ALKA SELTZER SUBMARINE

MECH 202 – Group 6

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Design Problem Statement

The students of the MECH 202 Mechanical Engineering Design class of Fall 2020 were tasked with planning, building, and optimizing a submarine to race near the end of the semester. Groups oversaw the whole design process for the submarine which included: team dynamics, time management, project oversight, analyzing competitors, hands-on building, testing and optimization, and the performance of device. Listed are requirements for the project

- Students can spend no more than 100 dollars on the project.
- Students must build a device within the dimensions 9 inches (length) x 6 inches (width) x 5 inches (height).
- Students must be safe and not use any hazardous energy to power device and cannot pollute the water with any fluids from device.
- Students may not use any biological materials.
- Students' device cannot change dimensions throughout the race by more than 1 inch in any direction.

The race consisted of a competition fixture as seen below in Figure 1, which would be filled with four feet of water. The submarines designed by the students would race each other in these fixtures (one for each team) and a double elimination tournament would determine who designed the fastest submarine. Each race consists of a 45 second buoyancy check of the device at which point the TA would say go and both teams would do one action to activate their device.

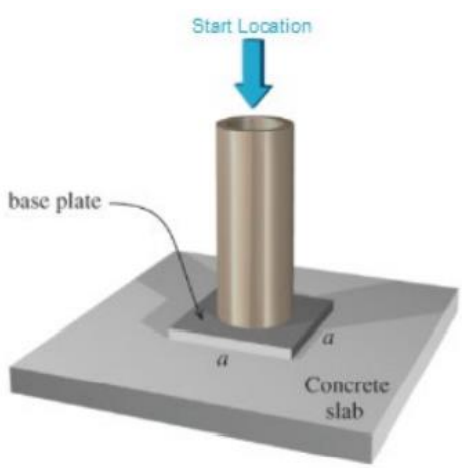

FIGURE 1 COMPETITION FIGURE [6]

The project allowed students to learn how to effectively plan the research and development of a product while maintaining good team dynamics, and this project teaches effective research and development practices which will be useful in the engineering field.

Specifications Development

Competitive Analysis

The team used a Quality Function Development template to perform a competitive analysis of several submarine designs. The analysis ranked each design idea on a 0 to 5 scale (5 being the best) in demanded qualities by customers, and those qualities include waterproofing, durability, competitive factor, ease of use, aesthetics, efficiency, cost, and reliability. Below is each design idea in each of the demanded categories.

Competitive Analysis
(0=Worst, 5=Best)

Alka Seltzer Device	Propellor Driven	Flipper driven	Water Influx Device	Bag of Rocks with a Balloon	Compressed Air Device
5	2	2	2	0	2
5	3	3	3	5	3
3	5	4	1	1	4
4	5	5	5	0	2
1	5	5	1	0	2
4	4	4	2	1	2
5	3	3	4	5	2
5	2	1	3	0	4

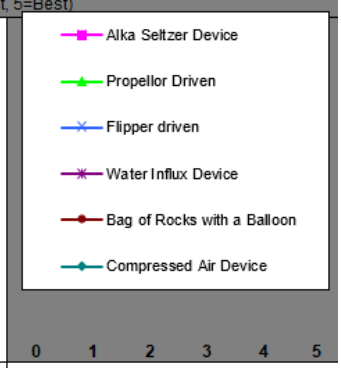

FIGURE 2. COMPETITIVE ANALYSIS PORTION OF THE QUALITY FUNCTION DEVELOPMENT

Alka Seltzer Device

Waterproof (5) – An Alka Seltzer Device would need to have a water intake system to bring water into the device, therefore the device will most likely adjust the buoyancy of the device. Since the Alka seltzer would need to be activated after it has sunk, the device would be

needed to have a systematic way of when to let water in. The only waterproofing need would exist on the inlet air value on the top of the device.

Durability (5) – The Alka seltzer device ranks the highest because of the minimal change in the control volume of the internal compartment of the device. Unlike a device that has fast moving components that would wear with time, an Alka seltzer device can take in water then expel it with a chemical reaction.

Competitive Factor (3) – Since the device does not have a propellent force downward, the time at which it sinks, and rises is dependent on the weight of the device. Furthermore, the internal compartment takes time to fill to begin the sinking process, and for the rising process to begin the Alka seltzer must activate and push the water out of the device. These two factors in combination result in a reliable, but not competitive device.

Ease of Use (4) – The device is simple and easy to use minus a couple components. The user will be able to push a button to allow the device to sink, and after every descent the device can be reset by putting more Alka seltzer tablets in the device. With no electrical components the user will never have to try to troubleshoot faulty electronical parts. Drying the compartment where the Alka seltzer sits is a necessary extra step for the device to work properly and makes the user experience with the device less smooth.

Aesthetics (1) – The Alka seltzer device is a buoyant container and has no flashy motors or electrical components, therefore the Alka seltzer device scores a 1 in this category.

Efficiency (4) – The efficiency of any device is how compact the device is, and how much time it takes to operate. Any good product for a user is compact, easy to carry, and values the time of the user (fast reload time or operating time). An Alka seltzer scores highly in both categories. The device needs Alka seltzer put in after each run which is a quick singular action, and the device utilizes a one button press start.

Cost Effective (5) – With no electrical components needed, the device becomes very cost efficient. Alka seltzer tablets are inexpensive and the housing of the device would make up the bulk of the device.

Reliability (5) – With other submarine devices, if their electronics are exposed to water the device will not work, and the Alka seltzer device remedies this problem by using an influx of water as the primary activating agent for it to sink and rise. Without a possibility of short-circuiting electrical components, the Alka seltzer device proves to be a reliable option to a high degree.

Propeller Design

Waterproofing (2) – This category evaluates the necessity of a device to be waterproofed. For any devices using electrical components the score will be lower because the device will need to prioritize water proofing of several electrical components. For a propeller design the Arduino, electronic speed controller, and the power supply will need to be waterproofed or housed in a sealed compartment while having wires run to the waterproof motors. This is a difficult design obstacle and can hinder other parts such as reliability.

Durability (3) – A propeller device will fail if water reaches components in the waterproofed compartments holding the electronic components. For example, in the competition water had breached a sealed compartment and destroyed many of the electrical components making the device fail.

Competitive Factor (5) – With a propellent force pushing the device downward and letting the buoyancy of the device bring it back to the surface, there is no lag time where the device is sitting at the top or bottom. Additionally, a more expensive motor will yield a substantial increase in speed to the bottom.

Ease of Use (5) – The waterproofed electronics allow the user to activate the device with a press of a button. Extremely easy to use and user friendly.

Aesthetics (5) – A propeller design would house electronics with wires wrapping around the container to each motor and having dual motors would give a ‘powerful’ look to the device and will be aesthetically pleasing to many people.

Efficiency (4) – The operating time is quick, and the features of the device are easy to use which enables the user to begin using the product right away at the press of a button. The device did not score a 5 because housing all the electrical components in a waterproof compartment will ultimately take away from the available space within the given dimensions.

Cost Effective (3) – The main components of this design: power supply, motors, and electronic speed controllers. One can purchase cheaper electronics for this design at the cost of a slower device. The more expensive the motor the faster it will go.

Reliability (2) – Two concerns of this designs’ reliability: stability within water and waterproofing the electronics. The electronics can be properly waterproofed, but stability in water is something of a concern. For the device to properly work the device needs to be propelled in a straight downward direction and cannot have any outside forces interact with the body. For example, if the device is moving downward and because of waves on the surface it causes is to rotate. The possibility of an overturning couple compromising the stability of the device is high.

Flipper Device

Waterproofing (2) – Waterproofing will need to be done for the electronics are not destroyed. If the slightest amount of water interacting with an electrical component, the water will act as a n conductor and short circuit part or all the component resulting in failure. Waterproofing for the flipper design scores a low 2 because of the liability it presents.

Durability (3) – The robust nature of the design is weakened with the use of electrical components. Possibility of failure is moderate to high considering the device will be submerged and experience variable pressure which could cause water to reach electrical components.

Competitive Factor (4) – The device uses a propellent force to reach the bottom of a control volume of fluid. The only reason competitive factor score is not a five is because propellers do this more effectively than flippers.

Ease of Use (5) – The ignition of the device is a button that would initiate the flippers and start flipping. The device only requires this singular action making the device simple and easy to use.

Aesthetics (5) – The flippers could be colored yellow and the device could be shape like a duck, and the device would be 'cute.' The flipper design is the only design that could be adapted into an animal submarine. This is the biggest pro of the flipper design.

Efficiency (4) – Most electronic devices in general use the press of a button of flipping a switch to complete a circuit to perform the desired operation. In this case a button push would be easy for the user to complete, and the device would do the rest.

Cost Effective (3) – Electrical components will increase the cost of manufacture and retail prices. This device will not be the most cost effective due to the electronics.

Reliability (1) – The flipper design suffers from the same concerns shared with the propeller design. First, if water compromises the electronics of the device it will not only fail, but it will ruin the functionality of the device. Second, keeping the device stable and moving in a straight downward line is hard to ensure.

Water Influx Device

Waterproofing (2) – A water influx device will use electronic pumps to pull water into a sealed container and then expel the water using another pump to have the device rise to the surface. The electronic pumps will require an Arduino, power supply, and an electronic button. All three of the electronics will need to be properly waterproofed to avoid failure.

Durability (3) – Electronic pumps used in a water influx device are built to remain in water and are robust within this environment. However, the electronics speed controller, Arduino, and the power supply are still a liability if water reaches them. To restate, since the electronic components are in water the duration of the device operation, possibility of them getting exposed to water cannot be overlooked. This makes the device less durable.

Competitive Factor (1) – Many small electronic pumps are limited by volumetric flow rate it can operate at. For example, a moderately priced pump is 10.99$ and its volumetric flow rate is 200 liters per hour [1]. After some calculations it would take 30-40 seconds for the pump to fill a submarine device to sink and rise, and this results in a durable but slow submarine device.

Ease of Use (5) – This device will require one singular action to activate the device such as a button press, and subsequently the device will sink and rise. Device is easy to use.

Aesthetics (1) – The device would be housed in a square like container with most of the internal components being hidden from the user. Device would be a submarine box and would not be aesthetically pleasing.

Efficiency (2) – Having one pump to bring in water and one to pump water the device operates slow and is not efficient in its design. Also, many pumps require a 12- or 18-volt voltage source which would take up space in the submarine.

Cost Effective (4) – The design only requires two pumps, Arduino, and a power source. Pumps are relatively cheap but getting the correct power supply for the device to work will cost more money. More expensive pumps will have a better volumetric flow rate but will increase in size.

Reliability (3) – Once the pumps are properly fitted in the container the device will be reliable to a degree. The pumps will perform the correct action every time, but if water breaches any of the other electronic components, the device will fail.

Compressed Air Device

Waterproofing (2) – This device also incorporates electronic devices; water cannot be able to meet such components. Waterproofing will need to be done on the device and if done improperly could result in a device failure.

Durability (3) – Since the device will most likely use electronics their durability is medium for a compressed air device. However, the main activating agent of this device is air rather than a propellent force from an electrical motor or flipper and is the reason it scores a three in this category.

Competitive Factor (4) – A compressed air device will be able to expel water easily of fill up a volume with an elastic material such as a balloon, and there is minimal lag time in doing so making a compressed air device competitive.

Ease of Use (2) – A compressed air device would require the exchange of CO_2 canisters after runs or the user must pump up a refillable canister with a pump. Both require the user to be involved after every test run or every couple which yields a lower score in the ease of use category.

Aesthetics (2) – Most of the interworking of the device would be housed in a container and would not be visible to the user. It would most likely be capsule or square shaped leading to a visually unappealing device.

Efficiency (2) – Since the air canisters would require attention after every couple of runs, the fluidity of the operations would not be smooth and would deter the user to setting up the device for another trial.

Cost Effective (2) – The design would require the purchase of reusable air canisters and serval electronic components. The device would not be cost effective to manufacture.

Reliability (4) – Reliability goes in hand with the durability of the device, and as mentioned above the compressed air is the primary activating agent within the device. The compressed air can be exposed to water without being destroyed, although other electronic components remain a liability.

Quality Function Deployment

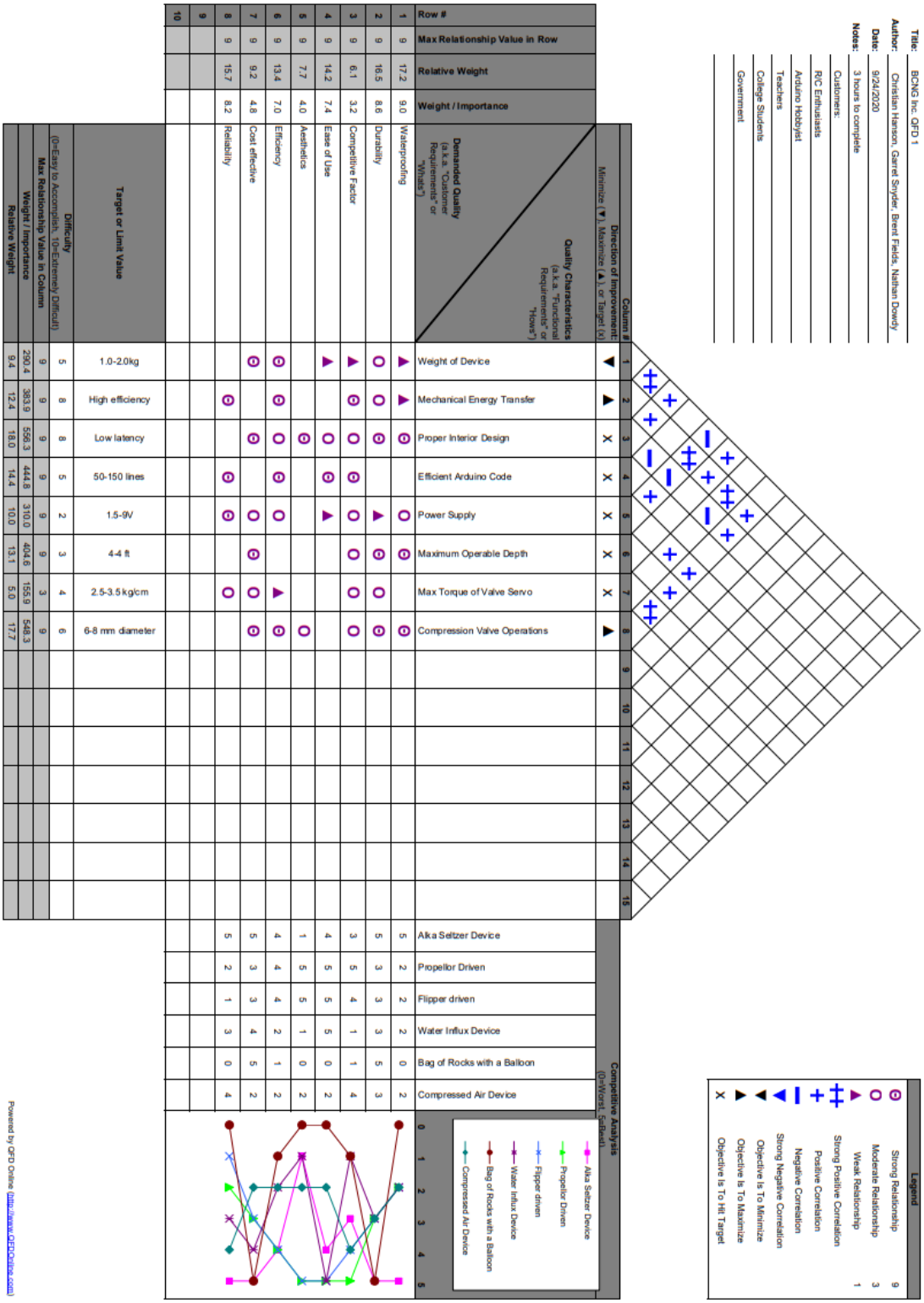

FIGURE 3. QUALITY FUNCTION DEVELOPMENT

Target Customers

The potential target customers the team decided to focus on are as listed:

- Teachers
- Children
- MECH 202 Engineering Class

Teachers could use the designed submarine device to teach students about buoyancy, floatation, and stability. When a submarine is placed in the water, it is met with a buoyancy force, and if an object overcomes this force it will not float but sink. Buoyancy force is the basis of how objects float in water. Stability is determined by the volume of the object. Long objects with weight unevenly distributed will rotate in water due to an overturning moment. Furthermore, submarines are appealing to children. A child could take a submarine toy to the pool and be satisfied for hours. Finally, the target group the team focused on was the MECH 202 engineering class. The team utilized the supplies provided to the students to meet the dimensions set out by the instructor for the course.

Specifications

For analyzing different design ideas, the group came up with eight demanded qualities that customers want as seen in Figure 2:

1. Waterproofing
2. Durability
3. Competitive Factor
4. Ease of Use
5. Aesthetics
6. Efficiency
7. Cost Effective
8. Reliability

These qualities were compared to eight engineering characteristics of the submarine device as seen in Figure 2 (in parenthesis are Target or Limit Values):

1. Weight of Device (1.0-2.0 kg)
2. Mechanical Energy Transfer (High Efficiency)
3. Proper Interior Design (Low Latency)
4. Efficient Arduino Code (50-150 lines)
5. Power Supply (1.5-9 V)
6. Maximum Operable Depth (4 ft)
7. Max Torque on Servo (2.5-3.5 kg/cm)
8. Compression Value Operations (6-8 mm Diameter)

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Weight of Device	Mechanical Energy Transfer	Proper Interior Design	Efficient Arduino Code	Power Supply	Maximum Operable Depth	Max Torque of Valve Servo	Compression Valve Operations
1	9	17.2	9.0	Waterproofing	▲	▲	⊖		O	⊖		⊖
2	9	16.5	8.6	Durability	O	O	⊖		▲	⊖	O	⊖
3	9	6.1	3.2	Competitive Factor	▲	⊖	O	⊖	O	O	O	O
4	9	14.2	7.4	Ease of Use	▲		O	⊖	▲			
5	9	7.7	4.0	Aesthetics			⊖					O
6	9	13.4	7.0	Efficiency	⊖	⊖	O	⊖	O		▲	⊖
7	9	9.2	4.8	Cost effective	⊖		⊖		O	⊖	O	⊖
8	9	15.7	8.2	Reliability		⊖		⊖	⊖		O	
9												
10												

FIGURE 4. DEMANDED QUALITY BY CUSTOMER AND ENGINEERING CHARACTERISTICS

Waterproofing

The waterproofing category rates a device based on how many components cannot be exposed to water because this factors into how safe and durable the device is. For example, a device that uses no electronics would not need much if any waterproofing done which in the eyes of a consumer is safety-safety in their investment and during use. On the other hand, let us say a submarine device uses electrical components and is priced on the lower end of the small-scale submarine market. A consumer could buy it and then drop it accidentally after two weeks of use and a crack forms making the device unusable, or the manufacturer did not seal a compartment well and water breached the electronic parts of the device. The amount of necessary waterproofing can make the customer more hesitant to purchase.

Durability

The durability category rates how robust the device inner workings and container are. How many parts make up the device and how the components wear down over time is a key aspect of how durable a device can be. Customers are more likely to invest money towards a product that will perform the desired task hundreds, thousands of times without failure or visible

wear. The group analyzed different design ideas and determined whether it would be durable or not. For example, if a device had many moving mechanical parts that were fragile and could become misaligned due to it being dropped it got a lower score. Durability is highly sought after within the consumer market.

Competitive Factor

The competitive factor is sometimes the most advertised aspect of a product. In this case different submarines can boast faster rise and sink times or maximum torque specifications to boast the best performance. Many products have great performance, but lack in other areas such as reliability which is why all eight of these demanded qualities must be present to make a great product. Competitive factors weighed heavily for the group to decide which idea to choose because of the MECH 202 Submarine Competition that we participated in.

Ease of Use

Many customers can be turned away from products that are too difficult to use, and therefore this category remains important. Once customers have invested money into something they are expected not to invest much time into the product working properly, and this is why some products will say “Batteries Included” so the user can be using the product within minutes of getting it. Ease of use and efficiency goes hand and hand. A product that requires five different steps to turn on is frustrating to a customer

Aesthetics

This quality is not related to any other quality but is important to the consumer. A device that looks more pleasing will not have a greater chance on winning the competition, but groups must still consider how it would look if their design were for sale.

Efficiency

Efficiency corresponds to the amount of parts listed on the bill of materials. A more effective device will be able to build a reliable device with less parts rather than more. Efficiency directly relates with being cost effective as having less parts will amount to a lower final cost. Efficiency relates with the engineering characteristic Proper Interior Design. A team will

struggle with having a good interior design with having to fit more parts with a constricted space which results is a less durable design-device could be dropped and jostle all internal parts making the device fail.

Cost Effective

The final cost of the device determines how cost effective the device is. If the cost is lower, the team built the device cost effectively, but if the cost is higher, the team was not cost effective with their design. Overall manufacture costs need to have a reference point to quantify the high or low regions of spending, and in this case the budget for the submarine was one hundred dollars. Anything under fifty dollars would quantify as cost effective while anything closer to the budget spanning towards over budget would range on the one to five scale (See Figure 1).

Reliability

After successive tests of a product, how many are successively? This is the main question regarding the reliability of a device, and the group analyzed the risk of different ideas to interpret approximately how successful a device will be through successive tests. For example, a propeller design has two factors of risk: housing electronic components and maintaining stability throughout the rise and sink process. They will fail if water breaches the electronics or if the center of pressure and centroid of the device are not properly calculated when designing the container of the device. As mechanical engineers design products, they analyze risk associated with the design to make sure the design is reliable. Reliability connects with other categories such as durability and waterproofing. Devices built with stronger components minimize the chance of failure and waterproofing electrical components does the same. Customers will not purchase any product if it cannot reliably do the desired operation. The competition requires reliable successive tests because each group will race up to five times and will lose if the device fails one of the races.

Customer Requirements

Customer Requirements	
Design Organization: BCNG Inc.	**Date: 12/2020**
Product: Alka Seltzer Device	
Who: Students from MECH 202 Engineering Class	
1. Who are the primary users of the product? Students from MECH 202 2. What skills or education will the primary users have? Teachers could use the designed submarine device to teach students about buoyancy, floatation, and stability. When a submarine is placed in the water it is meet with a buoyancy force, and if an object overcomes this force is will not float but sink. 3. Describe any primary user physical conditions that affect the design of the product. How the submarine is activated i.e. how many actions does it take to work the device (Ease of Use) 4. Who will purchase the product? If they design were for sale probably teachers would buy it to teach basic fluid mechanic concepts. 5. Who else is a stakeholder in the design of the product? CSU Mechanical Engineering Department 6. Describe any cultural practices or customs related to the product. A cultural practice would be competition and races. The designs could be purchased and raced against each other providing a fun competitive environment. 7. How much is the purchaser willing to pay for the product? 40$ 8. How much is the user willing to pay to operate the product? 5$ 9. How much is the user willing to pay to maintain the product? 0$	
How: Designed for optimization and competition	
1. For what specific purposes will the product be used? To race against other designs 2. What is the current process used? Testing, Optimization, and Engineering Design for ultimately racing the design 3. How often will it be used? Once Every few days 4. How long will it be used each time? 30 mins 5. Describe the quality expected by the user. Reliability in successive runs of the device 6. How far, how often and in what way will product be transported? Maybe a couple miles by car	
Where:	
1. Describe the surroundings for normal use. Outdoor/Indoor setting 2. Describe the noise, weather, temperature, or other environmental factors that may affect the design of the product. If used outside, exposed to rain, dirt, varying temperatures 3. Describe any size or weight limitations. Constrained Dimensions 9in x 5in x 4in 4. Describe the aesthetics of the use surroundings. Sunny, green, carpeted, walls all around 5. Describe the energy available when the product is in use. Energy available is the user, possibly a wall outlet	

Customer Requirements (include how well the product fulfills each requirement):	
1. Waterproofing 2. Durability 3. Competitive Factor 4. Ease of Use 5. Aesthetics 6. Efficiency 7. Cost Effective 8. Reliability	
Who Else (List other products that fulfill the requirements)**?**	
1. Remote Controlled Submarine 2. Wind up Submarine	
Team member: Nate Dowdy	
Team member: Garret Snyder	Prepared by: Nate Dowdy
Team member: Brent Fields	Checked by: Garret Snyder
Team member: Christian Hanson	Approved by: Christian Hanson
The Mechanical Design Process Designed by Professor David G. Ullman Copyright 2018 Form # 16	

Tradeoffs

The Quality Function Development Template allowed the team to analyze some tradeoffs between demanded qualities from customers and engineering characteristics associated with the device. Tradeoffs can be seen in the Figure 4 below.

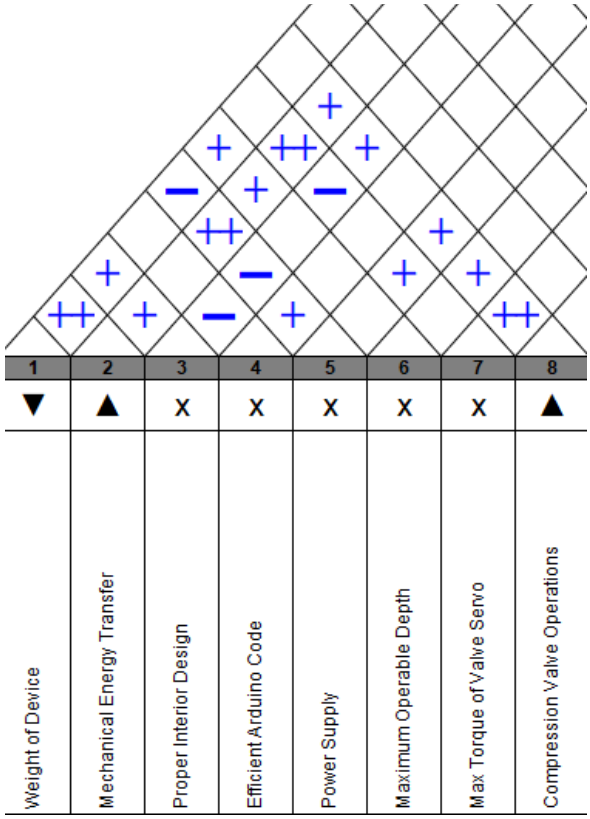

FIGURE 5. SPECIFIC TRADEOFFS FROM QUALITY FUNCTION DEPLOYMENT

The weight of the device has a positive correlation with mechanical energy transfer and proper interior design. With a placement of interior parts, the weight will be properly displaced to create stability in the device as it sinks in the water and same goes for mechanical energy transfer. The weight of the device is inversely proportional to the power supply because a bigger power supply would increase the weight of the device. As the max torque of a servo increases the size and power supply increase is size which is negatively correlated with a good interior design. Ideally, the submarine can operate with smaller parts to stay with dimensions of the competition. Tradeoffs highlighted through this process aided in choosing a concept to devote the semester to.

Competitors

Remote Controlled Submarine Toy

Figure 5 shows a competitor's product the team researched. It relied heavily on electrical component to rise, sink, drive forward, and drive backward.

FIGURE 6. REMOTE CONTROLLED SUBMARINE [2]

Many submarines available on the market for children are of this nature utilizing a remote to controller a submarine in water with ease. Although this submarine is an ideal design, the team's resources could not provide a perfectly casted plastic container to house the device and would go over budget. The number of similar devices on the market highlights the pleasing aesthetic nature of a toy submarine, and how the inclusion of remote controls appeals to customers.

Wind up Submarine

Figure 6 features a submarine geared towards kids of younger ages and is fully mechanical with wind up gears and no electronics.

FIGURE 7. WIND UP SUBMARINE [1]

This specific kind of submarine intrigued the team as it did not utilize any electronic within the design. The propeller would be wound up with a handle located on the side or bottom of the device, and once wound up the submarine would drive around a pool of water with no controlled sense of direction. After research is was no determined how the device sink and rises back up to the top, but the group speculated the user would forcibly push it to the bottom of a pool of water and the device would rise as the submarine is always buoyant. This stirred some interesting ideas within the group such as getting a buoyant object then have one team hit it with enough force to hit the bottom and rise back up to the top. The group ultimately decided that designing a device that can operate more independently from the user was more beneficial.

Research

Buoyancy, Flotation, and Stability

Every team member in the group was concurrently taking Fluid Dynamics (MECH 342) at the time of designing this project, and many of the research and concepts used for our device were based on equations and topics from the class.

The buoyant force is defined in Equation 1 below by Archimedes Principle.

$$F_B = \gamma V \tag{1}$$

Munson defines the buoyancy force: “the buoyant force has a magnitude equal to the weight of the fluid displaced by the body and is directed vertically upward.” [2] From his definition the group decided a change of weight device will be the most reliable option, and the only way to change the weight of a device is to bring in water into the device changing the buoyancy force anting on the device. The water displaced by the device decreases as the water is let into a device essentially decreasing the volume of the device and lowering the buoyancy force (Equation 1).

A stability issue arose when testing the first prototype of the final design (Figure 16). The device would rotate while it was sinking towards the bottom, and our one-way value would not activate causing it to stay at the bottom of the tank. It was imperative that the design hit the bottom of the tank the right way. The team discovered it was a stability problem and with the weight at either side of the device it created a moment arm with the centroid and center of gravity in the same point, Figure 7 from Munson’s textbook explains the importance of this concept.

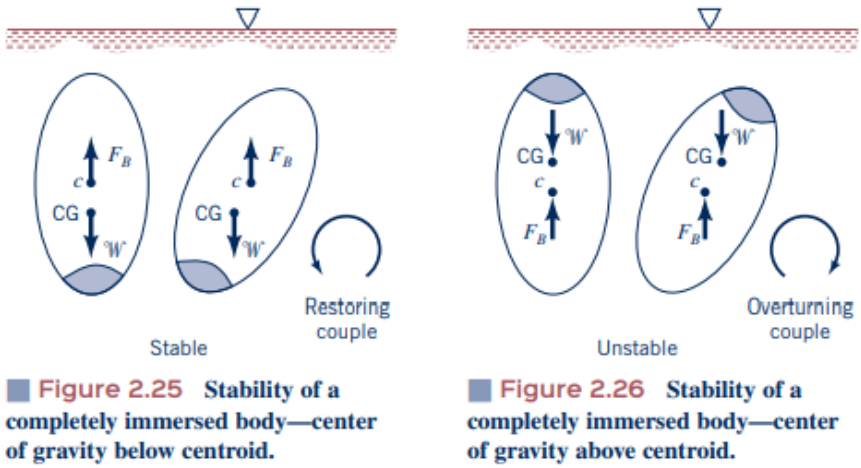

Figure 2.25 **Stability of a completely immersed body—center of gravity below centroid.**

Figure 2.26 **Stability of a completely immersed body—center of gravity above centroid.**

FIGURE 8. STABILITY OF A BODY IN WATER [2]

If the centroid is above the center of gravity the device will have restoring couple that will maintain the original orientation of the object, and if the centroid is below the center of gravity the weight of the object will cause an overturning moment which will cause the device to rotate. Researching and being familiar with these concepts before designing helped us determine what concepts would work, and when unexpected things happened within testing, the background we all had allowed us to diagnose the issue with engineering knowledge. Other research was done on current competitors for submarines (Page 23-24).

Concept Generation & Selection

Morphology			
Product: Submarine design Competition		Organization Name: BCNG Inc.	
Function	Piston Device	CO2 Canister	Propeller
Power Supply	Battery	Battery	Battery
Fuselage	PVC	PVC	PVC
Electronics	Arduino, Servo Motor	Arduino, Linear Actuator	Arduino, Dual Drive Electric Motor
Sinking Mechanism	Water Intake System	Vacuum Seal/Weight	Propeller
Floating Mechanism	Compressed Air	CO2 Gas Container	Propeller
Team member: Nate	Team member: Nate	Prepared by: Nate	
Team member: Garret	Team member: Brent		

The Mechanical Design Process
Designed by Professor David G. Ullman

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Form # 15

Several designs were considered throughout the duration of this project. It begins with an electronically controlled propeller device, then over time migrated to a simple mechanical device that's operation is based on a chemical reaction. The first three concepts were developed during the initial project planning stage of the project. The other concepts were developed throughout the course of this project as the group discovered problems with initial concepts.

Propeller Device (Concept 1)

This concept is the first concept that the group begin to get more serious about. The propeller design is based on the idea that two propellers were connected to a motor which would move the submarine up and down in the water. The device consists of two propellers of a given pitch and diameter powered by a waterproof motor that is controlled by an Arduino, that is powered by a battery. The device has a float on the top that will keep it buoyant prior to starting the motor. Propellers will have to provide a force that is greater than the buoyant force at maximum depth in order to hold the device at the bottom of the tank. To keep the device perpendicular to the tank floor as it travels down, trim pieces and weights will be used. During the rising operation of this device, three options were considered; reversing polarity to the motor in order to reverse motor output, cutting the motor entirely so that it rises based on the float, or having two separate motors, one for going down and one for going back up.

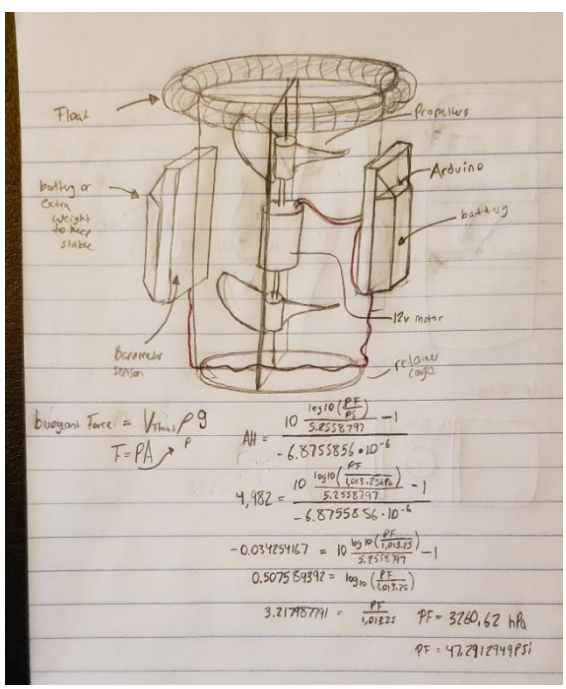

FIGURE 9

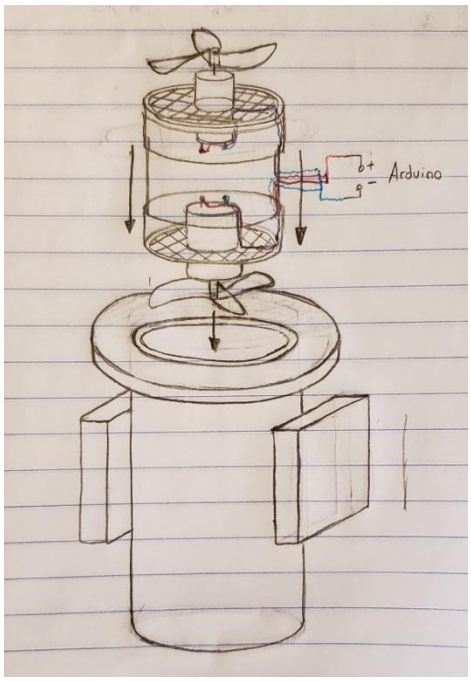

FIGURE 10

This design took on some changes prior to its elimination, such as moving to a PVC pipe body from the wireframe body. It was also decided to do two motors instead of one for ease of controlling. The propellers were where the problems begin, as they were hard to find. Propellers were expensive online and finding a RC boat with large enough propellers was hard and expensive. Another potential problem was balance. Just like in air, for something to be steady, weight must be distributed evenly, even the slightest imbalance in the system could cause catastrophic failure. Since these factors complicated the design past the budget and time limit, it was decided to move to an idea that seemed less complicated at the time

Piston Device (Concept 2)

This design was produced in the very beginning of the project, but never moved past a few drawings. The piston design relied on two pistons to draw in and expel water from the PVC pipe. The concept is simple; initially the device rest on top of the water with both pistons fully extended, then once the user is ready, the pistons would retract creating a vacuum in each cylinder which would draw water in through the holes (valves) drilled on each cap. The center of the device (between the two pistons) would compress the existing air, and the servo motor would have to have enough force to keep the pistons retreated. With the cylinders full of water, the device should sink down to the bottom. Once the bottom of the tank is reached, the pistons will

be pushed back to their initial position allowing the compressed air in the center to fill the entire canister as it did previously. At this point, the canister will rise to the top. This design was later modified to accompany a half circle piston (Figure 10). This modification allowed for an upper level within the canister for the Arduino and other electrical components so there would be no water contact. It also created an air space to act as a float.

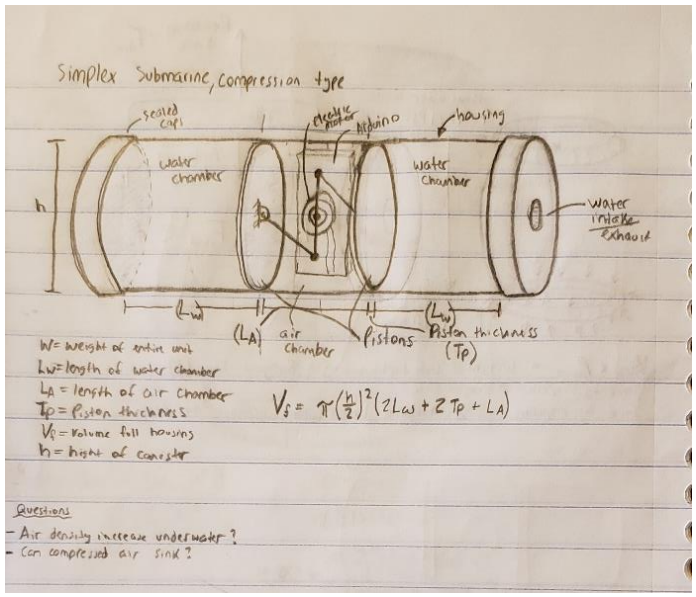

FIGURE 11

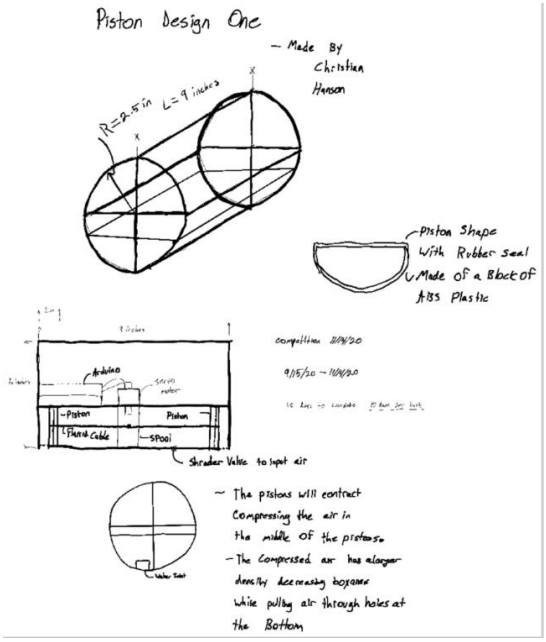

FIGURE 12

Both piston designs had their pro's and con's but, in the end, the cons outweighed the pros. To begin, the initial piston design had no designated place for the Arduino, which would have led to the Arduino being strapped to the outside of the device which would have caused balance issues. This problem led to the half piston design, although this design had its own set of problems. The half piston design was immediately withdrawn from the three initial concepts due to the complex piston design. Creating a half circle piston that could seal compressed air was too complicated given the tools that we had to work with. Another problem arose with the air chamber on top of the device. This chamber would seal off the Arduino, but the servo motor used to control the pistons would still be exposed. This chamber would also make it hard to access the electronics and would hold far too much air to allow the device to sink. Due to these considerations, the device was ruled out completely.

CO_2 Canister Device (Concept 3)

This concept was based on the idea of using compressed air to push water out of the submarine, and it would do that with a series of electric motors and valves. Powered by a 9-volt battery, the CO2 canister utilizes vacuumed sealed space and compressed air to sink down and float up. The fuselage would be split into three modules: one would have a pump to create a vacuum sealed container and a CO2 canister to compress the module, one would include the electronics, and the last one would have weight to aid with the sinking. These three sections were cleverly placed, the electronics being at the top of the submarine with the air, the CO_2 Canister, linkages and valves in the middle section (where water will fill), and the bottom section where the weight will be kept. This orientation was intended to direct the submarine straight down in the water, with the weight at the bottom pulling it down and the air at the top holding it in an upright position. The operation of the device starts with a linkage that connects both the upper and lower valves to a servo motor. This motor will only move a few degrees, just enough to allow water in from the valves. This linkage will also push a button on the CO2 canister at a specific angle. The servo motor is controlled by a code programmed into the Arduino, which is powered by the 9V battery. Both these components located at the top of the device in the air-filled chamber. Initially, the servo motor will retain the top valve in its

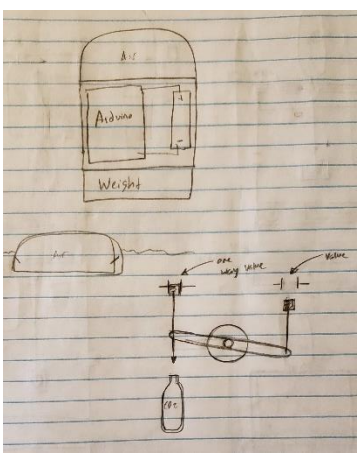

FIGURE 13

place, to prevent water from entering. Once the device is ready to sink, the servo will push the linkage down opening both the top and bottom valve (Figure 12). This will allow water to fill the device and then have it sink to the bottom. Once it hits the bottom, a button will be pressed to notify the Arduino to perform its next operation, which would be for the servo motor to push the linkage up, more than it was initially so that the CO2 canister gets activated. At this point the air from the CO2 pushes the water out the bottom 1-way valve, and fills the canister with air, which would allow it rise. This design was well thought out but required a lot of engineering to build.

FIGURE 14

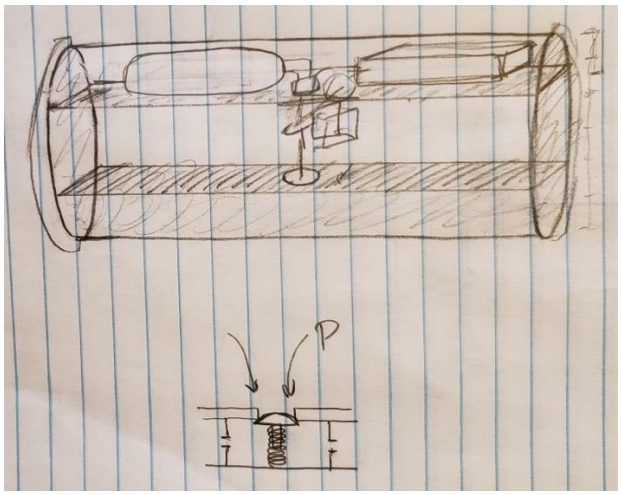

FIGURE 15

During the process of designing this device, it was brought to the group's attention that the dimensions of the current prototype violated the requirements. In this case, the device either

had to be flipped or redesigned entirely. This introduces the next modification to this design which involves the same body, just flipped with different floor levels. The levels were layered in the same orientation as the previous design with some modifications. As this design was being constructed, it was realized how difficult it would be to access some of the electrical components with the current layout. The device was also very complicated and required engineering all the parts entirely which would take up a lot of time and money. The CO2 design was later eliminated, due to a better design that was presented by a group member. Concept 3 was an exceptional design, but the overall design complications, and the dangers that the device brought to the table influenced to group to go another route.

Horizontal Alka-Seltzer Submarine (Concept 4)

This concept was introduced by a group member as complications were occurring with concept 3. The horizontal Alka-Seltzer submarine was based on a very simple concept; using the chemical reaction between Alka-Seltzer and water to bring the device back to the top of the water tank. This concept consisted of weights, Alka-Seltzer, 3-inch PVC body and caps, ½ inch PVC pipe, spray foam, glue sticks, a grommet, and grease. The valve is made from the ½ inch PVC pipe, with a stick of hot glue inserted into the middle of it. The glue is then glued to the pipe so that it does not move, and the pipe is now a solid. A valve hole is drilled at the top of the ½ PVC pipe at a 45-degree angle. The body is constructed from two end caps, and a 3-inch PVC pipe. Each end cap has an equal amount of weight attached to it to evenly distribute the weight throughout the device. These caps are then pressed to the 3-inch PVC pipe to assure a watertight fit. The 3-inch PVC pipe had a hold drilled through the middle (Figure 15) for the valve. A grommet was placed in one of those holes to create a seal for the valve, as well as provide a slight amount of friction to prevent the valve from sliding to easily. Before each use, one of the caps must be removed in order to place new Alka-Seltzer tablets inside. The device operates by first setting it in the water with the valve in the off position (both sides of the 45-degree hole are above the body). Then, once the user is ready to activate the submarine, the valve is pushed all the way down. Once the valve is pressed, air is now able to leave the body, allowing for water to fill. As water fills the canister, the device will sink. Once it hits the bottom, the valve will be pushed back up by the weight of the device, and no more water will be allowed to enter. At this point, CO2 is generated from chemical reaction that occurs from the Alka-Seltzer and water.

This CO2 replaces the water within the canister by pushing it out of the bottom hole, and in turn causes the device to rise back to the top. Between each use, new Alka-Seltzer will be needed

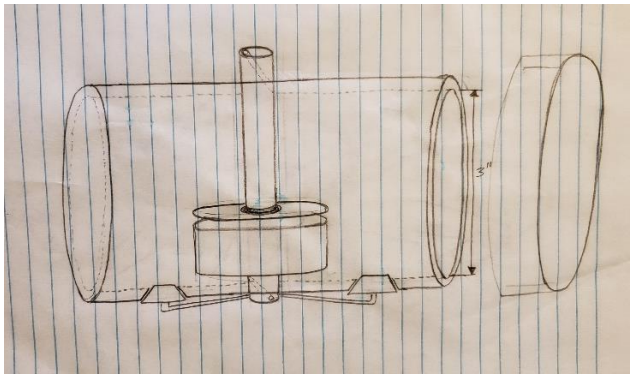

FIGURE 16

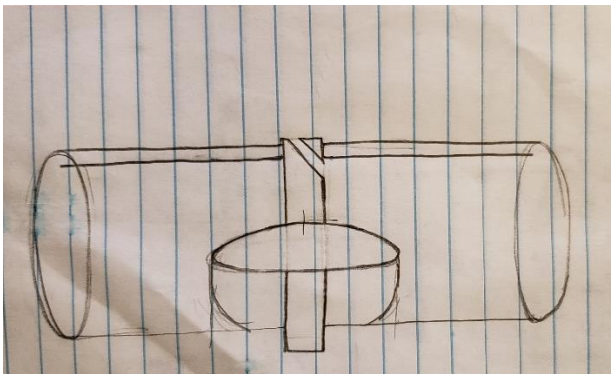

FIGURE 17

Once the concept was constructed into a prototype, it underwent multiple tests, the first one being buoyancy. The device was tested in the water with a different amount of weight added each time to find the correct weight that would keep the device in the water at the right level. Another test involved sinking the device to make sure that it landed on the valve each time. Unfortunately, due to the placement of the weights, the device failed this test each time. Since the weight was only located on each side of the device, if one side was just a little bit heavier than the other, the device would tend to tilt that way, then continue it's decent into the water with that side facing down. The problem with this is that it prevents the valve from being pushed, so it would go to the bottom of the tank and just sit there. Getting the device to be completely balanced was a nearly impossible with the current design, and therefore this design was reconfigured.

FIGURE 18

Vertical Alka-Seltzer Submarine (Concept 5)

This concept is based on the same fundamentals as concept 4. It uses Alka-Seltzer to bring the device back up from the bottom by a chemical reaction. The vertical version involves some of the same pieces as the previous design such as weights, Alka-Seltzer, 3-inch PVC body and cap, ½ inch PVC pipe, spray foam, glue sticks, a grommet, and grease. This concept has a few other pieces that the original design does not require such as a rounded 3-inch cap and a clear PVC pipe. This concept has three major components: the valve, the top and the bottom. The bottom consists of a 3-inch cap glued to the 3-inch PVC pipe. Inside the bottom cap, the clear PVC is glued in the middle to prevent the weights from falling into that bottom valve. A hole is drilled in both the bottom and top cap for the valve. The top consists of the rounded 3-inch cap with a hole drilled in the center. A grommet is then glued to the boarder of the hole to act as a seal just like it did in concept 4. The valve was constructed the same way it was constructed in concept 4. When the device is ready for use, the user can place the Alka-Seltzer on top of the weight, then the top piece can be placed on the bottom piece. At this point the valve can be placed into the grommet and bottom hole, and the portion where the valve meets the grommet should be greased to prevent air leakage. Once the user is ready the valve can be pressed, and the device will perform the same operation as was expected from the Horizontal Alka-Seltzer Submarine.

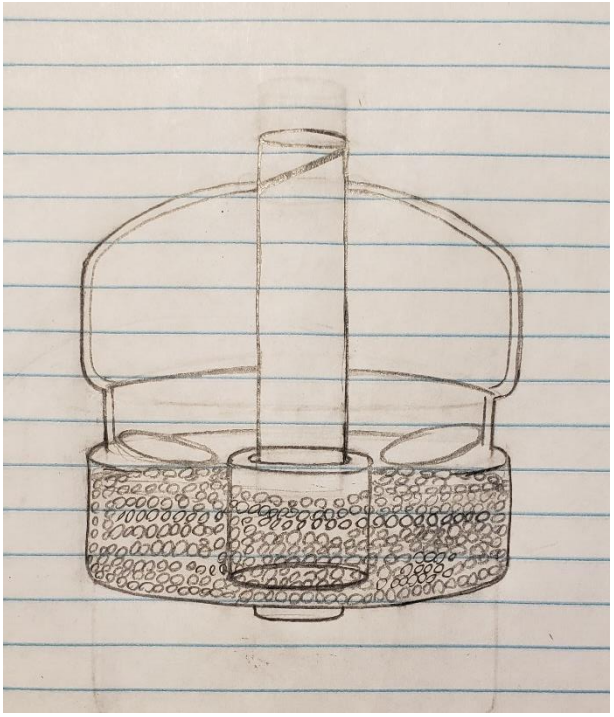

FIGURE 19

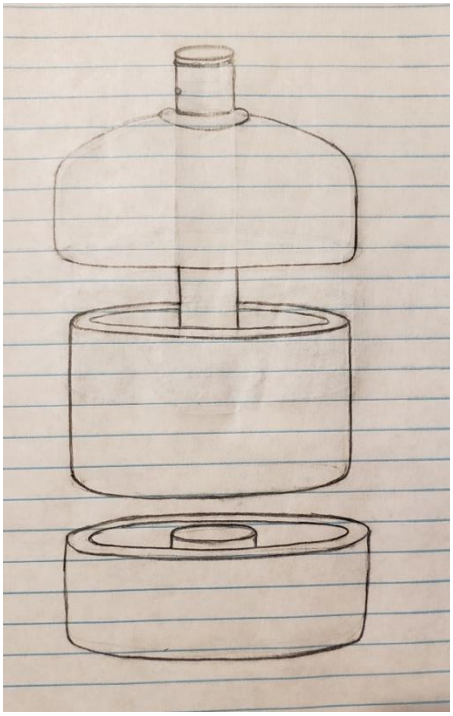

FIGURE 20

Multiple tests were performed on this design. Buoyancy tests helped determine the amount of weight needed. The sink test was important as the previous designs failure was the purpose of this new concept. Multiple tests were performed, and it passed each one, hitting the

valve on the bottom each time. A rounded cap was used on the top of this device due to its shape. The round top gives a space for air to build up keeping the device upright. The previous design has corners on either side so the air could travel to either side and that was problematic. Concept 5 also retained all the weight in one spot on the bottom of the device. This allowed the weight to pull down in only one area rather than two like the previous concept. These two factors alone allowed this device to sink down straight as an arrow every time making sure that the valve was pressed. The other test performed was the rising test. Due to the valve now being operated, the rise test did relatively well.

FIGURE 21

FIGURE 22

Concept 5 ended up being the groups final decision due to its ease of use, reliability, low cost to produce, simplistic design and its quick operation speeds. These factors make this device a worthy competitor. The final design fits within all requirements, and the cost along similar lines as other competitors devices.

Device Description

The final device worked better than the group expected. The first prototype was crude but proved the concept worked with a bit of assistance. It tended to tumble to one side or the other on its way down. This was because the center of gravity was in the center of the device and there was not an even distribution of weight, even after weighing both sides and resetting the pellets. The other issue that caused the group to the vertical design was the valve on the top pushing air out at an angle caused the device to turn whichever way it was directed. The final design took advantage of Archimedes principle using the center of buoyance and the center of gravity in combination. The design also used the moment of inertia to the submarines benefit. Because the weight was all the way at the bottom the container.

Product Decomposition & Reverse Engineering

Design Organization: BCNG Inc. | **Date: 11/27/2020**

Product Decomposed: Submarine Capsule

Description: Water and Alka-Seltzer, when mixed, produces CO2. The submarine is solely based on this concept as it uses the produced CO2 as a flotation method. The device will sink due to weight and rise due to the chemical reaction.

How it Works: The submarine takes in water through the bottom hole of the device until it reaches the bottom of the tank, at this point the valve is closed due to the force of the device hitting the ground. Once the valve is closed, the water within the capsule activates with the Alka-Seltzer and produces CO2. Since the CO2 cannot escape from the top valve now that it is closed, it has no choice but to push the water out of the bottom hole. This action allows the device to float back up to the top of the water as the water is displaced with CO2

Bill of Materials:

Item #	Mfg. Part #	Part Name	Qty	Material	Mfg. Process	Procurement Source	Image
1	PV3045	White round PVC cap	1	Polyvinyl Chloride	Polymer Extrusion through Forming Die	The Home Depot	

2	ERTR2 938	Black PVC cap	1	Polyvinyl Chloride	Polymer Extrusion through forming Die	The Home Depot	
3	PVC	Black PVC pipe	1	Polyvinyl Chloride	Polymer Extrusion through forming Die	The Home Depot	
4	N/A	Clear weight guard	1	Polycarbonate Plastic	Forming Die	School recycling bin	
5	N/A	Grom met	1	Rubber	Injection molding	The Home Depot	
6	N/A	Push Valve	1	Polyvinyl Chloride	Polymer Extrusion through forming Die	The Home Depot	

7	N/A	Weights	A lot	Metal	Precision wire cutting	Walmart	
8	N/A	E6000 Adhesive	1	Silicone Adhesive	Melted, combined with other Additives, Packed in a Plastic Tube	AutoZone	
9	N/A	Hot glue sticks	1	EVA (Ethylene Vinyl Acetate), APAO (Amorphous Poly Alpha Olefin), and PA (Poly Amides)	Combining polymers and additives, then shaped, cooled, and cut	Walmart	
10	N/A	Alka-Seltzer	4	aspirin (acetylsalicylic acid) (ASA), sodium bicarbonate, and anhydrous citric acid	Chemically combined solution, then molded	Walmart	

Disassembly:

Step #	Procedure	Item # Removed	Image

1	Remove the grease from around the grommet with a rag or towel. The valve can then be pulled out from the top. At this point the valve can be wiped down completely as well as the grommet that was retaining the valve	6	
2	The cap is removed by prying it off the rest of the main body. The cap is normally pressed tightly to the body to create a seal	1	

3	The Alka-Seltzer can now be lifted from the top of the weights. There will be 4 tables inside	10	
4	The weights consist of metal BB's. To remove these involves covering the valve hole on the bottom, then pouring them into a container	7	
5	With the Alka-Seltzer and weights removed, the clear weight guard can then be removed. This piece will require prying off as it is glued on. The glue can be removed by pealing or dissolving	4,8	

6	Removed BB's in a separate container	7	
7	Removed clear weight guard	4	
8	The grommet can be removed by prying just like piece #4 since it is glued into place. The glue can be pealed or dissolved off	5,8	
9	A hot glue stick (9) was placed in the ½ inch PVC pipe (6). To remove it would involve pushing the glue out from the body, or possibly melting out.	6,9	

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

Item #	Interface Item #	Energy Flow	Information Flow	Material Flow	Image

1	1,6,5 & 8	The grommet creates a friction force on the valve	The grommet is held into place by the force of the glue. The valve is held by the friction force implied by the grommet. When the valve is pressed, more force is required to move it	The grommet (5) is glued onto the cap (1). The Valve is held into place by the grommet.	
2	1,2,3	There is a compression force created when the cap and bottom are pressed onto the PVC pipe	The compression force created by the cap on the pipe is significant enough to hold the cap in place. This same force keeps the bottom cap on.	The cap (1) is pressed to the PVC pipe (3) which is glued onto the bottom cap (2)	
3	4,10,7,3,2	The weight of the metal BB's presses down on the bottom cap of the device which pulls it down. Part #4 forces the BB's away from the valve hole. The reacted Alka-Seltzer creates CO2 which pushes up on the cap to move the device back to the surface	The compression force of 2 on 3 holds the two pieces together with the help of glue. Metal BB's push the device down to the bottom with the addition of water. #4 allows for proper valve operation	2 is compressed to 3. The BB's sit on piece 2 and against piece 3. #4 is glued to #2 and BB's press up against it	

4	1,2,3,4,5,6,7,8,9	The grommet holds the valve into place. The grommet is glued to the top lid. The bottom hole and clear guard both keep the valve vertical. The force of the device hitting the floor will push the valve up enough to close it. At this point the buoyancy force of the CO2 pulls the device back to the surface and pushes water back out.	Pieces 1,2 and 3 are pressed together. The BB's apply a weight to the bottom cap. The grommet and guard hold the valve in place.	1,2 and 3 contact each other through pressing. The grommet and Guard are glued to pieces of PVC. The valve makes frictional contact to the grommet. The Alka-Seltzer is set on top of the weight.	
5	6,9	Hot glue is pressed into the ½ inch PVC pipe in order to make it a solid shaft. Glue is held in by friction as well as bonding as the ends of the glue sticks were melted to the PVC	The glue is held in by friction to the PVC pipe.	The glue makes frictional contact to the PVC. Holes are also drilled into the PVC for ventilation	
6	6,4,2	The valve (6) slides within the clear weight guard and through the valve hole	The clear guard and valve hole keep's BB's from interfering,	The clear guard (4) is glued to the inside bottom of part 2. The valve slides within this guide.	

		on piece 2. The only forces are guide forces, which keep the valve in place.	and keeps the valve in place		

Team member: Brent Fields	Team member:
Team member: Nate Dowdy	Prepared by: Brent Fields
Team member: Christian Hanson	Checked by: Nate Dowdy
Team member: Garret Snyder	Approved by: Garret Snyder & Christian Hanson

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Device Dimensions and Specifications

TABLE 1 DIMENSIONS AND SPECIFICATIONS

Dimension/Specification	Alka Seltzer Submarine
Length	3.12 in
Height	5.00 in
Width	3.12 in
Weight	2.51 lb.
Number of Components	8

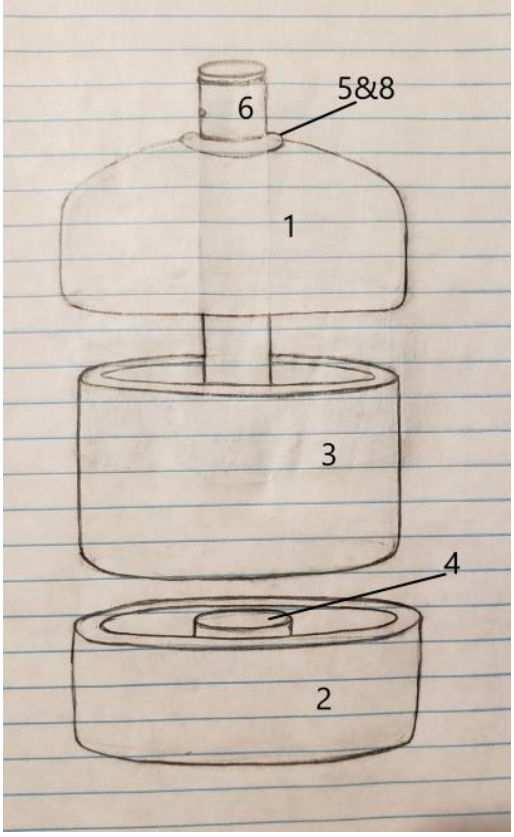

FIGURE 23

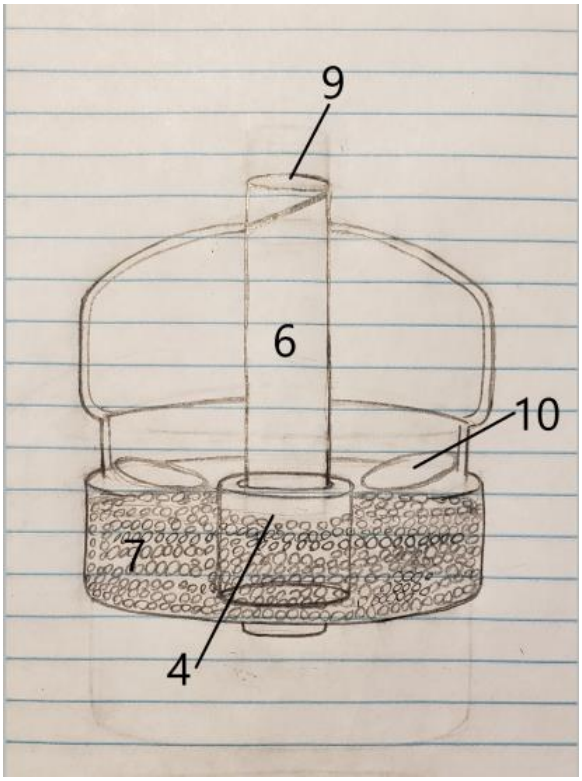

FIGURE 24

Design Structure Matrix

Design Structure Matrix (DSM)		Defining the problem	Project Conception	Designing the project	Building the design	Testing/Optimizing the design	Final Evaluation	Writing the report
Task		1	2	3	4	5	6	7
Defining the Problem	1	**1**						
Project Conception	2	X	**2**					
Designing the project	3		X	**3**				
Building the design	4			X	**4**			
Testing/Optimizing the design	5					**5**		
Final Evaluation	6		X			X	**6**	
Writing the report	7	X	X	X	X	X	X	**7**

FIGURE 25. DSM

Critical Elements

The most critical elements are highlighted in the FMEA template (Figure 33) because many of the trials that failed were due to the gromet-grease-shaft value. The gromet is the rubber piece that provides the seal between the hole in the PVC cap and the middle shaft. The grease provided a water resistance airtight seal around where the shaft enters the device, and the grease allowed for the shaft to fluidly slide up and down in the device. The gromet and grease worked together to make sure the device worked. For example, the buoyancy of the device depended on the air trapped in the device that would not allow any water to enter making the specific gravity less than 1. Any air leak would compromise this engineered feature, making the application of the grease on the gromet critical to the device's successful.

FIGURE 26 GROMET AND GREASE ON THE DEVICE

Clever Ideas

The Alka seltzer device uses a chemical reaction as the rising agent in the device, and the device is fully mechanical and features no electronics. The Alka seltzer idea was instrumental in the success of the device, as before the team wanted to use CO_2 canisters and electronic components to expels the water, and the Alka seltzer removed the need for electrical components because the water let into the deice would activate the reaction. Then the CO_2 from the tablets would push out the water returning to the state of buoyancy at the start of the race. No electronics removed the risk of having electronics fried from water exposure. Every part of the final Alka seltzer got exposed to water throughout the sink and rise process.

CAD Models and Drawings of Device

(Solidworks and Drawing of Device) - For the device description a group member created the device in Solid works allowing for a full drawing as well as a few rendered pictures of the device normally and in a section view. This was done by taking each component and measuring the device's dimensions with a caliper. The rendering is quite close to the actual device except for a few things. The end cap has a clear tube in the center but Solidworks would

not allow two different material settings. The second difference is the grommet on the top. A grommet was made in Solidworks, but the result looked ridiculous and did not represent the device well. Overall, the drawing and renderings look almost identical to the device.

FIGURE 27:ISOMETRIC VIEW OF RENDERING VS ACTUAL DEVICE

FIGURE 28: TOP VIEW OF RENDERING

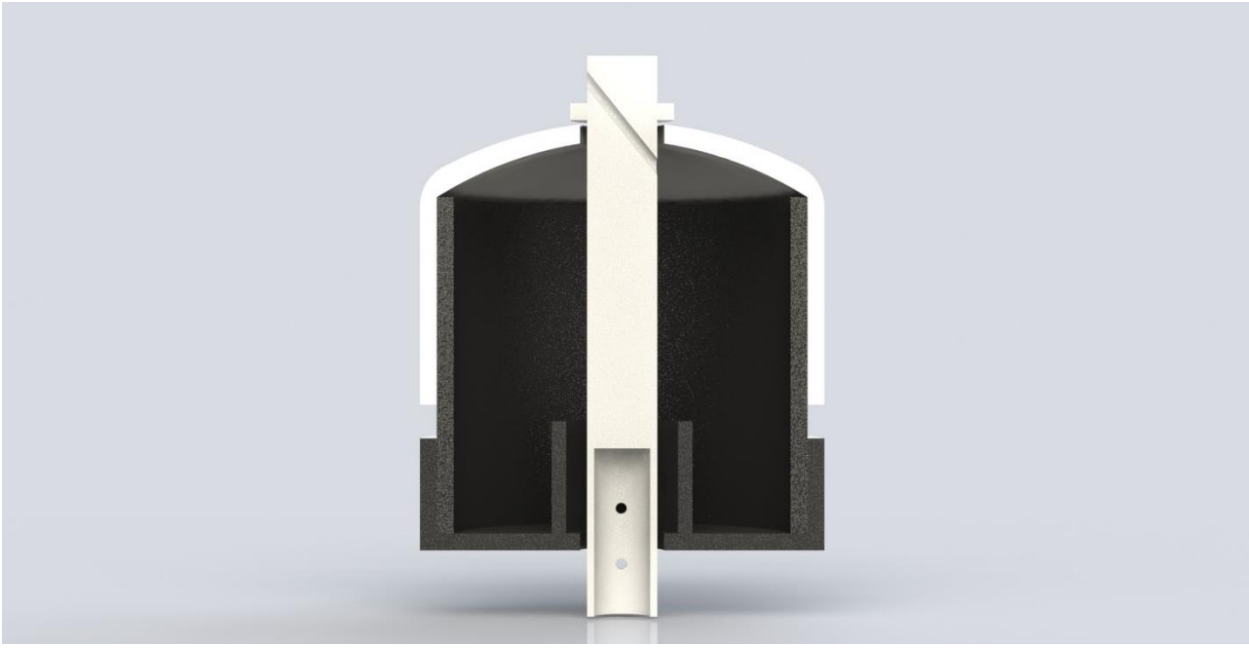

FIGURE 29: SECTION VIEW OF RENDERING

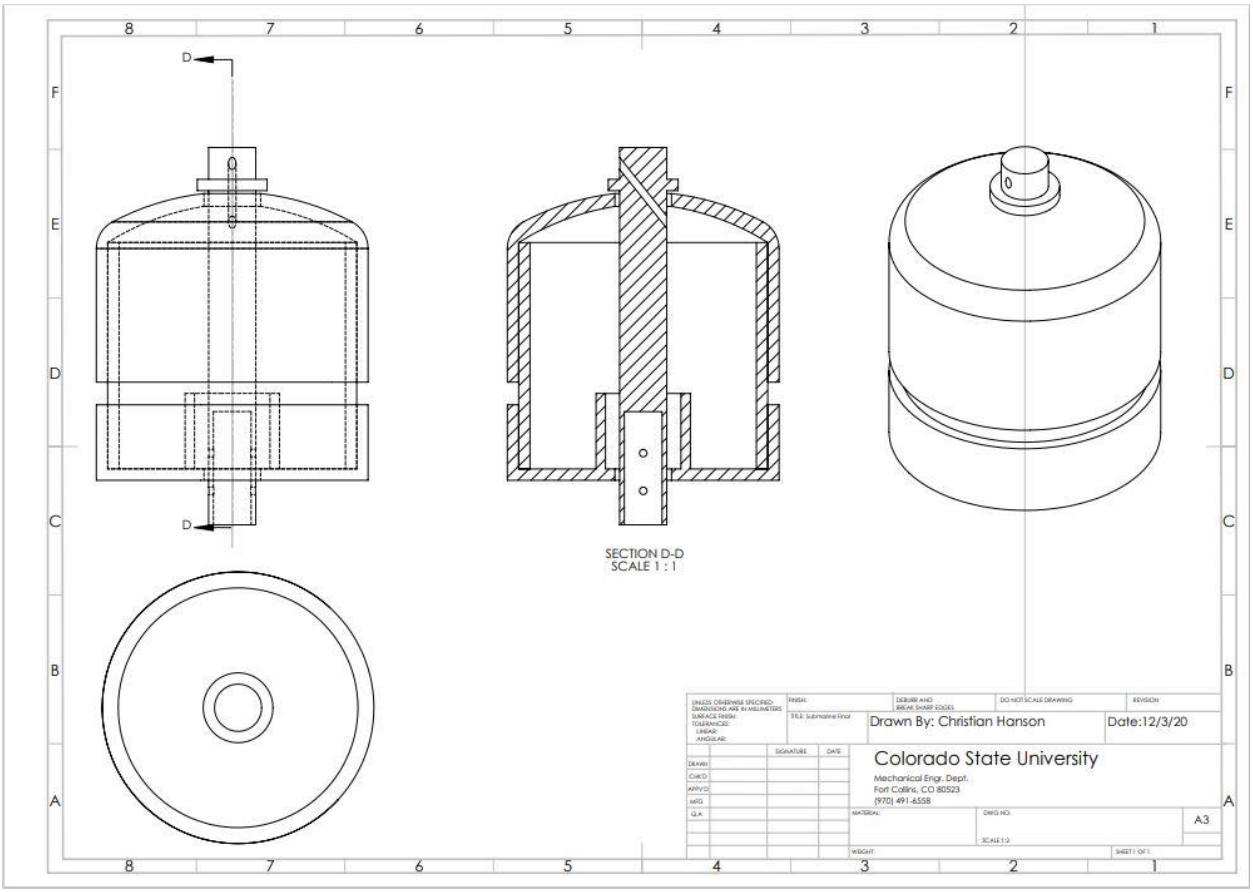

FIGURE 30: DRAWING OF THE DEVICE

Bill of Materials

Product: Alka Seltzer Submarine | Date:11/6/2020

Part #	Qty	Name	Material	Cost
2	1	3” ABS Cap	Acrylonitrile Butadiene Styrene	6.57
10	1	Box of Alka Seltzer (72 Tablets)	Alkaline Seltzer	8.42
7	1	Container Steel BB’s (240)	Steel	6.97
3	1	3in x 2ft ABS Pipe	Acrylonitrile Butadiene Styrene	5.70
1	1	3” ABS Dome Cap	Acrylonitrile Butadiene Styrene	4.21
6	1	½” PVC Pipe	Polyvinyl Chloride	1.31
5	1	5/8” Gromet	Rubber	1.47
4	1	Plastic Pipe Piece (for retention of BB’s)		*Provided
8	1	Permatex Adhesive		5.77
11	1	Spray Foam	Isocyanate and Polyol Resin [4]	3.78
9	1	Hot Glue	(EVA), (APAO), (PA)	2.47
Total	**11**			**44.20**

Team member: Nathan Dowdy	Prepared by: Nathan Dowdy
Team member: Christian Hanson	Checked by: Christian Hanson
Team member: Brent Fields	Approved by: Brent Fields
Team member: Garret Snyder	

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Engineering Analysis

The engineering involved in the submarine device involves buoyancy, friction, and chemistry. Due to the devices entirely mechanical nature, the shift from sinking operation to rising operation relies on outside forces. The group had to consider what caused the device to behave in certain ways while underwater in order to perfect the design. Initial prototypes revealed a lot of these behaviors and, with the help of some buoyancy formulas, allowed the group to make improvements to the device that overcame the failures of past prototypes.

A crucial concept to the device's success was staying upright while buoyancy was being evaluated as well as while the device was in operation. As detailed in the free body diagram in Figure 26, there is a center of gravity in the center of the device, around the top of the weighted portion. A weight force pulls the device down from that center of gravity, causing it to sink. An opposing buoyancy force forms when the device is underwater, attempting to allow the air trapped inside the device to rise back to its natural state above the water. If this buoyancy force is not directly coaxial to the center of gravity, there will be a rotation and even a chance of the device capsizing. The design was virtually rotationally symmetrical, so the center of gravity naturally sat on the central axis, but the buoyancy force was less predictable. Since it was caused by a pocket of air that is free to travel about the device in search of the location closest to the surface, the design had to guide this pocket of air toward the central axis. To do that, the team used a hemispherical top cap to center to air in the middle of the device, preventing rotation almost entirely, a major improvement over the previous device.

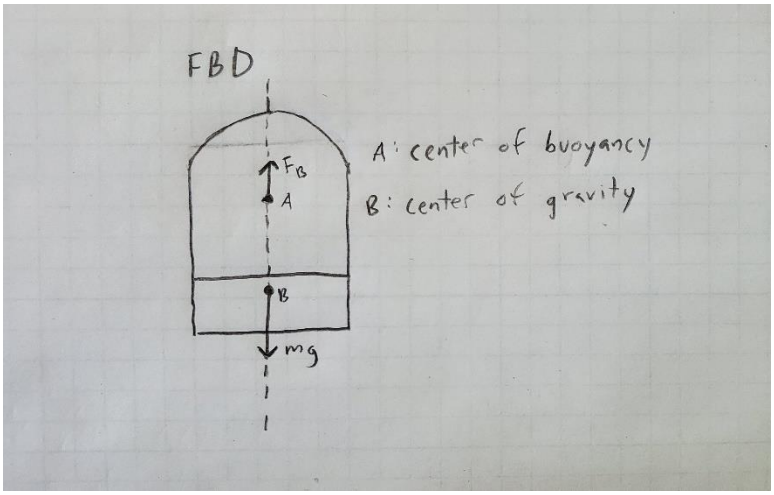

FIGURE 31

Another crucial consideration in our design was the valves ability to close again once the device hit the bottom of the water column. Grease was used to lubricate and seal the valve where a sliding motion would take place. The sum of forces in the y-direction led to the weight overcoming the buoyance force, accelerating the device into the ground. When the device met the ground, the valve shaft hit the bottom of the tank first, forcing it back upward. A friction force was working against the movement of the shaft. The friction was needed to keep the device sealed when the valve wasn't intended to move, but the lubrication of the grease was just enough to minimize the friction from the grommet and allow the devices downward momentum to shift the valve closed.

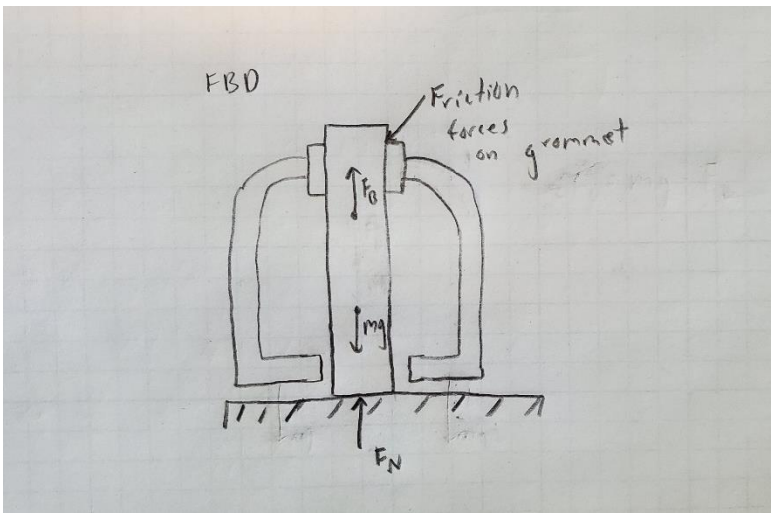

FIGURE 32

The chemical reaction that took place was what allowed our device to rise back to the top of the water column without the use of propellers or other compressed air solutions. The reaction is that which takes place when an Alka Seltzer tablet is placed in water. The water breaks down the Alka Seltzer, allowing the different chemicals inside of it to react to one another. Sodium bicarbonate reacts with acetylsalicylic and citric acid inside the table to generate carbonic acid and a few other molecules (Equation 2).

$$2NaHCO_3(s) + HC_9H_7O_4(s) + H_3C_6H_5O_7(s) \rightarrow 2H_2CO_3(aq) + NaC_9H_7O_4(aq) + NaH_2C_6H_5O_7(aq) \qquad (2)$$

The carbonic acid is unstable and quickly breaks down into water and carbon dioxide gas with the help of hydrogen ions present in the water (Equation 3) [5].

$$HCO_3^-(aq) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g) \quad (3)$$

That carbon dioxide gas is what floods the device, forcing the water out and allowing the device to float once again.

Testing

Test Reports

Test Report	
Design Organization: BCNG Inc.	**Date: 10/05/2020**
Device or system tested: Sinking Device in the Submarine	
Objective of experiment (Engineering Specifications to be verified): To see if the device floats with the given weight and sinks when an influx of water is let into the device. The Test is focused on testing the dimensions of our dimension.	
Methods and Materials (or Equipment): Bucket (3' by 3'), Water, Enclosure of the Device, Metal BB's.	
Experimental Procedure: First the group would load in an amount of metals BBs, then seal the device and conduct a bouncy test. Once we found the right number of BBs that satisfied the buoyancy check, we would fill the device with water with the weight still in the device and check if it sinks.	
Results: Appropriate number of BBs: 1800 Sink Time: 25 seconds	
Discussion: The group maximized the weight in order to decrease the amount of time it takes to sink. The weight force got close too but did not overcome the buoyancy force.	
Analysis: There is an exact amount of weight that will maximize the competitive factor. As mentioned above the group found the amount of weight that would be close to the buoyant force.	Interpretation: Having weight in the device is necessary for the sinking process. This particular test allowed the group the optimize that function of the device.
Team member: Nate Dowdy	Prepared by: Nate Dowdy
Team member: Garret Snyder	Checked by: Brent Fields
Team member: Christian Hanson	Witnessed by: Chris and Brent
Team member: Brent Fields	
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Test Report

Design Organization: BCNG Inc.	Date: 10/21/2020

Device or system tested: Valve Operation

Objective of experiment (Engineering Specifications to be verified): The purpose of this experiment was to determine if the valve would open and close smoothly as well as provide the proper amount of resistance to create a watertight seal.

Methods and Materials (or Equipment): Water, ½ inch PVC pipe, grease, gromet

Experimental Procedure: To begin, a small amount of grease will be applied to the ½ inch PVC pipe, then it will be placed into the grommet holes on the device itself. Once a smooth operation is ensured, the device will be filled with water. In order to test proper sealing of the valve, the device will be held in the air with the valve closed. No water should leak out. Then the valve will be pushed open, and water will be allowed to escape the bottom hole. The force of the falling submarine needs to be adequate for the valve to close all the way when it hits the ground.

Results: At this point the device valve works as it should since it contains water when it is closed and allows the water to escape when the valve is open. The operation of the valve once it hits the bottom is the only test that failed. The force of the device hitting the ground does provide enough force for the valve to close, but the device tends to land on an edge rather than the valve itself. This will be fixed by installing landing gear

Discussion: All in all, the valve seals water efficiently. The operation of the valve will need to be modified in order open and close efficiently

Analysis: The valve will open due to the push of the top of the valve, and it will be closed by the force of the device as it hits the ground. The valve will allow water in upon initial push, and it will allow water out upon final push.	Interpretation: The test has allowed us to realize that the valve will need modification to accommodate for this activation error that was encountered.
Team member: Nate Dowdy	Prepared by: Brent Fields
Team member: Christian Hanson	Checked by: Christian Hanson
Team member: Garret Snyder	Witnessed by: Nate Dowdy
Team member: Brent Fields	

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Test Report

Design Organization: BCNG Inc.	Date: 11/6/20

Device or system tested: Flotation System

Objective of experiment (Engineering Specifications to be verified): The objective is for the submarine to raise back up from the CO_2 with no leaks through the ends of the submarine and through the pin valve at the top.

Methods and Materials (or Equipment): The submarine will have 3 tests in this category. Each will have a different number of Alka seltzer tablets. They will be 2, 4, and 6 tablets between iterations. The other required materials are the submarine, grease, and extra tablets.

Experimental Procedure: This procedure starts when the submarine hits the bottom of the testing apparatus. When the submarine hits the bottom of the apparatus a valve is actuated on the bottom stopping the air from escaping from the top. Next the tablet will react with the water inside the submarine and create CO_2. The CO_2 will create pressure in the submarine forcing water out the bottom of it. This intern will make the submarine float back to the surface.

Results: After testing, it was observed that 4 tablets resulted in the best outcome

Discussion: 4 tablets provided enough CO2 to bring the device back to the top, overcoming the weight of the device and the water above it.

Analysis: The water will fill up from the bottom of the device until the device is sinking. At this point the water will have activated the tabs. Once the device hits the ground, and the valve closes, the CO2 produced from the tabs will push the water out from the bottom of the device and it will rise.	Interpretation: The 4 tablets allow the device to raise quickly enough to be competitive.
Team member: Nate Dowdy	Prepared by: Christian, Brent
Team member: Christian Hanson	Checked by: Garret Dowdy
Team member: Garret Snyder	Witnessed by: Nate Dowdy
Team member: Brent Fields	

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Test Report

Design Organization: BCNG Inc.	Date: 11/6/2020

Device or system tested: Complete Rise and Sink Test

Objective of experiment (Engineering Specifications to be verified): To preform several complete tests (Sinking and Rising) to optimize the competitive factor of our design.

Methods and Materials (or Equipment): Built Device, 4 ft test device (Filled with Water), Alka Seltzer Tablets

Experimental Procedure: Load Alka Seltzer Tablets into the device, show the device is buoyant, push down the button to allow water to enter and air to escape, have the device sink to the bottom pushing the button back to the closed position, allow the tablets to produce CO2 gas to have it rise to the top. Get time for rise and sink time.

Results: Shown in Figure 26

Discussion: After the enclosure was built and all the mechanism were in pace, the only changes we could make to the design were small such as

Analysis: After the enclosure was built only changes could be made to the amount of Alka seltzer that was contained in the device.	Interpretation: The successive tests allowed us to make the device more competitive so that we can go to win.
Team member: Nate Dowdy	Prepared by: Nate Dowdy
Team member: Christian Hanson	Checked by: Garret Snyder
Team member: Garret Snyder	Witnessed by: Brent Fields
Team member: Brent Fields	

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Results

The team divided the tests into three different section: Proof of Concept, Optimization, and Performance Testing.

Proof of Concept

The material the team decided to use for the submarine was PVC pipes, dividers, and caps. Using these materials, the team built the container of the device that did not include the internal mechanical devices. This testing phase was designed to ensure the container of the device would float, sink, and rise before exploring it further by testing it with water as soon as possible. In Phase I steel BB's are placed into the sealed device and, it is placed in the container of water to see if it floats (buoyancy check). In Phase II a team member would fill the device with water manually, by opening the top of the device, to see if the weight of the BB's and added water would cause it to sink. In Phase III the added water was removed from the device and placed at the bottom to ensure the buoyancy of the object would make it rise to the surface. This proof of concept test was done for every prototype built (Concepts 3-5) and below in Table 1 shows the results of these tests.

TABLE 2. PROOF OF CONCEPT TESTING

Prototype Tested	Phase I	Phase II	Phase III	Notes/Observations
Concept 3	Success	Success	Success	PVC provided a strong seal
Concept 4	Success	Success	Success	Device worked as it should
Concept 5	Success	Success	Success	Out of the three concepts, this design is the most stable

Optimization Testing

The optimization portion of the testing allowed the design to adapt into a competitive device by fixing any shortcomings, answering burning questions. Due to the rework of the design

from concept 3 to concept 4 optimization of the design was limited but not overlooked. The grease creates the air lock seal with the gromet to not let water or air out of the device. Without the grease being optimized, the device would not have worked as reliably as it did. Two different greases with different viscosity was tested with the device. The high viscosity grease was easier to put on, and it created a fluid seal while the thicker grease with at lower viscosity needed less and had a better hold. As seen in Table 2, the lower viscosity grease provided a better seal and yielded all successful tests.

TABLE 3. OPTIMIZATION TESTING: GREASE

Test	Low Viscosity Grease	High Viscosity Grease
1	Successful	Successful
2	Successful	Failure
3	Successful	Failure

Performance Testing

After proof of concept and optimization testing, the third and final test stage is performance testing. Successive tests were done to ensure the reliability of the device before competition, and small optimization changes were made to the device with these tests. All six tests of the device succeeded (device sank to the bottom and rose back up) with an average of 22.96 seconds (Table 2). On average the device sink time took up 60 percent of the overall time which is due to the time it takes for the water to fill the container and push the air out making the device not buoyant and sink. Once hitting the bottom, the Alka seltzer tablets would activate and could it to rise back to the top. Test five and six the device used different amounts of Alka seltzer to see the difference. As seen in Figure 26 when halving the amount of Alka seltzer doubled the amount of time the device took to complete the task while six tablets did increase the time but only by 2.3 seconds. Between having the one to four tablets the response seemed proportional, but any additional Alka seltzer would decrease the time slightly. The team ended up using four tablets for the competition.

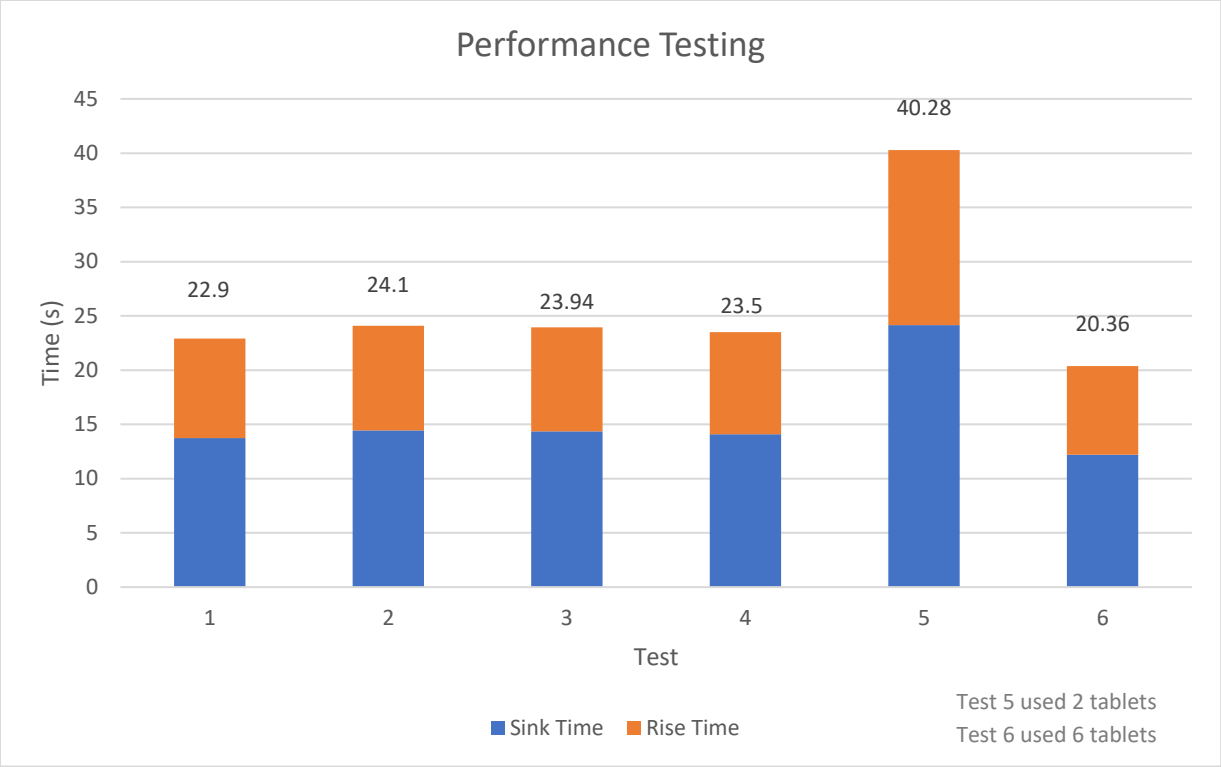

FIGURE 33. PERFORMANCE TESTING OF THE ALKA SELTZER DEVICE

TABLE 4. PERFORMANCE TESTING DATA

Test	Sink Time	Rise Time	Overall Time
1	13.74	9.16	22.9
2	14.46	9.64	24.1
3	14.36	9.57	23.94
4	14.1	9.4	23.5
5 (2 Tablets)	24.16	16.11	40.28
6 (6 Tablets in Half's)	12.21	8.15	20.36
Average	13.774	9.184	22.96
Standard Deviation	0.91754019	0.606901969	1.526040629

Risk & Reliability Analysis

FMEA

FMEA

Process/Product Name: Submarine
Organization Name: BCNG Inc.
Team Member Names: Chris, Garret, Nate, Brent

Prepared By: Entire Group
Checked By: Entire Group
Approved By: Entire Group
FMEA Date (Orig.): 12-Nov (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?				
Loading Weight	Not evenly distributed, not enough weight	It may sink at an angle or not sink at all	4	The metal pellets used for weight aren't secured in place evenly	4	Have a controlled amount of weight	2	32	Have a secured container for the metal pellets, Load it in with a funnel	Brent	Weight measured out, retained for even distribution 11/4/20	4	1	2	8
Loading Alka Setlzer	Alka Seltzer actiavtes early	Not enough Alka Seltzer for a complete run	4	The metal pellets are wet from last test	3	Visually checking if the inside of the device is dry, and metal pellets	2	24	Make sure the metal pellets are dry to ensure Alka Setlzer does not activate early	Nate	Alka seltzer set on top of weight, clean and dry pellets between uses 11/6/20	4	2	2	16
Displaying Bouancy	Air leaks in the body, valve left open	The device will not float for long enough, or at all. The device may not rise due to leaks	7	Not placing the caps on tightly. Not enough grease around the valve to create a full seal	4	A liberal application of grease	3	84	Making sure the valve is greased and properly sealed	Nate	Valve sealed with grease, 11/9/20	7	2	5	70
Phase One Activation	Button does not get pressed all the way down upon initial startup	The device won't move from its buoyanct state.	8	Button not pushed all the way down, until the valve hits the stopper	4	The valve stopper lets the user know the valve is open all the way	7	224	Pushing the valve down to the stopper	Garret	Valve stoppers glued into place, 11/10/20	8	1	4	32
Sinking	Device does not sink	The device will not achieve a key task	8	Not enough weight, valve not open all the way, alka seltzer activated early	4	User can see if the device isn't sinking properly	3	96	Ensuring the measured amount of weight is in the device, alka selzer is above initial water levels, valve is fully	Garret	Valve stoppers glued into place, 11/10/20	8	2	2	32
Phase Two Activation	The valve may not properly close	The submarine does not rise to the top, and is stuck at the bottom	8	Not enough force when the capsile hits the bottom, capsule hits bottom sideways, improper lubrication on valve	5	Weight of the device, greasing the valve, insuring no bubbles leave device after the device hits the bottom	3	120	Making sure there is the max weight when it hits the bottom (water and metal pellets)	Brent	Valve sealed with grease, 11/9/20	8	3	3	72
Alka Setlzer Activation	The alka setlzer may prematurely activate, causing the device to float due to too much carbon dioxide in	The device will never sink or will not rise if it manages to sink, tablets will be used up by then	8	Water breaches capsule or capsule has water in it already	4	The valve prevents water from reaching the alka setlzer. The metal pellets will also be dryed between each use	5	48	Drying the metal pellets between each use, ensuring a proper seal during buoyancy test	Chris	Alka seltzer set on top of dry weight pellets, 11/6/20	8	2	3	48

FIGURE 34 FAILURE MODES AND EFFECTS ANALYSIS

Fault Tree Analysis

This submarine design is simple and mechanical. This reduces possible risks significantly but does not remove them all together. There are only a few plausible failures that could happen while the submarine is in use.

1. The first area of variability that could affect performance is the usage of the grease on the valve on top of the submarine. Grease was used with a grommet to ensure a good seal but over time the grease can fall off making the seal leak a small

amount of water. The device still works with a small leak but if the leak became large enough it would not rise from the bottom of the tank. The possibility of this happening is medium to low if the grease is properly maintained.

2. The second area of variability is the valve function. If the submarine were to fall too slowly to the bottom of the tank it may not close the valve making it so that submarine will not float back to the top. Many iterations were done and a design with low risk chosen making it harder for the valve to stay open than to close properly.

3. Alka seltzer activation would be another area of variability. This one is very low risk because the water is guaranteed to interact with the tablets. If the tablets were manufactured incorrectly it could affect the production of the CO_2. This is a problem that could be fixed very easily and not common.

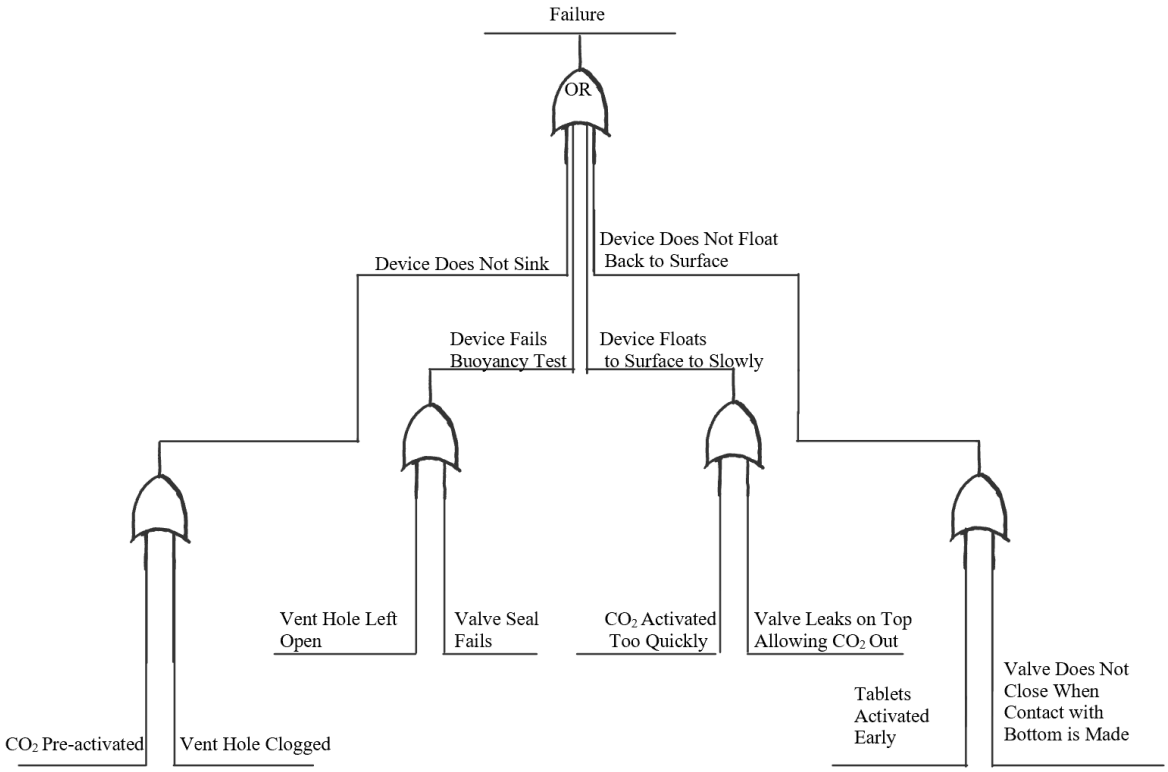

FIGURE 35 FAULT TREE ANALYSIS

Safety/Areas of Risk

Our device is a simple concept that does not include any heat, electricity, or high-pressure systems. This leaves us with minimal safety concerns. Since our device involves a carbon dioxide gas produced by Alka Seltzer tablets reacting in water, there is a miniscule chance that the capsule could become pressurized if the bottom valve somehow seals. This is a very low hazard level scenario because our device is not glued or sealed anywhere, meaning any excess air pressure has many routes to escape before the PVC/ABS capsule would ever rupture. It also always has a completely open valve on the bottom which is very unlikely to be sealed in the first place.

Improvements

The device could use tighter seal tolerance where the shaft/valve meets the top cap and grommet so that the use of grease would not be necessary to keep the capsule airtight. A lack of greasing would mean one less step is necessary to make the device work properly. Also, a mechanism that distributes the Alka seltzer could useful so that it does not activate too early causing it to float before it can sink to the bottom. This mechanism would time the release of the carbon dioxide to ensure the reliability of the device.

Service and Support Plan

The device created has simple steps that need to be taken between each run-in order to stop if from failing to sink or failing to rise. The first task is to re-seal the valve at the top of the submarine so that air cannot escape while the buoyancy test is in place. The second task is to dry the submarine's insides between tests so that the Alka seltzer does not prematurely create CO_2 inhibiting it from sinking. The third task is to take four new tablets and place them in the body of the submarine between runs so that there is an agent in the submarine that creates CO_2 each run. For emergencies extra supplies were brought. For the valve on the top grease was brought for resealing. Extra pellets were brought so that the weight of the device could be adjusted if necessary. Emergency drying materials were brought as well as a cup to remove the pellets and dry each component individually.

Type of Failure	Member Responsible for Fix	Steps to fix	Supplies Needed	Time Required
Submarine leaks air and/or CO_2 from top valve.	Brent and Nathan	• Apply grease on valve in a circular motion making sure not to fill air vent hole.	Grease and paper towels	45 seconds
Submarine does not sink due to CO_2 overflow.	Garret and Christian	• Remove submarine cap and empty pellets into cup. • Rinse the pellets in the cup to remove excess Alka seltzer material. • Dry entire inside of submarine and pellets, then place pellets back in designated location. • *	Paper Towels, cup, and water	2 minutes
Submarine does not sink due to air vent being clogged	Brent and Nathan	• Pull valve up slightly showing both ends of the 45-degree angle hole. • Take straight pick and slowly slide down hole removing grease and dirt, allowing for air flow. • *	Straight pick, grease	20 seconds
Submarine Sinks to bottom but does not float back due to valve not closing.	Brent and Christian	• Retrieve submarine with grandpa claws • Remove valve by slowing pulling from the top.	Paper towels and grease.	3 minutes

		• Wipe down valve and rotate to ensure the valve is not seized on body of submarine • *		
Submarine sinks to the bottom but tablets do not produce sufficient CO_2 and the submarine does not float to surface.	Christian and Garret	• Remove top of submarine and dry off components. • Remove old tablet residue. • Place four new tablets dry locations on the placement pad. • *	Paper towels, grease, Alka seltzer tablets.	4 minutes
Submarine does not sink even with valve open on top and filled with water	Christian and Nathan	• Remove top of submarine and empty pellets into cup. • Add a significant number of pellets to cup. • Place pellets back into body and test buoyancy. • Dry insides and reassemble with new tablets.	Paper towels, Alka seltzer tablets, pellets.	5 minutes

FIGURE 36. SERVICE AND SUPPORT PLAN. ***NOTE: "*" INDICATES THE SUBMARINE BEING GREASED. THIS STEP IS REQUIRED WHEN ANY ADJUSTMENT IS DONE TO ENSURE PROPER SEAL.***

Project Plan

Project Tasks

Project Planning		
Design Organization: BCNG Inc.		**Date: 9/15/2020**
Product Name: BCNG Sub: Mark I		
Task 1 Snapshots	**Name of Task:** Defining the Problem	
	Objective: Review the project rules and guidelines to actualize the work needed over the semester.	
	Deliverables: Team Contract, Project Plan, Gantt Chart, Design Structure Matrix	
	Decisions/Milestones with Dates: 1. Initial Meeting and documentation of guidelines – 9/14 2. Gantt Chart, DSM, Project Plan Completed – 9/15	
	Personnel Needed: Title: Entire Team Hours: 1 Percent full time:	
	Time: Estimated Total Hours: 1 Actual Total Hours: 3	
	Sequence: Predecessors: None Successors: Task 2 Planned Start Date: 9/14 Planned Finish Date: 9/15 Actual Start Date: 9/14 Actual Finish Date: 9/15	
	Costs: Capital Equipment: $0.00 Disposables: $0.00	
Task 2 Snapshots	**Name of Task:** Project Conception	
	Objective: Go through a create and refine process of ideas which includes calculations to flush out each idea deciding whether to refine the idea or scrap it. Create more than one project conception for a large variety.	
	Deliverables: Project drawings, mathematical calculations, through documentation of team meetings and ideas discussed	
	Decisions/Milestones with Dates: 1. Project Conception Evaluation – 9/29	
	Personnel Needed: Title: Entire Team Hours: 5 Percent full time:	
	Time: Estimated Total Hours: 5 Actual Total Hours: 5	
	Sequence: Predecessors: Task 1 Successors: Task 3 Planned Start Date: 9/16 Planned Finish Date: 9/29 Actual Start Date: 9/15 Actual Finish Date:	
	Costs: Capital Equipment $0.00 Disposables: $0.00	
Task 3 Snapshots	**Name of Task:** Designing the product	
	Objective: To take the project constraints into account and make a realistic and detailed design.	
	Deliverables: Solid works part files and drawings, measurements, and calculated values.	
	Decisions/Milestones with Dates: 1. Decide which design will be most efficient and effective for the task required of it. -9/29 2. Use software to further advance ideas past conception into a reliable plausible project. -10/1 3. Create drafts of the idea with different configurations. -10/3	
	Personnel Needed: Title: Entire team Hours: 15 Percent full time:	
	Time: Estimated Total Hours: 15 Actual Total Hours:	
	Sequence: Predecessors: Task 2 Successors: Task 4 Planned Start Date: 9/29 Planned Finish Date: 10/5 Actual Start Date: N/A Actual Finish Date: N/A	

	Costs: Capital Equipment: $0 Disposables: $0
Task 4 Snapshots	**Name of Task:** Building the Design
	Objective: To gather all materials, build the device and prepare it for initial testing.
	Deliverables: A working model that can be tested and improved upon, documentation of the assembly and manufacturing process.
	Decisions/Milestones with Dates: 1. Take the design and create a prototype that may work, if the prototype doesn't work than it will be back to design. -10/5 2. Once a prototype is successful, build it to the specifications required and move on to testing. -10/7
	Personnel Needed: Title: Entire team Hours: 30 Percent full time:
	Time: Estimated Total Hours: 30 Actual Total Hours:
	Sequence: Predecessors: Task 3 Successors: Task 5 Planned Start Date: 10/5 Planned Finish Date: 10/10 Actual Start Date: N/A Actual Finish Date: N/A
	Costs: Capital Equipment N/A Disposables: N/A
Task 5 Snapshots	**Name of Task:** Testing/Optimizing the Design
	Objective: To test the working prototype and identify and document its faults, to improve those faults and create a better model
	Deliverables: Multiple test reports and documentation of improvements to design and model.
	Decisions/Milestones with Dates: 1. Build a testing device that properly mimics how the submarine will respond with a body of water like the one being used for competition. -10/10 2.Collect data on how the submarine reacts to the testing and make necessary modifications to further improve design. -10/12 3. Complete finishing modifications needed for competition. -10/16
	Personnel Needed: Title: Entire team Hours: 30 Percent full time:
	Time: Estimated Total Hours: 30 Actual Total Hours: N/A
	Sequence: Predecessors: Task 4 Successors: Task 6 Planned Start Date:10/10 Planned Finish Date: 10/16 Actual Start Date: N/A Actual Finish Date: N/A
	Costs: Capital Equipment N/A Disposables: N/A
Task 6 Snapshots	**Name of Task:** Finalizing the Design/Final Evaluation
	Objective: To eventually reach a satisfactory, working model that is competitive and satisfies all competition requirements
	Deliverables: A working model, competitive test results and documentation of successful tests.
	Decisions/Milestones with Dates: 1.Create several similar drafts with slight differences for manufacturing. -10/17 2.Decide on a design and create a model and start inputting electronics. -10/18
	Personnel Needed: Title: Entire team Hours: 1 Percent full time:
	Time: Estimated Total Hours: 1 Actual Total Hours: N/A
	Sequence: Predecessors: Task 5 Successors: Task 7 Planned Start Date: 10/17 Planned Finish Date: 10/18 Actual Start Date: N/A Actual Finish Date: N/A

	Costs: Capital Equipment: N/A Disposables: N/A
Task 7 Snapshots	**Name of Task:** Writing the Report
	Objective: All data needs to be entered into a document in an orderly fashion
	Deliverables: A completed report, graphs, charts, data, meeting minutes, Gantt chart, health assessment, project drawings, project pictures, calculations, project statement, Gantt chart, health assessment, project drawings, project pictures, calculations, materials bill, test results etc.
	Decisions/Milestones with Dates: 1. Create an outline and rough draft of report. -10/20 2. Finalize report and submit. -11/14
	Personnel Needed: Title: Entire team Hours: 10 Percent full time:
	Time: Estimated Total Hours: 10 Actual Total Hours:
	Sequence: Predecessors: Task 6 Successors: None Planned Start Date: 10/20 Planned Finish Date: 11/14 Actual Start Date: N/A Actual Finish Date: N/A
	Costs: Capital Equipment: $0 Disposables: $0

Team member: Garret Snyder	Prepared by: Entire Team
Team member: Christian Hanson	Checked by: Entire Team
Team member: Nate Dowdy	Approved by: Entire Team
Team member: Brent Fields	

The Mechanical Design Process
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Designed by Professor David G. Ullman
Form # 10

Gantt Charts for Each Week

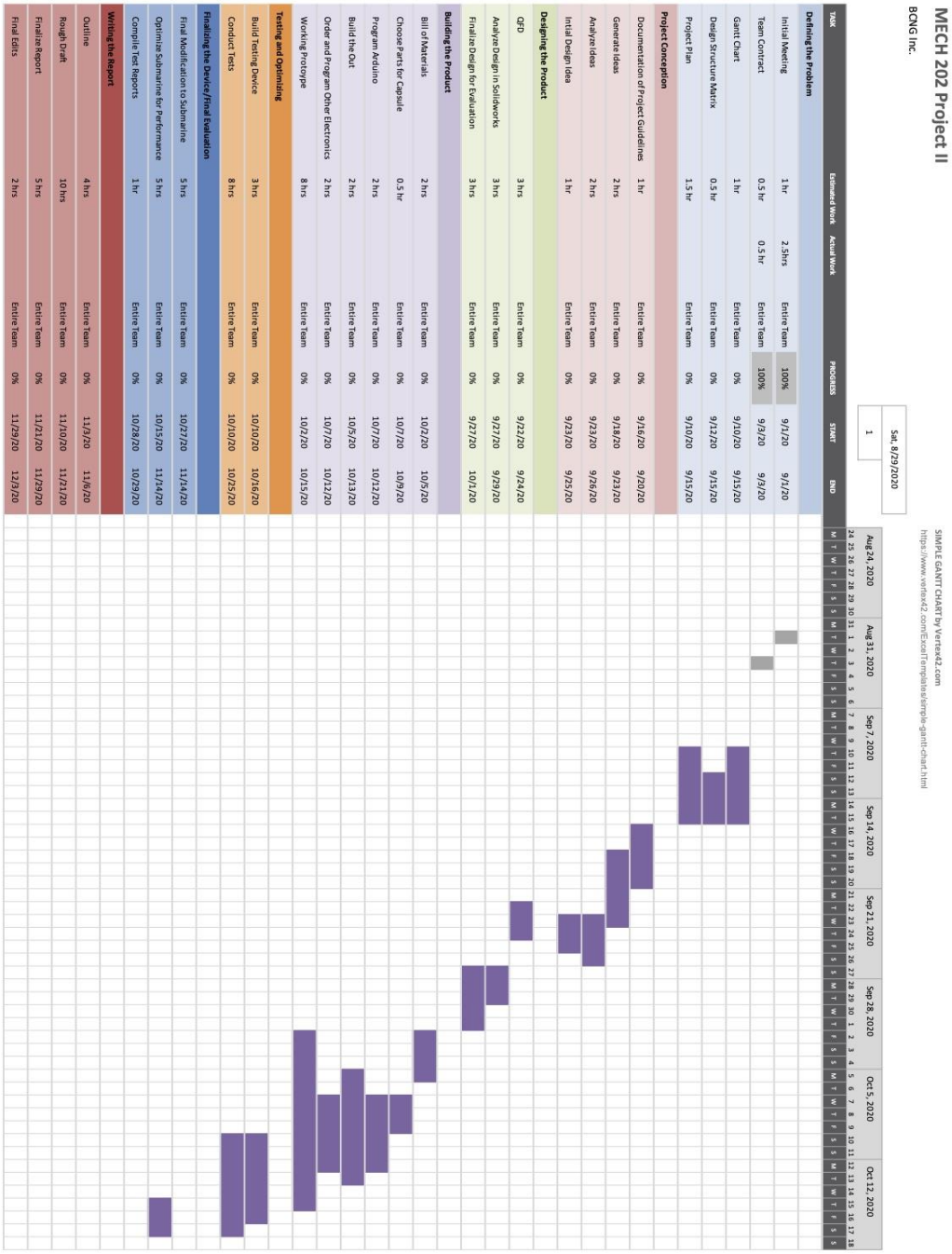

FIGURE 37. WEEK 1 GANTT CHART

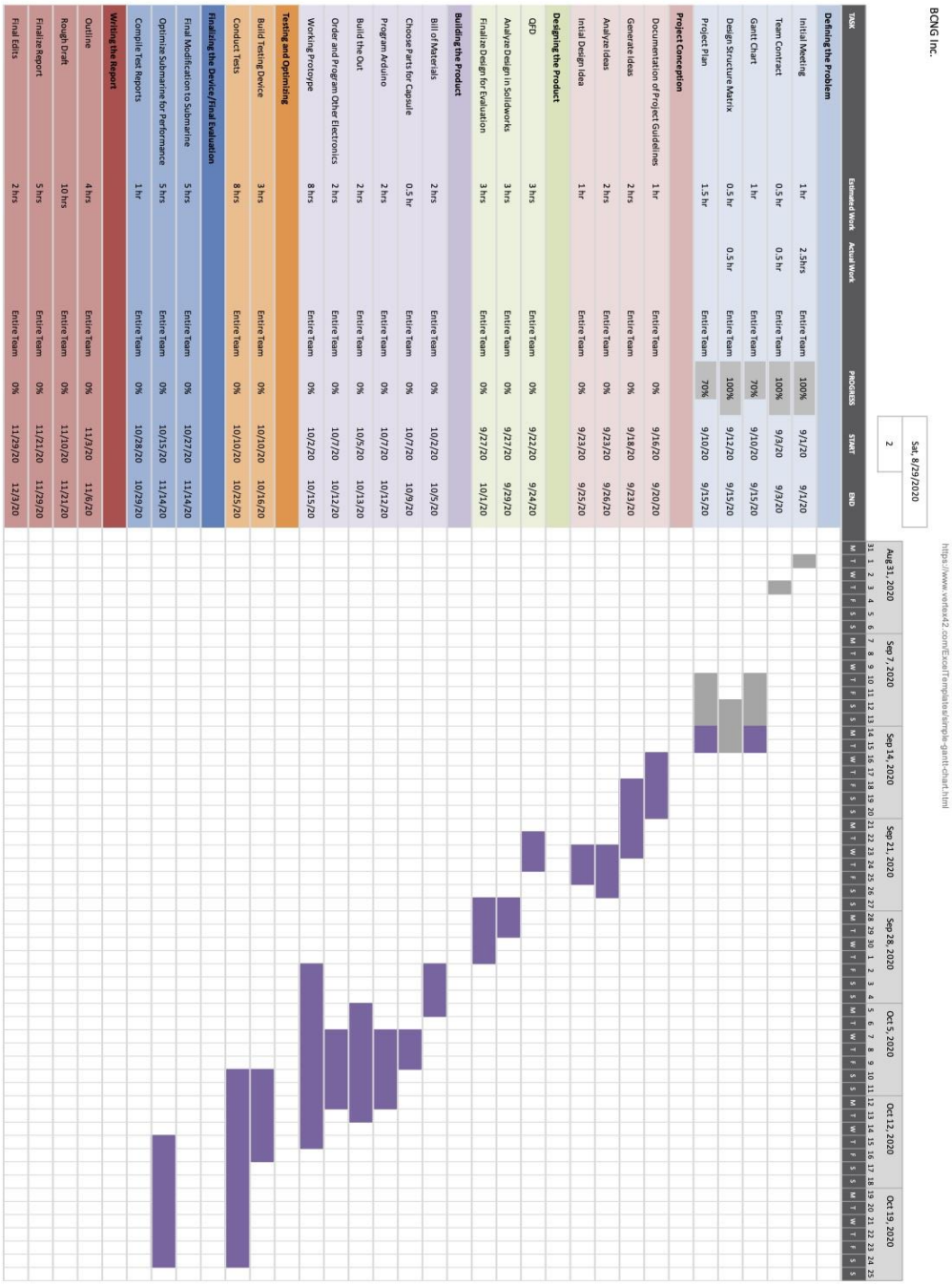

FIGURE 38. WEEK 2 GANTT CHART

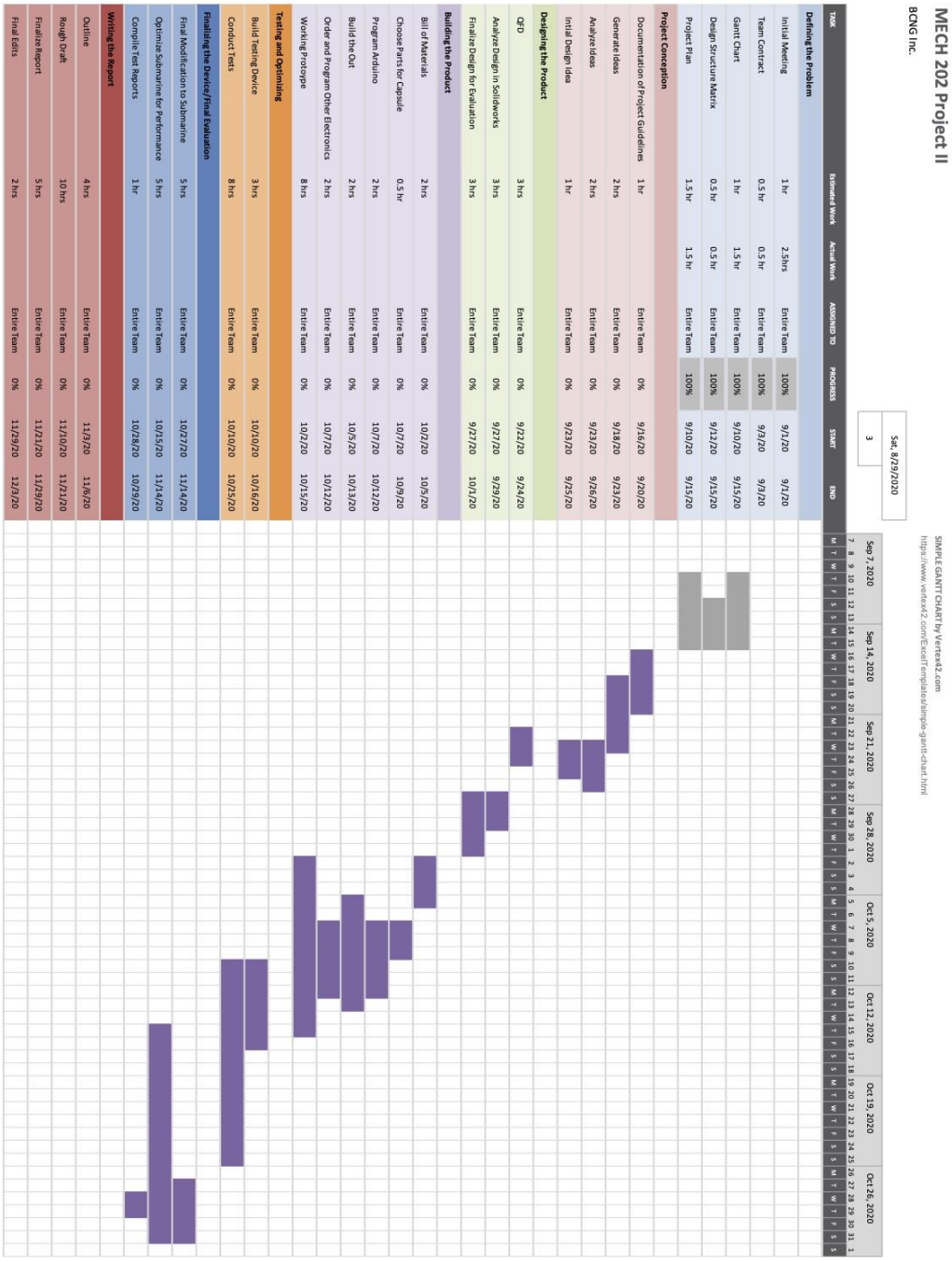

FIGURE 39. WEEK 3 GANTT CHART

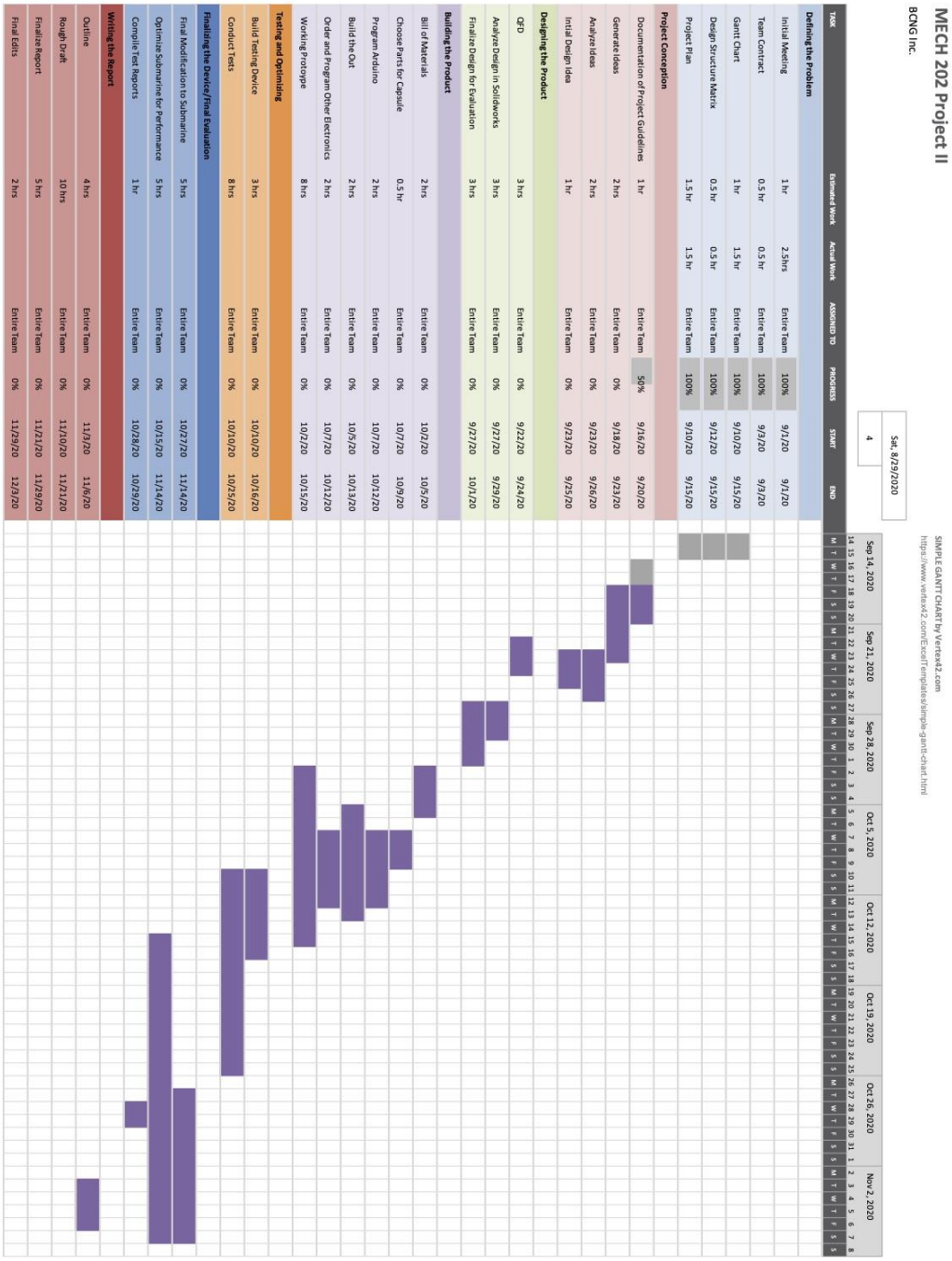

FIGURE 40. WEEK 4 GANTT CHART

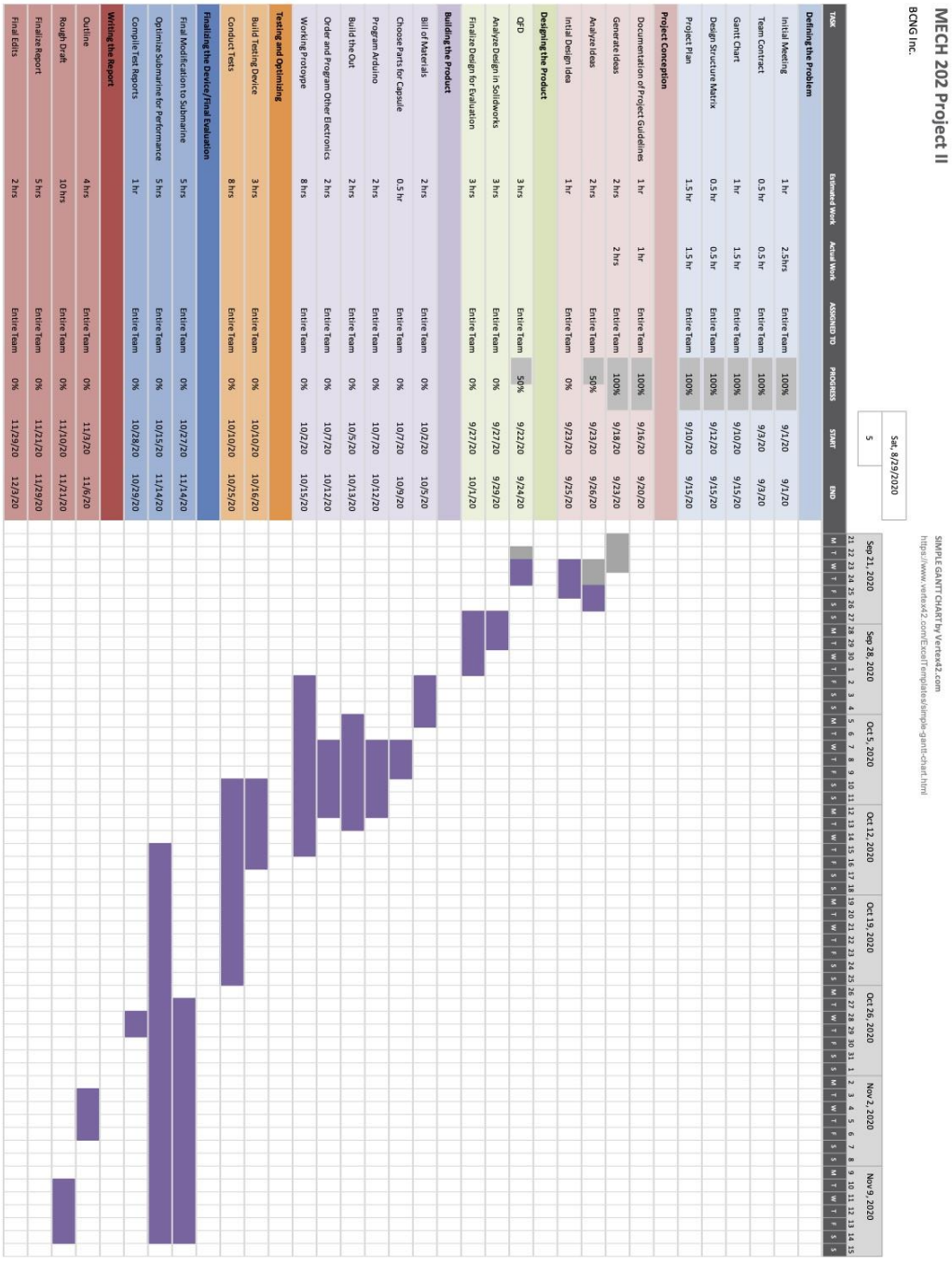

FIGURE 41. WEEK 5 GANTT CHART

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TASK	Estimated Work	Actual Work	ASSIGNED TO	PROGRESS	START	END
Defining the Problem						
Initial Meeting	1 hr	2.5hrs	Entire Team	100%	9/1/20	9/1/20
Team Contract	0.5 hr	0.5 hr	Entire Team	100%	9/3/20	9/3/20
Gantt Chart	1 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Design Structure Matrix	0.5 hr	0.5 hr	Entire Team	100%	9/12/20	9/15/20
Project Plan	1.5 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Project Conception						
Documentation of Project Guidelines	1 hr	1 hr	Entire Team	100%	9/16/20	9/20/20
Generate Ideas	2 hrs	2 hrs	Entire Team	100%	9/18/20	9/23/20
Analyze Ideas	2 hrs	1 hr	Entire Team	100%	9/23/20	9/26/20
Intial Design Idea	1 hr	1 hr	Entire Team	100%	9/23/20	9/25/20
Designing the Product						
QFD	3 hrs	1.5 hrs	Entire Team	100%	9/22/20	9/24/20
Analyze Design in Solidworks	3 hrs		Entire Team	70%	9/27/20	9/29/20
Finalize Design for Evaluation	3 hrs		Entire Team	0%	9/27/20	10/1/20
Building the Product						
Bill of Materials	2 hrs		Entire Team	0%	10/2/20	10/5/20
Choose Parts for Capsule	0.5 hr		Entire Team	0%	10/7/20	10/9/20
Program Arduino	2 hrs		Entire Team	0%	10/7/20	10/12/20
Build the Out	2 hrs		Entire Team	0%	10/5/20	10/13/20
Order and Program Other Electronics	2 hrs		Entire Team	0%	10/7/20	10/12/20
Working Protoype	8 hrs		Entire Team	0%	10/2/20	10/15/20
Testing and Optimizing						
Build Testing Device	3 hrs		Entire Team	0%	10/10/20	10/16/20
Conduct Tests	8 hrs		Entire Team	0%	10/10/20	10/25/20
Finalizing the Device/Final Evaluation						
Final Modification to Submarine	5 hrs		Entire Team	0%	10/27/20	11/14/20
Optimize Submarine for Performance	5 hrs		Entire Team	0%	10/15/20	11/14/20
Compile Test Reports	1 hr		Entire Team	0%	10/28/20	10/29/20
Writing the Report						
Outline	4 hrs		Entire Team	0%	11/3/20	11/6/20
Rough Draft	10 hrs		Entire Team	0%	11/10/20	11/21/20
Finalize Report	5 hrs		Entire Team	0%	11/21/20	11/29/20
Final Edits	2 hrs		Entire Team	0%	11/29/20	12/3/20

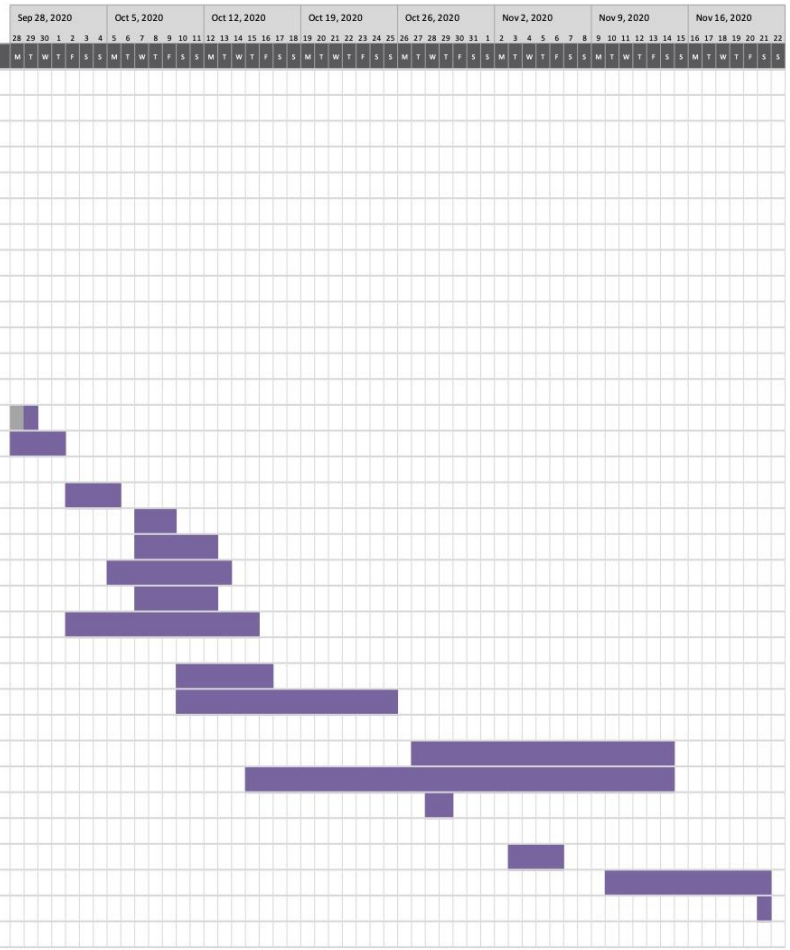

FIGURE 42. WEEK 6 GANTT CHART

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SIMPLE GANTT CHART by Vertex42.com
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TASK	Estimated Work	Actual Work	ASSIGNED TO	PROGRESS	START	END
Defining the Problem						
Initial Meeting	1 hr	2.5hrs	Entire Team	100%	9/1/20	9/1/20
Team Contract	0.5 hr	0.5 hr	Entire Team	100%	9/3/20	9/3/20
Gantt Chart	1 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Design Structure Matrix	0.5 hr	0.5 hr	Entire Team	100%	9/12/20	9/15/20
Project Plan	1.5 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Project Conception						
Documentation of Project Guidelines	1 hr	1 hr	Entire Team	100%	9/16/20	9/20/20
Generate Ideas	2 hrs	2 hrs	Entire Team	100%	9/18/20	9/23/20
Analyze Ideas	2 hrs	1 hr	Entire Team	100%	9/23/20	9/26/20
Intial Design Idea	1 hr	1 hr	Entire Team	100%	9/23/20	9/25/20
Designing the Product						
QFD	3 hrs	1.5 hrs	Entire Team	100%	9/22/20	9/24/20
Analyze Design in Solidworks	3 hrs	2 hrs	Entire Team	100%	9/27/20	9/29/20
Finalize Design for Evaluation	3 hrs	2 hrs	Entire Team	100%	9/27/20	10/1/20
Building the Product						
Bill of Materials	2 hrs	2 hrs	Entire Team	100%	10/2/20	10/5/20
Choose Parts for Capsule	0.5 hr		Entire Team	0%	10/7/20	10/9/20
Program Arduino	2 hrs		Entire Team	0%	10/7/20	10/12/20
Build the Out	2 hrs		Entire Team	0%	10/5/20	10/13/20
Order and Program Other Electronics	2 hrs		Entire Team	0%	10/7/20	10/12/20
Working Protoype	8 hrs		Entire Team	0%	10/2/20	10/15/20
Testing and Optimizing						
Build Testing Device	3 hrs		Entire Team	0%	10/10/20	10/16/20
Conduct Tests	8 hrs		Entire Team	0%	10/10/20	10/25/20
Finalizing the Device/Final Evaluation						
Final Modification to Submarine	5 hrs		Entire Team	0%	10/27/20	11/14/20
Optimize Submarine for Performance	5 hrs		Entire Team	0%	10/15/20	11/14/20
Compile Test Reports	1 hr		Entire Team	0%	10/28/20	10/29/20
Writing the Report						
Outline	4 hrs		Entire Team	0%	11/3/20	11/6/20
Rough Draft	10 hrs		Entire Team	0%	11/10/20	11/21/20
Finalize Report	5 hrs		Entire Team	0%	11/21/20	11/29/20
Final Edits	2 hrs		Entire Team	0%	11/29/20	12/3/20

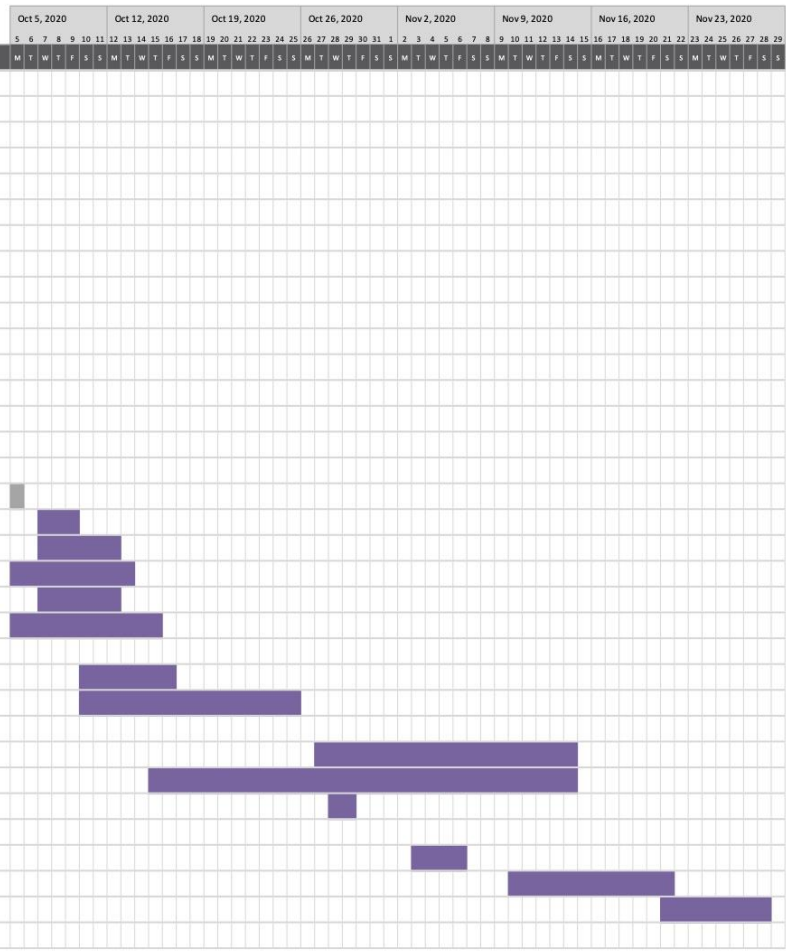

FIGURE 43. WEEK 7 GANTT CHART

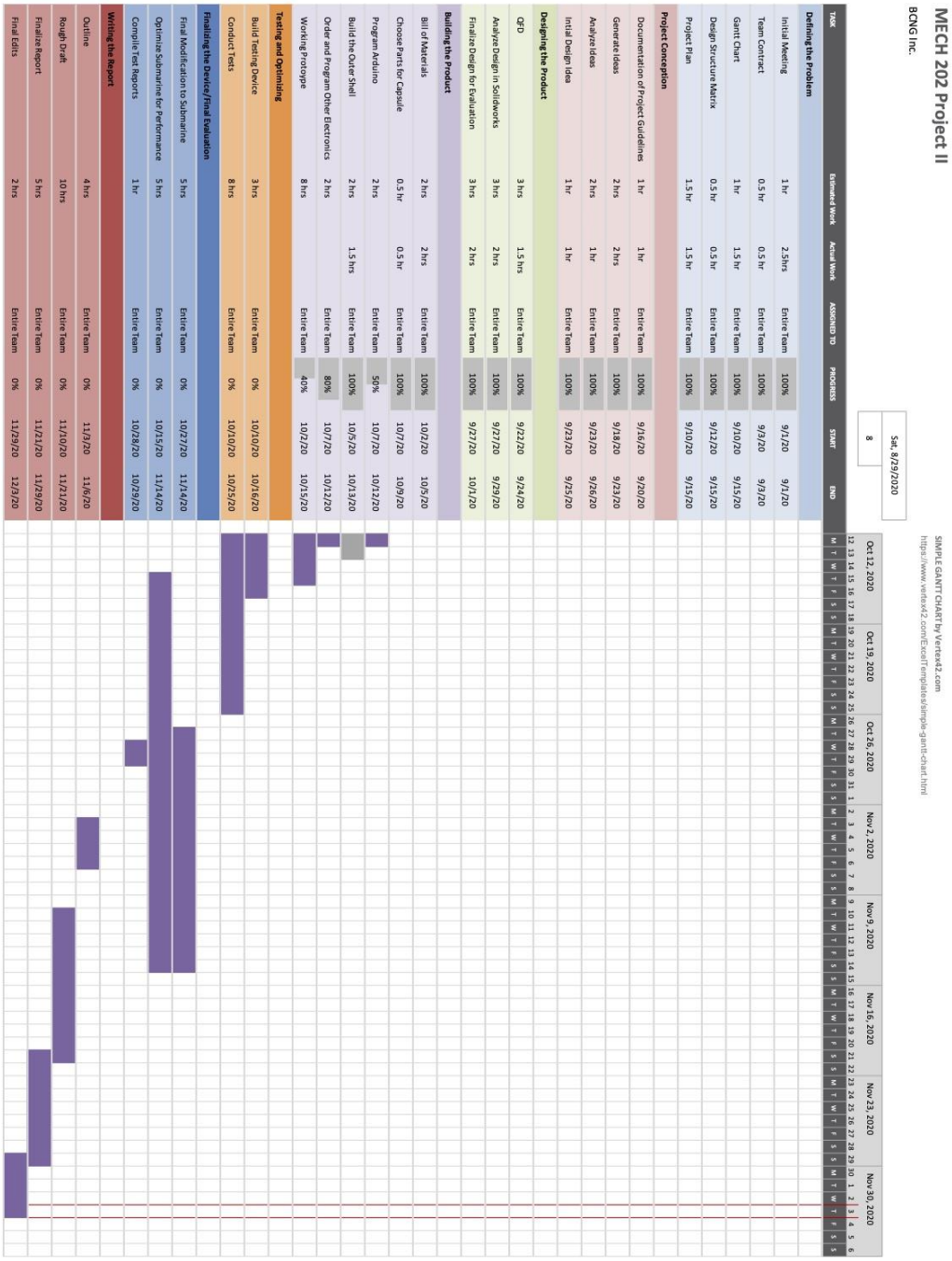

FIGURE 44. WEEK 8 GANTT CHART

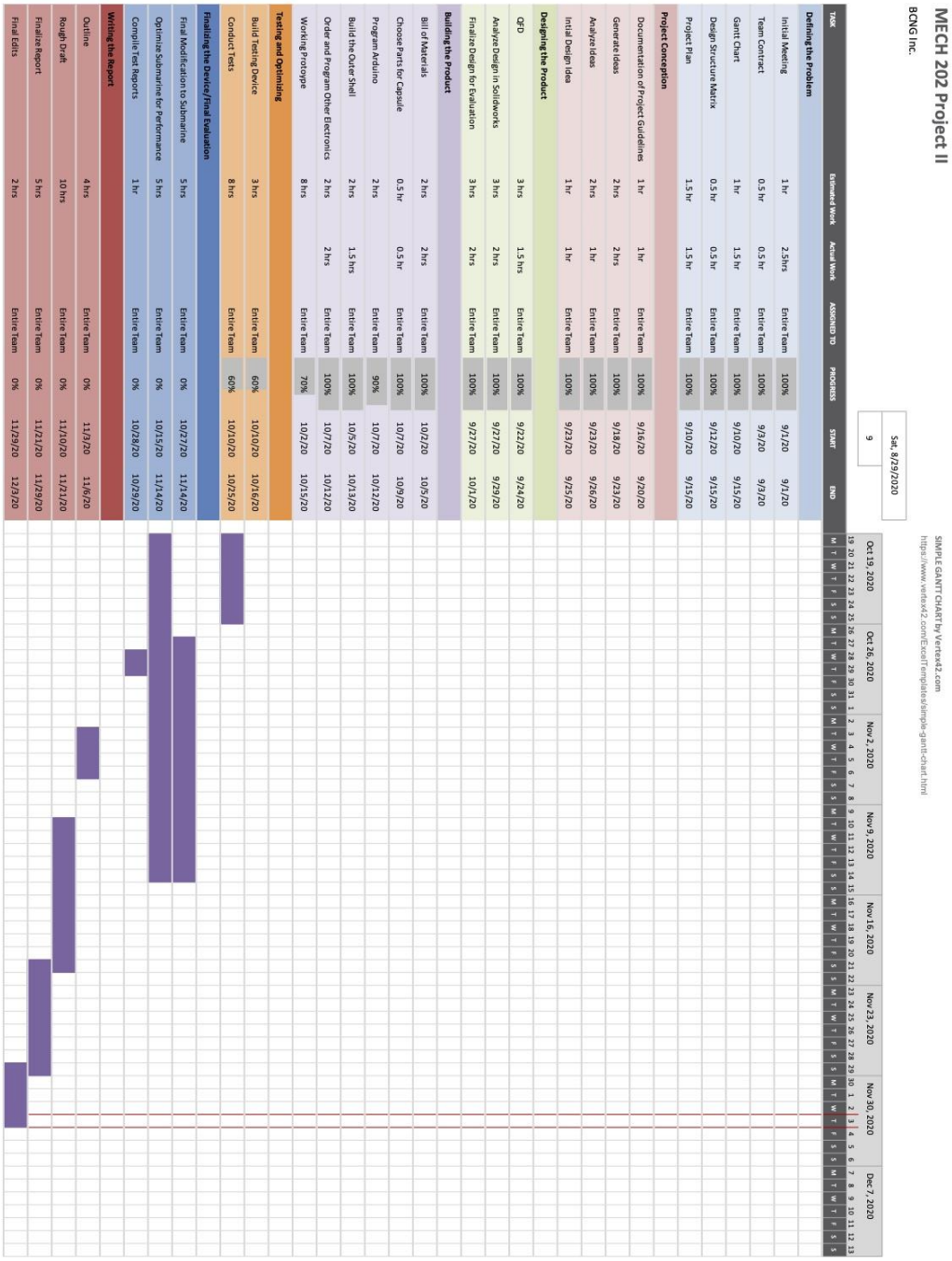

FIGURE 45. WEEK 9 GANTT CHART

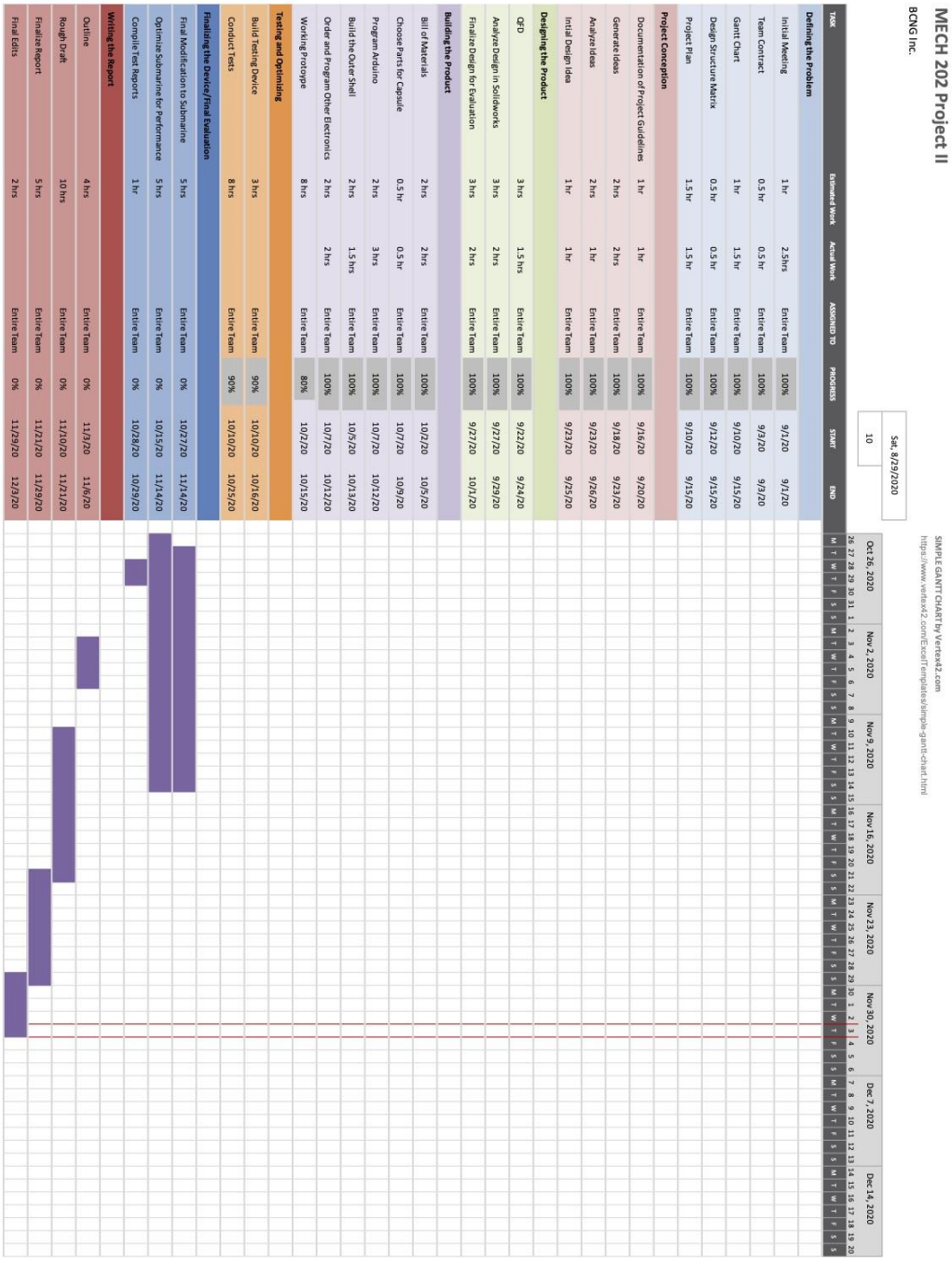

FIGURE 46. WEEK 10 GANTT CHART

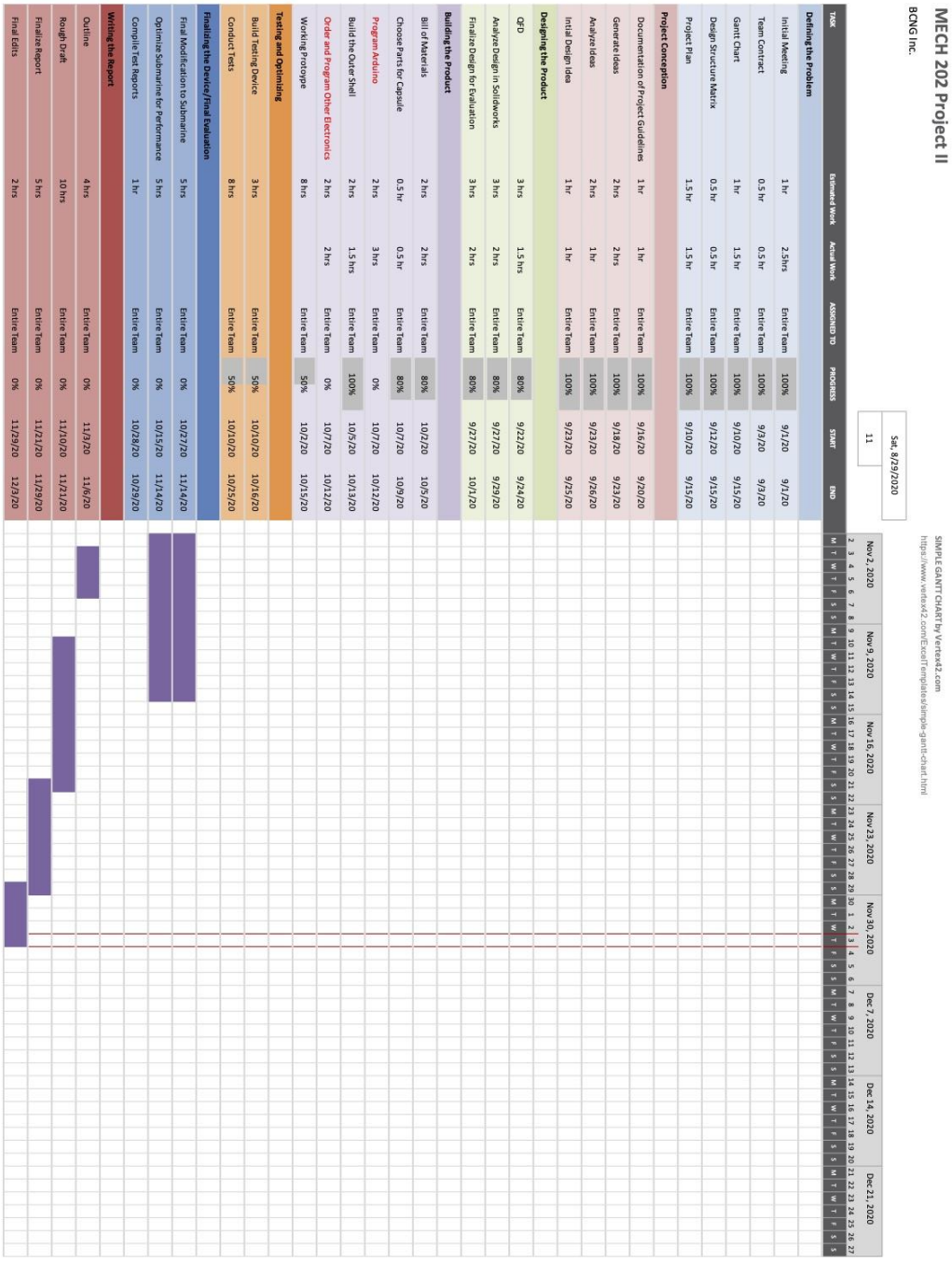

FIGURE 47. WEEK 11 GANTT CHART, WHEN WE BEGAN OUR COMPLETE REDESIGN

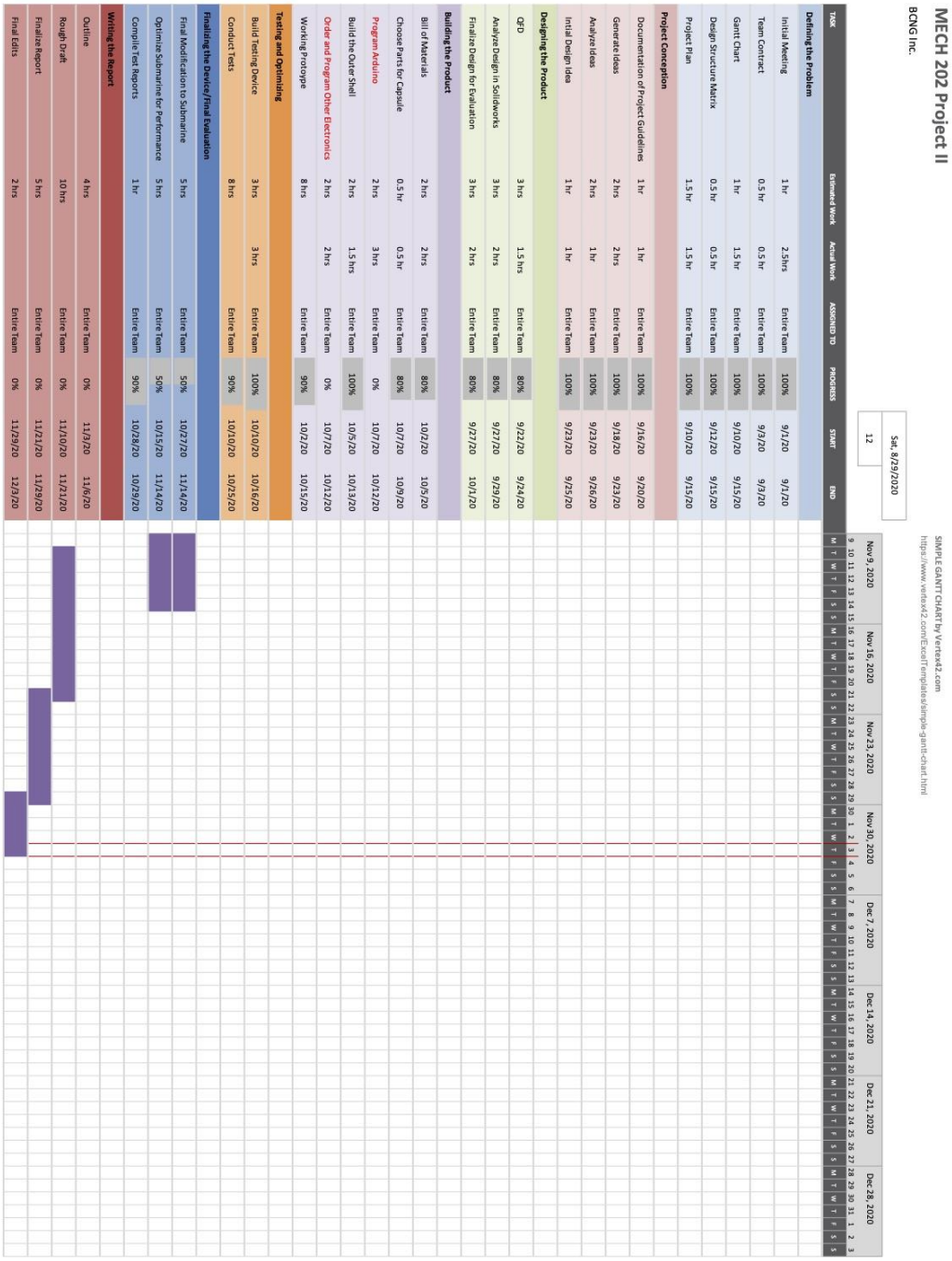

FIGURE 48. WEEK 12 GANTT CHART

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SIMPLE GANTT CHART by Vertex42.com
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TASK	Estimated Work	Actual Work	ASSIGNED TO	PROGRESS	START	END
Defining the Problem						
Initial Meeting	1 hr	2.5hrs	Entire Team	100%	9/1/20	9/1/20
Team Contract	0.5 hr	0.5 hr	Entire Team	100%	9/3/20	9/3/20
Gantt Chart	1 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Design Structure Matrix	0.5 hr	0.5 hr	Entire Team	100%	9/12/20	9/15/20
Project Plan	1.5 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Project Conception						
Documentation of Project Guidelines	1 hr	1 hr	Entire Team	100%	9/16/20	9/20/20
Generate Ideas	2 hrs	2 hrs	Entire Team	100%	9/18/20	9/23/20
Analyze Ideas	2 hrs	1 hr	Entire Team	100%	9/23/20	9/26/20
Intial Design Idea	1 hr	1 hr	Entire Team	100%	9/23/20	9/25/20
Designing the Product						
QFD	3 hrs	1.5 hrs	Entire Team	80%	9/22/20	9/24/20
Analyze Design in Solidworks	3 hrs	2 hrs	Entire Team	80%	9/27/20	9/29/20
Finalize Design for Evaluation	3 hrs	2 hrs	Entire Team	80%	9/27/20	10/1/20
Building the Product						
Bill of Materials	2 hrs	2 hrs	Entire Team	80%	10/2/20	10/5/20
Choose Parts for Capsule	0.5 hr	0.5 hr	Entire Team	80%	10/7/20	10/9/20
Program Arduino	2 hrs	3 hrs	Entire Team	0%	10/7/20	10/12/20
Build the Outer Shell	2 hrs	1.5 hrs	Entire Team	100%	10/5/20	10/13/20
Order and Program Other Electronics	2 hrs	2 hrs	Entire Team	0%	10/7/20	10/12/20
Working Protoype	8 hrs		Entire Team	100%	10/2/20	10/15/20
Testing and Optimizing						
Build Testing Device	3 hrs	3 hrs	Entire Team	100%	10/10/20	10/16/20
Conduct Tests	8 hrs	6 hrs	Entire Team	100%	10/10/20	10/25/20
Finalizing the Device/Final Evaluation						
Final Modification to Submarine	5 hrs	3 hrs	Entire Team	100%	10/27/20	11/14/20
Optimize Submarine for Performance	5 hrs	3 hrs	Entire Team	100%	10/15/20	11/14/20
Compile Test Reports	1 hr	1 hr	Entire Team	100%	10/28/20	10/29/20
Writing the Report						
Outline	4 hrs		Entire Team	40%	11/3/20	11/6/20
Rough Draft	10 hrs		Entire Team	10%	11/10/20	11/21/20
Finalize Report	5 hrs		Entire Team	0%	11/21/20	11/29/20
Final Edits	2 hrs		Entire Team	0%	11/29/20	12/3/20

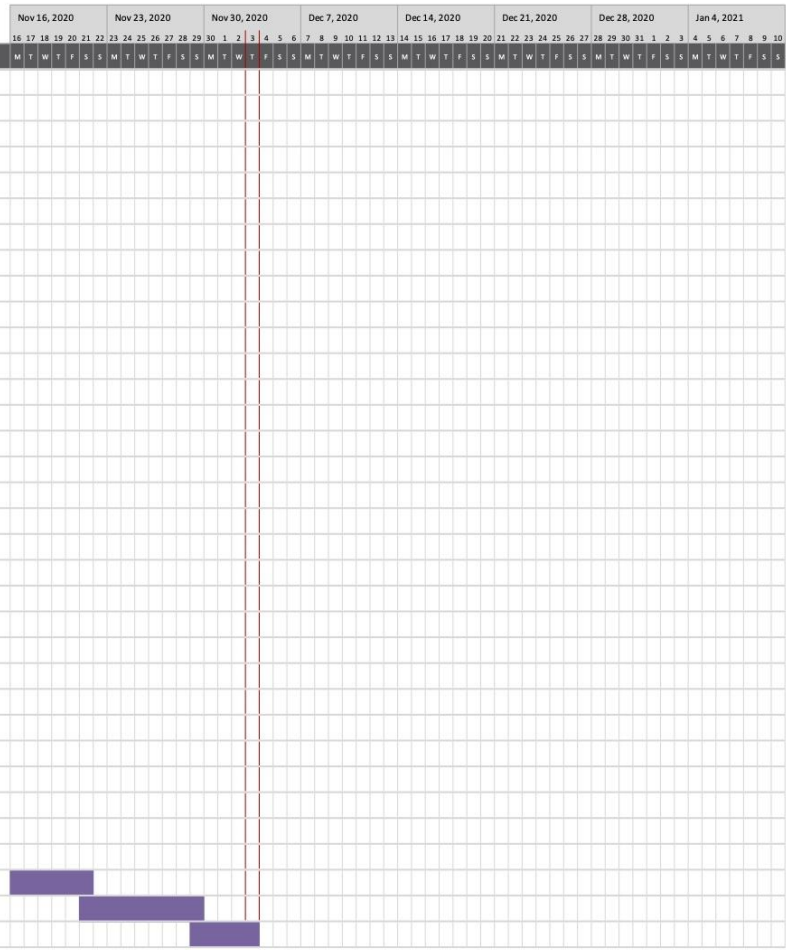

FIGURE 49. WEEK 13 GANTT CHART

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Sat, 8/29/2020

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SIMPLE GANTT CHART by Vertex42.com
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TASK	Estimated Work	Actual Work	ASSIGNED TO	PROGRESS	START	END
Defining the Problem						
Initial Meeting	1 hr	2.5hrs	Entire Team	100%	9/1/20	9/1/20
Team Contract	0.5 hr	0.5 hr	Entire Team	100%	9/3/20	9/3/20
Gantt Chart	1 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Design Structure Matrix	0.5 hr	0.5 hr	Entire Team	100%	9/12/20	9/15/20
Project Plan	1.5 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Project Conception						
Documentation of Project Guidelines	1 hr	1 hr	Entire Team	100%	9/16/20	9/20/20
Generate Ideas	2 hrs	2 hrs	Entire Team	100%	9/18/20	9/23/20
Analyze Ideas	2 hrs	1 hr	Entire Team	100%	9/23/20	9/26/20
Intial Design Idea	1 hr	1 hr	Entire Team	100%	9/23/20	9/25/20
Designing the Product						
QFD	3 hrs	1.5 hrs	Entire Team	80%	9/22/20	9/24/20
Analyze Design in Solidworks	3 hrs	2 hrs	Entire Team	80%	9/27/20	9/29/20
Finalize Design for Evaluation	3 hrs	2 hrs	Entire Team	80%	9/27/20	10/1/20
Building the Product						
Bill of Materials	2 hrs	2 hrs	Entire Team	80%	10/2/20	10/5/20
Choose Parts for Capsule	0.5 hr	0.5 hr	Entire Team	80%	10/7/20	10/9/20
Program Arduino	2 hrs	3 hrs	Entire Team	0%	10/7/20	10/12/20
Build the Outer Shell	2 hrs	1.5 hrs	Entire Team	100%	10/5/20	10/13/20
Order and Program Other Electronics	2 hrs	2 hrs	Entire Team	0%	10/7/20	10/12/20
Working Protoype	8 hrs		Entire Team	100%	10/2/20	10/15/20
Testing and Optimizing						
Build Testing Device	3 hrs	3 hrs	Entire Team	100%	10/10/20	10/16/20
Conduct Tests	8 hrs	6 hrs	Entire Team	100%	10/10/20	10/25/20
Finalizing the Device/Final Evaluation						
Final Modification to Submarine	5 hrs	3 hrs	Entire Team	100%	10/27/20	11/14/20
Optimize Submarine for Performance	5 hrs	3 hrs	Entire Team	100%	10/15/20	11/14/20
Compile Test Reports	1 hr	1 hr	Entire Team	100%	10/28/20	10/29/20
Writing the Report						
Outline	4 hrs	4 hrs	Entire Team	100%	11/3/20	11/6/20
Rough Draft	10 hrs		Entire Team	50%	11/10/20	11/21/20
Finalize Report	5 hrs		Entire Team	30%	11/21/20	11/29/20
Final Edits	2 hrs		Entire Team	0%	11/29/20	12/3/20

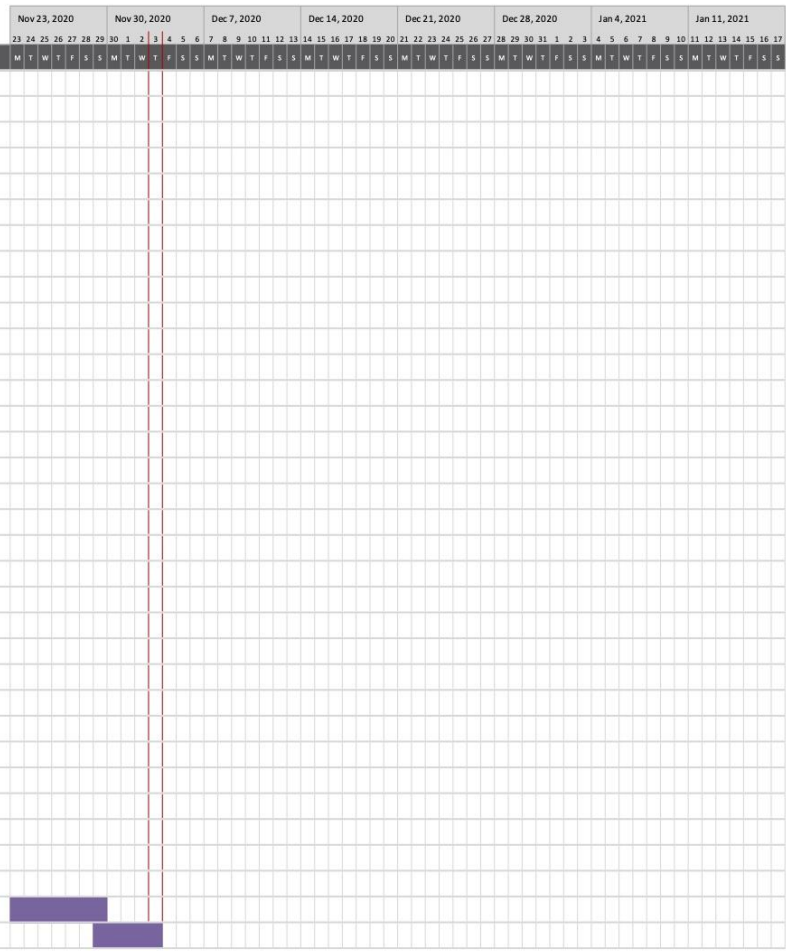

FIGURE 50. WEEK 14 GANTT CHART

MECH 202 Project II

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Sat, 8/29/2020

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TASK	Estimated Work	Actual Work	ASSIGNED TO	PROGRESS	START	END
Defining the Problem						
Initial Meeting	1 hr	2.5hrs	Entire Team	100%	9/1/20	9/1/20
Team Contract	0.5 hr	0.5 hr	Entire Team	100%	9/3/20	9/3/20
Gantt Chart	1 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Design Structure Matrix	0.5 hr	0.5 hr	Entire Team	100%	9/12/20	9/15/20
Project Plan	1.5 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Project Conception						
Documentation of Project Guidelines	1 hr	1 hr	Entire Team	100%	9/16/20	9/20/20
Generate Ideas	2 hrs	2 hrs	Entire Team	100%	9/18/20	9/23/20
Analyze Ideas	2 hrs	1 hr	Entire Team	100%	9/23/20	9/26/20
Intial Design Idea	1 hr	1 hr	Entire Team	100%	9/23/20	9/25/20
Designing the Product						
QFD	3 hrs	1.5 hrs	Entire Team	80%	9/22/20	9/24/20
Analyze Design in Solidworks	3 hrs	2 hrs	Entire Team	80%	9/27/20	9/29/20
Finalize Design for Evaluation	3 hrs	2 hrs	Entire Team	80%	9/27/20	10/1/20
Building the Product						
Bill of Materials	2 hrs	2 hrs	Entire Team	80%	10/2/20	10/5/20
Choose Parts for Capsule	0.5 hr	0.5 hr	Entire Team	80%	10/7/20	10/9/20
Program Arduino	2 hrs	3 hrs	Entire Team	0%	10/7/20	10/12/20
Build the Outer Shell	2 hrs	1.5 hrs	Entire Team	100%	10/5/20	10/13/20
Order and Program Other Electronics	2 hrs	2 hrs	Entire Team	0%	10/7/20	10/12/20
Working Protoype	8 hrs	5 hrs	Entire Team	100%	10/2/20	10/15/20
Testing and Optimizing						
Build Testing Device	3 hrs	3 hrs	Entire Team	100%	10/10/20	10/16/20
Conduct Tests	8 hrs	6 hrs	Entire Team	100%	10/10/20	10/25/20
Finalizing the Device/Final Evaluation						
Final Modification to Submarine	5 hrs	3 hrs	Entire Team	100%	10/27/20	11/14/20
Optimize Submarine for Performance	5 hrs	3 hrs	Entire Team	100%	10/15/20	11/14/20
Compile Test Reports	1 hr	1 hr	Entire Team	100%	10/28/20	10/29/20
Writing the Report						
Outline	4 hrs	4 hrs	Entire Team	100%	11/3/20	11/6/20
Rough Draft	10 hrs	9 hrs	Entire Team	100%	11/10/20	11/21/20
Finalize Report	5 hrs		Entire Team	90%	11/21/20	11/29/20
Final Edits	2 hrs		Entire Team	50%	11/29/20	12/3/20

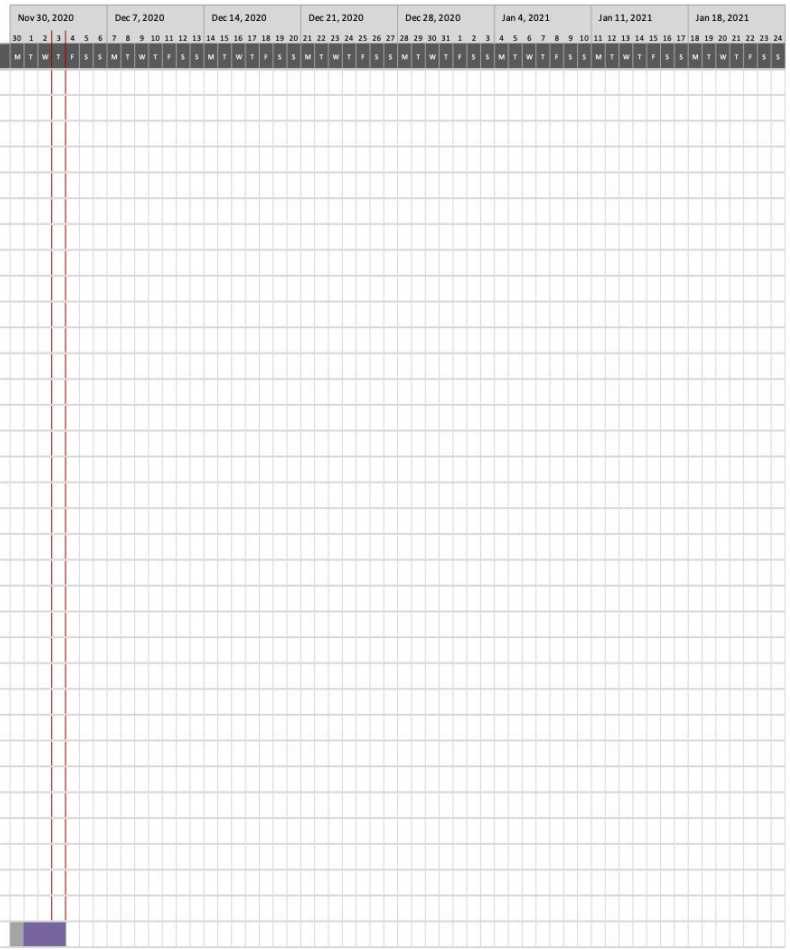

FIGURE 51. WEEK 15 GANTT CHART

MECH 202 Project II

BCNG Inc.

SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

Sat, 8/29/2020

16

TASK	Estimated Work	Actual Work	ASSIGNED TO	PROGRESS	START	END
Defining the Problem						
Initial Meeting	1 hr	2.5hrs	Entire Team	100%	9/1/20	9/1/20
Team Contract	0.5 hr	0.5 hr	Entire Team	100%	9/3/20	9/3/20
Gantt Chart	1 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Design Structure Matrix	0.5 hr	0.5 hr	Entire Team	100%	9/12/20	9/15/20
Project Plan	1.5 hr	1.5 hr	Entire Team	100%	9/10/20	9/15/20
Project Conception						
Documentation of Project Guidelines	1 hr	1 hr	Entire Team	100%	9/16/20	9/20/20
Generate Ideas	2 hrs	2 hrs	Entire Team	100%	9/18/20	9/23/20
Analyze Ideas	2 hrs	1 hr	Entire Team	100%	9/23/20	9/26/20
Intial Design Idea	1 hr	1 hr	Entire Team	100%	9/23/20	9/25/20
Designing the Product						
QFD	3 hrs	1.5 hrs	Entire Team	80%	9/22/20	9/24/20
Analyze Design in Solidworks	3 hrs	2 hrs	Entire Team	80%	9/27/20	9/29/20
Finalize Design for Evaluation	3 hrs	2 hrs	Entire Team	80%	9/27/20	10/1/20
Building the Product						
Bill of Materials	2 hrs	2 hrs	Entire Team	80%	10/2/20	10/5/20
Choose Parts for Capsule	0.5 hr	0.5 hr	Entire Team	80%	10/7/20	10/9/20
Program Arduino	2 hrs	3 hrs	Entire Team	0%	10/7/20	10/12/20
Build the Outer Shell	2 hrs	1.5 hrs	Entire Team	100%	10/5/20	10/13/20
Order and Program Other Electronics	2 hrs	2 hrs	Entire Team	0%	10/7/20	10/12/20
Working Protoype	8 hrs	5 hrs	Entire Team	100%	10/2/20	10/15/20
Testing and Optimizing						
Build Testing Device	3 hrs	3 hrs	Entire Team	100%	10/10/20	10/16/20
Conduct Tests	8 hrs	6 hrs	Entire Team	100%	10/10/20	10/25/20
Finalizing the Device/Final Evaluation						
Final Modification to Submarine	5 hrs	3 hrs	Entire Team	100%	10/27/20	11/14/20
Optimize Submarine for Performance	5 hrs	3 hrs	Entire Team	100%	10/15/20	11/14/20
Compile Test Reports	1 hr	1 hr	Entire Team	100%	10/28/20	10/29/20
Writing the Report						
Outline	4 hrs	4 hrs	Entire Team	100%	11/3/20	11/6/20
Rough Draft	10 hrs	9 hrs	Entire Team	100%	11/10/20	11/21/20
Finalize Report	5 hrs	4 hrs	Entire Team	100%	11/21/20	11/29/20
Final Edits	2 hrs		Entire Team	90%	11/29/20	12/3/20

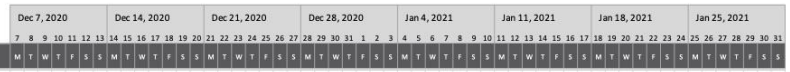

FIGURE 52. WEEK 16 GANTT CHART

Team Analysis

Assessment

Overall, the team worked well together. The whole team met up multiple times a week in person to work on our prototype and weekly reports. Some things would be assigned to specific group members to complete on their own time, and sometimes just a few members would meet up and work on a specific assignment. The group communicated well about problems or work that needed to be completed

Team Contract

Team Contract		
Design Organization: BCNG Inc.		**Date: 9/7/2020**
Team Member	Roles	Signature
Nate Dowdy	Finalizer and Diplomat	**Nathan Dowdy**
Garret Snyder	Idea Generator	**Garret Snyder**
Christian Hanson	Coach	**Christian Hanson**
Brent Fields	Expert	**Brenton Fields**

Team Goals	Responsible Member
1. To practice team dynamics to effectively create a project.	Nate
2. Have a common group goal for a project that benefits all of us.	Christian
3. Generate unique and diverse ideas for the group.	Garret
4. A "Progress Manager" – someone who checks deadlines and keeps group on track	Garret
5. Using prior knowledge to further advance the project	Brent
6. To create ideas with a social approach rather than self interest	Christian
7. Coach team members to perform to best ability	Brent
8. Make sure calculations are accurate and double checked	Nate
9. To create a trial and error project that produces failure and then success.	Chris
10. Use Constructive Conflict to resolve disputes within the group.	Nate

Team Performance Expectations	Initial				
● Strive to complete all assigned tasks before or by deadlines	**ND**	**GS**	**BF**	**CH**	
● Complete all tasks to the best of ability	**ND**	**GS**	**BF**	**CH**	
● Listen carefully and attentively to all comments at meetings	**ND**	**GS**	**BF**	**CH**	
● Accept and give criticism in a professional manner	**ND**	**GS**	**BF**	**CH**	
● Focus on results before the fact, rather than excuses after	**ND**	**GS**	**BF**	**CH**	
● Provide as much notice as possible of commitment problems	**ND**	**GS**	**BF**	**CH**	

● Attend and participate in all scheduled group meetings	**ND**	**GS**	**BF**	**CH**	
● Frequently reference the Team Contract to remember goals and expectations	**ND**	**GS**	**BF**	**CH**	
● Each person will be individually invested in the project	**ND**	**GS**	**BF**	**CH**	

Strategies for Conflict Resolution:

- Members will forward the project by engaging in Constructive Conflict.
- Constructive Conflict – Examine the "underlying desires" of each party to collectively find a resolution.
- Members will state to the other party if conflicts become destructive.
- As a Team we will avoid using compromises to solve issues. (Not Effective)

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Team Health

Team Health Assessment							
Team Assessed: BNCG Inc. Group 6		**Date: 10/10/2020**					
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.	X	☐	☐	☐	☐	☐
2	I feel that I am part of a team.	☐	X	☐	☐	☐	☐
3	I feel good about the team's progress	☐	☐	☐	☐	☐	☐
4	Respect has been built within the team for diverse points of view.	☐	☐	X	☐	☐	☐
5	Team environment is characterized by honesty, trust, mutual respect, and teamwork	☐	X	☐	☐	☐	☐
6	The roles and work assignments are clear	☐	X	☐	☐	☐	☐
7	Team treats every member's ideas as having potential value	☐	X	☐	☐	☐	☐
8	Team encourages individual differences.	☐	X	☐	☐	☐	☐
9	Conflicts within the team are aired and worked to resolution.	X	☐	☐	☐	☐	☐
10	Team takes time to develop consensus by discussing the concerns of all members to arrive at an acceptable solution	☐	X	☐	☐	☐	☐
11	Decisions are made with input from all in a collaborative environment.	☐	X	☐	☐	☐	☐
12	The environment encourages communication and does not "kill the messenger" when the news is bad.	☐	X	☐	☐	☐	☐
13	When one team member has a problem, others jump in to help	☐	X	☐	☐	☐	☐
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.	☐	X	☐	☐	☐	☐
16	There is no "them and us" on the team	X	☐	☐	☐	☐	☐
17	Our team cultivates a "what we can learn" attitude when things do not go as expected.	☐	X	☐	☐	☐	☐

Remedies for improving the Neutral (N), Disagree (D) and Strongly Disagree (SD) responses: Make sure every voice is being heard. Taking turns talking.	
Assessor: Nathan Dowdy	

Team Health Assessment

Team Assessed: BNCG Inc. Group 6	**Date: 11/10/2020**

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.	X	☐	☐	☐	☐	☐
2	I feel that I am part of a team.	☐	X	☐	☐	☐	☐
3	I feel good about the team's progress	☐	☐	☐	☐	☐	☐
4	Respect has been built within the team for diverse points of view.	X	☐		☐	☐	☐
5	Team environment is characterized by honesty, trust, mutual respect, and teamwork	☐	X	☐	☐	☐	☐
6	The roles and work assignments are clear	☐	X	☐	☐	☐	☐
7	Team treats every member's ideas as having potential value	☐	X	☐	☐	☐	☐
8	Team encourages individual differences.	☐	X	☐	☐	☐	☐
9	Conflicts within the team are aired and worked to resolution.	X	☐	☐	☐	☐	☐
10	Team takes time to develop consensus by discussing the concerns of all members to arrive at an acceptable solution	☐	X	☐	☐	☐	☐
11	Decisions are made with input from all in a collaborative environment.	☐	X	☐	☐	☐	☐
12	The environment encourages communication and does not "kill the messenger" when the news is bad.	☐	X	☐	☐	☐	☐
13	When one team member has a problem, others jump in to help	☐	X	☐	☐	☐	☐
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.	☐	X	☐	☐	☐	☐
16	There is no "them and us" on the team	X	☐	☐	☐	☐	☐
17	Our team cultivates a "what we can learn" attitude when things do not go as expected.	☐	X	☐	☐	☐	☐

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

Assessor: Nathan Dowdy	

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Team Health Assessment

Team Assessed: BNCG Inc. Group 6	**Date: 11/20/2020**

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.	X	☐	☐	☐	☐	☐
2	I feel that I am part of a team.	☐	X	☐	☐	☐	☐
3	I feel good about the team's progress	☐	☐	☐	☐	☐	☐
4	Respect has been built within the team for diverse points of view.	X	☐		☐	☐	☐
5	Team environment is characterized by honesty, trust, mutual respect, and teamwork	☐	X	☐	☐	☐	☐
6	The roles and work assignments are clear	☐	X	☐	☐	☐	☐
7	Team treats every member's ideas as having potential value	☐	X	☐	☐	☐	☐
8	Team encourages individual differences.	☐	X	☐	☐	☐	☐
9	Conflicts within the team are aired and worked to resolution.	X	☐	☐	☐	☐	☐
10	Team takes time to develop consensus by discussing the concerns of all members to arrive at an acceptable solution	☐	X	☐	☐	☐	☐
11	Decisions are made with input from all in a collaborative environment.	☐	X	☐	☐	☐	☐
12	The environment encourages communication and does not "kill the messenger" when the news is bad.	X		☐	☐	☐	☐
13	When one team member has a problem, others jump in to help	☐	X	☐	☐	☐	☐
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.	☐	X	☐	☐	☐	☐
16	There is no "them and us" on the team	X	☐	☐	☐	☐	☐
17	Our team cultivates a "what we can learn" attitude when things do not go as expected.	X		☐	☐	☐	☐

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

Make sure every voice is being heard. Taking turns talking.

Assessor: Nathan Dowdy	

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Meeting Minutes

Team Meeting Minutes	
Design Organization: BCNG Inc.	**Date: 8/29/2020**
Agenda: 1. First Formal Meeting 2. Introductions/fun fact about themselves 3. Discuss expectations for team members 4. Discuss how disputes should be resolved	
Discussion: What are the best habits/routines the team should put into practice to be successful.	
Decisions Made: NA	
Team member: Nathan Dowdy	Date for next meeting: 9/3/2020
Team member: Garret	
Team member: Christian Hanson	
Team member: Brent Fields	
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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 9/3/2020**

Agenda:

5. Complete Team Contract

Discussion: What roles does each person think they should fill based on their individual personality scores.

Decisions Made: Roles for each Team Member.

Team member: Nathan Dowdy	Date for next meeting: 9/14/2020
Team member: Garret	
Team member: Christian Hanson	
Team member: Brent Fields	

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 9/14/2020**

Agenda:

6. Complete Project Plan Template
7. Complete Gantt Chart

Discussion: How will the timeline look throughout the semester. Discuss who wants to be assigned to different tasks. Overall, divide the work effectively.

Decisions Made: The estimated amount of time required for the entire project. Estimated Weekly Time commitment.

Action Items	Person Responsible	Deadline
Start to Work on the QFD	Nathan Dowdy	
Team member: Nathan Dowdy	Date for next meeting: 9/24/2020	
Team member: Garret		
Team member: Christian Hanson		
Team member: Brent Fields		

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 9/24/2020**

Agenda:

1. Complete the Quality Function Development Template
2. Come up with Ten Demanded Customer Qualities

Discussion: What do customers look for in a product? Out of the customer qualities which ones are positively versus negatively linked? How should this influence the design we choose.

Decisions Made: Decided to go with a Compressed Air Device after completing the QFD.

Action Items	Person Responsible	Deadline
Start working on a Bill of Materials for the Device; Decide what parts need to be ordered	Brent Fields and Christian Hanson	9/29/2020

Team member: Nathan Dowdy	Date for next meeting: 9/29/2020
Team member: Garret	
Team member: Christian Hanson	
Team member: Brent Fields	

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 9/29/2020**

Agenda:

1. Generate 3 Concepts for Submarine
2. Evaluate Each one through research
3. Choose one to pursue

Discussion: From the last meeting and this meeting, the consensus is still for a compressed air device. The compressed air will be in the form of CO_2 canisters, and will be used to expel the water from the device to rise the device to the surface.

Decisions Made: Decided to build a CO_2 device. Decided that the group will need many reusable cartridges or expendable ones. Decided Action steps for upcoming week.

Action Items	Person Responsible	Deadline
Go shopping – see what we can buy to fit our needs Create a Bill of materials in the process	Nathan Dowdy	10/8/2020

Team member: Nathan Dowdy	Date for next meeting: 10/8/2020
Team member: Garret	
Team member: Christian Hanson	
Team member: Brent Fields	

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 10/8/2020**

Agenda:

1. Complete Reverse Engineering Template for Design

Discussion: How does the mechanical energy transfer throughout the device? How does the electrical components work with the other mechanical components? How expensive is the project so far?

Decisions Made: A value system would need to be designed for the CO_2 canister activation.

Action Items	Person Responsible	Deadline
Design Value System for CO_2	Christian Hanson	10/14

Team member: Nathan Dowdy	Date for next meeting: 10/15/2020
Team member: Garret	
Team member: Christian Hanson	
Team member: Brent Fields	

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 10/15/2020**

Agenda:

1. Finish Building Prototype
2. Compile Drawings
3. Head over to the school for Design to be Evaluated

Discussion: TA's were impressed with the engineering done for our design. Overall, the meeting went well and boosted team health. After meeting with the TA's, the team complied some next steps for the project.

Decisions Made: Continue with the CO_2 design. Continue to test and get a better working device.

Action Items	Person Responsible	Deadline
Start to Work on the QFD	Nathan Dowdy	

Team member: Nathan Dowdy	Date for next meeting: 10/29/2020
Team member: Garret	
Team member: Christian Hanson	
Team member: Brent Fields	

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 10/29/2020**

Agenda:

1. Discuss misinterpretation of dimensions for project
2. Look over clarification of the rules laid out int eh email received from the instructor
3. Problem solve – decide what is next

Discussion: The team thought the height dimension could be any direction so our device was technically 9 inches tall when it should be only 5 inches tall. Eventually after some time the team came up with an Alka Seltzer idea that would essentially work the same as the previous device

Decisions Made: Decided to come up with a new design but try to use the supplies from the other device. Decided to build a similar device but within dimensions and instead use Alka Seltzer as the Activating agent.

Action Items	Person Responsible	Deadline
Draw up and Build new Design	Everyone	11/5
Team member: Nathan Dowdy	Date for next meeting: 11/2/2020	
Team member: Garret		
Team member: Christian Hanson		
Team member: Brent Fields		

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 11/2/2020**

Agenda:

1. Build new Design
2. Get any other supplies that are needed

Discussion: The team build a working prototype that uses an airway value at the top of the device, metal BB's to weigh it down, and Alka Seltzer to expel the water once it hits the bottom.

Decisions Made: Continue to test and optimize device and make plans for a final build of the device.

Action Items	Person Responsible	Deadline
Testing Analysis	Nathan Dowdy	11/5

Team member: Nathan Dowdy	Date for next meeting: 11/5/2020
Team member: Garret	
Team member: Christian Hanson	
Team member: Brent Fields	

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 11/5/2020**

Agenda:

1. Meet with TA's to discuss the prototype
2. Do a complete test for them
3. Discuss next steps

Discussion: The prototype proves that the airway works but with the current design the device rotates and does not hit the bottom correctly to activate the shaft value. Need to Rework the design to build a final product. Luckily, many of the components are PVC pipe that can be reused and cut down to size.

Decisions Made: A final rework of the design needs to be done. The weigh needs to be at the bottom of the device as to not create a moment arm while sinking.

Action Items	Person Responsible	Deadline
Final Build of Device	Everyone	11/14/2020

Team member: Nathan Dowdy	Date for next meeting: 11/7/2020
Team member: Garret	
Team member: Christian Hanson	
Team member: Brent Fields	

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 11/7/2020**

Agenda:

1. Build Final Design

Discussion: Decided to use a short dome capsule contained from PVC pipe, an ABS cap, and an ABS dome cap. The weigh could be at the bottom and the center of gravity would be below the centroid creating a restoring moment as it fell.

Decisions Made: The final device was built and everything about the design was solidified.

Action Items	Person Responsible	Deadline
Perform more testing to ensure reliability	Nathan Dowdy, Brent Fields	11/13/2020
Team member: Nathan Dowdy	Date for next meeting: 11/25/2020	
Team member: Garret		
Team member: Christian Hanson		
Team member: Brent Fields		

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 11/25/2020**

Agenda:

1. Complete PowerPoint for project presentation
2. Run through presentation to ensure good timing

Discussion: What clever ideas do we want to highlight for the Audience? How can the team effectively teach and walk the audience through the design process?

Decisions Made: The estimated amount of time required for the entire project. Estimated Weekly Time commitment.

Action Items	Person Responsible	Deadline
Start work on the rough draft of Final Report	Everyone	12/2/2020
Team member: Nathan Dowdy	Date for next meeting: 12/2/2020	
Team member: Garret		
Team member: Christian Hanson		
Team member: Brent Fields		

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 12/2/2020**

Agenda:

1. Evaluate what parts still need done for the final Report
2. Schedule a time before its due to approve everything

Discussion: How can the team effectively manage their time to complete what needs to be done. Issuing a buddy system, every category of the report has two people working on it so there can be accountability.

Decisions Made: Buddy system for the finial sections of the report. Final time to meet up before the due date.

Action Items	Person Responsible	Deadline
Finish/Polish up report	Everyone	12/4/2020
Team member: Nathan Dowdy	Date for next meeting: 12/3/2020	
Team member: Garret		
Team member: Christian Hanson		
Team member: Brent Fields		

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Team Meeting Minutes

Design Organization: BCNG Inc.	**Date: 12/4/2020**

Agenda:

1. Check over every aspect of the report by checking for
   - Correct formatting
   - Fluidity of Speech
   - All required parts are present
   - Wow Factor

Discussion: Are we proud of the work that has been done and feel good about turning it in?

Decisions Made: Turn in the final document for the MECH 202 Design Competition Project. Team decided to celebrate after.

Action Items	Person Responsible	Deadline
NA	NA	NA

Team member: Nathan Dowdy	Date for next meeting: NA
Team member: Garret	
Team member: Christian Hanson	
Team member: Brent Fields	

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Failure Analysis

In the competition the submarine that was brought received 5th place out of 18 groups. In each race the submarine finished. It was a reliable design that required maintenance between bouts, but each time it was done correctly the submarine worked flawlessly. The submarine completed 5 races and was one of the last still working by the end. Of the five races the submarine won 3 races and lost two.

(Race 1) – The first race was quite nerve racking and gave the group a good jump when it did not work immediately. Luckily both groups had technical difficulties and another chance was given. The failure that occurred that first attempt (that did not count as a loss) was due to the Alka seltzer activating too early causing the submarine cavity to completely fill with CO_2. The force of the gas in the submarine was so strong that it flowed out the top and bottom of the submarine and did not allow it to sink. After it was reset, the submarine won the race advancing it to the next round.

(Race 2) – For race two the group was much better prepared. They were set in the tanks and when the race began there was a fairly large time difference. The cage balloon team's submarine dropped like a rock to the bottom of the tank and rose quickly. The Alka seltzer took much longer to sink to the bottom. They both floated back to the surface at a similar velocity, but the time down was the difference of the race. If the valve on the top of the Alka seltzer submarine was a larger hole, allowing more air to flow from the top, it may have stood a better chance. This was the first loss of the device. It was not necessarily a failure because it did complete to required tasks (just a bit slower than our group would have liked).

(Race 3) – Race three was quite an interesting bout. This was the point when the group realized that much more maintenance was required between bouts to dry all components off. This race started and the Alka seltzer device and the other device both just sat floating. The opponent's device sank and did not float back while the Alka seltzer device just sat there streaming CO_2 out of the vent on the top. The CO_2 had been pre-activated again. This time the group decided to just let it sit and see what would happen. It was known that it would sink eventually… After around 2 minutes or so the device began to sink and finally thud on the bottom of the tank. It closes the valve correctly, but our group and the other group did not expect what happened next to happen. The group watched as the device began the wobble slightly on

the bottom of the tank. After two or three seconds the device slowly began to rise off the bottom of the tank and back to the surface. This declared our group as the winner. That race showed the effectiveness of the Alka seltzer. Even after 2 minutes of the submarine draining the gas out of the top, there was still enough residual tablet material to push the water out of the bottom and bring the submarine back to the surface.

(Race 4) – After race three the group did a complete overhaul of the device drying every single component near the tablet inside the submarine, and this made the device even more reliable. For race four the Alka seltzer submarine was against a sub that was a propeller design with pill bottles holding the electronics (cannot forget that bright orange). This was a close race. We cleaned the entire system which gave new confidence. Both devices were placed in the water and they were set off. The opponent's device had a slight malfunction and did not sink. Because of this malfunction our device got a head start. Once the opponent's device start working it shot down to the bottom quite quickly, but once more a problem occurred with the electronics. The device's propellers were stuck on for too long. By the time the propellers were shut off, our submarine was on its way back up. This was the closest race and a good example of mechanical mechanisms having advantages by working based on their surroundings.

(Race 5) - Race five was the last race for the Alka seltzer submarine. The opponents had built a propeller design that had two props on the bottom and a Styrofoam body above it. Our group had done all the prep work drying the device to optimize the results. When the race started there was a significant difference between the sinking speeds of the device. With propellers the device has immediate acceleration downwards. The Alka seltzer must release enough air and take in enough water to start to sink. This was the downfall of the device for both losses that occurred. Our device sank, but the other team had the timing down for when the motors needed to shut off. Both rose at the same speed, but the other group had a significant lead due to the immediate downward motion. Again, the device worked reliably, but just more slowly than we would have liked.

The Alka seltzer worked great for the device that it is. Each race it completed the required task, and it did it efficiently. The device was not a failure, but it was a loser (5th place, so not that big of a loser). The main losing factor was the time to sink to the bottom of the tank. This trait caused both losses and could be easily optimized given more time. The valve on the top

had a small hole and could have been increased in diameter by at least 50%. If this adjustment were made it could have drastically changed the results. There were a few minor changes that could have been made to fix a few problems and make the device faster. First would be to chamfer the bottom cap so the valve would be the first thing to hit the ground. This would also make the device more aerodynamic. The second fix would be to create tablet holders inside the sub so that the tablet would not activate prematurely. Overall, it was a great learning experience for the group, and we were satisfied with the outcome. The submarine lost not because it did not work, but because others had designed something that was faster.

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