Preliminary Design Review

Autonomous hovercraft design

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ISSUED BY
TEAM #21

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I. ABSTRACT

Developed in the scope of the ENGR 290 course at Concordia University, the project goal is to create a simplified version of a hovercraft. The end-product shall contain a working hovercraft model that is able to finish the track in the time limit, complemented with the well-documented process of design and implementation. This goal is accomplished by following the steps of the engineering design process. This process is applied to three possible designs that we analyzed closely using the decision matrix to choose one design. The following is the analysis process and the decision-making process that the team went through. A schedule that the team will follow is also included.

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1.INTRODUCTION

A hovercraft is a vehicle that traps an air cushion underneath itself and then floats on top of it, hence it hovers over the floor and obstacles. One can consider this as a boat, airplane, and helicopter all in one because of its amphibious quality. One of the many uses of a hovercraft is its military application to access disaster zones.

1.1 Document Purpose:

This document specifies the project's requirements and constraints that must be followed in the design and implementation process. In this document, we establish the necessary conditions and requirements given to us to design and build a hovercraft that respects them and is able to finish the track in less than 2 minutes.

1.2 Document Scope:

This report was created in the scope of the ENGR 290 course and shows the details on three possible hovercraft designs that we could accomplish. It also shows how a final design has been chosen and how it will be implemented in detail with a time schedule. Our final design will be evaluated using the grading formula given by the professor of the course: $Score = \frac{d_{completed}}{N_c \ x \ t_{course}}$. Our final design is chosen by finding out which design out of the three would get the highest score possible. Hence we want to use the least amount of components possible but also have the fastest track time. This will boil down to a cost-benefit analysis.

1.3 Change Control and Update Procedures:

Although this report outlines all the steps to design our hovercraft in detail, it is inevitable that we will need to make some changes due to some unforeseen details. Therefore, we need an update procedure to deal with possible changes in the future. These changes and updates will be shown in the final project report. The update procedure that we will use, is to document any changes done to our design and include them in the final report. One possible change that we foresee, is to change the size of fans and batteries or reduce the number of components to get a higher score.

2.REQUIREMENTS

2.1 Mission Objectives:

In order to have a functional hovercraft that respects all the requirements and constraints given, we need to list them in detail. The following set is essential to design and create a hovercraft. This set will be used as a resource while building the hovercraft, ensuring that the requirements are met at every step. These requirements must be followed to ensure that our hovercraft completes the track below in the time limit. The final product that we will have should be capable of all requirements below.

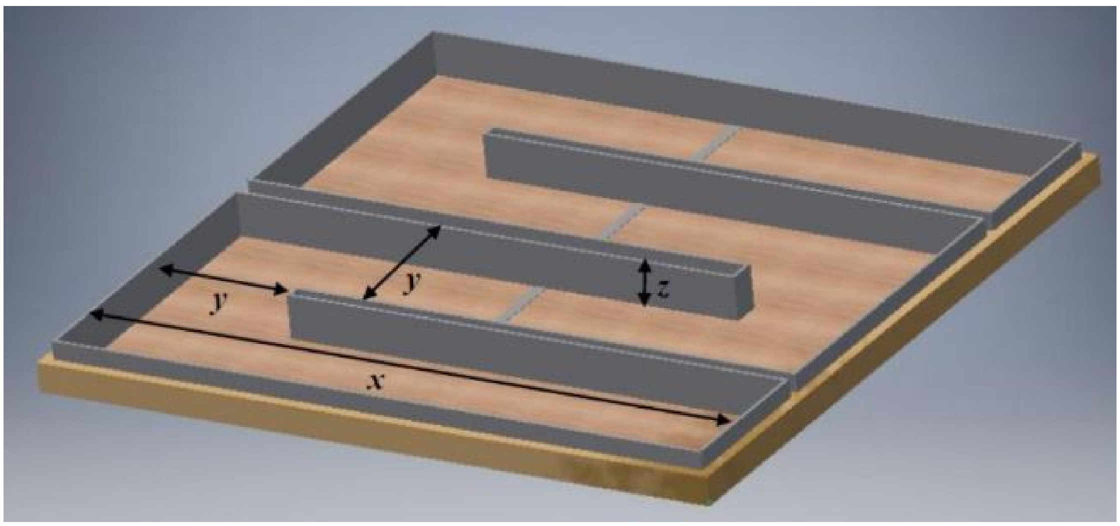


Figure 2.1: Track of the Hovercraft[1]

- x: 235cm
- y: 50-55cm
- z: 15cm

2.2 Design & Technical Goals:

- The shape of the hovercraft should be circular to facilitate going around corners.
- Have a width less than 50cm, preferably around 30 cm.
- Have a minimum of 3 designs
- We should analyze how each design moves and its operation to choose one design, using measurements and calculations.
- The 3 designs should be shown with the help of sketches and models
- The design should be original and any inspiration should be shown.

2.3 Competition Requirements and Operations:

- Should finish the track in Figure 1 in less than 2 minutes without discharging the battery before the end.
- The entire body should rotate when turning
- Has to travel the track autonomously, using sensors and servos controlled with a controller.
- Have to travel over obstacles placed on the track of a height of a maximum 3 mm.
    - I.e. have to hover at a minimum of 3 mm.

2.4 Target Score Analysis:

$score = \frac{d_{completed}}{N_c \; x \; t_{course}}$ [1]

Where:

- $d_{completed}$: Distance along the track that was successfully autonomously completed
- N_c : Number of components used. (fans and servo)
- t_{course} : Time (in seconds) taken to complete the track (120s if not completed)

This formula is used to analyze the design we have to get our score for the competition. It is our goal to have a design with the highest score possible. To accomplish this we want the longest distance traveled possible with the least number of components and the smallest time to complete the track. We have a total of 3 attempts to get the highest score possible. The time taken to travel the track is estimated for every design and taken into consideration when choosing the final design.

3.IDEAS AND RESEARCH

After the requirements are set, we need to do research and gather ideas on different possible hoverboard designs. We did some research with the goal to find designs that have a minimum number of components and the shortest time possible to finish the track, keeping in mind the requirements stated above. From this research, we created a couple of designs that we will like to analyze closer, in detail to choose a final design to produce.

During our research about hovercrafts, we found out the many uses of a hovercraft and different ways one can be built. There are a lot of different ways to design a hoverboard that many people have tried. But in general, a hovercraft needs a minimum of 1 fan and a servo to function properly and be able to do all the functions a hovercraft should be able to do. From there, we noted that a hovercraft can have infinite more fans and servos to make it more efficient. This becomes a question of cost-benefit. At what point does the cost of adding fans out-weight the benefits of doing so. With more research, we found out that having more than 3 fans on our hovercraft will be more costly than any possible benefits it will offer. In fact, placing more than 4 fans will make the hovercraft larger and heavier than necessary, any benefit gained by the extra fans will be lost to counteract its extra weight and large hovercraft. From this, we find 3 designs that have at least 1 fan & a servo and at maximum 3 fans.

With the requirements and the target score above in mind, we are set to find 3 possible designs to explore in more detail. We first set that all designs we create will have a skirt. We first came up with a heavy-duty and powerful hovercraft design with 3 fans. This is our first design detailed below. This is the most powerful design we could come up with that follows our requirements and the maximum number of components we should have from research. This design will be the heaviest but it will offer much more power and stability, which is a huge benefit. Next, we came up with a design that is the most popular, from our research, it consists of 2 fans: one to hover, one to move forward with a servo to control the direction. While researching, we found this to be the most common design used with slight modifications. It is not the most powerful hovercraft possible but it achieves our requirements with ease. Finally, our last design is the least powerful and heavy with only one fan used for both lift and movement, again a servo will be used to turn the design. Although this design uses the least amount of parts it causes the hovercraft to have little power and very low stability. It follows our requirements but it will much more time than our other designs.

Now that we had the basic locations of fans for the designs, we had to come up with the shape of the designs. Since the corners of the track the hovercraft should complete are square, we came up with the idea of having circular hovercraft bases to ease the cornering of the craft. Since the first two designs require fans at the back we could not make it round, therefore we had to make a circular rectangular shape with the back of the hovercraft being square and the front being circular. The last is simply a circle since we need to place the fan a couple of inches from the edge of the hovercraft to supply the skirt with air.

This process lands us with 3 different possible designs for our hovercraft to test in details to come up with one final designs, all design uses a skirt:

1. A heavy-duty hovercraft that consists of three fans, one for hovering and two for moving forward.
2. A medium-duty hovercraft that consists of two fans, one for hovering and one for moving forward. This design will require the use of a servo with rudders to steer the hovercraft in the wanted direction.
3. A light-duty hovercraft that consists of only one fan that will be used for both hovering and moving forward sharing its force. This design will also require a servo and rudders to steer the hovercraft.

After coming up with the three designs, we discussed what type of sensors we should use for our hovercraft. We have three sensors to choose from: an infrared (IR) rangefinder, an ultrasonic (US) rangefinder, and the IMU sensor. The pros and cons of each sensor were considered for our application. From our research, we found out that the IMU sensor offers us the most functionality for us. It includes multiple sensors that we can use to make our hovercraft more efficient. For example, we can use the gyroscope to know if the hovercraft is inclined and adjust the distance from the wall read from sensors. We can use the IR and US sensors to control our hovercraft autonomously, using these sensors will be much easier with code but it will be less efficient since we do not have the extra sensors offered by the IMU. Therefore, for the added control and information the IMU provides, we choose to use it for our design while keeping the regular sensors as a backup if using the IMU becomes too complicated.

4.DESIGN SELECTION

4.1 Hovercraft Model 1:

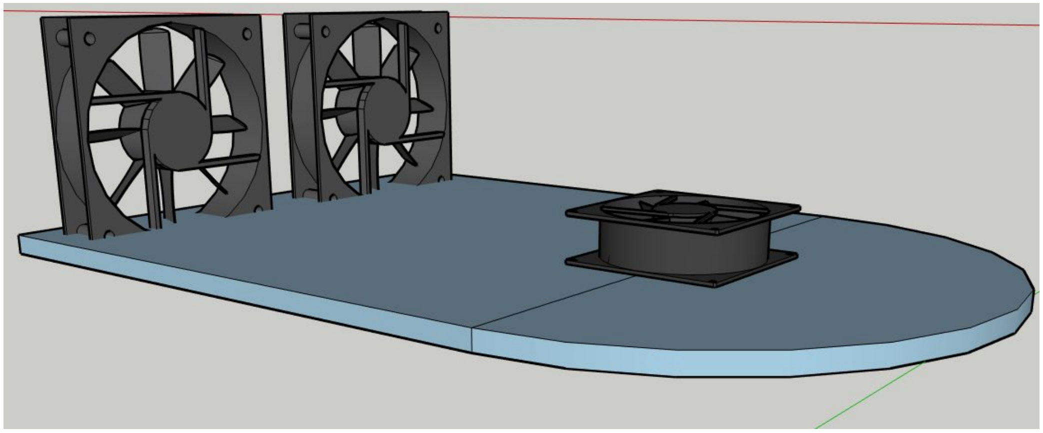


Figure 4.1: Design #1

This model will be equipped with two fans in the back and 1 fan in the middle. This hovercraft won't be equipped with a servo. Turning on and off one of the fans on the back will allow us to turn the craft, this eliminates the need for a servo. The first fan will be placed in the middle face down where the airflow will go under the hovercraft through a hole, in a skirt. This will allow us to lift the hovercraft from the ground. The second and third fans will be placed vertically in the back of the hovercraft. These fans will be used for direction changing and the horizontal force to go forward. This model will have a rounded-rectangle shape. Because the air is blown through a hole, for stability reasons, it will give us this shape. This model comes with some weaknesses. First, the shape of this model increases our chance to get stuck in a corner while turning. Second, this model can have a big weight so it will consume a lot of power to make it go forward. One of his great strengths is two fans in the back that allowed us to access more power and more control to travel the maze with ease and stability.

4.2 Hovercraft Model 2:

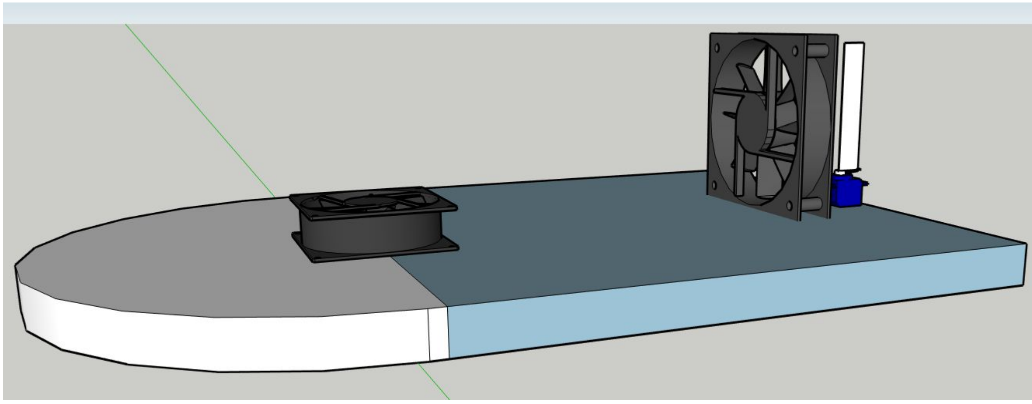


Figure 4.2: Design #2

This design will consist of two fans and one servo motor. The Base of the hovercraft will also have a rounded rectangular shape. This shape like the previous model increases the risk of getting stuck in a corner. The first fan like the previous model will be placed face down in the middle of the hovercraft. The air will go through a hole to lift the hovercraft vertically. The second fan will be used for the horizontal force to make the hovercraft go forward. In this design, a servo will be used to change the direction of the hovercraft. The problem with this model is weight and force consumption. It weighs a bit less than the previous model because we have one less fan but we lose in horizontal force power. This model contains a lot of components. The strength of this model is the fan in the back that allowed us to gain a good acceleration.

4.3 Hovercraft Model 3:

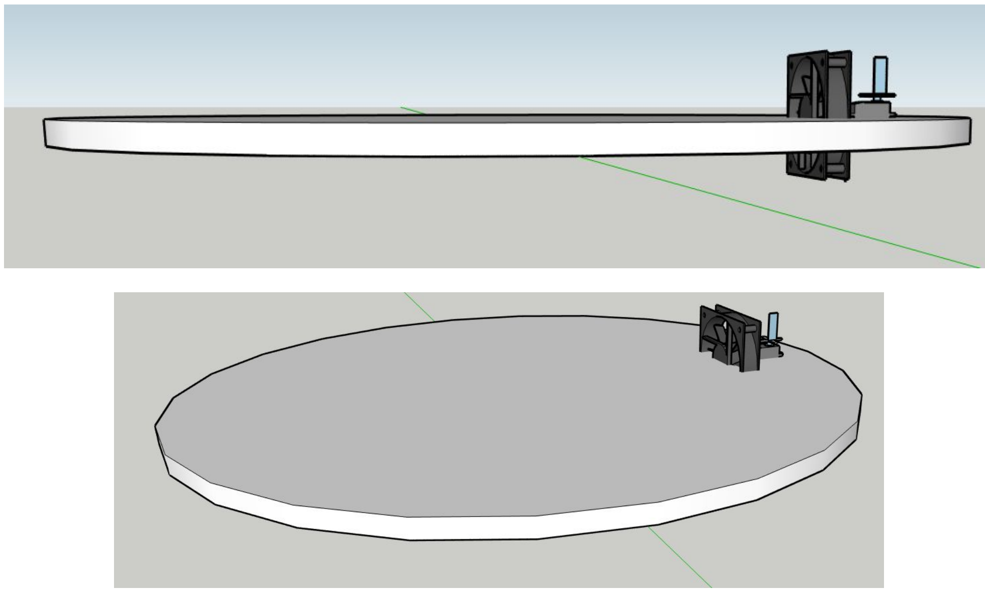


Figure 4.3: Design #3

The last model will consist of only one fan and one servo motor. The fan will be placed vertically at the back of the hovercraft. Air will be going through a hole in the hovercraft for the lifting using half the fan. The other half of the fan will be used for the horizontal force to move the hovercraft forward and a server will be used to turn it. This model has a circular shape. That shape decreases the chance of getting stuck in a corner while turning. The fact that we are using one fan for this model decreases the acceleration and the mobility of the hovercraft. The model contains fewer components than the previous two models, therefore it weighs less. It consumes less power than the other two models. As said before having one fan made the maneuverability very hard for this hovercraft and caused a lot of problems.

4.4 Mathematics:

We now have three different designs. As stated in the above section, these design all have their benefits and disadvantages for our application. Therefore, we had to do some mathematical analysis to find the best option for us.

4.4.1 Decision Matrix:

Comparison Criteria	Importance	Design 1		Design 2		Design 3	
		Score	**Result**	**Score**	**Result**	**Score**	**Result**
Number of components	0.1176	8	0.9408	9	1.0584	10	1.176
Lift	0.338	10	3.38	10	3.38	9	3.042
Propulsion	0.2561	10	2.561	9	2.3049	8	2.0488
Weight	0.1402	8.5	1.1917	9	1.2618	10	1.402
Algorithm difficulty	0.099	10	0.99	9	0.891	8	0.792
Power Consumption	0.04917	9	0.4425	8	0.39336	10	0.4917
Total	1	55.5	9.506	54	9.28946	55	8.9525

Table 4.4.1: Decision Matrix

This table shows that the first design has the highest score out of the three. Some of our criteria have better results with other designs but the first design shows that the average of scores is better.

4.4.2 SWOT Analysis:

The SWOT analysis was derived based on strengths, weaknesses, opportunities, and threats envisioned in the competition. According to the grading scheme mentioned in the document's scope ($Score = \frac{d_{completed}}{N_c \, x \, t_{course}}$), the distance, number of components and the time in which the course is completed are all criteria to be considered in the analysis. The number of components can be chosen, and therefore can be directly influenced. The time and distance covered by the aircraft are indirectly affected by aspects such as the weight of the aircraft, its power consumption, its lift, and propulsion. The volume of the design was also considered as it may affect the rotational speed. The aforementioned three designs have been characterized by these aspects. The opportunities found in the competition have to do with the number of attempts we have, the map of the track and the coding framework provided by our supervisor. Thanks to our knowledge of the track, we can design our software to work in tandem with the expected terrain and obstacles. We can place our sensors strategically to position itself with respect to its environment move along the track cautiously. The coding framework will help us save time in the implementation of our code. The threats deal with external influences to our performance such as the airflow in the hallway, the imperfections in the floor which may cause the aircraft to tilt on one side and the other team's performance, as we are ranked relative to each other.

Design	Strength	Weaknesses	Opportunity	Threats
Hovercraft Model 1 (1 fan on the bottom, 2 fans at back)	- Airflow under the skirt for lift - Airflow for propulsion, velocity, and acceleration	- Difficulty control algorithm - Volume of design - Weight - Power consumption -Number of components	- Three opportunities to complete track - Knowledge of track and grading scheme - Coding framework provided	- Imperfections in floor - Airflow - Competition
Hovercraft Model 2 (1 fan on the bottom, 1 fan at back with servo)	- Difficulty control algorithm - Airflow under the skirt for lift - Airflow for propulsion, velocity, and acceleration	- Weight - Number of components - Power consumption	- Three opportunities to complete track - Knowledge of track and grading scheme - Coding framework provided	- Imperfections in floor - Airflow - Competition
Hovercraft Model 3 (1 fan at back with servo)	- Power consumption - Weight - Number of components - Difficulty control algorithm	- Airflow under the skirt for lift - Airflow for propulsion, velocity, and acceleration	- Three opportunities to complete track - Knowledge of track and grading scheme - Coding framework provided	- Imperfections in floor - Airflow - Competition

Table 4.4.2: SWOT Analysis

4.4.3 AHP Analysis:

In the AHP analysis, we attempt to compare the criteria mentioned above against each other, in an effort to evaluate the level of importance we may attribute to each of them in respect to each other. While comparing them, we've taken the sum of each column in order to further analyze their contribution to the aircraft.

AHP Analysis						
	Reduced number of components	Increased lift	Higher propulsion	Reduced weight	Reduced algorithm difficulty	Reduced power consumption
Number of components	1	0.33	0.5	0.25	2	3
Lift	3	1	2	3	4	5
Propulsion	2	0.5	1	5	3	4
Weight	4	0.33	0.2	1	0.5	3
Algorithm difficulty	0.5	0.25	0.33	2	1	2
Power consumption	0.33	0.2	0.25	0.33	0.5	1
SUM	10.83	2.61	4.28	11.58	11	18

Table 4.4.3: AHP Analysis

4.4.4 Normalized AHP Analysis:

The normalized AHP analysis allows us to better visualize the differences in importance. The average column will allow us to derive a priority vector, with the highest average being the most important aspect of the aircraft.

Normalized AHP Analysis							
	Reduced number of components	Increas ed lift	Higher propulsio n	Reduce d weight	Reduced algorithm difficulty	Reduced power consumption	Average
Number of components	0.09233610342	0.12643 67816	0.116822 4299	0.02158 894646	0.1818181818	0.1666666667	0.11761 15183
Lift	0.2770083102	0.38314 17625	0.467289 7196	0.25906 73575	0.3636363636	0.2777777778	0.33798 68819
Propulsion	0.1846722068	0.19157 08812	0.233644 8598	0.43177 89292	0.2727272727	0.2222222222	0.25610 27287
Weight	0.3693444137	0.12643 67816	0.046728 97196	0.08635 578584	0.0454545454 5	0.1666666667	0.14016 45275
Algorithm difficulty	0.04616805171	0.09578 544061	0.077102 80374	0.17271 15717	0.0909090909 1	0.1111111111	0.09896 467829
Power consumptio n	0.03047091413	0.07662 835249	0.058411 21495	0.02849 740933	0.0454545454 5	0.05555555556	0.04916 966532
Previous SUM	10.83	2.61	4.28	11.58	11	18	N/A
New SUM	1	1	1	1	1	1	1

Table 4.4.4: Normalized AHP Analysis

4.4.5 Ranked priority vector:

The following ranked priority vector will be used to compare the three designs in more detail, by applying these factors as weights to the SWOT analysis.

Ranked priority vector		
1	0.338	Lift
2	0.2561	Propulsion
3	0.1402	Weight
4	0.1176	Number of components
5	0.099	Algorithm difficulty
6	0.04917	Power consumption

Table 4.4.5: Ranked priority vector

4.5 Selected Design:

To find a final design to make for our project we had to do a number of mathematical analyses. The analysis clearly shows that one design is better for our application than the other two models. That is the first design we came up with 3 fans. This design shows the fulfill all our requirements the best. The benefits of the extra fans outweigh the disadvantages of doing so. The two fans used for thrust offer a higher level of control and power.

4.6 Design Calculations & Simulations:

Now that we choose a design to implement, we had to do some simulations and calculations to choose which parts to use on our hovercraft. We will use mechanics learned in class to do so, notably the Lagrangian and Newtonian mechanics to calculate the position and velocity effects of the hovercraft system with different possible parts. Although the design calculations and simulations that we did show the behavior of the hovercraft, it is important to note it is only a close approximation in ideal condition. Real-life conditions might affect our results with a real hovercraft model. For simplicity, we will only look into the X & Y axes calculations and simulations, assuming the Z-axis is constant since the hovercraft should not be moving up and down. To simulate the hovercraft we use the Matlab software to get the performance of it during the competition. We do a simulation to remedy any problems that may arise when a model is done to avoid wasting time and resources trying to overcome problems when the hovercraft model is created.

First, we saw in our lectures that the equations of motion of a hovercraft depend on the surge that represents the longitudinal motion and the sway represents the lateral motion. The vertical motion can be represented by the heave but we choose to ignore this since we assume that the hovercraft does not move vertically, as stated above.

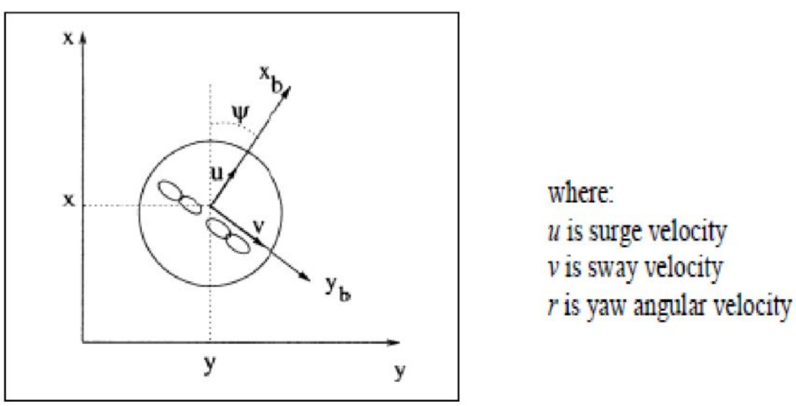


Figure 4.6: The Hovercraft Model [2]

From this model, we can derive the equations of motion using the Euler Lagrange equation with Langrangian $L = T - V = KE - PE$. Potential energy is ignored for system lifting as stated above.

$$x = cos(\psi)u - sin(\psi)v$$
$$y = sin(\psi)u + cos(\psi)v$$
$$\psi = r$$

Given that the system will require dynamic modeling, we can generate new equations of motions from the free-body diagrams of the hovercraft's tasks. Given that the hovercraft has 2 fans for thrust and 1 fan for lift, we can derive its translation, lateral and yaw velocities based on the position of the fans, moment of inertia and thrust.

From the straight line task, we can derive that mx'' = -ux' + fx, where (u) is the coefficient of friction from the weight of the skirt, taken as a very small number, and fx is the force along the x-axis generated by the 2 fans.

We can generate a secondary equation of motion from the lateral movement, whereby my'' = -uy' + fy. Once again, u is the friction coefficient and fy the force generated by the two fans along the y-axis.

A third equation may be generated from the rotational motion of the hovercraft, involving its moment of inertia (J), rotational friction coefficient (R), and torque exerted by the fans (T) as J*theta = R*theta + T.

$$\frac{d}{dt}\begin{bmatrix} x \\ y \\ \theta \\ \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & -\frac{\mu}{m} & 0 & 0 \\ 0 & 0 & 0 & 0 & -\frac{\mu}{m} & 0 \\ 0 & 0 & 0 & 0 & 0 & -\frac{\psi}{J} \end{bmatrix} \begin{bmatrix} x \\ y \\ \theta \\ \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ \frac{1}{m} & 0 & 0 \\ 0 & \frac{1}{m} & 0 \\ 0 & 0 & \frac{1}{J} \end{bmatrix} \begin{bmatrix} f_x \\ f_y \\ T \end{bmatrix}$$

The moment of inertia of the hovercraft, it's mass and friction coefficients have been calculated below. Given these sets of equations, we may create a Simulink model to determine displacement and velocity.

4.6.1 Fan Comparison:

From our list of available parts, we can see that we have the choice between two fans: the MEC0251V1-000U-A99 [3] and the AFB1212SH [4]. We got their datasheets from Digikey and chose which one will be the most efficient for our thrust and lift fans.

From the datasheets, we create the following table to find the most powerful fans:

	MEC0251V1-000U-A99 [3]	AFB1212SH [4]
Power Consumption	5.5 Watts	6.36 Watts
Rated speed	3100 RPM	3400 RPM
Airflow	108.2 CFM/ 3.03 m^3/min	113.11 CFM/ 3.17 m^3/min
Current	455 mA	530 mA
Dimensions	120x120x25 mm	120x120x25
Area	0.0144 m^2	0.0144 m^2
Weight	162g	198g
Pressure	69.7 Pa	107.1 Pa
Thrust Force (N) = pressure *area	1.00368	1.5422

Table 4.6.1: Fan Comparison

From this table, we can see that the AFB1212SH is the most powerful one with a thurst force of 1.5422N compared to 1.00368N for the other fan. This fan has a higher force since it has a higher RPM but this comes with a consequence of drawing more current and hence has a higher power consumption of 6.36 watts. The MEC0251V1-000U-A99 fan is the least powerful fan out of the two since it has less thrust force, although it has less power it has the benefit of having less power consumption.

For our design, it will be ideal to use three of the most powerful fans but that will cause too much current to be drawn from the battery and it will weigh too much. This will cause 1590 mA to be drawn on the battery and a total weight of 594g added to the hovercraft weight. Therefore, we will use one of the most powerful fans, face down on the hovercraft, as a lift fan and two of the least powerful fans as the thrust fans. This will reduce the current drawn to 1440mA and the total weight of the components to 522g. Although this is not a great difference, it makes a lot of difference to determine if we will finish the track or not.

4.6.2 Component Placement:

We need to place the components on the hoverboard so that the center of mass is as close to the center of the hovercraft as possible. This will make the hovercraft more stable to traverse the track. If the center of mass is not close to the center of the craft, it will have more chances to tip over and won't rotate around the track as intended. We already know that both thrust fans must be placed at the back of the hovercraft and the lift fan should be placed in front of it. Therefore, we need to work with it and place the remaining components around it to assure the center of mass is correct.

To find the center of mass of our design, we first set that the fans will be all placed 0.1m from the center both the thrust and lift fans. This will make the hovercraft have a diameter of 20cm. Then the remaining parts, i.e. the battery and controller, will be used as a counterweight to make the hovercraft stable.

$$c = \frac{\sum_{i=1}^{n} m_i x_x}{\sum_{i=1}^{n} m_i}$$

Battery weight: 0.045kg

Controller weight: 0.135kg

$0 = 0.522(0.1) + (0.045+0.135)x$

$x = \ -0.29m$

Therefore, we need to place the batteries and controller at 0.29 of the reference point to obtain the desired center of mass.area

4.6.3 Area of the Body Frame:

Considering all the components our design will have a weight of 0.702kg and the fans will offer pressure of 246. 5Pa. Hence, the area of the body frame is

$Area\ =\ 0.702\ x\ 9.81/107.1.\ =\ 0.0279\ m^2$

4.6.4 Skirt Specifications:

Since our end goal is to have a fully autonomous hovercraft, we need to make sure that the fans work most efficiently, therefore our hovercraft will have a skirt made of fabric surrounding the base. The skirt will help to keep the pressurized air from escaping out of the bottom and help to lift the hovercraft up. Since we will not be using points using this, we saw it as necessary. For know, we chose to use a simple garbage bag for its low mass, and low friction since its made out of plastic and relatively smooth. This may change if we run into problems doing the creation of the design.

4.6.5 Inertia:

To make sure that the hovercrafts travel the track correctly, we need to make sure to take the inertia of the craft in mind. We use the formula, $I = \sum_{i=1}^{n} m_i r_i^2$.

This number may not be accurate because the actual size of the final hovercraft may not be the same. We want the center of mass placed at the center of the design

Therefore, we found the inertia of our design to be of $kg * m^2 = 0.702 * 0.29m^2 = 0.059$

4.6.6 Battery Capacity:

We have the choice between 5 batteries for our project: GRAVITY 4S 14.8V, Gens 450 mAh, Rhino 460mAh, Rhino 360mAh, Turnigy nano-tech.

First, we need to find the discharge time of the batteries. Our fans will draw a maximum input current of 1440 mA and a maximum input power of 17.36 W. We then use the following formula:

$$Discharge\ time = \frac{Battery\ volt\ x\ Battery\ Ah}{Applied\ load\ (power)}$$

The following table shows the values of each type of battery and the discharge time our design will have.

	GRAVITY 4S 14.8V [5]	Gens 450 mAh [6]	Rhino 460 mAh [7]	Rhino 360 mAh [8]	Turnigy nano-tech 180 mAh [9]
Voltage	14.8V	7.4V	7.4V	7.4V	7.4V
mAh	2200mAh	450 mAh	460 mAh	360 mAh	180mAh
Mass	258g	30g	28.5g	22.5g	13g
Energy/Mass	454 J/g	400 J/g	430 J/g	426 J/g	369 J/g
Size	105x34x35 mm	56x31x10mm	52x30x8mm	43x15x21m m	35x20x10mm
Energy/Volume	0.94 J/mm^3	0.69 J/mm^3	0.98 J/mm^3	0.71 J/mm^3	0.69 J/mm^3
Discharge time	1.8756h 6752.16s	0.1918h 690.48s	0.1961h 705.96s	0.1534h 552.24s	0.0767h 276.12s
Discharge time(x2 batteries in	N/A	0.3836h 1380.96s	0.3922h 1411.92s	0.3069h 1104.84s	0.1534h 552.24

series)					

Table 4.6.6: Battery Capacity

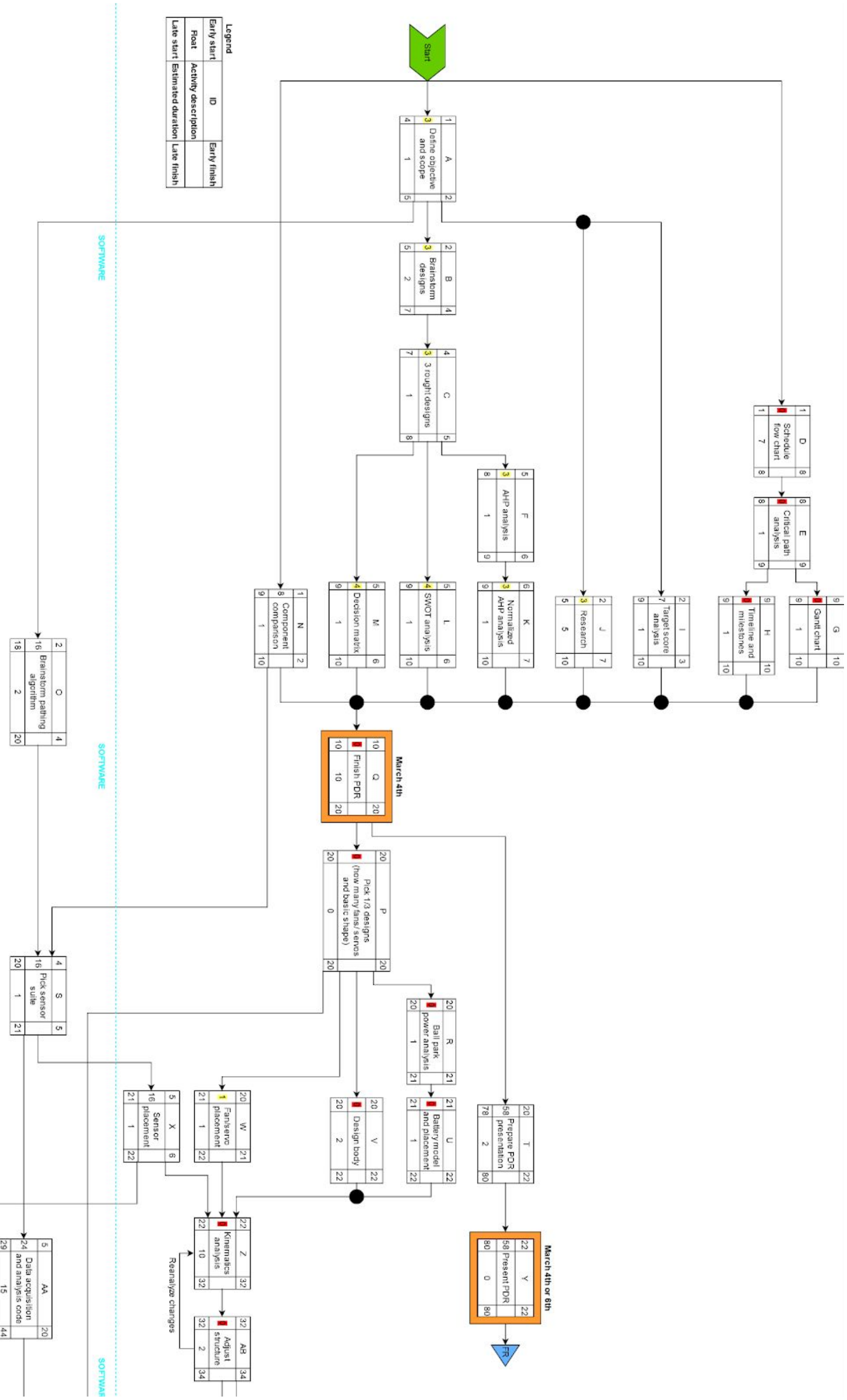
Since, we need to complete the track in a maximum of 2 minutes, 120 seconds, it is useless to have a battery that can keep the hovercraft going more than necessary. We have three tries to complete the track so we need the hovercraft to run for a maximum of 6 minutes, 360 seconds. Also, the fans require a minimum of 12 volts to function properly, therefore if we use anything but the GRAVITY 4S 14.8V battery, two batteries will be needed to power the hovercraft. We also want to be sure that there's enough battery left for any unexpected errors that may occur or extra components that we may add while building the hovercraft. With this in mind and the fact that we will probably want to test the hovercraft before running it in the competition, we choose to have two of the Rhino 360 mAh battery that offers a 1104.84 seconds discharge time which should be enough for all our needs without having to recharge the day of the competition, time that could be spent troubleshooting and testing.

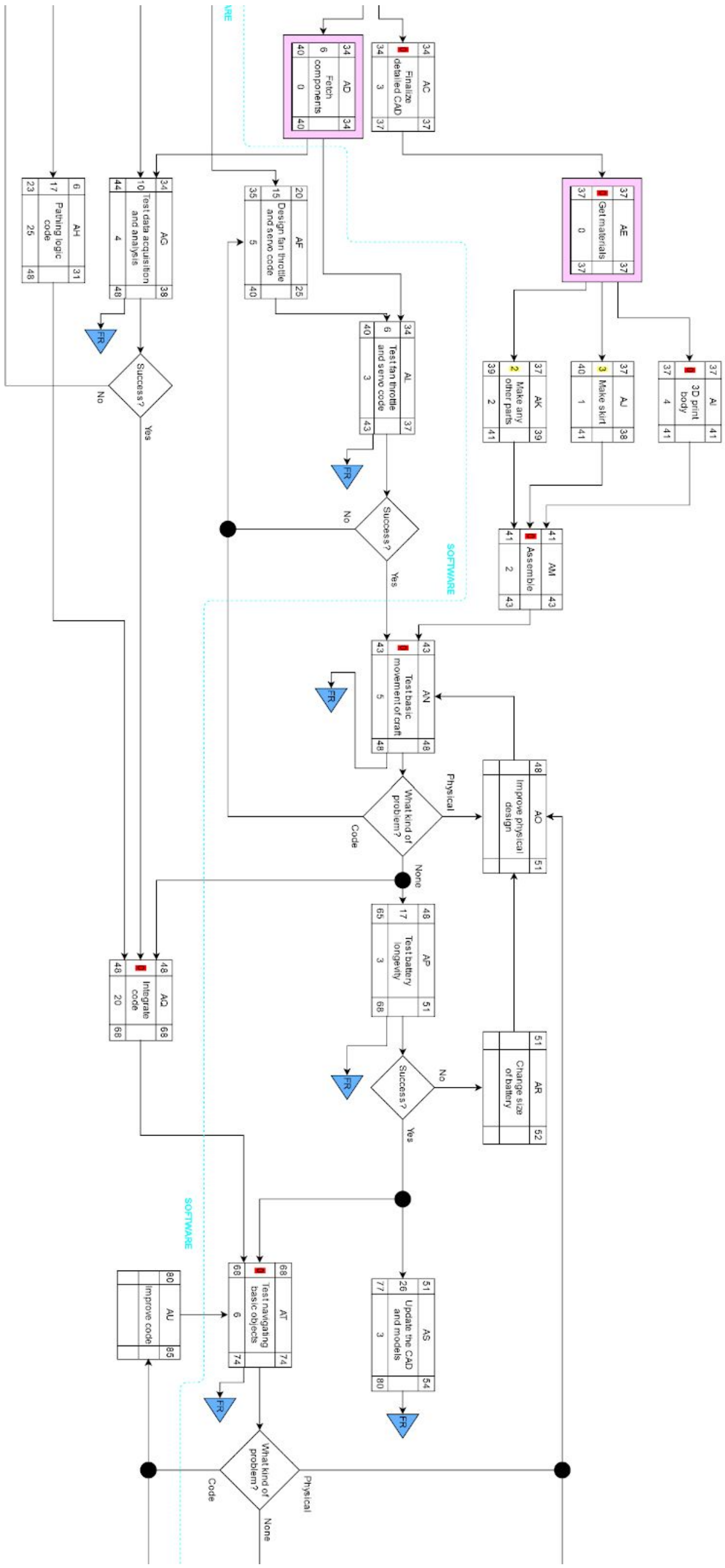
4.6.7 Calculations and Path Breakdown:

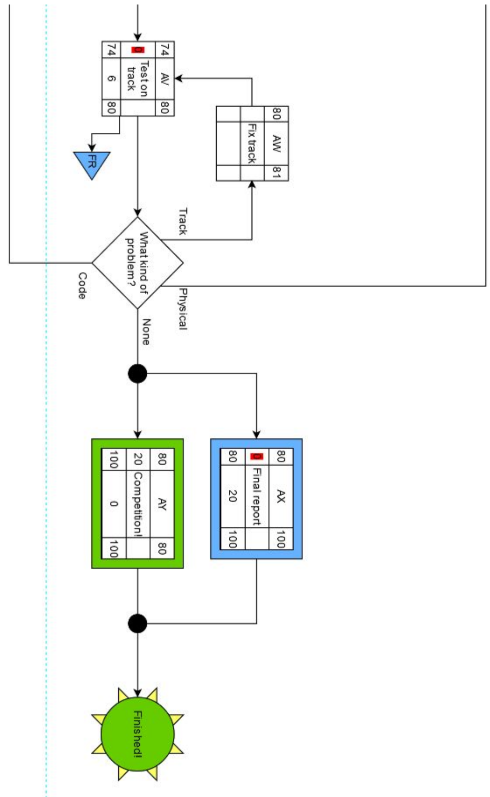
The track shown in Figure 2.1, shows that our hovercraft needs to go through three 180 degrees turns and overcome obstacles placed on the track of a maximum height of 3mm. We need to traverse 940 cm with a 180 degree turn every 235cm autonomously without human intervention. This path should be traversed in under than 2 minutes.

5.SCHEDULE

5.1 Master Schedule:




SOFTWARE
AC
Finalize detailed CAD
AD
Fetch components
AE
Get materials
AF
Design fan throttle and servo code
AG
Test data acquisition and analysis
AH
Pathing logic code
AI
3D print body
AJ
Make skirt
AK
Make any other parts
AL
Test fan throttle and servo code
AM
Assemble
AN
Test basic movement of craft
AO
Improve physical design
AP
Test battery longevity
AQ
Integrate code
AR
Change size of battery
AS
Update the CAD and models
AT
Test navigating basic objects
AU
Improve code
Success?
What kind of problem?
Yes
No
Code
Physical
None
FR



74
AV
80
Test on track
74
6
80
FR
80
AW
81
Fix track
Track
What kind of problem?
Code
Physical
None
80
AY
80
20
Competition!
100
0
100
80
AX
100
Final report
80
20
100
Finished!

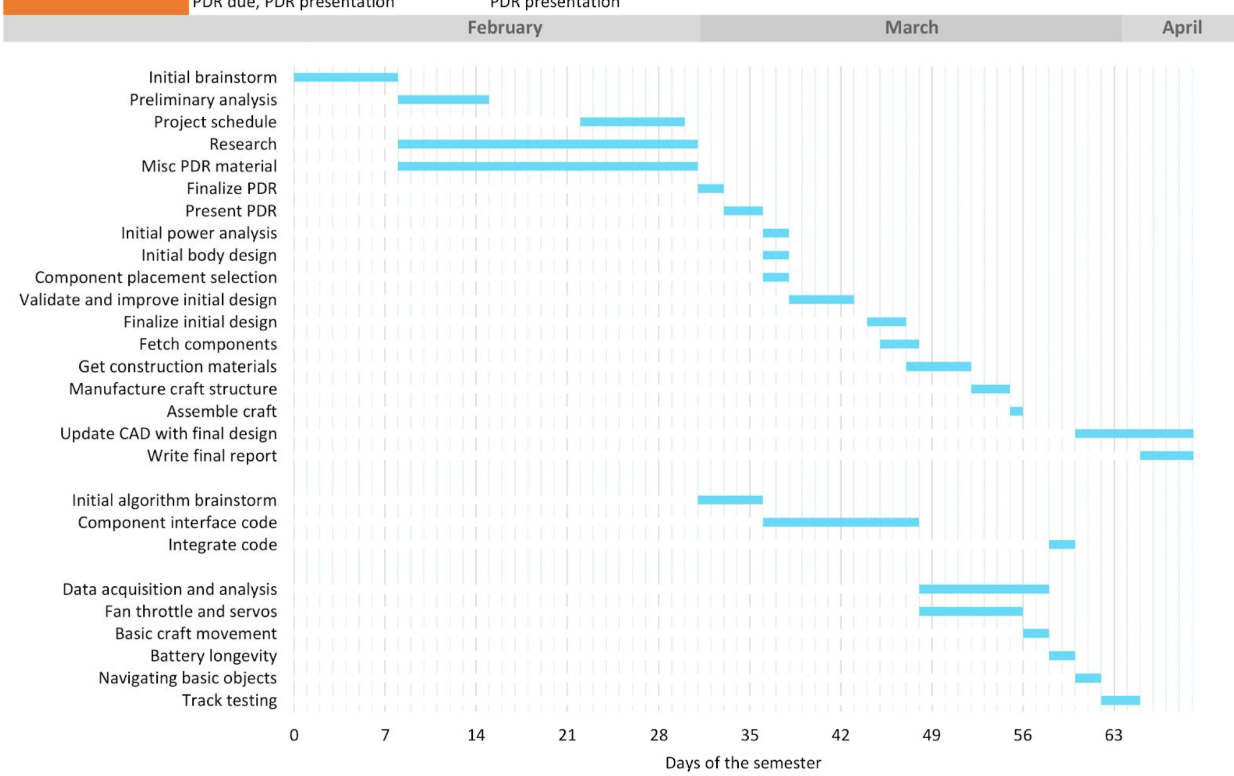
5.2 Gantt Chart:

Team 21 Hovercraft Timeline

* = an automatically calculated cell

TASK NAME	IDs	START DATE	DAYS SINCE JAN 31ST*	END DATE	DURATION* (WORK DAYS)	DAYS COMPLETE*	DAYS REMAINING*	TEAM MEMBER	PERCENT COMPLETE
General									
Initial brainstorm	A,B,C	1/31	0	2/7	8	0	8		0%
Preliminary analysis	F,K,L,M	2/8	8	2/14	7	0	7		0%
Project schedule	D,E,G,H	2/22	22	2/29	8	0	8		0%
Research	J	2/8	8	3/1	23	0	23		0%
Misc PDR material	I,N	2/8	8	3/1	23	0	23		0%
Finalize PDR	Q,T	3/2	31	3/3	2	0	2		0%
Present PDR	Y	3/4	33	3/6	3	0	3		0%
Initial power analysis	R,U	3/7	36	3/8	2	0	2		0%
Initial body design	V	3/7	36	3/8	2	0	2		0%
Component placement selection	W,X	3/7	36	3/8	2	0	2		0%
Validate and improve initial design	Z,AB	3/9	38	3/13	5	0	5		0%
Finalize initial design	AC	3/15	44	3/17	3	0	3		0%
Fetch components	AD	3/16	45	3/18	3	0	3		0%
Get construction materials	AE	3/18	47	3/22	5	0	5		0%
Manufacture craft structure	AI,AJ,AK	3/23	52	3/25	3	0	3		0%
Assemble craft	AM	3/26	55	3/26	1	0	1		0%
Update CAD with final design	I,N	3/31	60	4/9	10	0	10		0%
Write final report	I,N	4/5	65	4/9	5	0	5		0%
Software									
Initial algorithm brainstorm	O,S	3/2	31	3/6	5	0	5		0%
Component interface code	AA,AF	3/7	36	3/18	12	0	12		0%
Integrate code	AQ	3/29	58	3/30	2	0	2		0%
Testing									
Data acquisition and analysis	AG	3/19	48	3/28	10	0	10		0%
Fan throttle and servos	AL	3/19	48	3/26	8	0	8		0%
Basic craft movement	AN	3/27	56	3/28	2	0	2		0%
Battery longevity	AP	3/29	58	3/30	2	0	2		0%
Navigating basic objects	AT	3/31	60	4/1	2	0	2		0%
Track testing	AV	4/2	62	4/4	3	0	3		0%

IMPORTANT DATES:	March 4th	March 6th
	PDR due, PDR presentation	PDR presentation



6.SUMMARY

The goal of this report was to come up with the design of a hovercraft that we will create and use in a competition where it will run on a track shown in Figure 2.1, autonomously, as fast as possible. We first came up with three different possible designs shown in Figure 4.1,4.2, & 4.3 after considering multiple designs from research and previous years student designs. The three designs we ended up with were all previously done by multiple people, therefore we knew it would work. This was a safer bet than trying a unique design from scratch. By further analyzing all the designs, we found the first design to be more efficient for our case. This choice was proven mathematically in the SWOT and AHP analysis on table 4.4.1, 4.4.2, 4.4.3, 4.4.4, and 4.4.5.

Next, we did some calculations and analysis to choose which fan to use on the chosen design. We chose to use the AFB1212SH fan as the lift fan and two MEC0251V1-000U-A99 fans as the thrust fans. By using these fans, the hovercraft will weigh a total of 522g and draw 1440mA from the battery. These fans should offer enough force for our needs.

With the fans chosen, it was time to choose the batteries to use. After some calculations, on all the available batteries we were able to calculate the total discharge time the battery will have with the fans we chose. From this, we chose the battery that offers enough discharge time without having too much power for nothing. This will increase the weight. We chose to have two Rhino 360mAh batteries that will offer a discharge time of 1104.84 seconds for our application. This should be enough for all our needs without having to recharge the day of the competition, time that could be spent troubleshooting and testing.

With the design process done, we did a schedule that we will need to follow to finish our project on time.

7.REFERENCES

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- [3]:https://www.digikey.ca/product-detail/en/sunon-fans/MEC0251V1-000U-A99/259-1470-ND/2021098
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