

Restated Project Definition & Plan Report

Team No. 20

Development of Consumer Grade Levitating Hoverboard



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Born and raised in Orlando, Florida, Brian grew up playing many sports as well as musical instruments. Having a passion for golf, he hopes to utilize engineering skills to help develop the next generation of golf clubs. He is currently a senior and will graduate with a Mechanical Engineering degree and Physics minor from Florida State University. He plans to further explore the field of materials science in the near future in hopes to receive his Master's Degree

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ABSTRACT

At the end of the Fall 2016 term, Group 20 has narrowed the selection process of a levitating hoverboard by analyzing the market need from various tables and charts of data. Using the HOQ and morphological chart, a final design has been prototyped, but there are still issues that may arise. Due to the fact that this hoverboard is a new product, analysis on each step of the way must be completed. Similar to a start-up company, a product is introduced, in which the company has done extensive research before-hand to ensure that no failures will occur. This stage is known as the research and development of the product. The next area that requires analysis is the manufacturing side, and how each sub-component will be made or if the component will be supplied from a vendor. At the immediate moment, the majority of calculations have been completed and the main area of concern is the skirt. In the next few weeks, the geometric shape of the board will be evaluated to ensure no failure in the sealing of the skirt to board. This levitating hoverboard will be introduced in the coming months and will provide safety and entertainment to all children around the world.

ACKNOWLEDGMENTS

We would like to acknowledge the FSU/FAMU College of Engineering, Mechanical Engineering Department, as well as the Industrial Engineering Department for providing resources and allowing us to progress through our senior design project. In particular, we would like to say thank you to Dr. Shih (our advisor) and Dr. Devine (our sponsor). Also we would like to give a big thanks to Alfred Rogers, a hovercraft enthusiast in England who has been offering his expertise to the project. Throughout this next semester, we will utilize their help and resources in order to complete our senior design project, scheduled to be completed in April of 2017.

1. Introduction

The idea of some kind of levitation hover board was unheard of until the movie: Back to The Future was filmed in the 1980's. Throughout the series, Marty McFly traveled around town on his hover board, which looked very similar to a skate board, but with no wheels. Since then, scientists, engineers, handymen, and others have attempted to create an actual performing model, but few have truly succeeded. In recent news, Lexus successfully created a hover board made from super cooled magnets and liquid nitrogen. Though, the track they tested their prototype on had magnets underneath the surface to help oppose the force, hence the levitation. Another company that created a successful levitation hover board is Hendo Hover [1]. Both seem to be lacking a steering mechanism though so direction is still of importance.

It is a slow transformation, but futuristic looking devices are starting to emerge when it comes to transportation. Nearby locations that do not necessarily require vehicles have allowed people to use bicycles, skate boards, roller blades, and much more. Bicycles have evolved over the years with gear mechanisms and aerodynamics. Skate boards were created as a different means to get around quicker than walking as well, utilizing the board and trucks for steering. Afterwards, scooters emerged, changing the toy industry due to an easier turning mechanism (handle bars). From scooters, Segway created personal transportation mechanisms used anywhere from security to personal use. The latest, possibly the most "futuristic looking" mechanism that has been designed is the hover board, created by HX, though it does not levitate. This design incorporates self-balance to determine speed and direction. One thing is still missing though, the levitation aspect.

It is believed that a design that can include the true levitation affect can greatly alter the transportation industry. This mechanism will include a rechargeable feature in an easy and convenient portability setup. A design has already been constructed, but this will be a base model for further implementation. Studies of aerodynamics can enhance the travel distance; materials will determine costs but conditions must be met whether environmental or any other surrounding conditions so the lifetime of the levitating hover board will last. Many components will be analyzed before the actual design process and manufacturing actually begins.

2. Project Definition

The ideology of the project is to build an air powered device that can function not only as a recreational device, but also as short-range transportation. The principal that will make this idea possible relies on an upward force that pushes against gravitational force and makes the device float. Air, applied with different pressure ranges, is the prime component that creates the upward force. The air supply can be sourced from several optimum options of machines. When the air is propelled, a downward thrust can be created; the capability of this force will determine how much levitation is obtained.

The levitation not only depends on the force, but also on different factors such as weight, balance, and loads. There are other physics principles that can be used to create “levitation”, such as magnetism and chemical reactions. These principles are not going to be taken into consideration due to the fact that they aren’t cost effective or convenient, which is one of the goals.

The concept of the levitating hoverboard comes from the original model of the larger existing hovercrafts. A hovercraft is a medium of mobility that is sustained on a pad of air that is provided by a powered fan, which is placed on the craft. Hovercrafts were originally designed to travel over land and water surfaces by floating on a coat of air, which reduces friction between the device and surface. The project’s design will follow a different scope from hovercrafts by being smaller, portable, easier to use, and able to go on land [2].

2.1 Need Statement

There are only two prototypes of commercial floating hoverboards, the Hendo Hoverboard and the Lexus Hoverboard. Both model’s budget starts around \$10,000 and are not available for purchases yet nor targeted for people who are not properly trained to use it. The physics principles behind these mentioned prototypes are what make it so expensive and only directed to professionals. For this reason, a simpler and inexpensive approach can be used to create an innovative product for a vast market [2]. Furthermore, several homemade hoverboard attempts are not practical. The simpler models with low-cost applications of physics principles don’t possess steering control

systems and needs to be plugged into the wall, which restricts mobility. Because of this, a better prototype can be created in order to resolve these constraints.

2.2 Background Research

People are always looking for the most innovative gears out there in the market. The success of technologic gadgets/toys around young generations seems to keep growing. The idea of a floating hoverboard can overcome the current success of “wheel” hoverboards. By the end of 2015, 40,000 wheel hoverboards were coming into the U.S. each day. While nobody tracks total sales, manufacturers have shipped more than \$2 billion worth of hoverboards over the past year and a half, by Fortune’s estimates. According to statisticbrain.com the average retail sale price of a “wheel hoverboard” is \$386.

Since the main competitor is the wheel hoverboard, the project’s design will be entering an existing market and attempt to dominate it with its innovation. Therefore, the same market can be accounted for the floating hoverboard. The targets of this recreational idea are people from the ages of five years old and up. With a realistic scope of people over 70 years old not being able to use it because of physical limitations, the project’s age range can be based for research purposes [3].

According to the US Census, as for 2010 the population number of people of ages from 5 to 69 years old was 260,711,455; this would be absolute market size of the project. As for an exact market size, extensive research must be completed to know what number of this population quantity wouldn’t be taken into consideration. Different social classes, special needs people, handicaps, and many other factors might reduce this number [4].

2.3 Goal Statement and Objectives

The objective of the project is to create an air powered hoverboard that can be used for recreational purposes. Modifications will be made to a simpler “do it yourself” design in order for a more reliable system as well being more appealing to the customer’s eye. The design will still be safe, enjoyable, and fully-functional. The engineering characteristics that will estipulate the design of

the prototype will be influenced by the customer's voice. In order to achieve the mentioned assessments, surveys and analysis of data would need to be performed. From several prototype builds as well as time constraints, the rectangular design is still favored, but a "backup" design has been implemented. The overall engineering design will consist of either 1 or 2 wireless blower(s), therefore conducting tests and trials to decide which alternative is better to achieve is a high priority. The steering mechanism of the design has been cut due to timing constraints.

2.4 Constraints

One of the most considerable constraints is the geometry of the board which is directly correlated to the overall shape of the skirt. Previous attempts were successful on stability with the rectangular board but due to the rectangular shape of the board, it is nearly impossible to seal the board and skirt together completely. The easiest geometric shape that would allow the most seal is a circular design of the board due to the constant diameter. The circular shape was in fact how this project came about. These are conceptions that need to be taken into consideration and worked through testing of designs and calculations. Along with the balance, comes the ability to hold certain amount of loads.

Another significant constriction is sound. Some blowers and fans can be very loud when they are on use. Also, the airflow created from the blower creates a cushion of air below the board itself and if it comes into heavy contact with solid surfaces, it can create a loud sound. For this reason, the different types of terrains become a problem as well. It is desired that the prototype can be able to ride over various types of land without any interference and/or excessive noise production and if it comes into heavy contact with solid surfaces, it can create a loud sound. For this reason, the different types of terrains become a problem as well. It is desired that the prototype can be able to ride over various types of land without any interference and/or excessive noise production.

2.5 House of Quality (HOQ)

A House of Quality was created as part of the Quality Function Deployment (Figure 2). The proposed customer requirements (CR) are listed on the left, while the engineering characteristics (EC) occupy the top row. The numbers obtained for the CR were obtained from a survey done by the group members to 100 people between the ages of 12 and 50; the scores of this survey are further explained after the HOQ explanation in Table 1.

Group 20 went through and decided upon correlations among the EC's ranging from strongly negative to strongly positive. Afterwards, Group 20 went through the body of the HOQ and used critical thinking to decide upon relationship strengths between the CR's and EC's by using strong (9), moderate (3), and weak (1) relationship values. There were other criteria represented in different symbols and colors used to analyze the roof of the HOQ and the quality characteristics (Figure 2).

The template for the HOQ was sourced from QFD Online [# reference]. Using an established template with mathematic functions for the desired calculations included allowed the team to obtain more accurate results. The template automatically calculated the relative weight on the bottom of the HOQ when it examined the team's analysis results for the body of the structure. The relative weight obtained gives a number to each quality characteristic. The characteristics with the higher values represent the features that need to be taken as a priority for the design of the prototype of the project. These chosen characteristics are meant to satisfy both customer and engineering's independent priorities of design at the same time.

Legend		
⊙	Strong Relationship	9
○	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
-	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	

Figure 1 – Legend for House of Quality

Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)											
				▼	X	▼	▲	X	▼	▼	▲	X	X	▲	X
			Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Weight	Dimension	Cost of Production	Life Cycle	Speed	Safety Risks	Emissions	Efficiency	Load	Number of Colors	Battery Life	Output force of blower
9	6.1	5.6	Aesthetics			▲			▲				⊙		
9	9.5	8.8	Durability	▲		⊙	⊙		⊙		⊙	⊙		▲	
3	9.2	8.4	Ease of use	▲	⊙			▲	⊙			▲			▲
9	7.9	7.2	Capability	⊙	⊙	⊙	▲	⊙	▲	▲	⊙	⊙		⊙	⊙
9	8.3	7.6	Portability	⊙	⊙	⊙			▲		▲				
9	6.4	5.9	Size	⊙	⊙	⊙		⊙	⊙	▲	▲				⊙
9	4.9	4.5	Capacity		▲		⊙	⊙	▲		⊙	⊙		▲	⊙
9	5.6	5.2	Noise			▲		▲				⊙			⊙
9	9.8	9.0	Performance	⊙		⊙	⊙	⊙	⊙	⊙	⊙	⊙		⊙	⊙
9	6.7	6.2	Weight	⊙	⊙	⊙	⊙	⊙	▲		⊙				
9	7.9	7.2	Life Cycle	▲		⊙	⊙			⊙	⊙	⊙		⊙	⊙
9	9.5	8.7	Safety		▲	▲		⊙	⊙			⊙			⊙
9	8.2	7.5	Low Cost	▲	⊙	⊙		▲	▲		⊙		⊙	⊙	⊙
Max Relationship Value in Column				9	9	9	9	9	9	9	9	9	9	9	9
Weight / Importance				280.3	282.9	474.5	287.6	199.2	289.6	125.7	362.1	377.2	79.3	268.5	358.9
Relative Weight				8.3	8.4	14.0	8.5	5.9	8.6	3.7	10.7	11.1	2.3	7.9	10.6

Figure 2 - House of Quality

Understanding the potential audience for the product increases chances for a successful outcome. Finding an audience that has an interest and those that understand its need was a priority. The engineering criteria's that was formed was based on public feedback through a survey that was created. The results from the survey were analyzed, and it was noticed that performance, durability, and ease of use was the top 3 criteria our audience chose. The result from the survey is ranked with respect to importance, which is shown below in Table 1 [6].

As for the results of the house of quality, the outcomes are going to help in the design process of the project. According to relative weight results it can be seen that the cost of production is the most important thing to focus on; it got the highest percentage out of all, a 14%. Following the

highest score is efficiency with a 10.7% and the output force of the blower is very close with just a 10.6%. Subsequently is the consideration safety risk with an 8.6% along with lifecycle with an 8.5%. The rest of the results can be directly seen from Table 2 [5].

Table 1 – Survey Results for Customer Requirements.

	Total	Score
Aesthetics	90	5.58
Durability	92	8.75
Easy to Use	94	8.43
Capability	91	7.21
Portability	90	7.58
Size	97	5.87
Capacity	98	4.54
Noise	91	5.16
Performance	91	8.95
Weight	96	6.19
Life Cycle	98	7.23
Safety	97	8.73
Low Cost	97	7.51

Table 2 - Relative Weight Results from HOQ [5].

Relative Weight Results			
Engineering Characteristic	Result (%)	Engineering Characteristic	Result (%)
Weight	8.3	Emissions	3.7
Dimension	8.4	Efficiency	10.7
Cost of Production	14.0	Load	11.1
Life Cycle	8.5	Number of Colors	2.3
Speed	5.9	Battery Life	7.9
Safety Risks	8.6	Output force of the blower	10.6

2.6 Failure Mode and Effect Analysis

The Failure Mode and Effects Analysis (FMEA) describes what can go wrong with the product and if it did, what it would mean to the overall function of the product. Below in Table 3, the FMEA is explained for major part of the board.

Sources of failure would come from errors in manufacturing/assembly as well as misuse and poor maintenance. Failure would not occur under ideal operating conditions such as a smooth riding surface, properly charged batteries, and a steady riding position.

Since the components of the board are heavily dependent on each other, then the board's operation hinges on each one to not fail. The general pattern in the FMEA below is that components that relate to inflating and lifting the board would severely affect the overall function of the board; and components related to propulsion/steering would limit the "fun" of the board but would not outright render it useless.

Table 3 – Failure Mode and Effect Analysis

Component/Function	Failure Mode	Cause	Effect	Severity
Skirt	Broken Seal	<ul style="list-style-type: none"> Improper assembly Damaged 	<ul style="list-style-type: none"> Hoverboard will not inflate 	High – Will not be able to operate if skirt is flat
Air Blower	Insufficient flow rate	<ul style="list-style-type: none"> Low Power supply Product Defect 	<ul style="list-style-type: none"> Hoverboard will not inflate 	High - Will not be able to operate if skirt is flat
Board	Cracks, Dents	<ul style="list-style-type: none"> Too much weight Improper use 	<ul style="list-style-type: none"> Unsafe to ride 	High – Will not be able to support customer weight
Power Supply	Dead battery/insufficient supply	<ul style="list-style-type: none"> Uncharged Improper Battery 	<ul style="list-style-type: none"> Blower will not work Thrust will not work 	High – the whole operation depends on the power supply

3. Final Design

3.1 Concept Generation of Final Design

The first part of concept generations begins with brainstorming. Brainstorming is used to solve complications and to effectively provide solutions to those constraints that appear. Some initial constraints that were encountered for the designs were the geometry of the body, the material needed and the run time for the hover board. Many of the ideas that were presented through brainstorming gave team 20 an overall concept to how the design of the hover board should look like. All ideas were narrowed down to feasible ideas so that a morphological chart can be constructed. From the morphological chart three preliminary designs were sketched out using CAD software.

3.1.1 Morphological Chart

Brainstorming helped team 20 to come up with the final efficient concepts that might need to be taken into consideration in order to achieve our goal. Table 4 shows the final morphological chart that includes the selected ideas in order. The concept designs were constructed by selecting characteristics from the mentioned chart and Table 4 shows the results for the selections.

Table 4 – Morphological Chart

Attribute	Design	Alternate Design
Board Shape	Rectangular	Circular
Number of Motors	1 (Inflate)	2 (Inflate)
Motor Location	Front of board	Front and Back of board
Energy Source	Electric	Electric
Power Bank Type	Plug-in	Plug-in
Terrain	Land	Land
Riding Style	Standing	Standing

3.2 Final Concept Design

Based on the results obtained from the concept design generation in the previous section, the final concept design was selected. The model consists of a rounded rectangular base and can be observed in Figure 3.

The rectangular shape of this design attributes to the performance of the prototype as well since, unlike the circular first design, this one is more stable in a forward direction. The design dimensions will have a near 2:1 ratio, mainly for providing stabilization to the hoverboard. The bag skirt design is also very cheap, strong, lightweight, and should produce enough of a gap to ensure near frictionless travel over smooth surfaces and water. Unfortunately, due to time constraints the propulsion and steering systems will not be focused on at this time and will be added back to the design should the schedule permit.

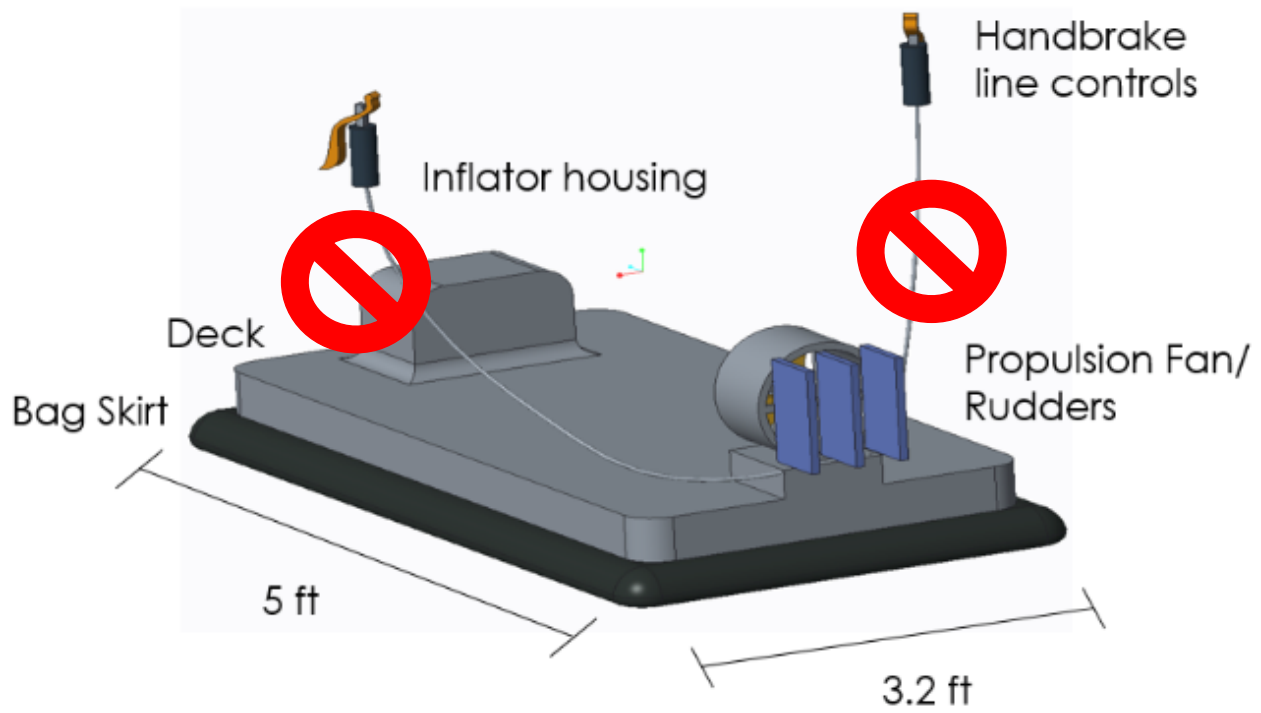


Figure 3 – Updates to chosen concept

The current prototype is shown in Figure 4 and it shows the simplified concept.

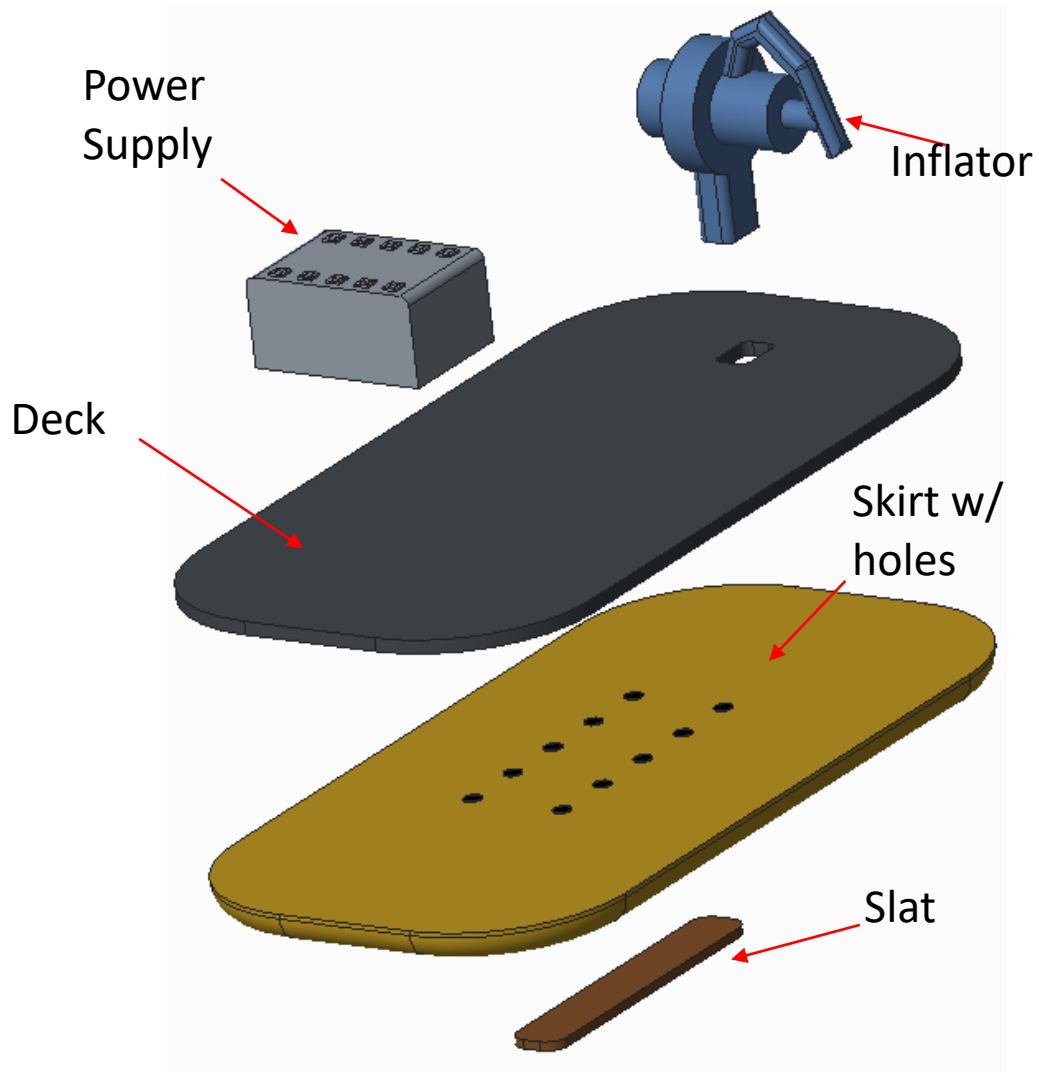


Figure 4 – Current Design CAD Model, exploded view

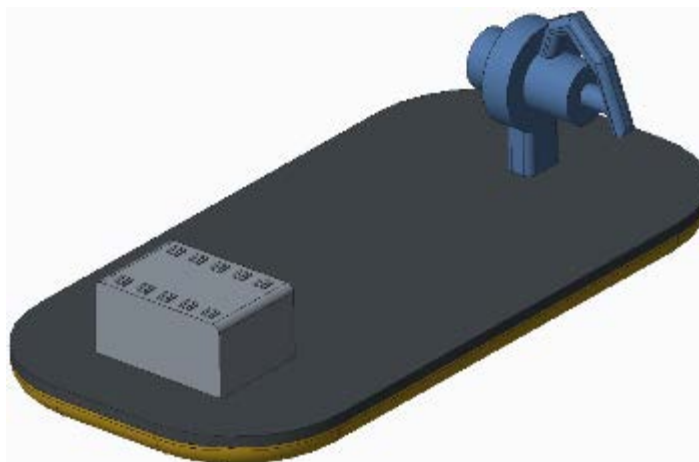


Figure 5 – Current Design CAD Model, assembled

3.3 Preliminary Calculations

Team 20 chose the dimensions of the hover board base in order to choose the air blower required to create lift and increase the stability of the board as it moves forward. The closer the length to width ratio is to 2:1 the more stable the craft will be when moving forward. It was concluded that the length and width of the hover board were to be 1.525 m and 0.975 m, respectively. These dimensions were based on a ratio of 2:1 as previously stated. The depth of the hovercraft, also known as the hull, was determined to be around 1 inch. The hovercraft will also incorporate a skirt which will be attached underneath. The skirt is a durable, tear resistant material, which provides an air cushion for the hover craft. The skirt will need to hold a certain air pressure without rupturing. The team determined that the air gap, the length of air between the skirt and the ground, will be 0.2 inches. This should allow a near frictionless passage over most smooth terrains.

The arbitrary estimated weight of the craft will not exceed 45 kg (100 lbs) in order to allow a maximum load including the rider to approach 136kg (300lbs). This weight on the craft base would require a cushion pressure of approximately 865Pa in order to create the desired 0.2in air gap. The inflating blower will need to match that with an acceptably high volumetric flow rate of air, approx. 1100CFM, in order for operation to occur [8]. However, due to the unavailability of a high CFM, battery-operated air blower, the 1100CFM flow rate would be simulated by two smaller 530 CFM leaf blowers that came with their own batteries. These blowers were designed to be light weight, rechargeable, very efficient, and could be picked up at any local hardware store. All major non-custom components of the hover board are listed in Table 5.

Table 5 – Components and Important Specifications

Component	Image	Vendor	Specifications	Cost	Weight
Lift Fan		EGO	530 Max CFM Air Speed 110 MPH 56 Volts 140 Watt Hours Includes Battery and Charger	\$199/ Each 2X	9.8lbs

3.4 Alternate Design

An obstacle in the current design is the construction of the skirt. It is essential to the operation of the hovercraft as a whole, otherwise the board will not hover. The rectangular design that is being used now is creating problems with skirt assembly due to its lack of uniformity in all directions. To simplify this, an alternate design was drafted, seen in Figures 6, 7 and 8, that uses 2 circular boards that will functionally be the same as the rectangle. The circular shape makes it easier to assemble a skirt to the board.

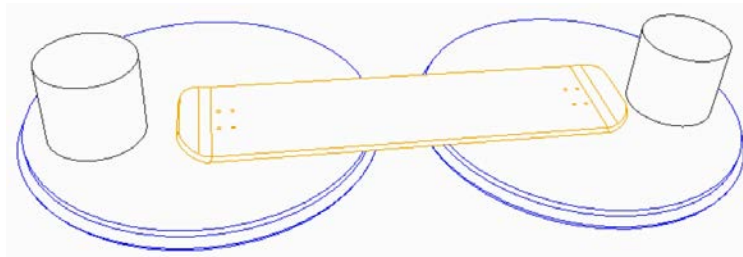


Figure 6 – Wireframe of the alternative concept

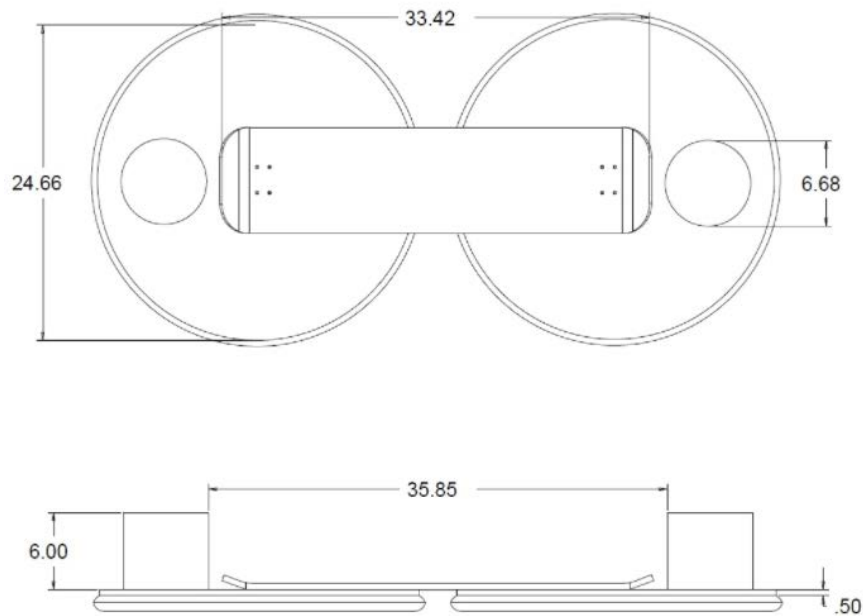


Figure 7 & 8 – Top-down and side drawings of the alternative design

The alternate design consist of two circles with identical diameter of 24.66 inches. Located between the two circles is a board identical to a skateboard, used to connect the two circles together

and support the user weight. The circular design was chosen specifically for evenly distributed air lift for the device. The air blower will be installed on both circular pads. The blower inlet diameter is 6.68 inches. With this design, the blower will be installed air tight so that air distribution is even. This design will still support at least 200 lbs minimum, while providing comfort to the user.

3.5 Materials Selection

When it comes to the materials selection of a design, specifically a levitating hoverboard, two important factors come into play stiffness and strength. Between these two characteristics, stiffness is the more important of the two due to the fact that the platform in which customers will stand on, should not deflect, and if so, very minimally. This deflection may cause issues with the air flow or excessive friction between the skirt and ground. Multiple characteristics pertaining to the design effect the decision based off of the stiffness. In the automotive industry, minimizing the mass is the goal. It reduces cost, and it improves gas mileage, which in today's world, everyone desires.

The material selection process in our levitating hoverboard will be conducted very similar to companies in the automotive industry, which is to minimize the mass of a stiff and strong object. The analysis will be conducted only for the board, which will be treated as a rectangular plate, therefore our goal is to select a material by minimizing the mass of a stiff and strong rectangular plate. Once the equations are completed, a material index emerges from the final equation. This material index, represented by a sloped line, easily identifies numerous materials that will act the same when it comes to a mathematical standpoint.

Though, the selection will be based upon the design and the purpose for the design. In this case, a material that satisfies the stiffness and strength requirements with a minimal mass, also being durable with a sufficient thickness. Materials that came of interest included carbon fiber reinforced plastic, polystyrene foam with epoxy resin, fiberglass, and several others. Further calculations will be completed so that there is viable evidence as to why a certain material was chosen based on the previously stated characteristics as well as a monetary characteristic as well.

In order to determine the best material by minimizing the mass and cost, Eq. (1) is used below Strength will be the first of the two major constraints analyzed.

$$m = (V)(\rho) = (A)(t)(\rho) = (L)(b)(t)(\rho) \quad (1)$$

Following this will be Eq. (2) which is the equation for the strength constraint.

$$\sigma = \frac{(0.75)(F)(b^2)}{(t^2) \left(1.61 \left(\frac{b^3}{L^3} \right) + 1 \right)} \quad (2)$$

Rearranging these variables for the force, F, is shown below in Eq. (3).

$$F = \frac{(\sigma)(t^2) \left(1.61 \left(\frac{b^3}{L^3} \right) + 1 \right)}{(0.75)(b^2)} \quad (3)$$

The next step for the analysis is to equate the mass and force by using Eq. (1) and Eq. (3), which can be seen below.

$$F = \frac{(\sigma) \left(\frac{(m)}{(L)(b)(\rho)} \right)^2 \left(1.61 \left(\frac{b^3}{L^3} \right) + 1 \right)}{(0.75)(b^2)} \quad (4)$$

Solving for the mass in Eq. (5) is the next step, which is seen below.

$$m = \frac{(0.75)^{\frac{1}{2}}(b)^2(F)^{\frac{1}{2}}(L)(\rho)}{\left(1.61 \left(\frac{b^3}{L^3} \right) + 1 \right)^{\frac{1}{2}} (\sigma)^{\frac{1}{2}}} \quad (5)$$

From this, a material index is identified. The material index consists of the material property variables and can be seen below in Eq. (6).

$$M_{STR} = \frac{(\sigma)^{\frac{1}{2}}}{\rho} \quad (6)$$

Below, Fig. (9) shows the material index for strength and density relations.

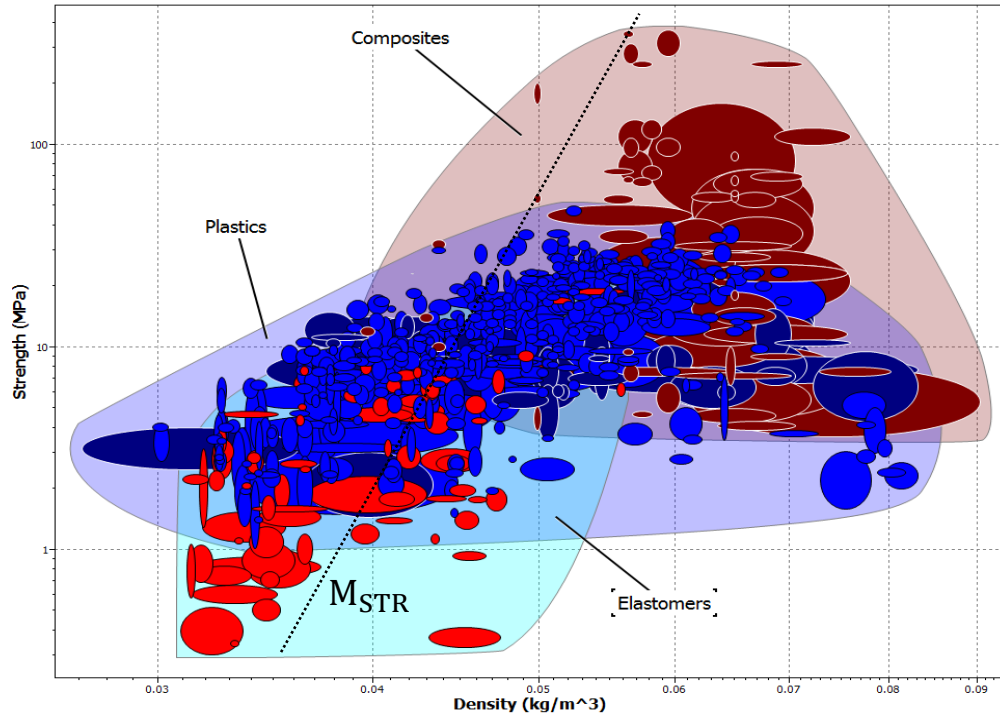


Figure 9 - Strength vs. Density chart for materials selection.

The analysis for the stiffness constraint involves deflection, which is shown below in Eq. (7).

$$\delta = \frac{(0.142)(F)(b)^4}{(E)(t)^3 \left(2.21 \left(\frac{b^3}{L^3} \right) + 1 \right)} \quad (7)$$

Using Eq. (1) and rearranging those variables in terms of thickness is then plugged into Eq. (7) which is shown below in Eq. (8).

$$\delta = \frac{(0.142)(F)(b)^4}{(E) \left(\frac{(m)}{(L)(b)(\rho)} \right)^3 \left(2.21 \left(\frac{b^3}{L^3} \right) + 1 \right)} \quad (8)$$

Once again, solving for mass will then yield Eq. (9) below.

$$m = \frac{(0.142)^{\frac{1}{3}}(F)^{\frac{1}{3}}(b)^{\frac{7}{3}}(\rho)(L)}{(\delta)^{\frac{1}{3}}(E)^{\frac{1}{3}} \left(2.21 \left(\frac{b^3}{L^3} \right) + 1 \right)^{\frac{1}{3}}} \quad (9)$$

Identifying the material properties from Eq. (9) is shown below in Eq. (10) as the material index for stiffness.

$$M_{\text{STF}} = \frac{(E)^{\frac{1}{3}}}{\rho} \quad (10)$$

From Eq. (10), the plot for stiffness vs. density is used to determine the best material, which is shown below in Fig. (10).

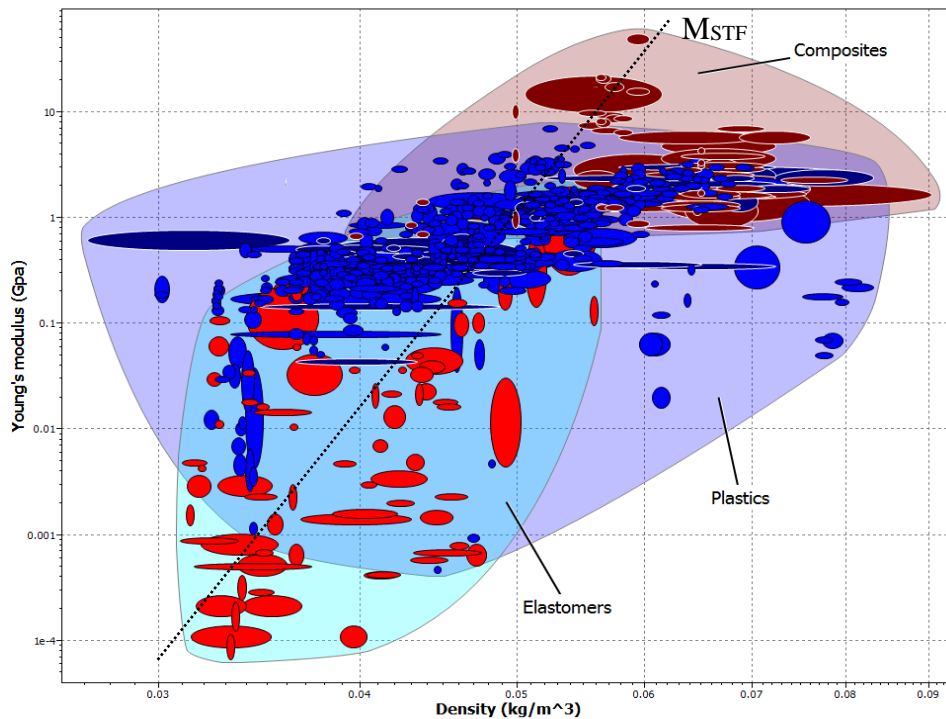


Figure 10 - Stiffness vs. Density chart for materials selection.

Due to the fact that both strength and stiffness are equally important, a coupling equation needs to be solved for so that a comparison can be made between the two constraints. Below, Eq. (11) and Eq. (12) represent the strength and stiffness indices respectively with cost.

$$M_{\text{STR}} = \frac{(\sigma)^{\frac{1}{2}}}{(\rho)(C_m)} \quad (11)$$

$$M_{STF} = \frac{(E)^{\frac{1}{3}}}{(\rho)(C_m)} \quad (12)$$

The next thing to do is solve for total cost with the previous 2 indices included. The total cost for strength and stiffness can be seen below in Eq. (13) and Eq. (14) respectively.

$$C_{tot-STR} = \frac{(0.75)^{\frac{1}{2}}(b)^2(F)^{\frac{1}{2}}(L)}{\left(1.61\left(\frac{b^3}{L^3}\right) + 1\right)^{\frac{1}{2}} (M_{COST-STR})} \quad (13)$$

$$C_{tot-STF} = \frac{(0.142)^{\frac{1}{3}}(F)^{\frac{1}{3}}(b)^{\frac{7}{3}}(L)}{(\delta)^{\frac{1}{3}}\left(2.21\left(\frac{b^3}{L^3}\right) + 1\right)^{\frac{1}{3}} (M_{COST-STF})} \quad (14)$$

The next step in the analysis is to equate Eq. (13) and Eq. (14) and manipulate the variables in terms of $y = mx + b$ format. This can be seen below in Eq. (15).

$$M_{COST-STF} = \frac{(0.142)^{\frac{1}{3}}(b)^{\frac{1}{3}}\left(1.61\left(\frac{b^3}{L^3}\right) + 1\right)^{\frac{1}{2}}}{(\delta)^{\frac{1}{3}}\left(2.21\left(\frac{b^3}{L^3}\right) + 1\right)^{\frac{1}{3}} (0.75)^{\frac{1}{2}}(F)^{\frac{1}{6}}} (M_{COST-STR}) \quad (15)$$

A coupling constant was calculated to be roughly $2 (1/Pa)^{1/6}$ which identifies the most suitable material between the 2 constraints. This can be seen below in Fig. (11).

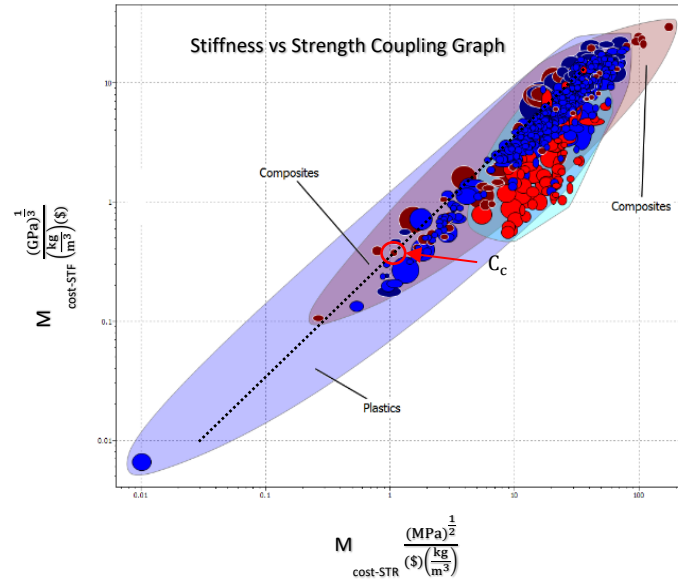


Figure 11 – Coupling graph of Stiffness/Cost Index vs. Strength/Cost Index

Another material to consider for a consumer grade levitating hoverboard is for the skirt. Most of the subcomponents will be purchased from other vendors so that the only manufacturing process being done is for the board and the skirt. Materials being considered for the skirt though consist of PVC, visqueen, or some type of vinyl. Examples of these materials are water proof and vary in shape and size. Calculations for a proper thickness will be done so that the skirt will not fail depending on the terrain in which it travels over.

3.6 Potential Manufacturing Plan

This section provides an overview of a basic manufacturing plan for the materials of the board and skirt, as well as the assembly process of the rest of the components into the final model. As mentioned in section 3.4, the material to be fabricated into the main board is carbon fiber reinforced polymer. A vacuum bagging process would be the optimal process used to manufacture the selected composite material into the desired board dimensions. As for the development of the skirt, a thermoset laminate manufacturing process would be implemented to create it. The rest of the components that make up the levitating hoverboard would be purchased and assembled to create the final product.

The vacuum bagging process was selected due to its ease to create our board dimensions and accessibility to acquire it. Figure (12) shows the process behind the vacuum bagging used to create carbon fiber reinforced plastic. The team is currently in contact with the High Performance Materials Institute (ran by faculty of the Industrial and Manufacturing Engineering department of FAMU-FSU College of Engineering) to create the final board.

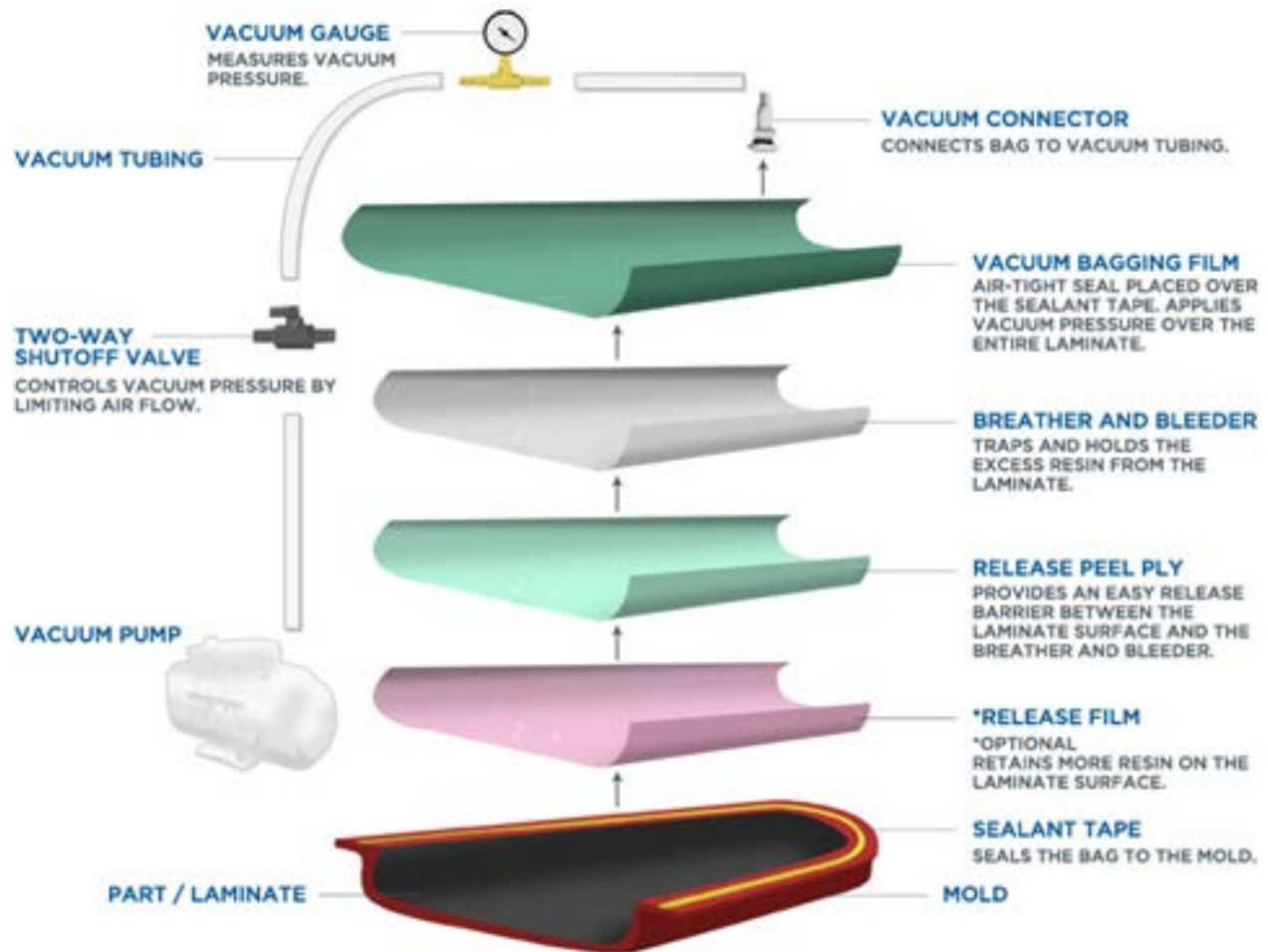


Figure 12 – Vacuum Bagging Process for the Production of Carbon Fiber Reinforced Polymer [9]

4. Entrepreneurial Aspect

The Horizon Hover board is being developed to satisfy our customers with cost effectiveness and the ability to perform all around. Our team is participating in the InNOLEvation challenge, which requires the fulfillment of the business aspect of our product. Team 20 will participate in the Shark Tank challenge to compete with other innovative projects. The name of our product and the tagline is shown below:

- Product Name: HH Board
- Tagline: "Let Us Lift You"

4.1 Customer Discovery and Market Analysis

To understand what our potential customer wants in our product, the team developed an effective survey that displayed important aspects to our design. After approximately one hundred surveys were completed, it was noticed that our potential customers were interested in performance, affordability, and versatile uses such as indoors and outdoors. This led the team to focus on customers of ages 7 and older. Further analysis of the market revealed that, the Horizon Hover board will potentially be successful, as it would be the only hover board on the market that is of consumer grade quality and affordable.

4.2 Target Customers and Business Model Canvas

Our product will be used by many different purposes with the ages of 7 and older. It is best to target customers that can use our product for commuting, and outdoor and indoor recreational purposes. However, the general public will not be secluded and will be able to purchase our hover boards directly from the website. The infrastructure of Horizon Hover board business starts with the Business Model Canvas (BMC). The BMC provides details to how our business will run. The business model canvas that was developed by team 20 is shown in Table 7.

Table 6 - Business Model Canvas

Key Partners <ul style="list-style-type: none"> - FAMU-FSU College of Engineering - Common Vendors 	Value Propositions <p>Service</p> <ul style="list-style-type: none"> - Customer Convenience <p>Customer needs</p> <ul style="list-style-type: none"> - Recreational Aspects
Cost Structure <ul style="list-style-type: none"> - Material Cost - Manufacturing Cost - Worker Compensation - Advertisement Cost 	Customer Relationships <ul style="list-style-type: none"> - Market Ambassadors - Rental at Parks, Malls, and Technological Conferences - Keep open customer communication
Key Resources <p>Intellectual Property</p> <ul style="list-style-type: none"> - Trademark Name, Tagline, and LOGO - Patent design details 	Revenue Streams <ul style="list-style-type: none"> - Google AdSense - Direct Sales - Rental Services
Channels <ul style="list-style-type: none"> - Social Media - Posters - Commercials - Stores - Magazines 	Customer Segments <ul style="list-style-type: none"> - Age 7 and older - Outdoor users - Indoor users
Key Activities <ul style="list-style-type: none"> - Research and Development - Manufacturing - Logistics and Supply Chain 	

As is it shown, the business model canvas is broken down into segments. These segments focus on specific business aspects such as how the team will satisfy customers, develop relations, and even generate revenue from the product. Each segment will be discussed individually.

4.3 Value Proposition and Customer Relationship

The Horizon Hoverboard offers effective performance for fun recreational activities. The Hoverboard will be used by most of the population and it will cost less than existing hoverboard that is previously on the market. The product will be easily accessible through rentals services either at parks, technological conferences or direct purchases. To establish customer relationship, the team will open direct communications to our targeted customers. This will be done through social media, advertisement, and a question and answer on our company owned website.

To deliver on those valued proposition, further research and development is required in order to provide better efficiency for longer use of product. R&D will be focused more on improving performance, quality, durability and life duration. The team will also improve aesthetics constantly to appeal to customers preferences. Another key activity is manufacturing. The manufacturing cost of the horizon hover board is not desired to be expensive. Therefore, the production of our hover board will need to be simple and effective. To deliver and take direct orders from customers, the team must focus on distribution as well as receiving direct orders. One important key partners is PayPal. PayPal will be used to effectively handle online purchase. One advantage of using PayPal is the ease of money transfer between the team and our customers. Another priority is to focus on gaining key partners that will aid in shipping/delivery such as major shipping companies like FedEx. One of team 20 goals is to reach out to customers on an international level. Furthermore, Google will be used as a form of advertisement, this allows for further exposure to customers worldwide.

4.4 Cost Structure and Key Resources

There are three key points that determines the revenue streams for the horizon hover board, the cost of assembly, the cost of advertisement, the cost of materials. These points determines how much profit one horizon hover board can make. The cost of advertisement will be heavily invested in for rapid increase in customer populations. It is important to reach out to new customers to make this product successful. The LOGO and the Tagline, will be trademarked and protected. The overall design concept details will be patented. Having protection of what is ours, our design cannot be replicated on the market by other competitors.

5. Methodology

5.1 Work Breakdown Schedule

For the first phase of the project, which consist of Fall 2016 semester, Team 20 focused on researching and creating the basic component architecture of the hoverboard. The last phase of the project, Spring 2017, will have to focus on physically making a functional prototype and functional final product. To have a better overview on the steps that needs to be taken to achieve the model, a Work Breakdown Schedule was created and can be seen in Figure 6. In order to achieve the goal for this term the team should focus on two main things, accurate research and a design concept that would result from the study of the subject. At this point, the team should have the majority of the work breakdown schedule fulfilled and under control.

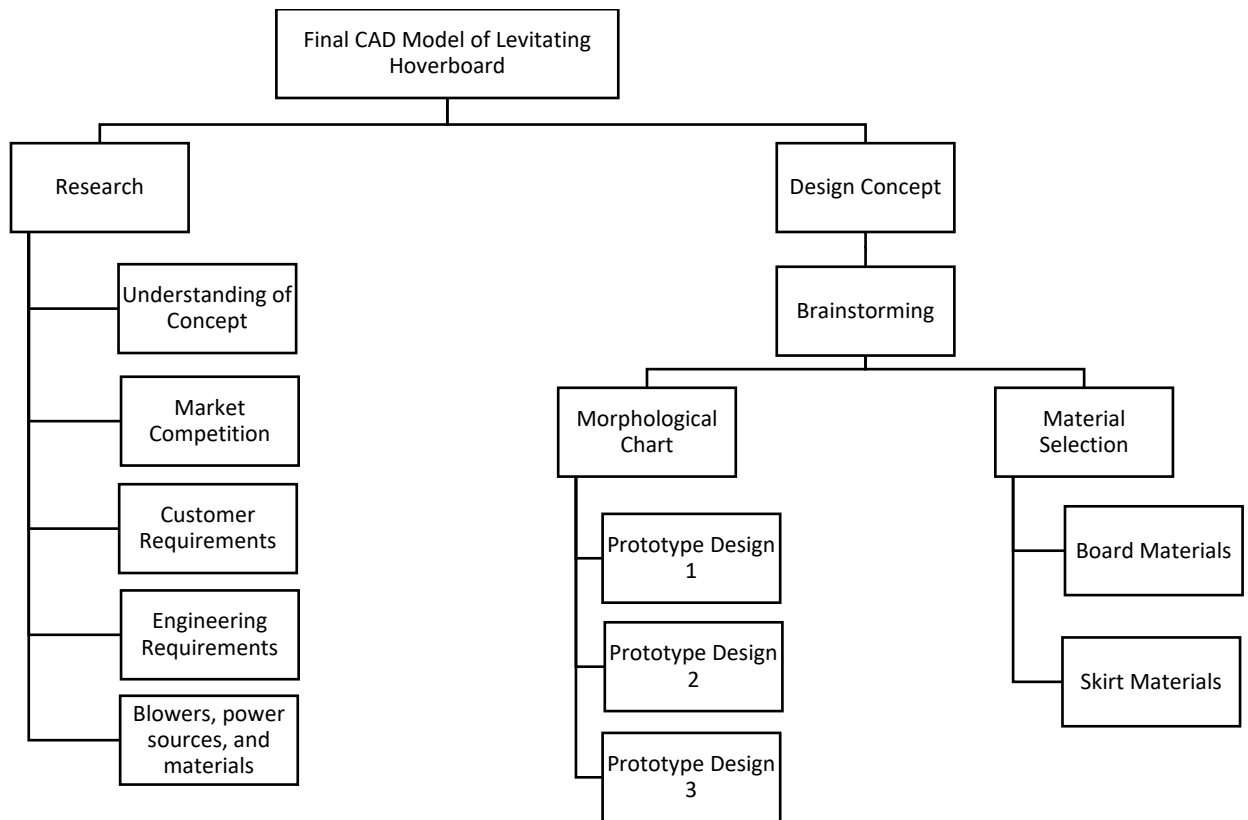


Figure 13 – Work Breakdown Schedule

5.2 Gantt Chart

The success of any project relies on the planning behind it. For this reason the team generated a Gantt Chart (Figure 9); in order to have a visual representation of the project's timeline that needs to be followed. At the inception of creating the Gantt, the team identified a logical order of tasks in which each step completed would aid the next step in the project.

Like most plans, things change as time actually passes and the team has had to make adjustments to the schedule in order to ensure that work was done properly. For example, research was intended to be completed within a month of starting the project, but in reality research continues passively throughout the project.

For the Spring 2017 semester, the team will begin by focusing on the skirt design. Currently the skirt design was hastily made and improvised, and it provided inflation, but no lift. For the success of the project, this is vital. Following this task, the semi-finals of the InNOLEvation challenge will take place and the team must prepare a 7 minute pitch and a presentation to advance. Once this is completed, the prototype will continue to be tested upon and troubleshooted to discern any remaining errors in the design before ordering parts for the project. Once the purchase order is made and the parts are shipped and received the team can then begin assembling the final product. This should prove easier as the team will have the experience from the prototype.

Spring break is included in the Gantt chart as it is a large time block and minor inconvenience. This will be a flex time in case some parts take longer to arrive and to make sure this time is not wasted the final deliverables will be worked on to be proactive for April. Once the final product is assembled, it will be optimized through testing and polishing any aspects that are not up to expectations. Once the hoverboard is completed the visual appeal of the board will be worked on to make it aesthetically pleasing to consumers. Towards the middle of April which will be the chopping block for senior design presentations, the final poster and demonstration will be prepared for and executed.

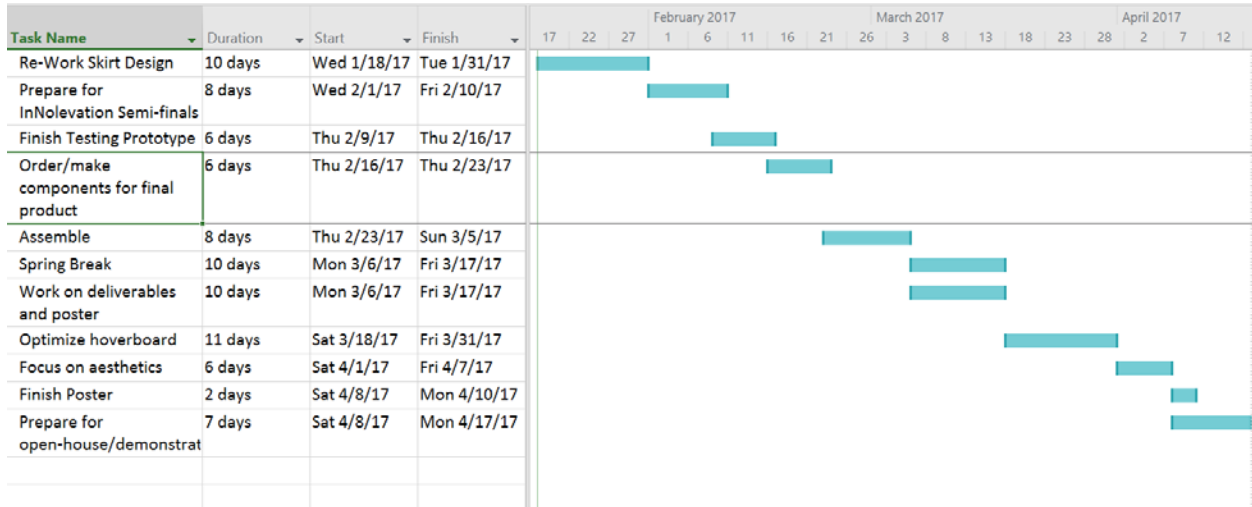


Figure 14 – Spring 2017 Gantt Chart

5.3 Upcoming Work

The conceptual phase is generally the longest phase of design, but that is not the case here. Due to the difficulties being faced in regards to the skirt during the prototype build, alternate design shapes were considered. As shown in the alternate design, the circular shape board will allow an easier sealing process for the skirt, ultimately ensuring no failure to be possible. Although the team is behind on tasks, this is only to ensure that the progress is made thoroughly. Before this can be done, the final cad model needs to be decided upon. Once this is done, the rest of the work will be considerably more straightforward. In the coming weeks of this semester, the team will move forward with a final design and Horizon Hoverboards will introduce the new and improved consumer grade hoverboard.

6. Conclusion

The goal of this project is to innovate and produce a fully-functional, battery operated, marketable hoverboard capable of hovering on a cushion of air. With the application of different methods of analysis, such as morphological charts, a final concept was chosen. The optimal design selected provides satisfaction to customer needs and the team's scope for the project. Methods such as house of quality charts and surveys were used to clearly state what was desired from a manufacturing

and customer point of view. Also, optimal materials and components were carefully chosen in this report with the goal of maintaining a light prototype weight and good efficiency. Any hoverboard selected must carry 1 person, approximately 130 – 180lbs, for a period of at least 15mins in order to conform. Everything together will allow the team's levitating hoverboard to compete with other locomotive toys such as wheeled hoverboards, and gas-powered hovercraft in the future. For this reason, the entrepreneurial aspect of the project has been analyzed as well.

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