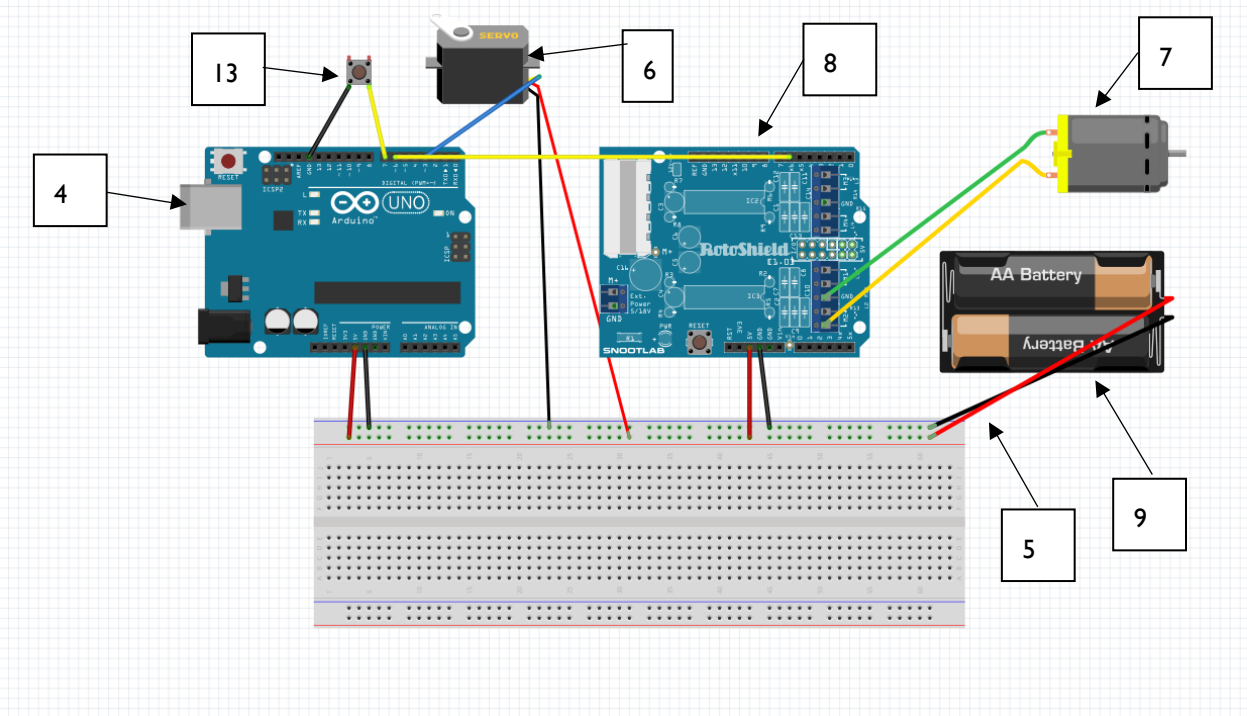
Critical Elements

The concept of how our device moves across the water and to the bottom is somewhat simple. The complexity comes in designing the electronics and ensuring no water interacts with them. The ESC is a big part of the electronics setup, allowing us the setup we want without adding to much complexity, this is a huge benefit in terms of reliability, and also makes it easier to troubleshoot if something went wrong. The ESC allows a larger motor to be used, increasing the acceleration and final velocity, and allows for bigger servos to be used ensuring it has the torque to open the hull, a crucial function of our design. Once the electronics are configured and working as they should be, it is important to make sure they stay in place, away from any water. Once the button is pressed, the device is completely reliant on the electronics, so waterproofing is extremely critical. The waterproofing relies on a sealed pod covering the controls as well as a layer of waterproof grease as a backup. Having a system to keep the electronics dry, in addition to a backup system, allows for a reliable design that will function correctly time after time.

Clever Ideas

Our design utilizes an ESC for higher power, full size servos packed into the small design for more torque and availability, and an Arduino to control all the necessary functions precisely. It also uses the unique design of the split hull, to keep the boat above water until the last minute where it is absolutely necessary for it to become a submarine. The boat hulls will open and let in as much water as possible to quickly sink the device, while it continues to move forward, until it reaches the bottom. This should allow for the submarine to be as quick as possible, easy to reset and retest, and keeps it simple enough to easily service.

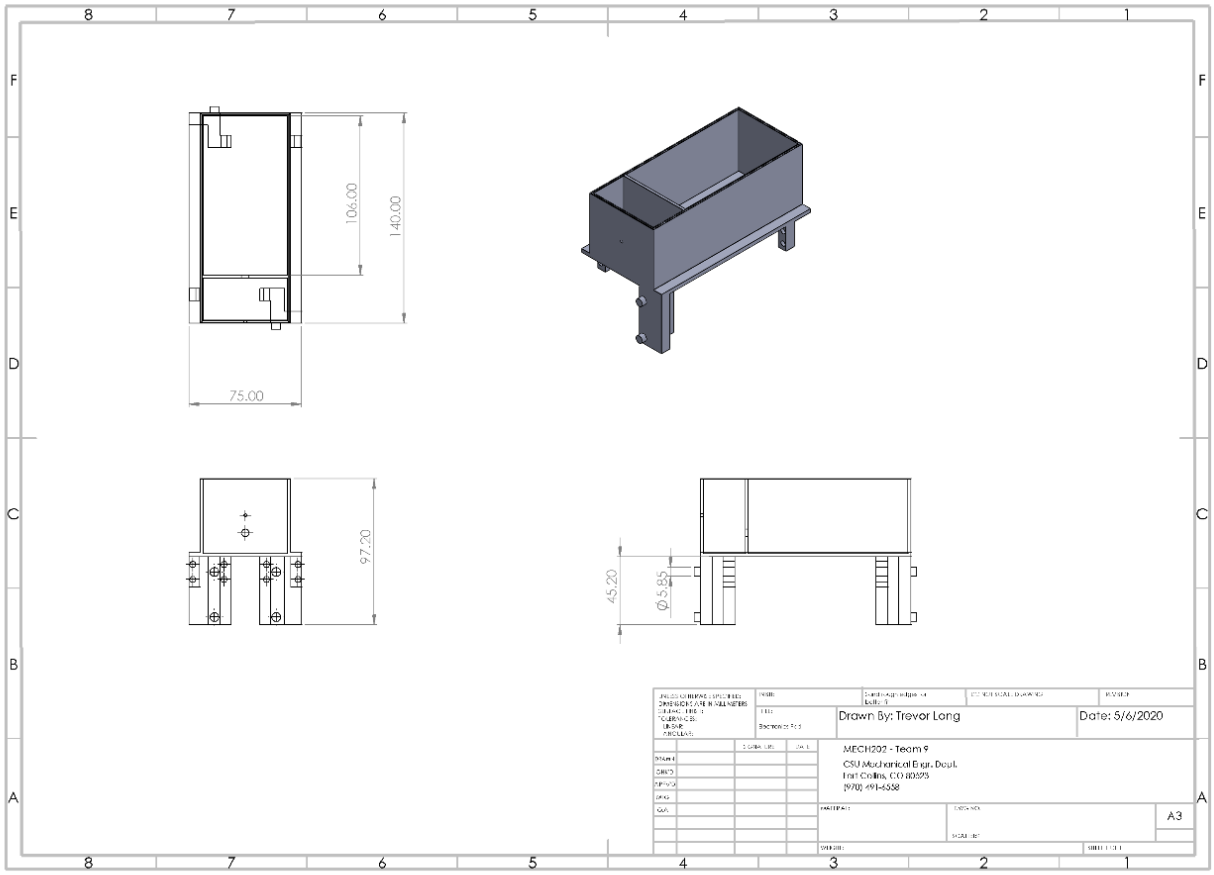
Arduino Code and Wiring Schematic:



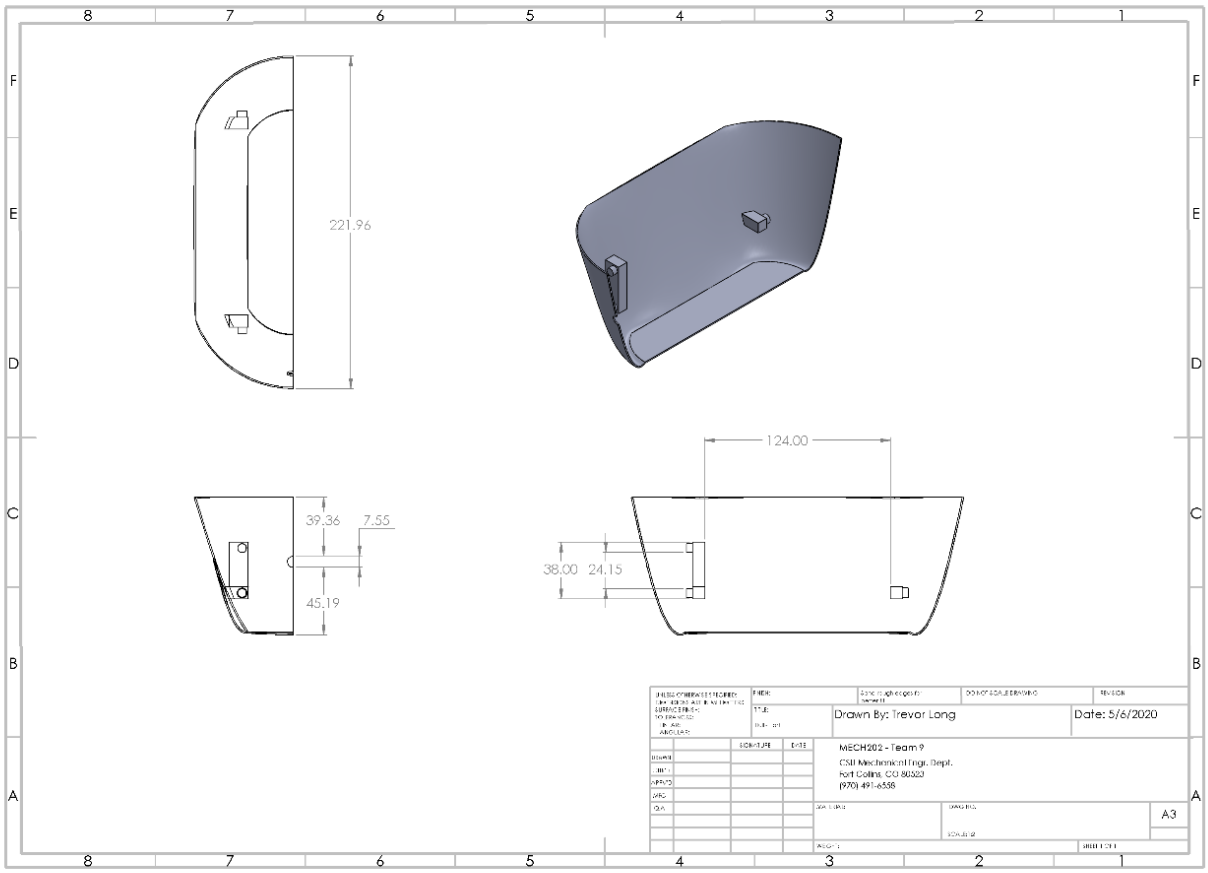

```
#include <Servo.h> //Using servo library to control ESC

Servo ESC1,Servo1; //Creating a servo class with name as esc

int pos = 0; //Sets position variable

int buttonPin;

void arm(){

setSpeed(0); //Sets speed variable delay(1000);

}

void setSpeed(int speed){

int angle = map(speed, 0, 100, 0, 180); //maps servo  to different speeds as percentage

ESC1.write(angle);

}

void setup() {

ESC1.attach(6); //Adds ESC to certain pin.

Servo1.attach(3); // Adds Servo to pin

buttonPin = 7; //This is the button that will start the sequence

  pinMode(buttonPin, INPUT_PULLUP);
```

```
arm();
}
void loop() {
Servo1.write(0); // Sets the servo to initial position of ()
 if(digitalRead(buttonPin) == LOW)
 {
int speed; // speed variable
for(speed = 0; speed <= 70; speed += 5) { //Cycles speed up to 70% power to reduce strain on mechanical parts
setSpeed(speed); //Creates variable for speed to be used in in for loop
delay(100);
}
delay(2000); //Stays on for () ms
Servo1.write(90); // Sets the servo to final position
delay(2000); //Keeps the motor on while the bottom has been opened
for(speed = 70; speed > 0; speed -= 5) { // Cycles speed down to 0% power to reduce strain on mechanical
setSpeed(speed);
delay(100);
}
delay(5000); //keeps the servo open
Servo1.write(0); //Sets the servo back to initial position
delay(100000000000); // delays the motor, essentially stops the loop.
 }
}
```

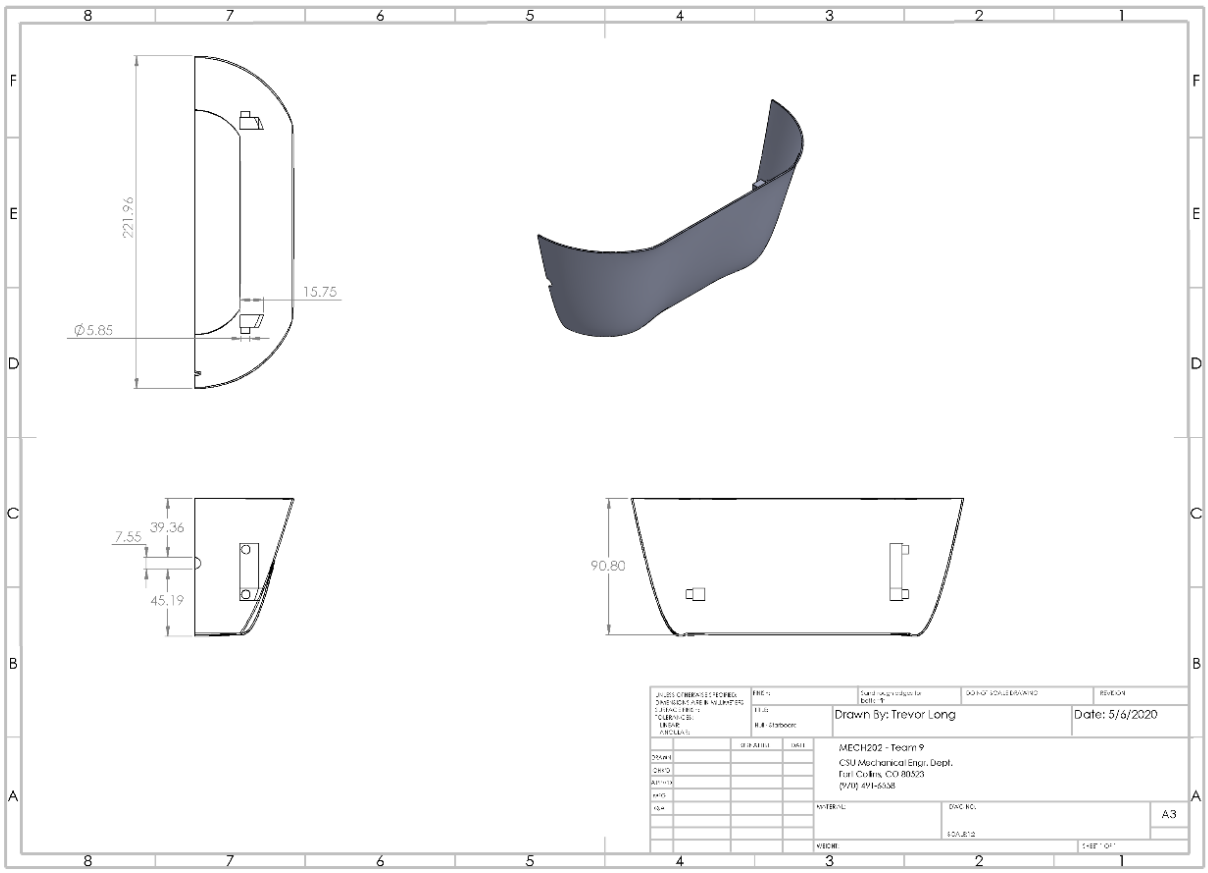
Engineering Drawings



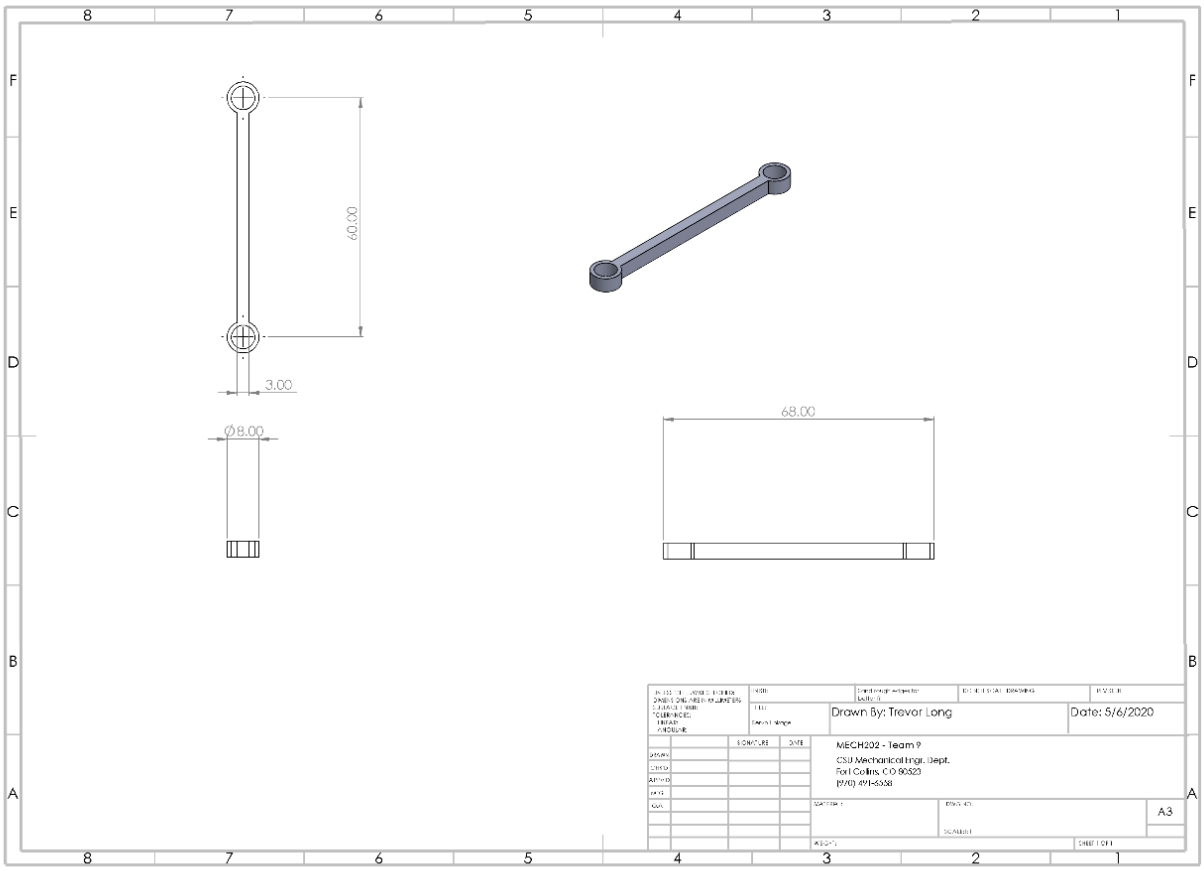
This is the electronics pod, and its main objective is to contain all the electronics that could be damaged by water and keep the water outside where it cannot mix with any electronics. This part interacts with parts (4), (7), (9) and (10). This pod contains parts (4), (7) and (9) and keeps them separated from any water. This part interacts with part (10) through a direct connection. Part 10 fits onto the underside of this pod and provides the watertight seal that keeps the water out of the pod and keeps the electronics safe and sound within the pod.



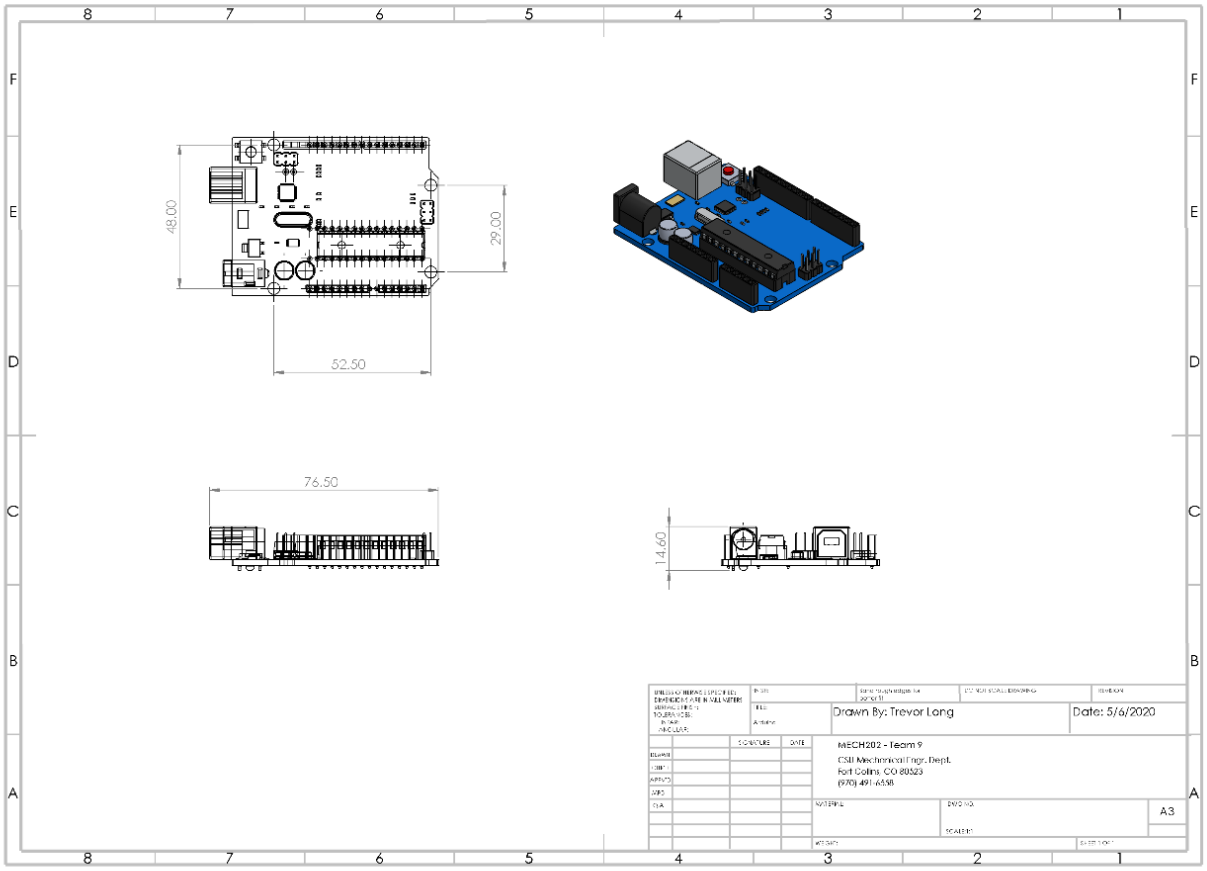
The hull is a very important part of the submarine. Its main purpose is to keep water from flowing up through the submarine. This half of the hull links with the other half and keeps water out of the submarine. Therefore, the submarine stays buoyant when the hull is connected. This part interacts with part (3), the linkages. These linkages raise up when programed to and raise the two halves of the hull with them, separating the hull and allowing the submarine to submerge and sink to the bottom of the pool.



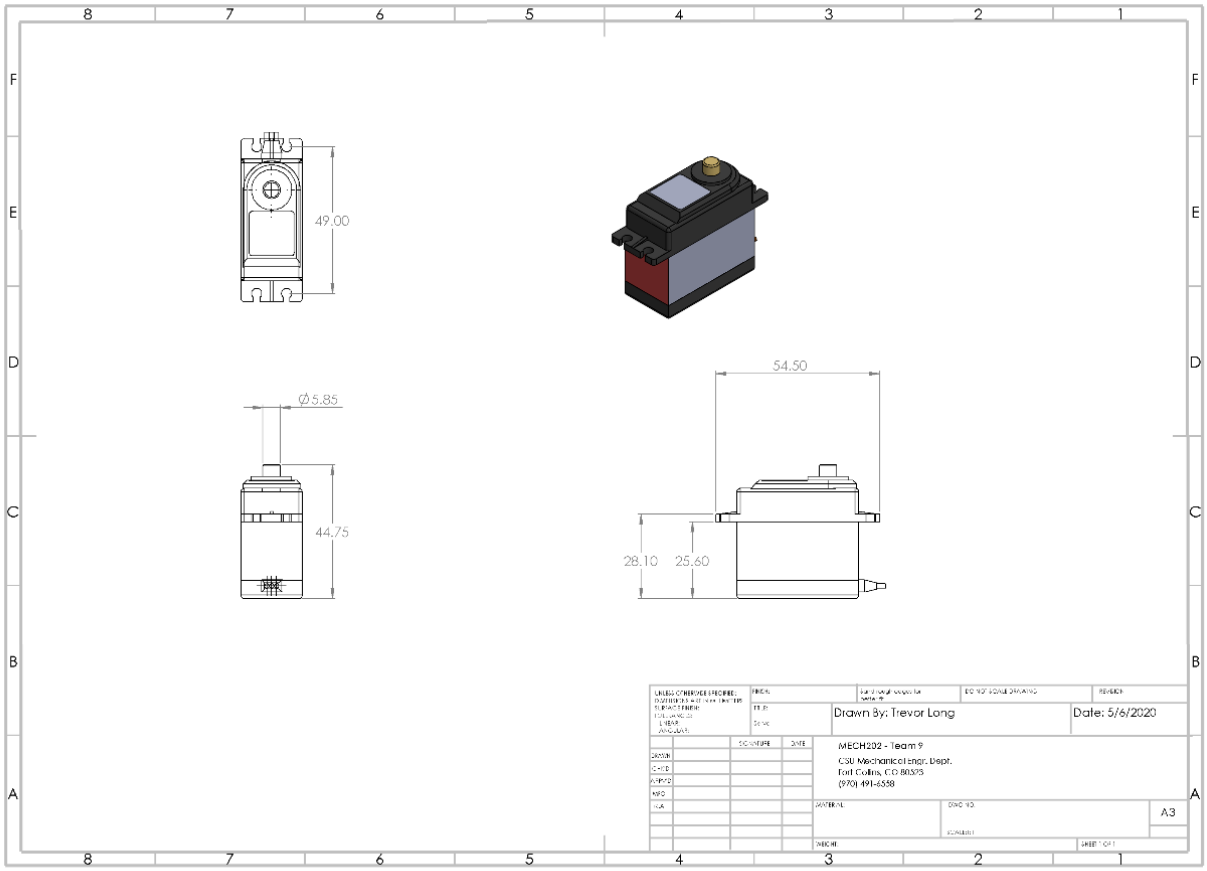
This is the other half of the hull. This part functions the same as the other half of the hull. See above description.



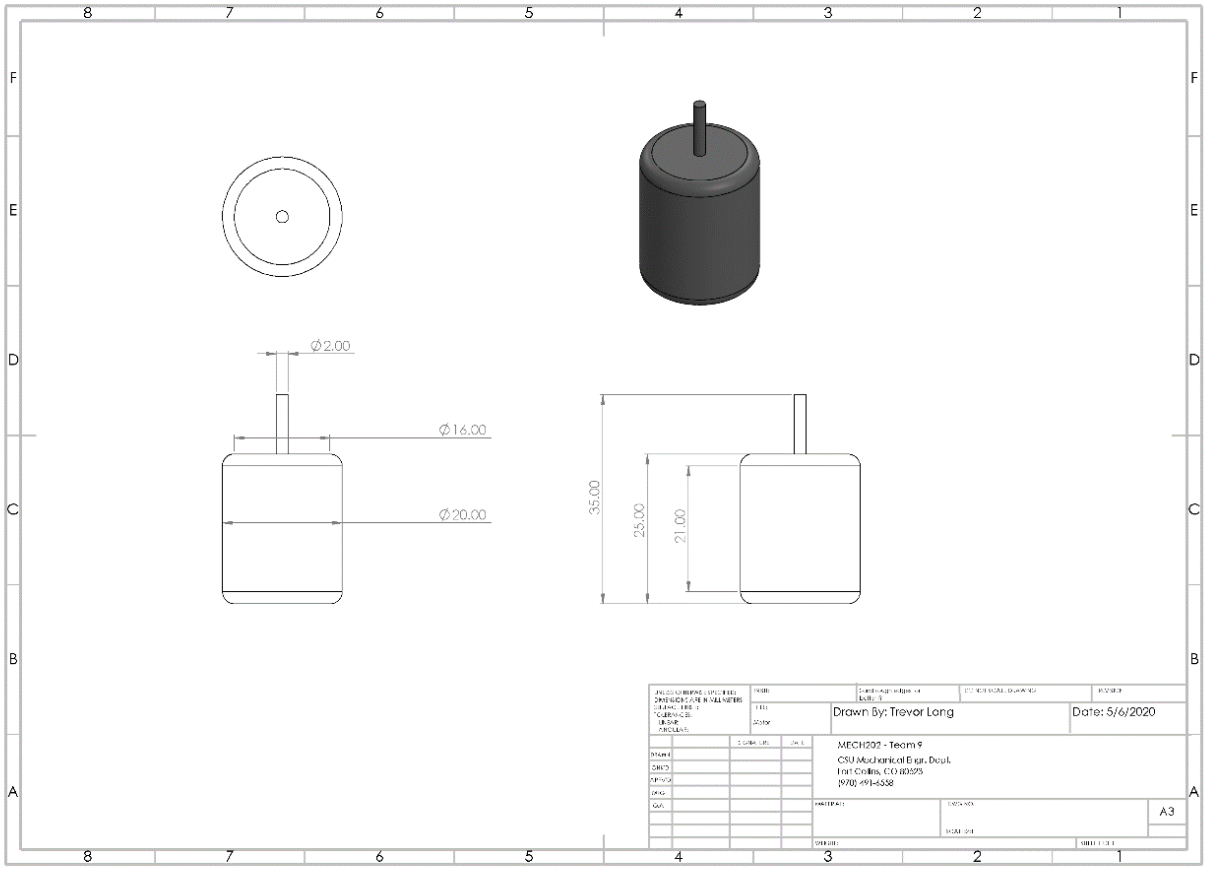
This linkage is a crucial part in the submerging of the submarine. Powered by the servo motor, part (6), these linkages are rotated when the motor is activated. One end of the linkage is attached to the servo motors while the other end is attached to part (2), the hull. When the linkages are rotated, they separate and raise the two halves of the hull, allowing water to flow into and around the submarine. This allows the submarine to sink to the bottom of the pool



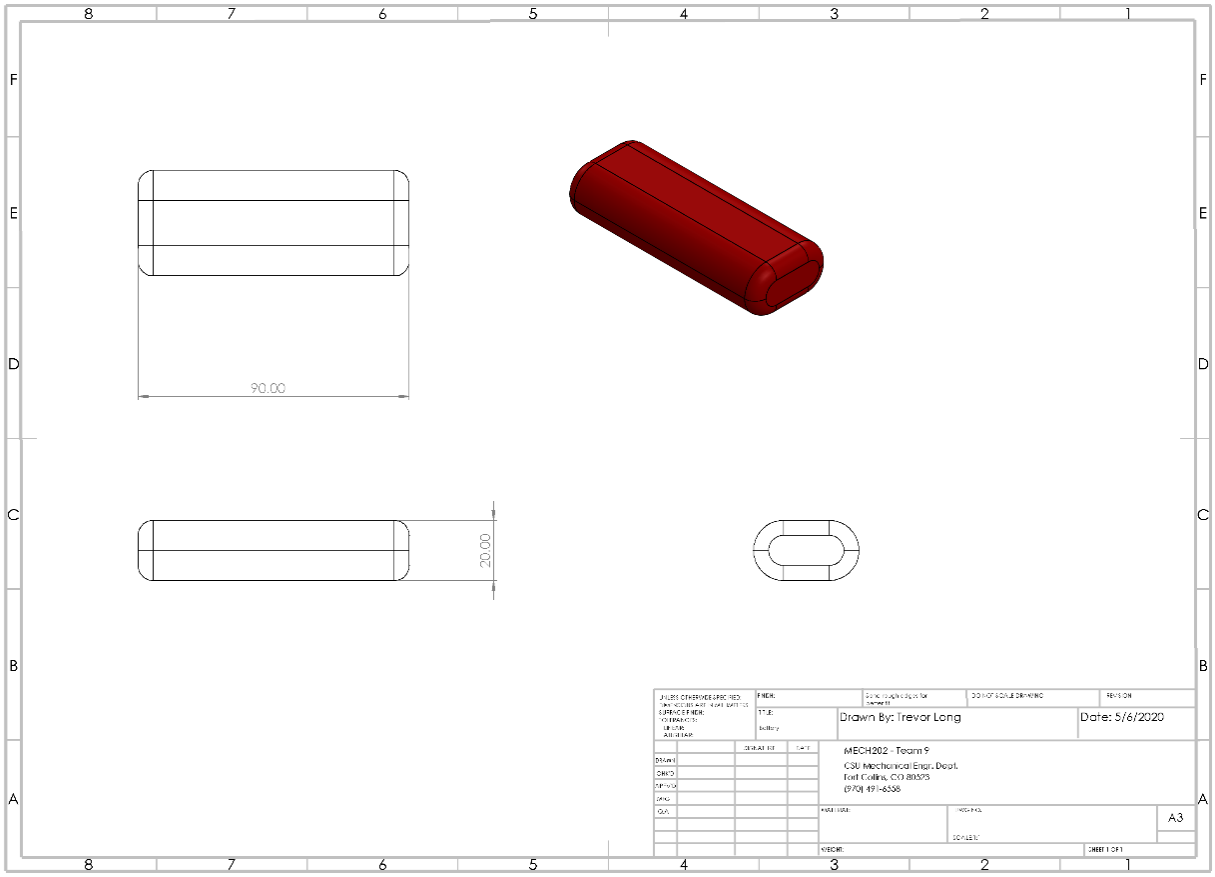
This is the Arduino Uno microcontroller (4). The Arduino controls the servos by using the desired angles and ESC by using pulse width modulation control, allowing the motor speed to be limited and also the acceleration to lessen the stress on physical components. The Arduino is powered from the 5v output of the ESC, which is powered by the battery.



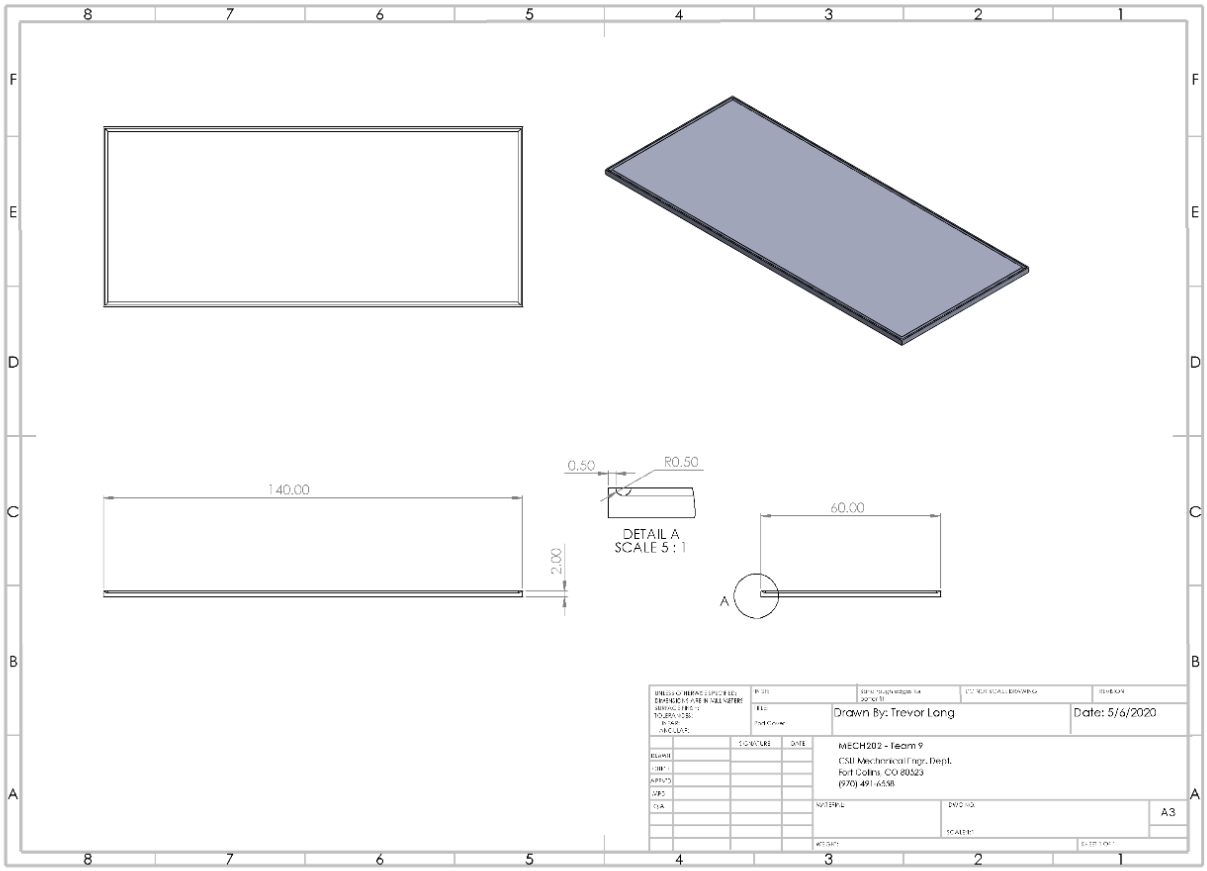
This servo motor is essential for the vertical motion of the submarine. When programed to do so by the Arduino code, this servo motor rotates its shaft a specified amount. This part interacts with parts (3) and (13). Part (13) connects the Arduino to this servo motor in order to communicate the code needed to operate the motor. Part (3) is connected to the shaft of the servo motor. When the servo shaft rotates, it rotates the linkage as well. This causes the linkages to separate and raise part (2), the hull of the submarine, allowing the vessel to submerge.



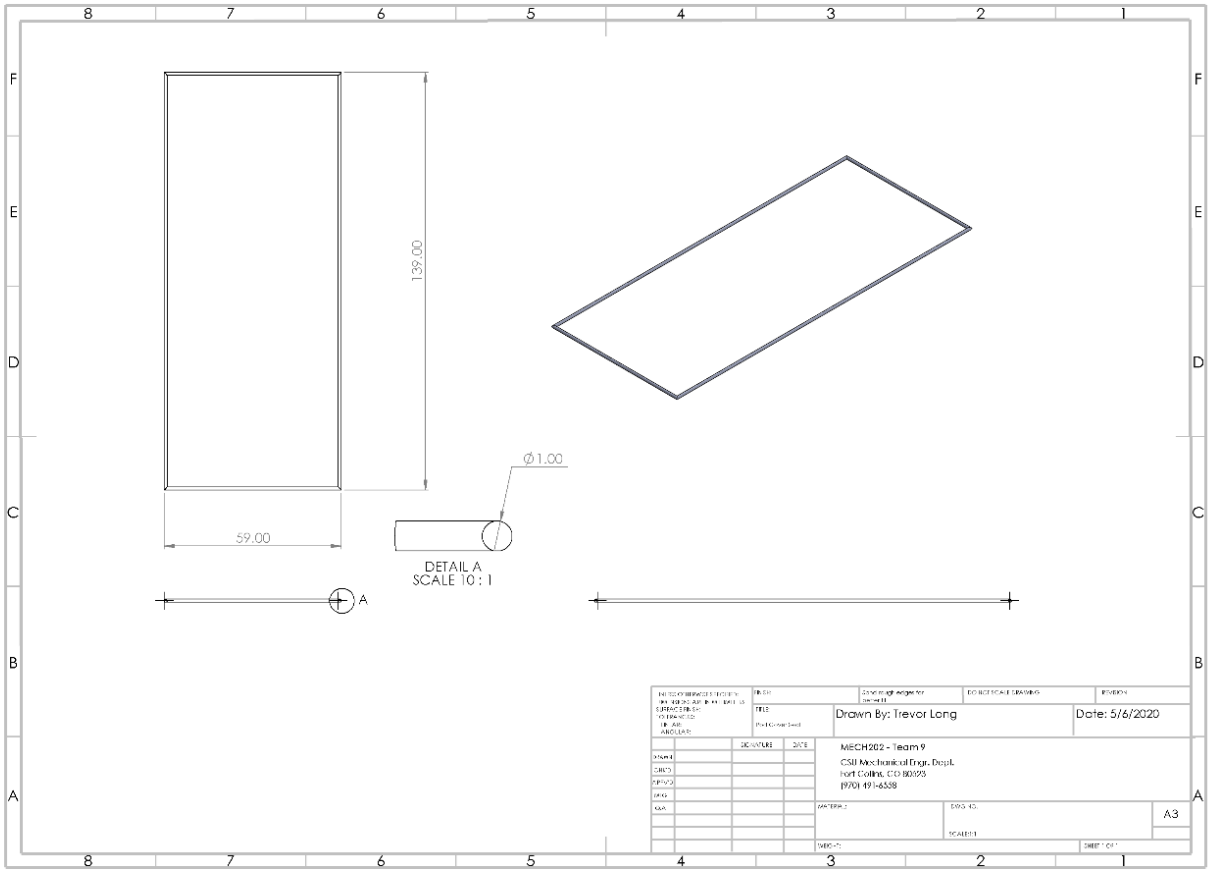
The main function of this DC motor is to propel the propeller shaft and propeller which leads to the horizontal acceleration of the submarine. This part interacts with parts (5), (9), (11), (12) and (13). Part (5), the 12-gauge wire, transmits power from the battery, part (9), to the motor. The Arduino wire, part (13), transmits the instructions from the Arduino code to start and stop the motor. Parts (11) and (12) are powered by the motor, and spun at a high speed in order to propel water near the propeller backwards, and therefore shoot the submarine forward.



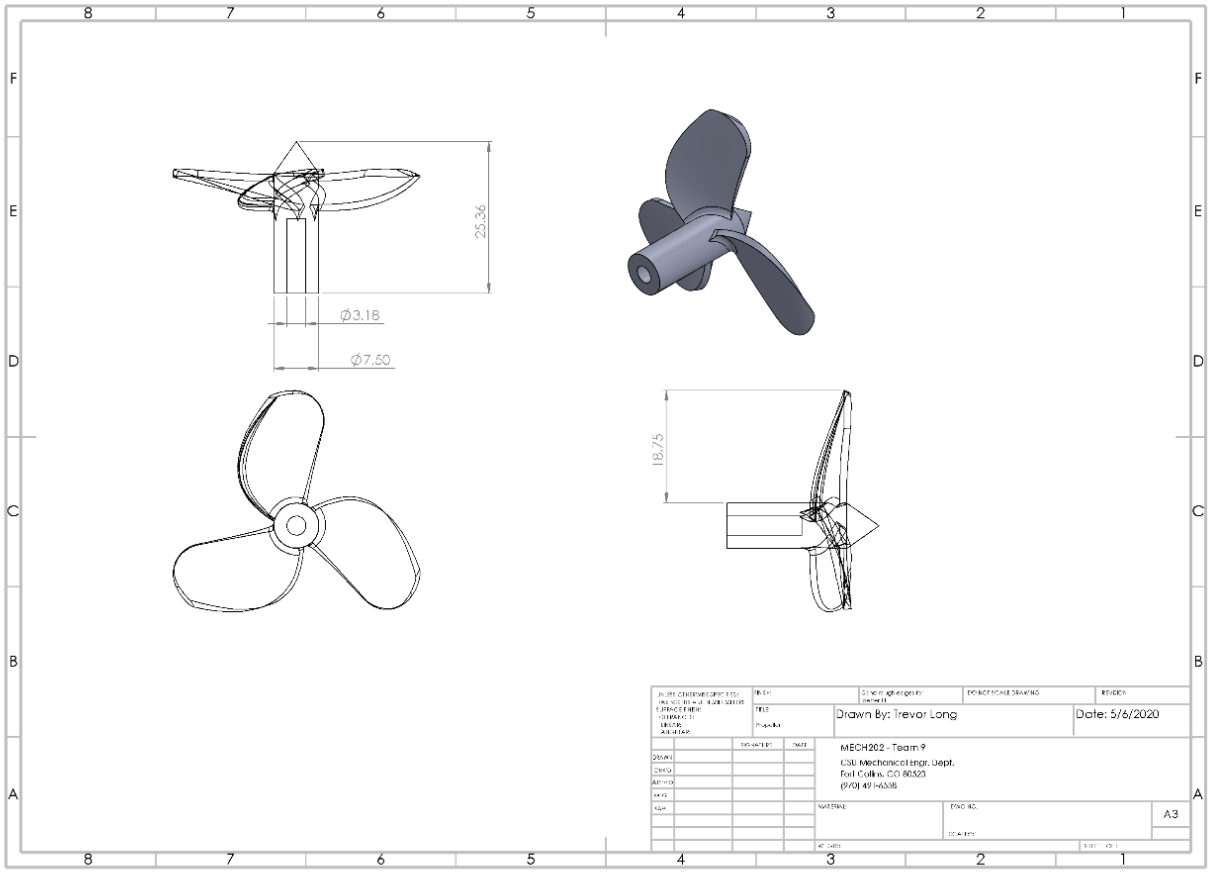
The battery (9) provides power to the ESC and Arduino. Our device uses a 6 cell NiMH battery that has a nominal voltage of 7.2V.



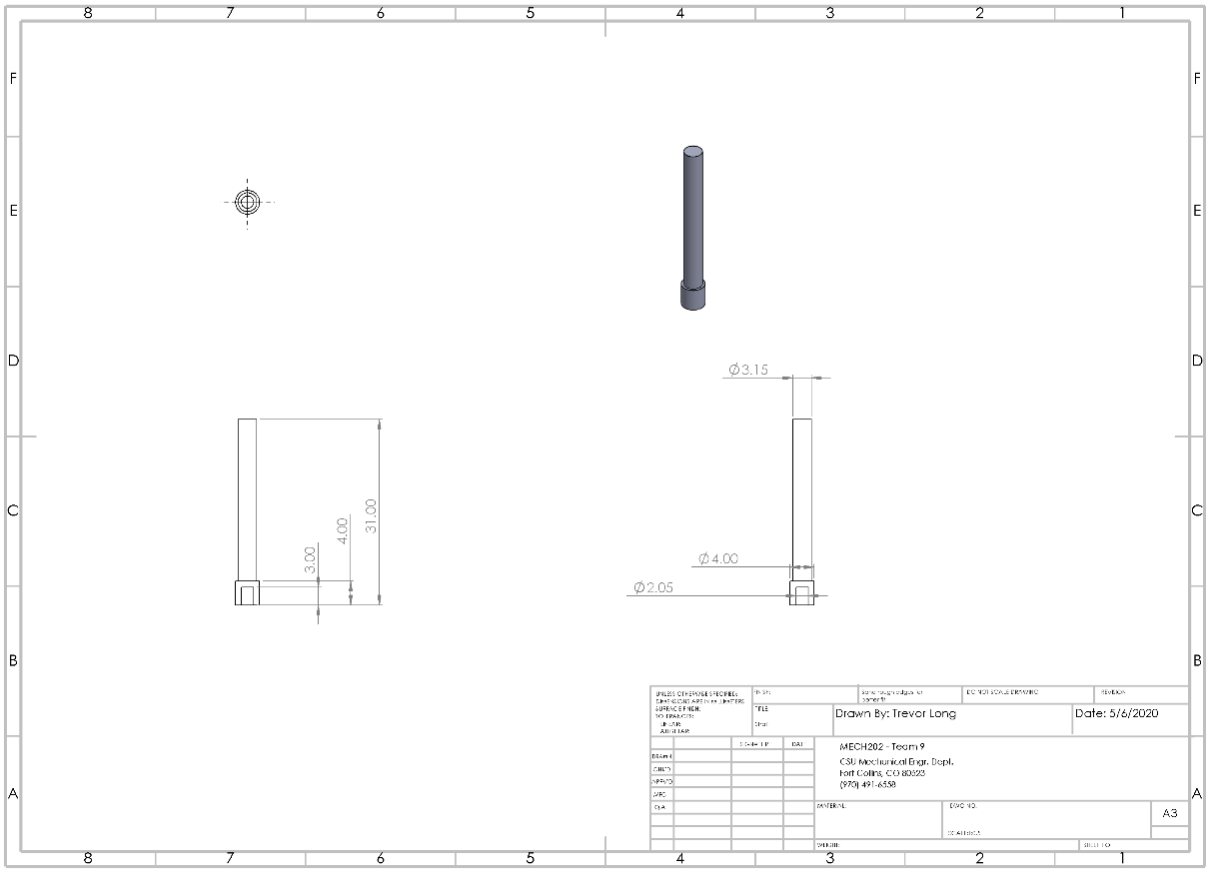
This piece is the electronics pod cover (10), it allows for the electronics inside to be serviced and installed and still remain waterproof by using a rubber gasket to seal the edges. It interacts with part (1) through a direct connection. This piece fits onto the bottom of the electronics pod and seals the pod from the outside environment (water).



This is the upper electronics pod cover, it functions similar to the lower piece but is not removeable, it is sealed into place and firmly attached. Once it is installed it should never need to be removed. Its main function is to provide the watertight seal of the electronics pod, which will hopefully keep all the water away from any electronics that could be damaged.



The main function of the propeller is to rotate and push water backwards, accelerating itself and the submarine forwards. The propeller interacts with part (12) by a direct connection. Part (12), the propeller shaft, rotates along with this propeller, and the angular velocity is used to propel the submarine forward. Both the propeller shaft and the propeller are powered by part (7), the DC motor. These parts interact until the DC motor is stopped after a set period of time.



This propeller linkage is very important in transferring power from the DC motor to the propeller. This part acts as an axel, rotating with the DC motor and the propeller. It interacts with these two parts (7 and 11) by direct connection. The DC motor shaft spins at a high speed which turns this part along with the shaft. The opposite end of this linkage is attached to the propeller, which rotates with this part and the shaft of the DC motor. This system is solely responsible for moving the submarine horizontally along the surface of the water.

Competitive Analysis

Our submarine design was created through analysis of our QFD, Project Plan, and multiple proposed designs. However, to fully analyze the final chosen design, it must be compared to multiple products from numerous competing companies. Included in these comparisons were several autonomous submarines and one remote controlled underwater vehicle. The products were reviewed and the companies that released these products were looked over to understand their mission statements. The products that were reviewed are listed below:

- Atlantis WWII Gato/Balao Class Submarine
- DIY Mini RC Submarine
- Green Toys Submarine
- Diving Submarine
- Electric RC Submarine Boat Torpedo Assembly

Atlantis WWII Gato/Balao Class Submarine

Atlantis Battery Powered WWII Gato/Balao Class Submarine Toy and Hobby

by Atlantis

47 ratings | 15 answered questions

Amazon's Choice for "submarine"

Price: $24.99 prime & FREE Returns

Get $70 off instantly: Pay $0.00 ~~$24.99~~ upon approval for the Amazon Prime Rewards Visa Card. No annual fee.

- Measures 12 Inches Long
- Molded in Sea Black
- Required 1 AA battery not Included
- Cruises on the Surface

Report incorrect product information.

★☆☆☆☆ **Sub value**

Reviewed in the United States on January 20, 2019

Verified Purchase

After using the sub in the water it got Rusty near the switch. Making it difficult to turn on and off. Also it stopped working after a few weeks. The electrical inner workings are not well protected from the water. A waste of my money.

10 people found this helpful

★★☆☆☆ **Two Stars**

Reviewed in the United States on July 9, 2018

Verified Purchase

Sunk to the bottom of the pool within seconds and didn't move after that. Disappointing

8 people found this helpful

About the company

About US

Atlantis Model Company was founded in 2009 by the former owners of Megahobby.com, Peter Vetri and Rick DelFavero. We manufacture injection-molded plastic model kits and hobby related products. When we started Megahobby.com back in 2000, we had dreams of becoming more than just another retail hobby shop. We wanted to become an actual model production company like the Aurora Model Co and Revell-Monogram. As Megahobby grew, it gave us the opportunity to create Atlantis and finally come out with our own branded model kits.

Atlantis is a company that focuses on creating model cars, ships and submarines. These models can either come assembled, or they sometimes require the user to put them together.

This company is a strong competitor for us because as most of their vehicles are simple models, some water vessels come with battery powered motors. Most of these vehicles simply travel horizontally through the water, but some have the ability to submerge, like the Gata/Balao class submarine that we chose to compare our submarine to.

DIY Mini RC Submarine

DIY Mini RC Submarine Remote Control Boat Under Water Ship Model 6 Channels Water Toy Waterproof Diving for Swimming Pool, Fish Tank Kids Gift

Write a review Generic

$39.50 List $79.00

Out of stock

Qty: 1

Get in-stock alert

Delivery not available

Pickup not available

Sold & shipped by Novashion | Return policy

Add to list Add to registry

★★★★☆ January 13

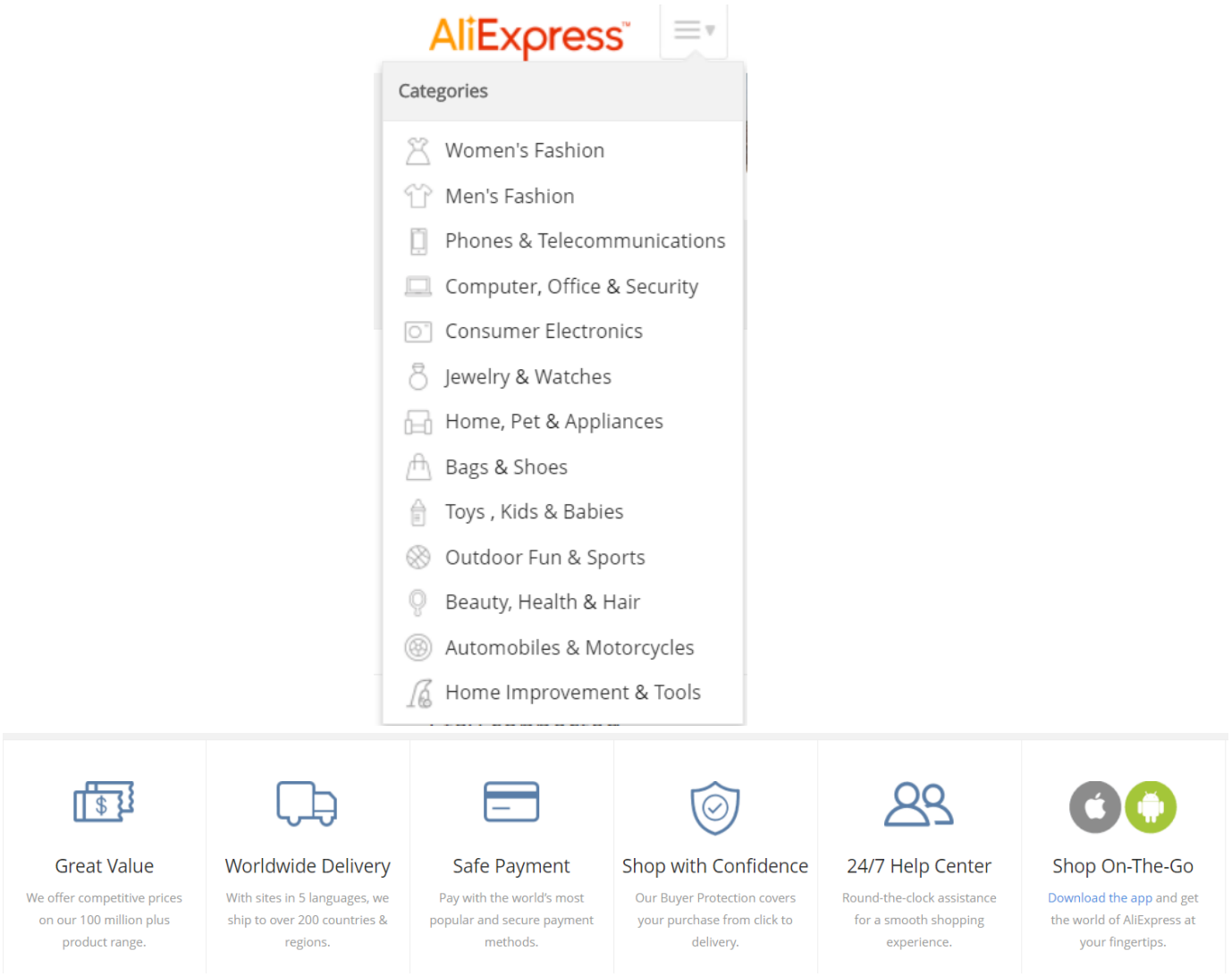
Philippe Bendenoune

Coorect

★★★★☆ May 27

Sergey Kovylin

About the company



AliExpress is the main seller for the DIY Mini RC Submarine. While the company does not have a mission statement, some information can still be gathered from their website. AliExpress sells many different types of products, as seen by their drop down window pictured above, but they seem to mostly focus on children's toys.

This company is not a strong competitor for us because their only submarine toy is remote controlled, making it unacceptable for the competition our submarine is competing in. Additionally, AliExpress only focuses a very small percent of their time and resources on their submarines, as they have a vast range of other products sold on their website.

Green Toys Submarine

Great toy

Would recommend

djcrackhouse - 10 months ago, Verified purchaser

Great toy. Very durable plastic.

Awesome toy smiling face

Basias - 1 year ago

originally posted on greentoys.com

I have 2 boys and they love playing with this when taking a bath. After a week I notice the top snaps open so you can pure water inside and use it to rinse shampoo of my boys hair. The sub it's really easy to clean. I always check bath toys for mold or mildew but I don't have any issues with the sub. [This review was collected as part of a promotion.]

About the company

About Us

At its core, Green Toys Inc. has always been an eco-friendly toy company. In fact, we say that to us, "every day is Earth Day." Our commitment to sustainability and playfulness is part of our DNA and we hope to inspire others to share in this passion.

From our 100% recycled materials to our US-based manufacturing, we're raising awareness about sustainability while delivering unquestionably safe products. We believe that the best way to encourage environmental change is through goods people buy and use every day—and in our case that's children's products.

We care about your kids – how they play, what they play with, and what the future holds. We are constantly exploring and innovating to deliver the best products possible for a playful planet for all.

Green Toys is a children's toy company that focuses most of their resources on the sustainability of their products. They do not use any batteries, and they solely make their products out of recycled plastics.

Green Toys is not a major competitor to us as there is no power delivery in their products. While by chance their submarine could float downward and a diagonal angle and make it to the far end of a pool, this is not the likely outcome. Green Toys focuses more on sustainable and green products than on the performance of their products. Their toys are just that, toys. They are meant mostly for playing and making up imaginary situations with, not traveling quickly and accurately through the water.

Diving Submarine

Diving Submarine

SKU #SUB-10

★★★★½ (8 reviews) Read Reviews | Write a Review

Availability: **In Stock**

◉ $3.95

○ 8 points (Points accrued: 0)

Qty. 1 ADD TO CART / QUOTE

Learn about Extra Credit Points®

Powered by baking powder, it dives and surfaces just like a real sub.

Needs a little finesse

★★★★★ Aug 6, 2018

I bought this for teachers in a science workshop to help them think about floating and sinking. Some of the submarines rose and sank quickly. Some never did. The directions are a little vague and need a little finesse and experience to work properly. Some of the teachers were disappointed in their submarines as a result.

Therese Shanahan

Was this review helpful?

👍2 👎0

Cute

★★★★☆ Mar 4, 2017

It works. My six year old was entertained.

Maurice Karpman

About the company

About Us

The staff at Educational Innovations is a tight-knit, friendly crew committed to serving our customers' needs. If you'd like to learn more about some of them, "EI's Pick-and-Pack Customer Service Crew" blog is a fun introduction!

Educational Innovations is a teacher run website that strives to educate children about concepts of physics and science through fun toys. The company is managed by two teachers and their dog. They work with other teachers around the country to educate children in schools or at home.

Educational Innovations is not a major competitor for us because their products do not perform to the capabilities that our submarine does. The Diving Submarine fully submerges, but it is not buoyant on its own before submerging. The submarine also does not travel horizontally in the water, it solely rises and sinks. It is for these reasons that this company is not a major competitor for us.

Electric RC Submarine Boat Torpedo Assembly

ELECTRIC RC SUBMARINE BOAT TORPEDO ASSEMBLY MODEL KITS DIY EXTRACURRICULAR TOYS KID`S GIFTS

$48.49

Shipping calculated at checkout.

★★★★★ ▾

2019-07-02 04:04:26

Realy fun simple toy . Good quality of navigation, esay building , without gule

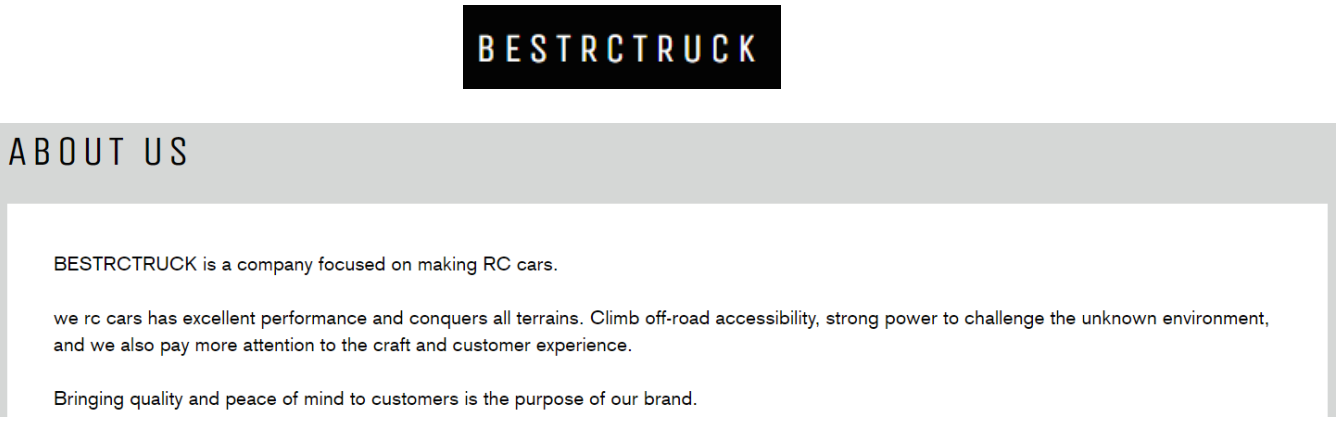
0 Comments

★★★★☆ ▾

2019-11-04 15:29:01

At first glance, it is well built and looks good. NEGATIVE SIDE, I BUYED A GRAY OR BLACK TORPED, ACCORDING TO THE IMAGE THAT APPEARS AND RECEIVED A BLUE. IS INCORRECT BECAUSE THE PORTAL IS NOT MADE TO REFER TO ANOTHER COLOR

About the company



BestRCTruck is a company that makes remote controlled cars, boats, submarines and torpedoes. They also produce some products that do not require the control of the user, such as the Submarine Boat Torpedo Assembly shown above.

This company is our main competitor in this competition because the product shown above travels quickly through the water in the direction that the user points it in. While the direction of travel of this submarine is not as reliable as ours, BestRCTrucks product travels faster than our submarine. It is also autonomous and requires one single action to start, as our submarine does. Because of these reasons, this company is our main competitor.

Engineering Analysis

Buoyancy is the most crucial concept to our prototype's successful function because it is directly linked to two of the competition guidelines. It must first have enough buoyancy to travel the length of the pool, and then the buoyancy must be drastically reduced on the device, allowing it to sink to the required depth of the pool. The equation to calculate the force of buoyancy is given by:

$$F_{Buoyancy} = V_{object} * \rho_{fluid} * g \quad (1)$$

In order for the device to float on top of the water, this buoyancy force must equal the weight of the device. Initially the hull is closed making the volume equal to the hull material and the air that it carries; a traditional boat hull design ensures the volume is large enough to offset its weight. Further analysis of this equation helped deduce the final design of the prototype. Since the density of the fluid and acceleration due to gravity will be held constant on our device, the only method to allow it to move along the surface of the water in addition to sinking will be to adjust the volume of water displaced by the device. When the hull splits, water fills in the volume in the hull occupied by the air, reducing the volume and lowering the buoyancy force.

To allow the hull to split in half, multiple engineering concepts were evaluated and applied. The hull opening applies a 4-bar linkage system, which is common throughout machine design when reliability and simplicity are necessary. Using dynamics knowledge, this effective linkage can be designed to specific dimensions and the device will fall within size specifications, regardless of whether the hull is open or closed. The systems for the motor function and one-button start system rely on an Arduino algorithm, commonplace among simple autonomous systems. Making this algorithm is simple, as Arduino allows the use of MatLab, something each of us has experience in.

Testing

Test Report

Design Organization: MECH 202 – Team 9	**Date: 4/21/20**

Device or system tested: Submarine – Buoyancy and Vertical Travel

Objective of experiment (Engineering Specifications to be verified):

The objective of this experiment is to verify that the submarine is buoyant on its own and also able to travel vertically through the water.

Methods and Materials (or Equipment):

- Pool (filled with water)
- Submarine

Experimental Procedure:

- Place the submarine on the water with the hull shut
- Let it float for 10 minutes to ensure buoyancy and waterproofing
- Activate the servo motors the split the hull
- Ensure the device sinks to the desired depth within 30 seconds to verify vertical travel

Results:

Device successfully completes all tasks although there was a slow fill of water into the hull when testing buoyancy

Discussion:

Analysis:	Interpretation:
Device could benefit from a rubber seal around the hull to prevent the slow intake of water. Submarine did sink quickly once hull was split; the hull did turn a bit which created some drag. A stabilizer arm could allow the submarine to sink more quickly.	Since the device was able to meet all criteria, we can call this design a success. From here we can make minor improvements so that the performance and reliability is increased. From this test a rubber seal and stabilizer arms would increase performance and reliability.

Test Report

Design Organization: MECH 202-Team 9	**Date: 4/21/2020**

Device or system tested: Submarine-Servo System

Objective of experiment (Engineering Specifications to be verified):

The objective of this experiment is to verify that the servo system functions as it should during multiple tests.

Methods and Materials (or Equipment):

- Submarine
- Level surface

Experimental Procedure:

- Place submarine where the hull can be opened without exterior interference
- Activate servo motors to open the hull
- Close the hull and repeat the process 14 additional times

Results:

The servo motors successfully opened the hull 15/15 trials

Discussion:

Analysis:	Interpretation:
The movement of the hull pieces is simple enough so that the system can function accurately 100% of the time.	The vertical motion through the water is a necessary function of our submarine, and this test is extensive enough to show the system will function repeatedly.

Test Report

Design Organization: MECH 202 – Team 9	**Date: 4/21/2020**

Device or system tested: DC Motor for Horizontal Travel

Objective of experiment (Engineering Specifications to be verified):

The objective of this experiment is to ensure the DC motor successfully activates and allows the submarine to travel to the opposite end of the pool.

Methods and Materials (or Equipment):

- Pool (filled with water)
- Submarine

Experimental Procedure:

- Place submarine at one end of pool
- Activate the DC motor to begin horizontal travel
- Measure how long the submarine takes to reach the opposite end of the pool over 20 tests
- Average the data and use that time as the time for how long before the DC motor will shut off, allowing it to have the best chance to reach the opposite end of the pool every time

Results:

The device was able to successfully travel the length of the pool for all tests and the averaged time to cross it was added the code

Discussion:

Analysis:	Interpretation:
The device successfully crossed the pool, however the time for it to cross was varied, so there is a chance that it may not make it if it travels any slower than the mean time to reach the other end	To ensure a 100% success rate, the slowest time to reach the other side of the pool should be used in the code with a small margin of error added as well to make sure it will not come up short of the other end

Test Report

Design Organization: MECH 202 – Team 9	**Date: 4/21/20**

Device or system tested: Arduino Start button

Objective of experiment (Engineering Specifications to be verified):

The objective of this experiment is to make sure the start button reliably starts the sequence of events that are programmed and cause the submarine to function, while the device is in the water

Methods and Materials (or Equipment):

- Boat/submarine device
- Pool/water filled reservoir

Experimental Procedure:

- Place the submarine in the water
- Make sure area in front of the sub is clear as it will move forward once button is pushed
- Press Arduino button once, and see if the device moves and sequence starts
- Repeat until 15 tests have been performed to ensure accurate results

Results:

The device moved 15/15 times the button was pressed

Discussion:

Analysis:	Interpretation:
The button functioned as expected, however a button with a lighter spring internally to allow for less force to actuate it would help the submarine to stay perfectly straight in the water, as it was noted that sometimes the device would move when the button was pressed.	A lighter button should be procured and retested to ensure reliability.

Test Report

Design Organization: MECH 202 – Team 9	**Date: 4/21/2020**

Device or system tested: Impact resistance

Objective of experiment (Engineering Specifications to be verified):

To ensure that the submarine is built strong enough to withstand the expected impacts associated with the competition.

Methods and Materials (or Equipment):
- Pool or large tub filled with water
- Submarine
- Screwdriver and other tools required to take submarine apart

Experimental Procedure:
- Let the submarine float on the surface of the pool
- Turn on the motor and let the submarine accelerate and hit one of the pool's walls
- Open the hull and let the submarine sink all the way to the bottom of the pool
- Retrieve the submarine and check that all systems are functioning properly
- Repeat the previous 4 steps 10 times
- Take the submarine apart enough to fully check the parts and mechanics of the device

Results:

All submarine parts remained intact and all systems continued to function.

Discussion:

Analysis:	Interpretation:
All aspects of the submarine survived the impact tests. However, this does not necessarily mean that they will survive varied or even the same tested impacts in the future.	The submarine should still be treated as if it was very fragile. If any parts are thin or show signs of stress they should be reinforced or replaced with stronger parts.
Team member: Trevor	Prepared by: Noah
Team member: Nolan	Checked by: Ryan
Team member: Noah	Witnessed by: Trevor
Team member: Flynn	

Form # 19

Reliability Analysis

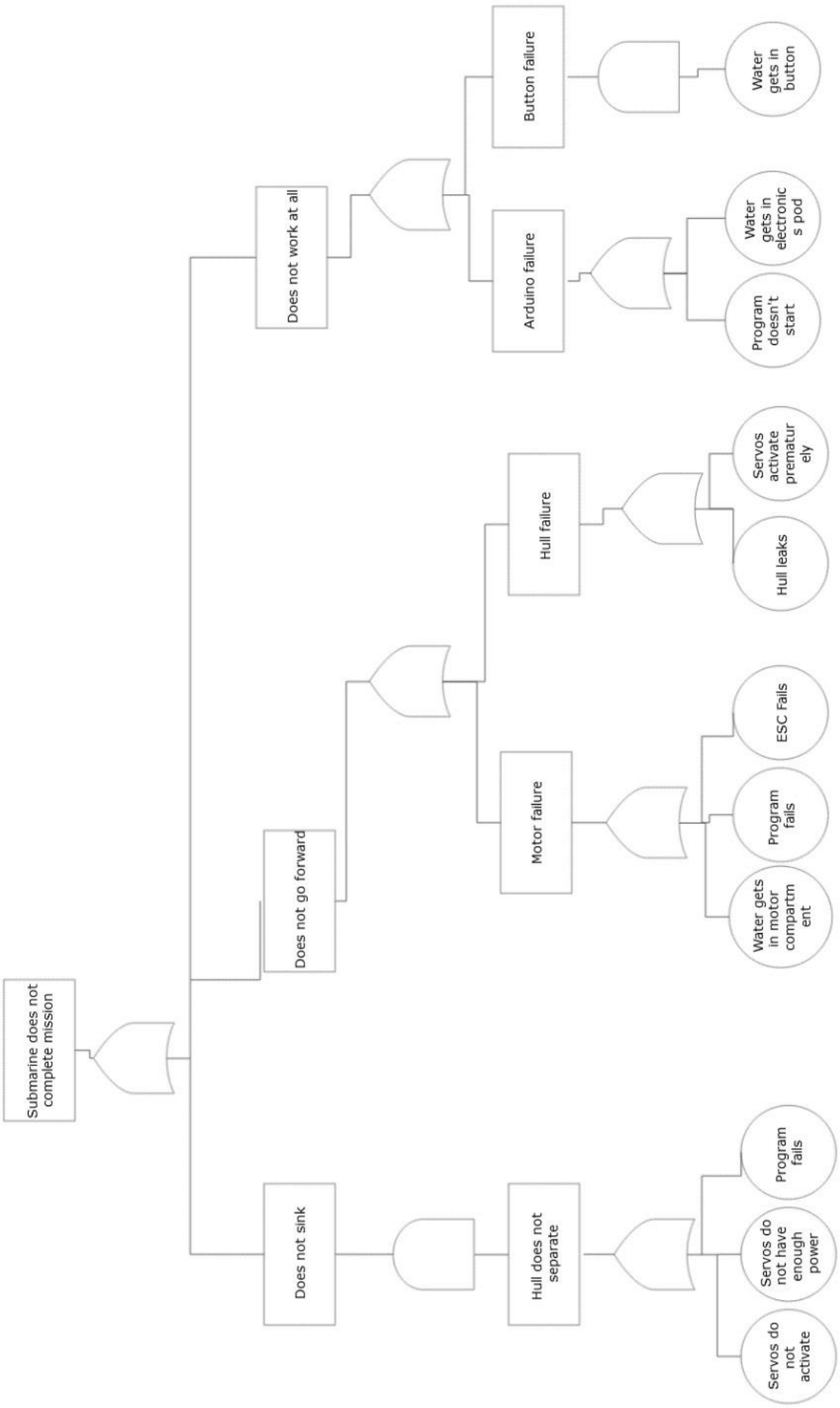
Process/Product Name: Submarine

Responsible: MECH 202 Team 9

Prepared By: Noah Schenck

FMEA Date (Orig.): 23-Apr (Rev.):

Process Step/Input	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 10)	Potential Causes	OCCURRENCE (1 - 10)	Current Controls	DETECTION (1 - 10)	RPN	Action Recommended	Resp.	Actions Taken	SEVERITY (1 - 10)	OCCURRENCE (1 - 10)	DETECTION (1 - 10)	RPN
What is the process step, change or feature under investigation?	In what ways could the step, change or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?		What causes the step, change or feature to go wrong? (how could it occur?)		What controls exist that either prevent or detect the failure?			What are the recommended actions for reducing the occurrence of the cause or improving detection?	Who is responsible for making sure the actions are completed?	What actions were completed (and when) with respect to the RPN?				
Button press to activate device	Submarine fails to activate	Complete failure to deliver submarine prototype for competition	8	Dead battery	7	Voltage check to ensure battery is supplying power	1	56	Replace battery day before competition	All team members	Checked battery voltage with multimeter before every run	8	1	5	40
			8	Wires not connected/damaged	6	Double checking all wire connections before competition	7	336	Replace wires day before competition	All team members	Shrink wrapped wires and checked before every run	8	2	6	96
			10	Water damage to electronics	5	Visual check of electronic components	2	100	Check electronics day before necessary operation	All team members	Rechecked rubber seal on electronics pod and added oil after every open	10	2	2	40
Traveling across the pool	DC Motor fails to activate	Failure to deliver on the horizontal movement	8	Wires not connected/damaged	6	Double checking all wire connections before competition	5	240	Replace wires day before competition	All team members	Shrink wrapped wires and checked before every run	8	2	5	80
			10	Water damage to electronics	5	Visual check of electronic components	7	350	Check electronics day before necessary operation	All team members	Rechecked rubber seal on electronics pod and added oil after every open	10	2	6	120
	Hull lets in water		8	Not properly waterproofed causing it to sink and drag on bottom	8	Conduct waterproofing test	2	128	Replace waterproof seal day before competition	All team members	Added rubber seal and oil to seal and tested to ensure its watertight	6	4	2	48
Diving into the pool	Servo Motor fails to activate	Failure to deliver on diving criteria	8	Wires not connected/damaged	6	Double checking all wire connections before competition	7	336	Replace wires day before competition	All team members	Shrink wrapped wires and checked before every run	8	2	6	96
			8	Water damage to electronics	5	Visual check of electronic components	2	80	Check electronics day before necessary operation	All team members	Rechecked rubber seal on electronics pod and added oil after every open	10	2	6	120
	Arms fail to raise the hull halves		8	Malfunction in the arm connections	5	Visual check of arm connections	3	120	Check arm connections before placing into pool	All team members	Checked arm movement before every run, lubricate joints	8	3	2	48
			8	Material failure resulting in arms snapping	6	Ensure strength of all arm connections	10	480	Replace arm connections day before competition	All team members	Arms thickened and extras 3D printed	8	3	10	240


Submarine does not complete mission
Does not sink
Hull does not separate
Servos do not activate
Servos do not have enough power
Program fails
Does not go forward
Motor failure
Water gets in motor compartm ent
Program fails
ESC Fails
Hull failure
Hull leaks
Servos activate prematur ely
Does not work at all
Arduino failure
Program doesn't start
Water gets in electronic s pod
Button failure
Water gets in button

List of Improvements:

- More powerful servo to power the separation of the hull
- Redundancies programmed into the code to separate the hull
- Airtight seal on motor compartment
- Airtight seal on the hull's seem
- Rubber bulb around button to keep water and dirt out
- A waterproof box to prevent leaks into the Arduino
- Waterproof electronics (servo and ESC)

Safety Analysis

If the device has a malfunction where is moves without stopping, and the motor continues to be powered after it has reached its destination, a person could potentially be injured by the spinning propeller. The hull opening is also a pinch point, as the two halves could close on a finger or other extremities, although the servo is not powerful enough to cause harm. If the device has an accidental start, such as the button being pressed out of the water or when being held, the propeller could contact someone or something and cause serious damage. This can be fixed by always being cautious when holding the device, leaving the battery disconnected until ready to deploy, and making a guard for the propeller. Overall, the device is safe, it just requires a few precautions during use to avoid harm.

Service and Support Plan

We will need to have a large supply of paper towels and Q-tips available in case any water leaks in and the submarine needs to be cleaned. We will have duct tape and super glue in order to fix any minor cracks or leaks. We will have replacement parts for the fragile pieces of the submarine, such as the arms that separate the hull and the button to start the motor. We will also keep an extra battery, Arduino, motor, esc and servos just in case any of the electronics get wet and need replacement. The device has been designed to service easily, which should make replacing these parts a simple task that any customer could accomplish.

Project Planning

Design Organization: Mech 202 Winning Team	**Date: 2/15/2020**
Product Name: Competition Prototype	

Task 1 Snapshots	**Name of Task:** Project II Concept Generation & Evaluation
	Objective: To analyze multiple prototype concepts to begin the first prototype development
	Deliverables: 3+ design concepts, evaluation of all concepts, drawings of all prototypes
	Decisions/Milestones with Dates: 1. Assembled deliverables due on Canvas by 3/10/2020
	Personnel Needed: Title: Team effortHours: 20 Percent full time: 20%
	Time: Estimated Total Hours: 15 Actual Total Hours: TBD
	Sequence: Predecessors: None Successors: Tasks 2-6 Planned Start Date: 3/3/2020 Planned Finish Date: 3/9/2020 Actual Start Date: TBD Actual Finish Date: TBD
	Costs: Capital Equipment: Computer Disposables: None
Task 2 Snapshots	**Name of Task:** Project II Working Prototype
	Objective: Create a working prototype
	Deliverables: Prototype, reverse engineering process, DSM, annotated exploded assembly
	Decisions/Milestones with Dates: 1. Assembled deliverables due on Canvas by 4/7/2020
	Personnel Needed: Title: Team effortHours: 25 Percent full time: 30%
	Time: Estimated Total Hours: 25 Actual Total Hours: TBD
	Sequence: Predecessors: Task 1 Successors: Tasks 3-6 Planned Start Date: 3/10/2020 Planned Finish Date: 4/6/2020

	Actual Start Date: TBD Actual Finish Date: TBD
	Costs: Capital Equipment Disposables: None
Task 3 Snapshots	**Name of Task:** Project II Testing Analysis
	Objective: Complete testing on prototype to ensure it meets specifications established
	Deliverables: Testing analysis report
	Decisions/Milestones with Dates: 1. Report due on Canvas by 4/21/2020
	Personnel Needed: Title: Team effortHours: 25 Percent full time: 30%
	Time: Estimated Total Hours: 25 Actual Total Hours: TBD
	Sequence: Predecessors: Task 2 Successors: Task 4-6 Planned Start Date: 4/8/2020 Planned Finish Date: 4/20/2020 Actual Start Date: TBD Actual Finish Date: TBD
	Costs: Capital Equipment: Prototype, computer Disposables: None
Task 4 Snapshots	**Name of Task:** Project II FMEA & FTA Analysis
	Objective: To analyze potential failures of prototype and variability in performance
	Deliverables: FMEA & FTA tables, safety analysis, and a service & support plan
	Decisions/Milestones with Dates: 1. All required materials due on Canvas by 4/23/2020
	Personnel Needed: Title: Team effort Hours: 15 Percent full time: 25%
	Time: Estimated Total Hours: 15 Actual Total Hours: TBD
	Sequence: Predecessors: Task 2 Successors: Task 5,6 Planned Start Date: 4/8/2020 Planned Finish Date: 4/22/2020 Actual Start Date: TBD Actual Finish Date: TBD
	Costs: Capital Equipment: Prototype, computer Disposables: None

Task 5 Snapshots	**Name of Task:** Project II Presentation
	Objective: To create an 8-10 minute presentation on the design details and supporting analysis
	Deliverables: Presentation slides
	Decisions/Milestones with Dates: 1. Presentation slides due on Canvas by 4/27/2020
	Personnel Needed: Title: Team effort Hours: 5 Percent full time: 10%
	Time: Estimated Total Hours: 5 Actual Total Hours: TBD
	Sequence: Predecessors: Tasks 1-5 Successors: Task 6 Planned Start Date: 4/23/2020 Planned Finish Date: 4/26/2020 Actual Start Date: TBD Actual Finish Date: TBD
	Costs: Capital Equipment: Computer, Prototype Disposables: None
Task 6 Snapshots	**Name of Task:** Project II Report
	Objective: To compile all work from Project II into a detailed and organized report
	Deliverables: Assembled final report
	Decisions/Milestones with Dates: 1. Report to be turned into Canvas by 5/7/2020
	Personnel Needed: Title: Team effortHours: 15 Percent full time: 25%
	Time: Estimated Total Hours: 15 Actual Total Hours: TBD
	Sequence: Predecessors: Tasks 1-6 Successors: None Planned Start Date: 4/27/2020 Planned Finish Date: 5/6/2020 Actual Start Date: TBD Actual Finish Date: TBD
	Costs: Capital Equipment: Computer, Final prototype Disposables: None

Team member: Nolan	Team member: Flynn
Team member: Trevor	Prepared by: Noah

Team member: Noah	Checked by: Trevor
Team member: Ryan	Approved by: Ryan
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Team Assessment

Team Contract

Design Organization: MECH202 Team 9 | **Date: 2/15/2020**

Team Member	Roles	Signature
Trevor	Idea Generator	Trevor Long
Nolan	Finalizer	Nolan Sherrill
Noah	Actualizer	Noah Schenck
Flynn	Actualizer	Flynn Yoder
Ryan	Diplomat	Ryan Walkowicz

Team Goals	Responsible Member
1. Generate ideas for submarine design	All members
2. Evaluate ideas for submarine design	All members
3. Create final submarine prototype	All members
4. Assess final design for safety and failures	All members
5. Test final design	All members
6. Make & implement improvements to final design	All members
7. Compete against other groups	All members

Team Performance Expectations

- Strive to complete all assigned tasks before or by deadlines
- Complete all tasks to the best of ability
- Listen carefully and attentively to all comments at meetings
- Accept and give criticism in a professional manner
- Focus on results before the fact, rather than excuses after
- Provide as much notice as possible of commitment problems
- Attend and participate in all scheduled group meetings

Initial				
FY	NS	TL	RW	NS
FY	NS	TL	RW	NS
FY	NS	TL	RW	NS
FY	NS	TL	RW	NS
FY	NS	TL	RW	NS
FY	NS	TL	RW	NS
FY	NS	TL	RW	NS

Strategies for Conflict Resolution:

- Discuss problems as they arise with team members
- Conflict resolution center

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Team Meeting Minutes

Design Organization: MECH202 Team 9	**Meeting Dates:** **4 Days Before an Assignment is due**

Agenda:

1. Sub-divide upcoming assignment into deliverable tasks
2. Begin work on assignment
3. If assignment is not finished, delegate people to finish the remainder of the assignment
4. Team members that do not actively work on certain tasks will check others work on tasks before it is turned in
5. Decide which team member will be responsible for turning in the assignment

Discussion: The discussion revolved around delegating tasks on the upcoming assignment. Once this was decided, work began until the decided time for how long the meeting was. If the assignment was not finished during the meeting, the remainder of it would be divided between group members. Once COVID-19 prevented physical meetings, they were held digitally as normal to maintain open communication as well as discussions in the team's group chat.

Decisions Made: Who works on what within the given assignments

Action Items	Person Responsible	Deadline
Project Plan	Noah, Ryan, Flynn, Nolan	2/18/2020
Gantt Chart	Trevor	2/18/2020
QFD	All team members	3/3/2020
Concept Generation	Trevor	3/10/2020
Concept Evaluation	Noah, Ryan, Flynn, Nolan	3/10/2020
Working Prototype	All team members	4/16/2020
Testing Plan	All team members	4/21/2020
FMEA	Noah, Trevor	4/23/2020
FTA	Trevor	4/23/2020
Presentation Slides	All team members	4/27/2020
Project Report	All team members	5/7/2020

Team member: Noah	Dates for all meetings: • February 14, 2020 • February 29, 2020 • March 6, 2020 • April 12, 2020 • April 17, 2020 • April 19, 2020 • April 23, 2020 • May 3, 2020
Team member: Flynn	
Team member: Ryan	
Team member: Nolan	
Team member: Trevor	
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Overall, the team worked well together. Tasks on assignments were distributed and completed on time and communication was maintained through the teams group chat. The main difficulty that plagued our progress was obviously COVID-19, as it prevented any physical meetings from happening as well as changing the project guidelines while we were working on it. It was disappointing that we never got to see our ideas come to fruition in the competition which undermined the team's motivation due to the lack of payoff at the end. All things considered, internet difficulties and lack of physical meetings aside, our team pulled together and pushed through the adversities to have a very polished outcome.

Team Health Assessment

Team Assessed: MECH202 Team 9	**Date: 5/7/2020**

SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree, NA = Not Applicable

	Measure	SA	A	N	D	SD	NA
1	Team mission and purpose are clear, consistent and attainable.	☑	☐	☐	☐	☐	☐
2	I feel that I am part of a team.	☑	☐	☐	☐	☐	☐
3	I feel good about the team's progress	☑	☐	☐	☐	☐	☐
4	Respect has been built within the team for diverse points of view.	☑	☐	☐	☐	☐	☐

5	Team environment is characterized by honesty, trust, mutual respect, and team work	☑	☐	☐	☐	☐	☐
6	The roles and work assignments are clear	☐	☑	☐	☐	☐	☐
7	Team treats every member's ideas as having potential value	☑	☐	☐	☐	☐	☐
8	Team encourages individual differences.	☑	☐	☐	☐	☐	☐
9	Conflicts within the team are aired and worked to resolution.	☑	☐	☐	☐	☐	☐
10	Team takes time to develop consensus by discussing the concerns of all members to arrive at an acceptable solution	☐	☑	☐	☐	☐	☐
11	Decisions are made with input from all in a collaborative environment.	☐	☑	☐	☐	☐	☐
12	The environment encourages communication and does not "kill the messenger" when the news is bad.	☑	☐	☐	☐	☐	☐
13	When one team member has a problem others jump in to help	☐	☑	☐	☐	☐	☐
14	Dysfunctional behavior is dealt with in an appropriate manner	☑	☐	☐	☐	☐	☐
15	When someone on the team says they are going to do something, the team can count on it being done.	☐	☑	☐	☐	☐	☐
16	There is no "them and us" on the team	☑	☐	☐	☐	☐	☐
17	Our team cultivates a "what we can learn" attitude when things do not go as expected.	☐	☑	☐	☐	☐	☐

Remedies for improving the Neutral (N), Disagree (D) and Strongly Disagree(SD) responses:

N/A

Assessor: Noah Schenck	

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Team Health Assessment

Team Assessed: MECH202 Team 9	Date: 5/7/2020

SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree, NA = Not Applicable

	Measure	SA	A	N	D	SD	NA
1	Team mission and purpose are clear, consistent and attainable.	○	☐	☐	☐	☐	☐
2	I feel that I am part of a team.	○	☐	☐	☐	☐	☐
3	I feel good about the team's progress	○	☐	☐	☐	☐	☐
4	Respect has been built within the team for diverse points of view.	○	☐	☐	☐	☐	☐
5	Team environment is characterized by honesty, trust, mutual respect, and team work	☐	○	☐	☐	☐	☐
6	The roles and work assignments are clear	☐	○	☐	☐	☐	☐
7	Team treats every member's ideas as having potential value	○	☐	☐	☐	☐	☐
8	Team encourages individual differences.	○	☐	☐	☐	☐	☐
9	Conflicts within the team are aired and worked to resolution.	☐	○	☐	☐	☐	☐
10	Team takes time to develop consensus by discussing the concerns of all members to arrive at an acceptable solution	○	☐	☐	☐	☐	☐
11	Decisions are made with input from all in a collaborative environment.	○	☐	☐	☐	☐	☐
12	The environment encourages communication and does not "kill the messenger" when the news is bad.	○	☐	☐	☐	☐	☐
13	When one team member has a problem others jump in to help	○	☐	☐	☐	☐	☐
14	Dysfunctional behavior is dealt with in an appropriate manner	☐	○	☐	☐	☐	☐

15	When someone on the team says they are going to do something, the team can count on it being done.	☐	☐	☐	☐	☐	☐
16	There is no "them and us" on the team	☐	☐	☐	☐	☐	☐
17	Our team cultivates a "what we can learn" attitude when things do not go as expected.	☐	☐	☐	☐	☐	☐

Remedies for improving the Neutral (N), Disagree (D) and Strongly Disagree(SD) responses:

N/A

Assessor: Flynn Yoder	

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Team Health Assessment

Team Assessed: MECH202 Team 9	**Date: 5/7/2020**

SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree, NA = Not Applicable

	Measure	SA	A	N	D	SD	NA
1	Team mission and purpose are clear, consistent and attainable.	☑	☐	☐	☐	☐	☐
2	I feel that I am part of a team.	☑	☐	☐	☐	☐	☐
3	I feel good about the team's progress	☑	☐	☐	☐	☐	☐
4	Respect has been built within the team for diverse points of view.	☑	☐	☐	☐	☐	☐
5	Team environment is characterized by honesty, trust, mutual respect, and team work	☑	☐	☐	☐	☐	☐
6	The roles and work assignments are clear	☑	☐	☐	☐	☐	☐
7	Team treats every member's ideas as having potential value	☑	☐	☐	☐	☐	☐

8	Team encourages individual differences.	☑	☐	☐	☐	☐	☐
9	Conflicts within the team are aired and worked to resolution.	☑	☐	☐	☐	☐	☐
10	Team takes time to develop consensus by discussing the concerns of all members to arrive at an acceptable solution	☐	☑	☐	☐	☐	☐
11	Decisions are made with input from all in a collaborative environment.	☐	☑	☐	☐	☐	☐
12	The environment encourages communication and does not "kill the messenger" when the news is bad.	☑	☐	☐	☐	☐	☐
13	When one team member has a problem others jump in to help	☑	☐	☐	☐	☐	☐
14	Dysfunctional behavior is dealt with in an appropriate manner	☑	☐	☐	☐	☐	☐
15	When someone on the team says they are going to do something, the team can count on it being done.	☑	☐	☐	☐	☐	☐
16	There is no "them and us" on the team	☑	☐	☐	☐	☐	☐
17	Our team cultivates a "what we can learn" attitude when things do not go as expected.	☑	☐	☐	☐	☐	☐

Remedies for improving the Neutral (N), Disagree (D) and Strongly Disagree(SD) responses:

N/A

Assessor: Trevor Long

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Team Health Assessment

Team Assessed: MECH202 Team 9	**Date: 5/7/2020**

SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree, NA = Not Applicable

	Measure	SA	A	N	D	SD	NA
1	Team mission and purpose are clear, consistent and attainable.	☑	☐	☐	☐	☐	☐
2	I feel that I am part of a team.	☑	☐	☐	☐	☐	☐
3	I feel good about the team's progress	☑	☐	☐	☐	☐	☐
4	Respect has been built within the team for diverse points of view.	☑	☐	☐	☐	☐	☐
5	Team environment is characterized by honesty, trust, mutual respect, and team work	☑	☐	☐	☐	☐	☐
6	The roles and work assignments are clear	☑	☐	☐	☐	☐	☐
7	Team treats every member's ideas as having potential value	☑	☐	☐	☐	☐	☐
8	Team encourages individual differences.	☑	☐	☐	☐	☐	☐
9	Conflicts within the team are aired and worked to resolution.	☑	☐	☐	☐	☐	☐
10	Team takes time to develop consensus by discussing the concerns of all members to arrive at an acceptable solution	☑	☐	☐	☐	☐	☐
11	Decisions are made with input from all in a collaborative environment.	☐	☑	☐	☐	☐	☐
12	The environment encourages communication and does not "kill the messenger" when the news is bad.	☑	☐	☐	☐	☐	☐
13	When one team member has a problem others jump in to help	☑	☐	☐	☐	☐	☐
14	Dysfunctional behavior is dealt with in an appropriate manner	☑	☐	☐	☐	☐	☐
15	When someone on the team says they are going to do something, the team can count on it being done.	☑	☐	☐	☐	☐	☐
16	There is no "them and us" on the team	☑	☐	☐	☐	☐	☐
17	Our team cultivates a "what we can learn" attitude when things do not go as expected.	☑	☐	☐	☐	☐	☐

Remedies for improving the Neutral (N), Disagree (D) and Strongly Disagree(SD) responses: N/A	
Assessor: Nolan Sherrill	
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Team Health Assessment

Team Assessed: MECH202 Team 9	**Date: 5/7/2020**

SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree, NA = Not Applicable

	Measure	SA	A	N	D	SD	NA
1	Team mission and purpose are clear, consistent and attainable.	OBJ	☐	☐	☐	☐	☐
2	I feel that I am part of a team.		☐	☐	☐	☐	☐
3	I feel good about the team's progress	☐		☐	☐	☐	☐
4	Respect has been built within the team for diverse points of view.		☐	☐	☐	☐	☐
5	Team environment is characterized by honesty, trust, mutual respect, and team work		☐	☐	☐	☐	☐
6	The roles and work assignments are clear	☐		☐	☐	☐	☐
7	Team treats every member's ideas as having potential value		☐	☐	☐	☐	☐
8	Team encourages individual differences.		☐	☐	☐	☐	☐
9	Conflicts within the team are aired and worked to resolution.		☐	☐	☐	☐	☐
10	Team takes time to develop consensus by discussing the	☐		☐	☐	☐	☐

	concerns of all members to arrive at an acceptable solution						
11	Decisions are made with input from all in a collaborative environment.	☐		☐	☐	☐	☐
12	The environment encourages communication and does not “kill the messenger” when the news is bad.		☐	☐	☐	☐	☐
13	When one team member has a problem others jump in to help	☐		☐	☐	☐	☐
14	Dysfunctional behavior is dealt with in an appropriate manner		☐	☐	☐	☐	☐
15	When someone on the team says they are going to do something, the team can count on it being done.		☐	☐	☐	☐	☐
16	There is no "them and us" on the team		☐	☐	☐	☐	☐
17	Our team cultivates a "what we can learn" attitude when things do not go as expected.	☐		☐	☐	☐	☐

Remedies for improving the Neutral (N), Disagree (D) and Strongly Disagree(SD) responses:

N/A

Assessor: Ryan Walkowicz	

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