APSC 258 Application of Engineering Design

Hovercraft Final Report

Written by

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Executive Summary

As the agriculture around the world is continuously advancing, farmers are constantly trying to increase the efficiency of the process of delivering pesticides and have decided that a hovercraft is the best solution. We have been assigned the task of designing and building a hovercraft that is capable of performing the pesticide delivery that the farmers need.

Some major accomplishments documented in this report include:

-Developed a strong understanding of the functions and uses of hovercrafts

-Documented the detailed design process

-Evaluated the design problem and formulated relevant objectives and constraints

-Described in-depth key hovercraft components including the hull, wiring, dropping mechanism, thrust and propulsion systems, skirt and steering system

-Separated the project into its relative engineering disciplines

-Created schematics and 3D models of preliminary designs, key components, and the final product

-Explained choice of materials and the importance of material selection

Overall, the hovercraft project provided our team with a greater appreciation of the complexity of hovercrafts and the many variables needed to be considered when undergoing a comprehensive design process. The next step is to hopefully appear in the final competition with the top 20 groups occurring on April 4, 2017.

1.0 Introduction

This report will outline the entire hovercraft project and what decisions led to the creation of our design. With the available resources and equipment this is our team's design from ideas to the prototype and lastly the final product. Here is the breakdown of our choices and changes throughout this project.

1.1 Background

A hovercraft is an air cushion vehicle that can travel over land, water, ice, and mud. Invented in the 1900's the hovercraft was created for military uses. It was great at carrying cargo with efficiency and was built in mind of the military and is still used by them all around the world today. It did not find much progress till the early 1950's by Christopher Cockerell a british engineer made a successful skirt using an idea from an experiment that involved a coffee can and a tin of cat food. Thought not used commonly the hovercraft has a place with disaster relief and military applications.

1.2 Project Goal

The objectives of this project are to use several methods to prepare, analyze, and build the hovercraft design to achieve the purpose in maximizing the efficiency of the hovercraft. This includes many styles such as brainstorming, scamper and mind mapping to create new and innovative types of hovercraft designs. The design we chose is created to satisfy the basic functional standards and the consumer's requirements that they desire. Therefore many steps have been taken to build a prototype before the final consumer product. As the goal is to increase the total efficiency there are many ways to improve the pesticide delivery system.

1.3 Objectives / Constraints / Needs

Using a need statement you can find objectives and constraints to define and help focus on what are the important aspects. The need statement we have decided to go with is "The current pesticide delivery methods are not efficient enough" In this hovercraft design we decided efficiency was one of the many things that was very important but is also restricted by the speed that we can move. Another objective is the cost or expense of the final product, the farmers need to be able to afford the hovercraft and all of its expenses. The constraint to this however, is the quantity and the types of materials we will be using for the hovercraft as higher quality items will be harder to obtain. Lastly another important factor is that the pesticide drop needs to be accurate enough to be placed only where needed. The distance from the drop point will determine its accuracy and will be restricted to point.

Need Statement: Current pesticide delivery methods are not efficient enough

Table 1: Design Objectives and Corresponding Constraints

Objective	***Constraints***	***Units***
Efficient	*Speed*	*Seconds (s)*
Inexpensive	*Quantity and Type of Material*	*Dollars ($)*
Accurate	*Distance from drop point*	*Centimeters (cm)*

2.0 Design Process

Extensive brainstorming, planning and preparation was key in the completion of this project. To stay organised and on task we decided to track our process based on the design steps that were covered in the APSC 258 lectures, and we worked on developing a deeper understanding for the materials which would be used.mrch

2.1 Engineering Aspects

The building of the hovercraft will be divided into three components, mechanical, civil and electrical. These are the main basis and what we will be focusing on throughout this project. With the split of these three categories we can divide up how sections will be done. The mechanical work will be the servo, skirt design, rudders and the dropping system that will be used to drop the pesticides. Next will be the civil work which will include the structure of the hovercraft, the placement of the components and the weight distribution. Finally the electrical work will consist of the use of the arduino, the circuitry and the bluetooth connection for wireless control.

2.2 Process Breakdown

2.2.1 Recognizing the Need

A group of farmers in the Okanagan valley are looking for better ways to deliver pesticides to their crops. They are trying to increase the efficiency of the process of delivering pesticides, and have decided that a hovercraft is the best solution. We have been assigned the task of designing and building a hovercraft that can perform the pesticide delivery that the farmers need. With this task in mind, our group devised a need statement with which our project was based off. Our need statement is: “Current pesticide delivery methods are not efficient enough.” The goal of this statement is to accurately recognize the need while remaining simple yet effective. Once it was agreed upon, project progression continued.

2.2.2 Defining the Problem

After the need was established, the problem need to be defined. With this in mind, a problem statement was conceptualised to fit the needs for the project. In order to create the best problem statement possible, we decided it would be in our best interest to split up the design into its relative engineering and customer requirements to get a better idea of what we needed to accomplish. See figure 1 below for an organised table of our ideas in the form of a QFD chart.

	Engineering Requirements							
Customer Requirements	Lift	Thrust	Cost	Power	Weight	Structure thickness	Carrying capacity	Response time
Durability					×	×		
Reliability				×				×
Ease of use	×	×						×
Efficiency				×	×		×	
Inexpensive			×					
Protects crops	×	×						
Handle all weather					×	×		
Long life time				×	×	×		
Units	$Kg*m/s^2$	$Kg*m/s^2$	$	Watts	Newtons	mm	grams	sec.
Engineering Targets	2	20	100	25.6	22	70	800	0.5

Figure 1: QFD Chart Comparing Engineering and Customer Requirements

The problem statement we derived was "Design a hovercraft capable of supporting, transporting and dispensing pesticides on to plants as efficiently and as quickly as possible." Like our need statement, the goal of our problem statement was to remain simple while still encapsulating the idea for the project.

2.2.3 Planning the Project

The objectives of this project are to use several methods to prepare, analyze, and build the hovercraft design to achieve the purpose in maximizing the efficiency of the hovercraft. The hovercraft design is desired to satisfy the basic functional standards and the consumer's requirements. These objectives were kept in mind during the initial brainstorming phases. See figure 2 below for our Gantt Chart which was used to track our progress and keep up-to-date with the project.

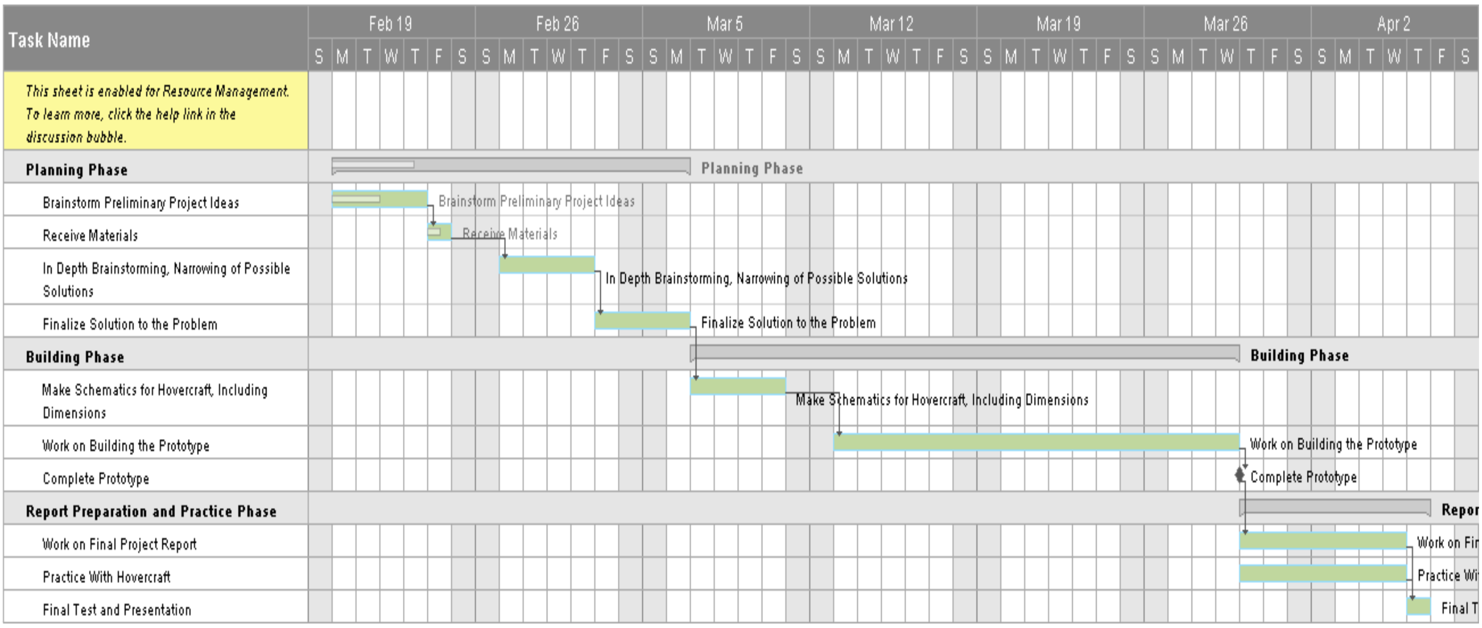


Figure 2: Gantt Chart Used to Track Project Progress

During the planning phase, keeping up with our expected progress was taken very seriously by all group members, as its importance to the completion of the project was very relevant. With the help of careful planning and cooperation between all team members, we were able to remain on schedule for the entirety of the project.

2.2.4 Gathering Information

In order to complete this project there is a great deal of new knowledge that needed to be acquired. Subject material from APSC 253 and APSC 260 needed to be applied in order to acquire an understanding of the fluid movement for the hovercraft propulsion system as well as the yield stresses of our structure. In APSC 258 the Arduino controller experiment introduced the Arduino, Potentiometer and Servo motor. Knowledge of connection, power inputs and outputs and any other electrical components was covered in this lab. The pressure map under the hull lab introduced the dynamic properties of lift variation with different clearance distances (see figure 3).

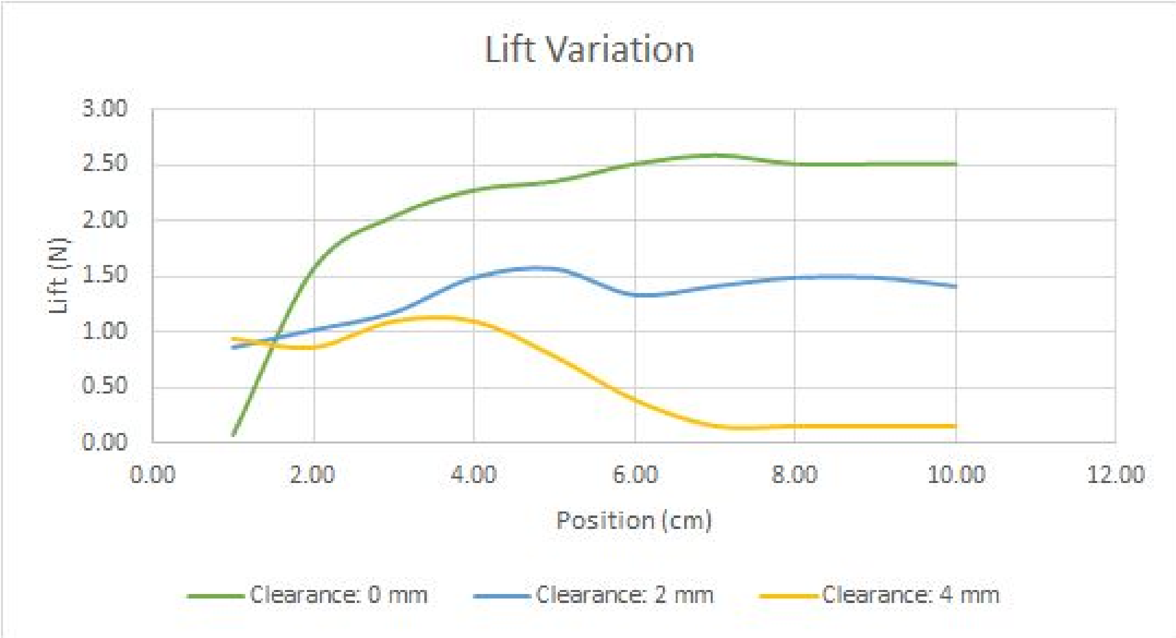


Figure 3. Lift variance vs. position relation

The data shown above gave us information on how the lift produced under the hull decreases as the clearance from the hull to the ground increases. With this it was discovered that our hovercraft had to be as close to the ground as possible without creating significant friction with the ground. During the brainstorming stage this data was made useful in designing our hull shape and skirt design.

Through the internet we researched different materials to use as the structure of our hovercraft. Styrofoam hovercraft designs like Flight test's (2016) inspired us to look into the possibility using it as our material choice. Figure 4 shows how the electrical and mechanical components of a hovercraft can be placed on a styrofoam structure.

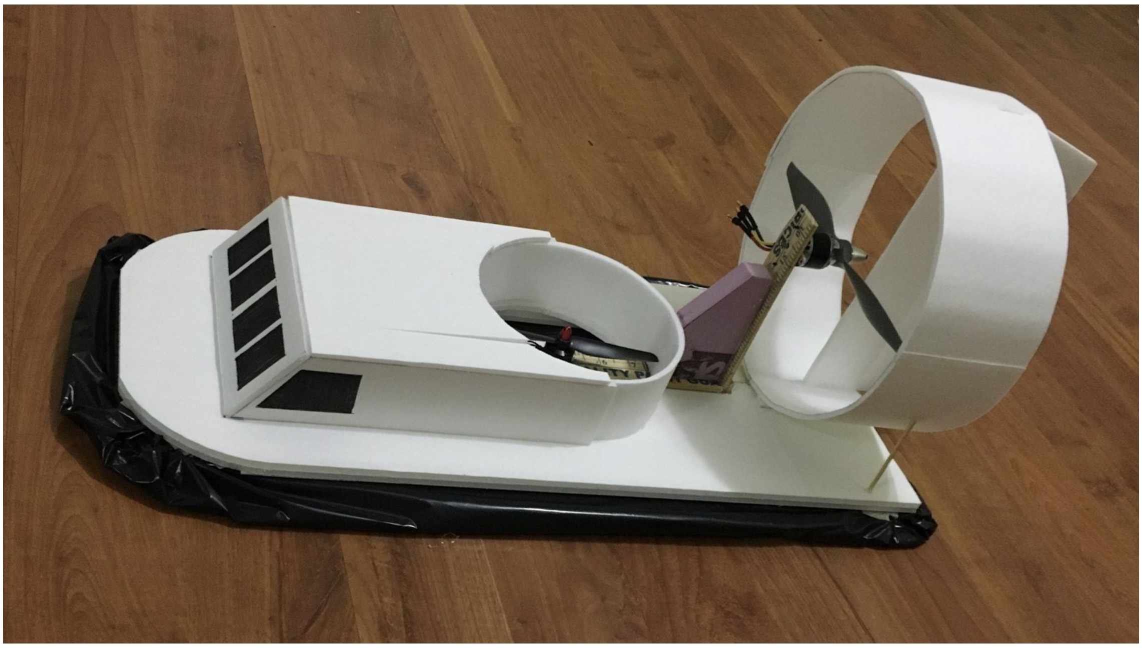


Figure 4: Styrofoam hovercraft design example. Reprinted from "Flight Test," by kkmalu, 2016. Copyright 2016 by Flight Test. Reprinted with permission.

2.2.5 Conceptualising Alternative Approaches

Before finalizing our proposed solution, alternative solutions were discussed with their relevant pros and cons in relation to the problem. In order to do this, we analyzed any possible ideas with the four levels of creative design:

Selection Design: We used this to take into account all the pre existing components that are being used in hovercrafts. Included in this is the propulsion and lift systems, motors, engine and power source as well as the basic design and structure.

Configuration Design: In this step our goal was to arrange and modify the standard components previously discussed and to brainstorm ways to improve performance and/or reduce size, while taking advantage of the attractive configurations. Our main modification was having two fans allocated to thrust and two to lift, with the goals of efficiency and agility in mind. Another modification was having rigid thrust fans with a moving rudder to limit the chance of error with wiring and the motor mechanisms.

Parametric Design: This level is focused on defining the objectives for the project as functions of their corresponding performance parameters. This aspect was completed early on in the "Defining the Problem" stage of our design process.

Original Design: This level was very dominant during the brainstorming phase. We used a very broad approach when brainstorming and encouraged one another to voice any idea they had, no matter how ridiculous it seemed. This helped us gain a broad understanding of what our main focuses should be and helped us to narrow down more feasible and probable design.

Once we completed these steps we were able to have a much better idea of what the goals for our project are. Once our objectives were narrowed enough, we evaluated possible designs and ranked them based on their feasibility, probability and reasonability towards the task at hand. We communicated with each other to decide what the optimal design is based off of these rankings, taking into account the previous objectives and constraints that were thought of. Once it was decided that styrofoam was to be used for the main body of the hovercraft due to its low density, low cost and ability to easily shape and mould, a shape for the hull was brainstormed. The first shape we came up with was a simple rectangle with dimensions 55x35 cm. After this, the same design was carved out to make a triangular bow instead of the rectangle with the gal of decreasing bulkiness while increasing the structures aerodynamics. As an effort to further increase the aerodynamics and to make a more realistic design, the triangular bow was shaped into an arc as while as the back edges were rounded off. See figure 5 below for the step by step conceptualization of our possible alternative approaches.

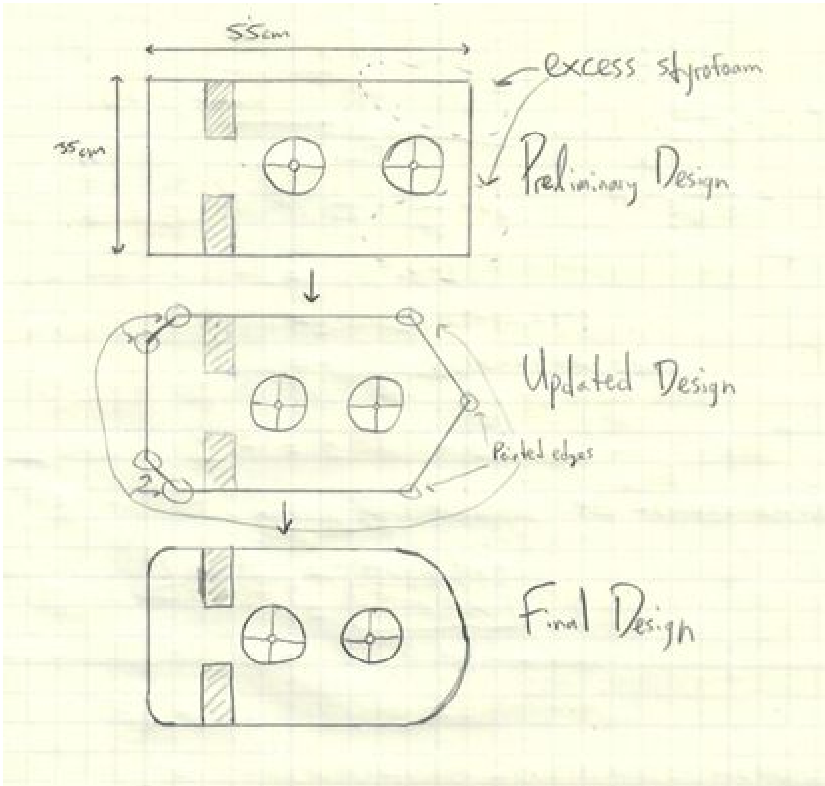


Figure 5: Design Process For Planned Hull Construction.

2.2.6 Evaluating the Alternatives

The preliminary design was quickly seen to be quite bulky with a large excess of Styrofoam that took up too much empty space. It was also decided that a long rectangle would be too difficult to control in the tight scenarios we were to face on the final course. For this reason, we decided to update our design to have a pointed bow with any excess Styrofoam cut off to make a smaller, more streamlined shape. This design resulted in many pointed edges protruding out from the hull which led to speculation of the effect the edges would have on the airtight seal of the attached skirt.

2.2.7 Selecting the Preferred Alternative

After further discussion with the group's assessments in mind, a final design was decided on. It was chosen to use a more traditional hovercraft shape with an arc at the bow and curved edges at the stern. This solved any worries related to keeping the skirt sealed while greatly increasing the maneuverability and ease of use of the craft.

2.2.8 Communicating the Design

Every important decision made towards the construction, design, layout and modification of the hovercraft was made with all group members present, ensuring everyone's input was heard and taken into careful consideration. Design decisions were only acted on if the entire team was in agreeance. Everyone was always on the same page and kept up to date with design changes to ensure if any task was affected, applicable changes could be made accordingly.

2.2.9 Implementing the Preferred Design

Once the design specifications were agreed upon and finalized, construction began. The group was split up into various disciplines. Yuan and Evan were tasked with the Arduino and Bluetooth connection for the dropping mechanism and the servo motor for the rudders. Damien began work on the wiring of the fans and the detailed solidworks modeling. Alexander conceptualised several designs for the skirt, applying his knowledge taken from APSC 253. Braden began construction of the rudders and connection system for the thrust fans and Peter worked on the placement of the thrust and lift fans, the weight distribution as well as the overall shape of the hovercraft. Splitting the construction up into separate tasks ensured everyone constantly had a job to do while maintaining up-to-date with our prospected progression.

2.3 Material Selection

In addition to the materials given to us for this project, we were assigned select materials for our hovercraft structure, rudders, skirt, and adhesive substances. The materials have been chosen with the objective to be as light as possible while taking the constraints into consideration such as not failing from the lift and thrust loads present.

Selecting a material for the hovercraft structure was an extremely important decision to be made in our design process. The material must be strong enough to support the weight of the components while being light enough to ensure lift is achieved. Our team decided that styrofoam is the best material for our structure as well as thrust fan supports. The main advantage found with using styrofoam is the ability to cut into it which we used to create the lift fan supports. This feature makes it so the lift fans are directly connected to the hull, creating a strong connection. The cost of styrofoam is extremely cheap costing only $3 for a 1ft x 5ft piece 1.5 inches thick. The brittle nature of styrofoam provides a study bulid to the hovercraft while being able to take a slam into a wall unmarked.

The material selected for the rudders must be strong enough to withstand the thrust force from the fans while being as light as possible. The balsa wood provided to use turned out to be the best material to use. When the balsa wood is cut into a long and thin strip it is very flexible but when it is cut into short pieces it becomes stronger. The two main factors why balsa wood was the best material is the free cost and its light qualities. The thin fibers in the wood make it so the weight relative to its volume is low. Since the rudders are supported on two poles, it is important that the material is light to minimize the moment created as much as possible.

A skirt must be composed of a material that is flexible so it can inflate and strong enough so it can withstand the lift and frictional forces while being light. For our skirt we used a piece of a garbage bag. Due to its flexible properties it can withstand high damage tolerance due to frictional forces without failing. The extremely low cost of a garbage bag was a main factor in choosing it as our material. Its smooth material properties provided low frictional forces to the hovercraft which increases power efficiency and speed.

Without picking a sufficient adhesive material the strength of the structure and rudders would not matter as the entire hovercraft would fail. The most efficient adhesive material was found to be hot glue. Its high yield strength ensured that all connections would be stable. Due to its fast dry time, quick progress was made in the construction of the hovercraft. If a mistake was made in a connection, the solidified glue could be reheated to fix the error. Hot glue is a good price when compared to other adhesive materials such as gorilla glue.

2.4 SolidWorks Modeling

Solidworks was an integral part of the design process for our hovercraft. We used the program consistently throughout the project to help us with part placement, frame analysis and mechanical solutions. We made and updated multiple models throughout the project to help us modify and improve our design. The program allowed us to analyze design solutions before committing time and resources to testing them in person. Our first SolidWorks model, pictured in figure 6 below, was made before we were given our components.

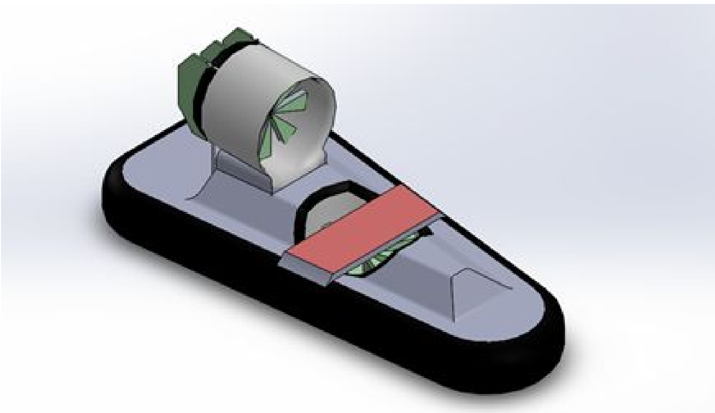


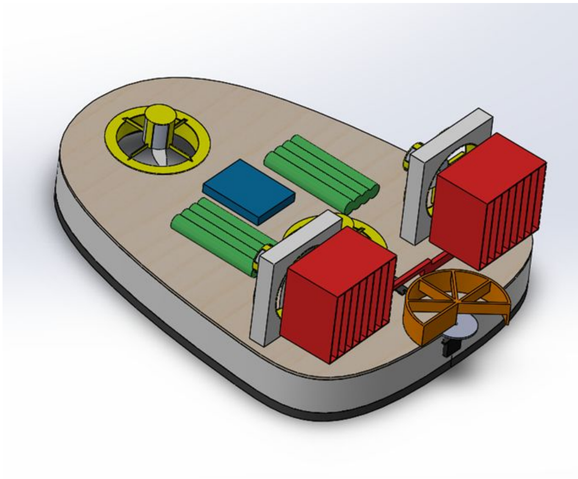
Figure 6: Conceptual Hovercraft Model

This model was purely conceptual, and was made before we were given our parts. It gave us a better idea of roughly what we wanted to do with our hovercraft. We wanted to keep our hovercraft as inexpensive and fast as possible.

After we were given our parts for the hovercraft, we brainstormed ideas to decide what we wanted our hovercraft frame to look like. We modeled all of the components that we knew needed to be placed on the hovercraft to scale, and began experimenting with frame composure, size, and part placement. After some experimenting we came up with the design pictured in figures 7 and 8 below.

Graphic Legend

- Rubber Skirt
- Styrofoam Body
- Wooden Frame
- Fans
- Arduino
- Batteries
- Rudder & Rudder Rotation Mechanism
- Servos
- Dropping Mechanism



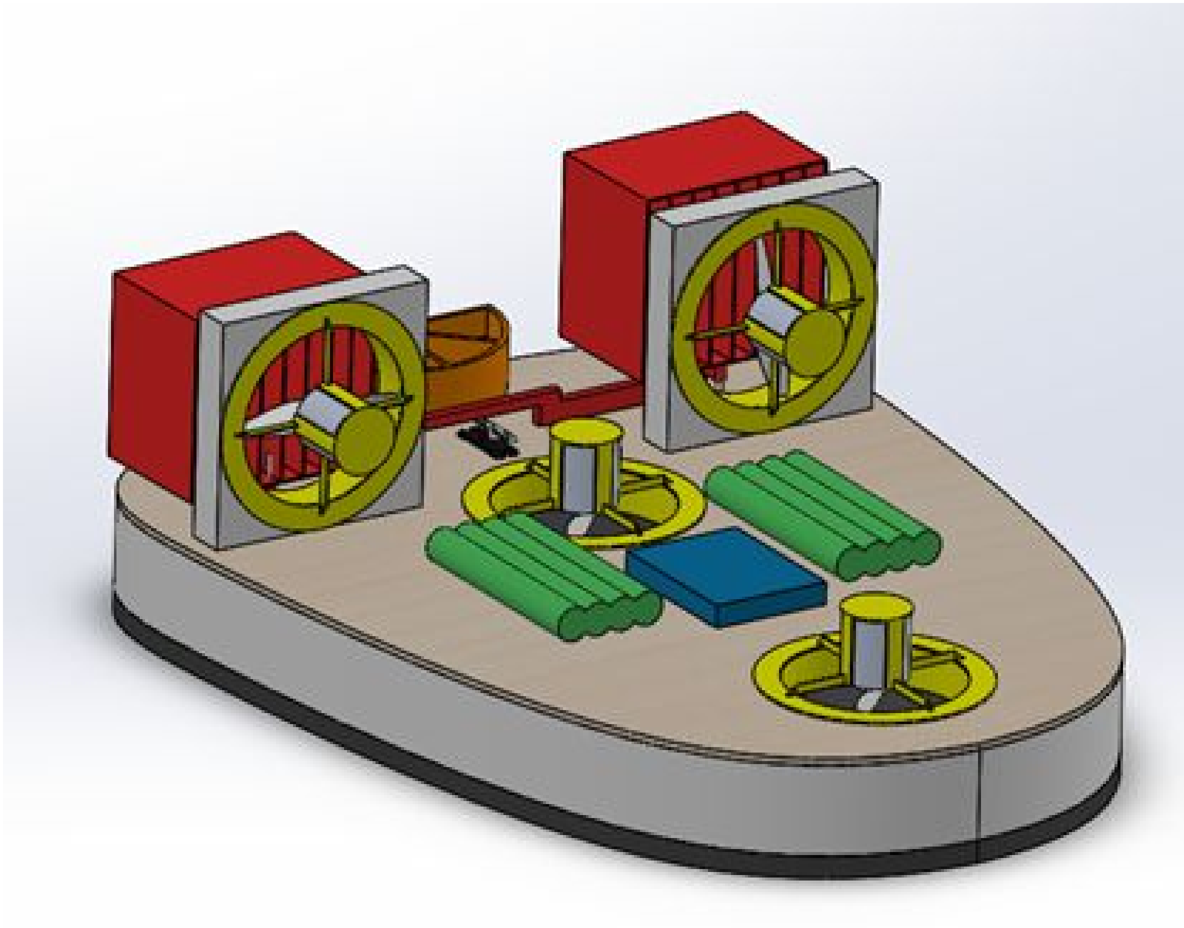


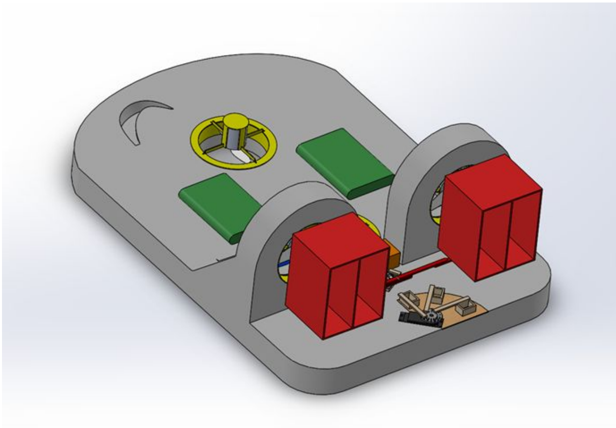
Figure 7 (top): Rear View of Prototype Design

Figure 8 (bottom): Front View of Prototype Design

This model is quite similar to our final design, and is what we used for reference throughout building. As you can see, this diagram is the introduction of our rudder system and our dropping mechanism. This prototype design gave us a really clear idea of what we wanted our part placement to look like. We knew that our final design would be similar in size to the model, and the parts fit very well on the model. Initially we designed our hovercraft to have a wooden top with wooden supports underneath, but after analysis we discovered that it would be lighter and stronger to use the high-density styrofoam that we purchased. Pictured in figures 9 and 10 below is a model of the final hovercraft design.

Graphic Legend

- Rubber Skirt
- Styrofoam Body
- Fans
- Arduino
- Batteries
- Rudder & Rudder Rotation Mechanism
- Servos
- Radio Receiver



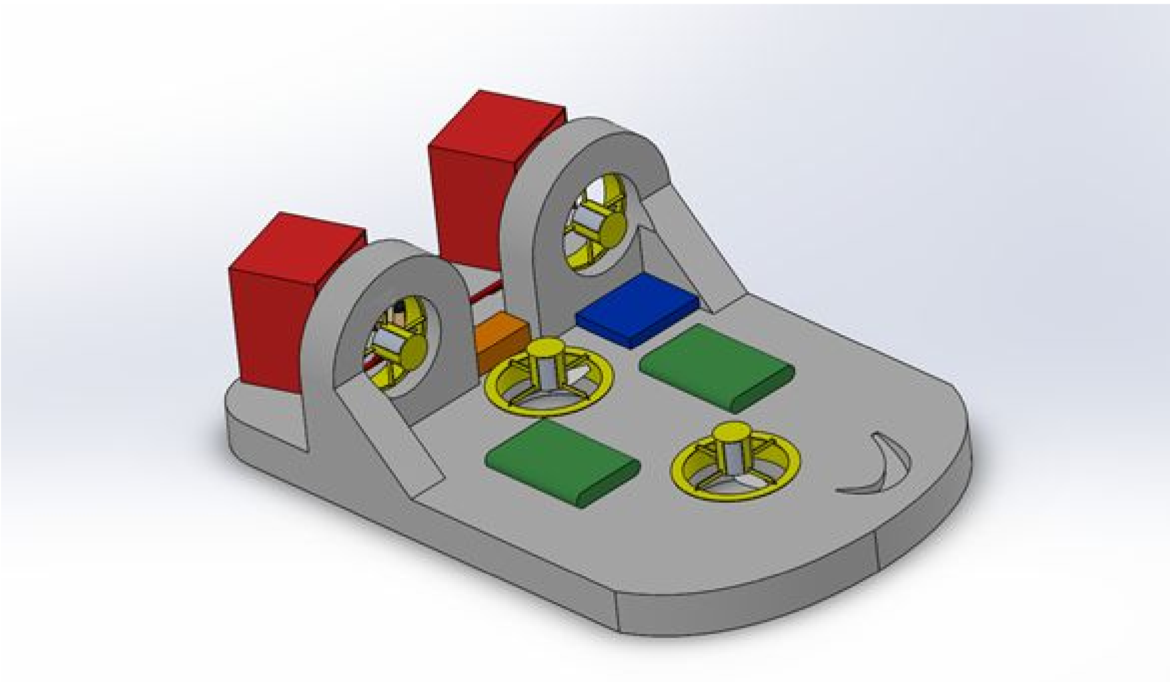


Figure 9 (top): Rear View of Final Design

Figure 10 (bottom): Front View of Final Design

Our final design if very similar to our prototype design. The main differences between the prototype and final design are as follows: The frame is now completely made out of styrofoam, we upgraded our dropping mechanism to be much more low profile, and we moved some parts around to allocate more space. Having the prototype design in front of us at all times while working on the final design was immensely helpful. It helped us orient our parts correctly, it is where we first tested our rudder system as well as our dropping mechanism. Using SolidWorks to test all of our design choices made our project building significantly faster and smarter. Without using SolidWorks throughout our design process, we would not have been able to incorporate all the components into our design that we wanted.

3.0 Physical Design

The physical design, broken up into its relative sections is described below.

3.1 Structural

3.1.1 Frame

The frame of our hovercraft has been designed entirely out of 3.75 cm thick high-density styrofoam. This material is exceptional for fulfilling many of our design requirements; in particular the material is inexpensive, lightweight and easy to use. Using styrofoam that is 3.75cm thick allowed our body to be structurally strong enough to support all of the components, but is still thin enough for the hovercraft to stay lightweight. Pictured below in figure 11 is a model of our hovercraft frame.

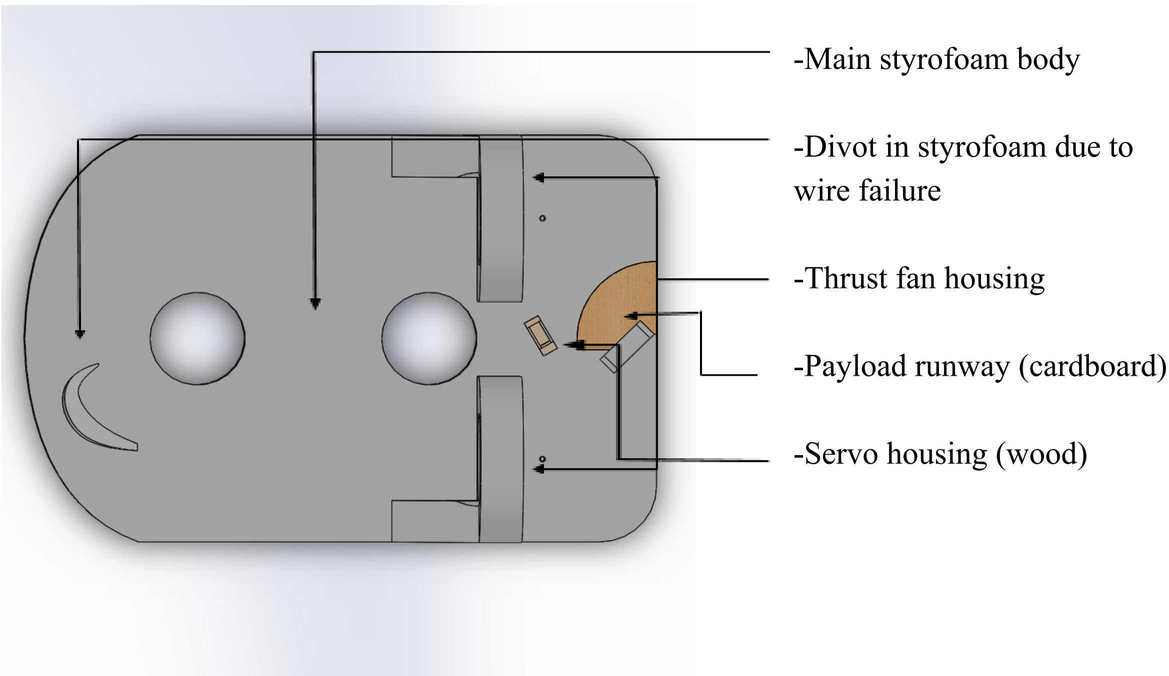


Figure 11: Schematic of the Hull of the Hovercraft

The base of our hovercraft is moulded from one piece of our high-density styrofoam. It measures 55x35x3.75 cm. The size of our hovercraft was determined after creating a layout for all of our components. We wanted to keep our hovercraft as small as possible to avoid unnecessary mass, but we prioritized fitting all of our components on the craft evenly and neatly. The dimensions of our hovercraft allowed for all of our components to be symmetrical, ensuring that each component has enough space to run properly. The edges and front of the hovercraft have been rounded in order for the hovercraft to be less susceptible to extreme damage (rounded edges allow for collision force to be distributed over an area), but also allows it to be capable of turning around incase it runs into a wall.

The second component of the frame is the fan housing. Our fan housing has been made out of styrofoam for the same reasons as stated above; inexpensive, easy to work with and lightweight. Since the fans produce an exceptional amount of force, the fan housing has to be sturdy enough to endure the forces and moments produced by them. To ensure that the fan housing wouldn't break, we have added triangular pieces of styrofoam on the outside edge of each fan housing for support. The triangle supports are hot-glued to the base of the hovercraft and the fan housing, providing additional support to counteract the force of air rushing through.

3.1.2 Part Allocation

It is important that our hovercraft's weight is centered along the base of the hovercraft in order for it to perform well. If the weight of the hovercraft is not centered, then it will lean to one side when the skirt is inflated, which will cause major problems with steering, as well as possible lift issues. Part allocation was a very big consideration while we were designing our frame, and we have designed our hovercraft with symmetry in mind. Pictured below in figure 12 is a general layout of the hovercraft parts.

Graphic Legend

- Rubber Skirt
- Styrofoam Body
- Fans
- Arduino
- Batteries
- Rudder & Rudder Rotation Mechanism
- Servos
- Radio Receiver

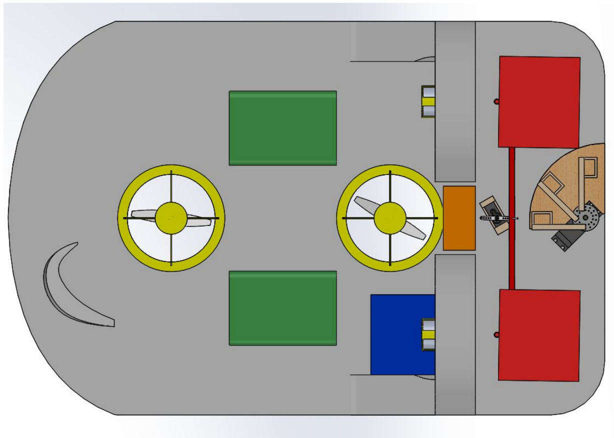


Figure 12: Hovercraft Part Allocation

Note. The space in between batteries on the diagram is occupied by our breadboard and wiring.

As you can see in the figure above, our hovercraft is almost perfectly centered along its lengthwise axis (horizontal axis on the diagram). The items that are uncentered, which consists of the arduino, dropping mechanism and crescent hole, are of negligible mass. Even though the mass is negligible, all of these un-centered items cancel eachother out.

Our hovercraft is almost perfectly centered along its lengthwise axis, but not along its widthwise axis (vertical axis on the diagram). As you can see pictured, many of the components are placed near the back of the craft. This has been done on purpose to counteract the additional weights that are added for out testing. Our frame was designed with space on the front, in order to allocate space for the weights that we need to add for our tests. Since our weights are all placed on the front, we made the center of mass of our hovercraft near the back, so that once the weights are placed the hovercraft is balanced.

3.1.3 Skirt

The purpose of our hovercraft skirt is to reduce the friction value between our craft and the ground, as well as allocating the displacement of air used to control the power and direction of lift. The skirt of our hovercraft is made of a large piece of low density polyethylene (garbage bag) that is wrapped around the bottom and edges of the base of the frame, with holes cut on the bottom to let out air. The skirt has been taped to the top of the base using duct tape to ensure an airtight seal. When the craft's lift fans are activated, the skirt inflates, allowing the hovercraft to be supported only by the low friction plastic. Pictured below in figure 13 is a view of the deflated skirt from below the hovercraft.

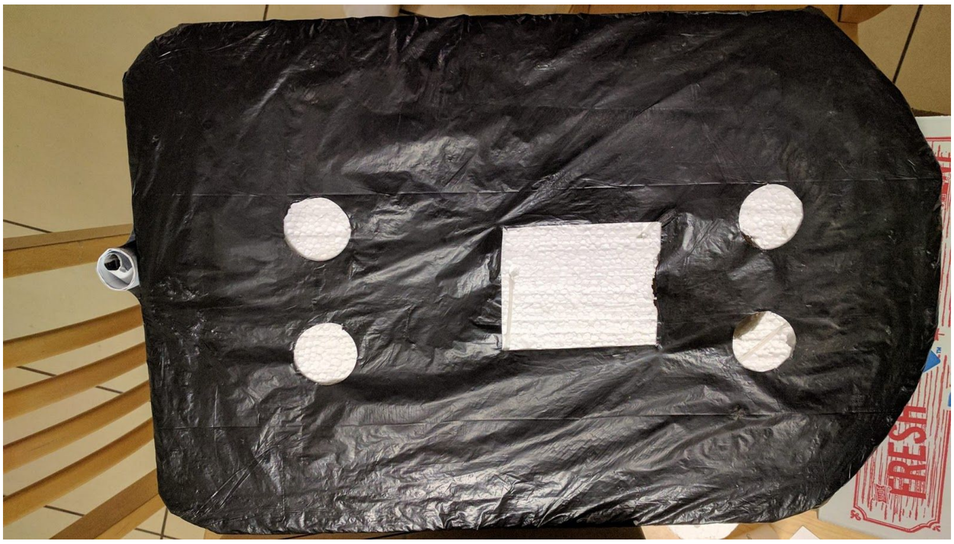


Figure 13: Final Hovercraft Skirt Design

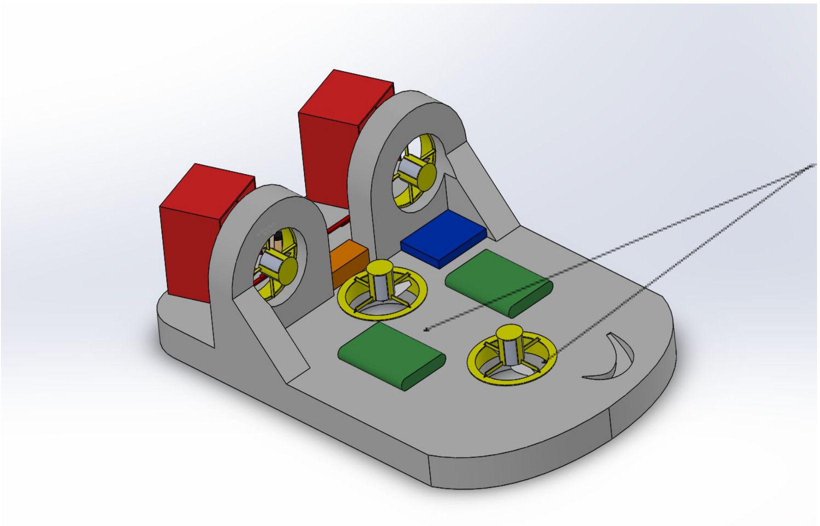
Our final skirt design was achieved on our third attempt at creating one. The first two skirts were made of the same material, but with different hole patterns. On both of the failed skirt designs, we tried making the holes smaller and more spread out. The main issue that we were having with our other skirts was a lack of lift; our air allocation was not good enough. Due to the nature of our base, when the skirt is inflated it has a semi-rounded shape. Our original skirts had holes that were situated on the curved parts, blowing air out the side. Blowing air out of the sides is a waste of air as it provides no lift. Due to the results we observed after our first two skirts, we realized that for maximum lift all of our holes needed to be placed on the flat bottom. We initially cut the four circles seen in the figure above, but after testing it was determined that we had too few holes and the skirt was overinflating, which could cause the duct tape seal to break. Due to this, we cut the large square in the middle. After calibration and testing, our skirt works incredibly well and allows for maximum lift power, which allows for a much faster hovercraft.

3.2 Mechanical

The mechanical engineering components on this report dealt with the majority of the moving parts. This consists of the fans, rudders and dropping mechanism. Without any of these functions, our hovercraft would not be able to travel. It is crucial that the mechanical aspects of this project are designed properly.

3.2.1 Lift and Thrust Fans

Hovercraft's need to have two sources of power to operate; lift, to actually hover the craft and allow it to travel, and thrust to propel it along the surface. Since we were give fans as a power source, we had to decide how many fans we wanted to allocate to each force. After performing analysis and measurements, we decided to allocate two fans to thrust and lift, as shown in figure 14.



Double Thrust Fans

Double Lift Fans

Figure 14: Fan positioning model

In order for a hovercraft to travel, it needs to apply enough lift force the thrust fans to move it. The more lift you can get, the easier it is for the hovercraft to move. If you supply too much lift though, the hovercraft will become too hard to steer and stop. It is important to find a balance; so the hovercraft can be light enough to move, but is also easily controllable. After weighing all of our components and calculating the force produced by the fans, we determined that if we made our frame light weight, we would only need to use two fans to produce sufficient lift force. Having our frame made out of styrofoam allowed us to allocate two fans to thrust force, which makes our hovercraft very fast. We prioritized velocity on our hovercraft because of our interpretation of the project description, " to increase the efficiency of local pesticide delivery to a crop." In order for pesticide delivery to be more efficient, the deliverer must travel quickly. We have also made sure that our hovercraft is very maneuverable, even at high speeds. This is possible due to our rudders, discussed in the next section.

3.2.2 Rudders

A crucial aspect of hovercraft travel is it's turning ability. Due to the frictionless nature of hovercrafts, the only way to change direction is by changing the direction of the airflow. This makes it much harder to control than tired vehicles. We initially considered two types of turning; static fans that had their steering controlled by rudders, or having both of our fans swiveling. In figure 15 below, you can see detailed models of our final rudder mechanism.

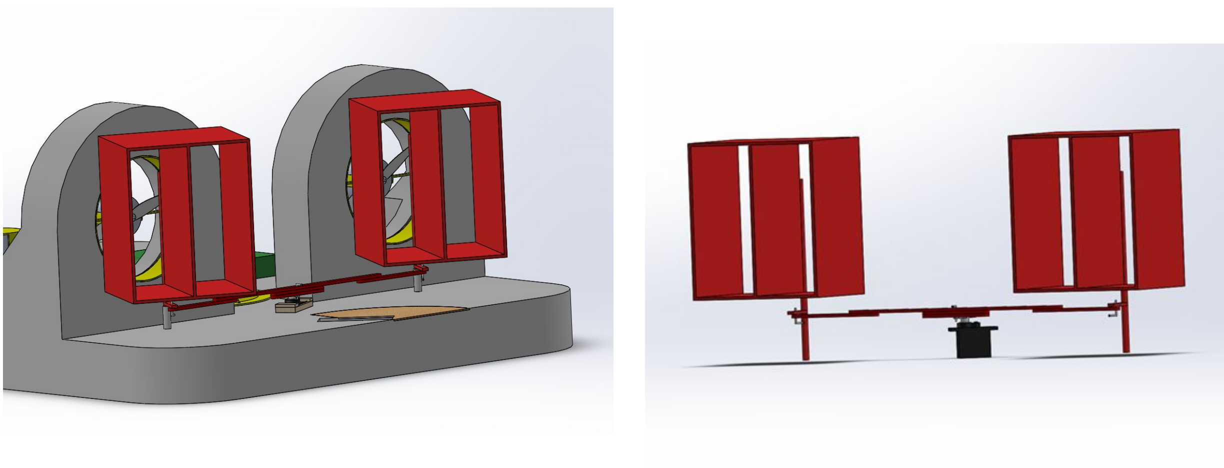


Figure 15: Fan Rudders.

After discussion, our group decided to go with a rudder mechanism instead of having the fan swivel itself. Having a swiveling fan can allow for 360 degrees of rotation, but to do that we would need to purchase additional expensive motors. We were also concerned about being able to support a swiveling fan, as styrofoam would be hard to shape in a way that could support a spinning fan while allowing adequate airflow. Instead, by using a rudder mechanism, we are able to keep the fans secure and always with maximum airflow. The rudder mechanism has been designed to use the servo that was provided in a way that gives us the smallest turning radius possible.
Figures 16-19 below show detailed depictions of the rudder and servo mechanism.

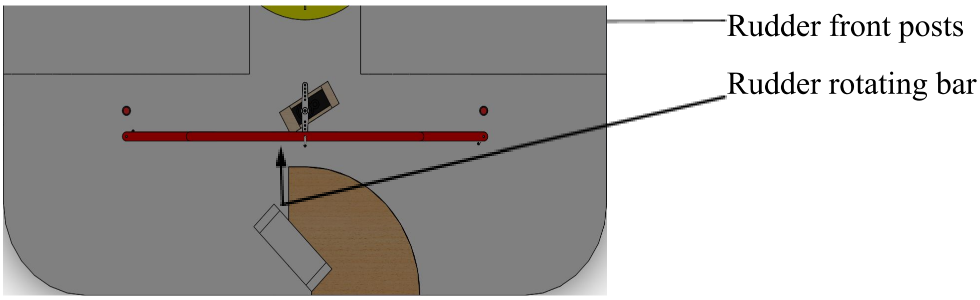


Figure 16: Rudder front posts and rudder rotating bar

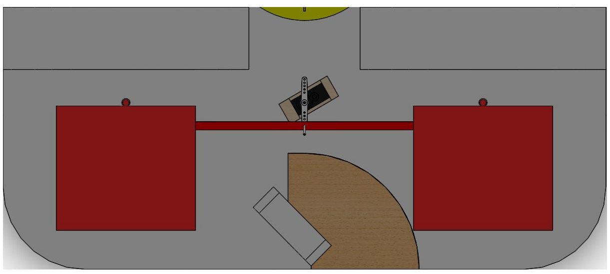


Figure 17: Rudder and rudder rotating bar.

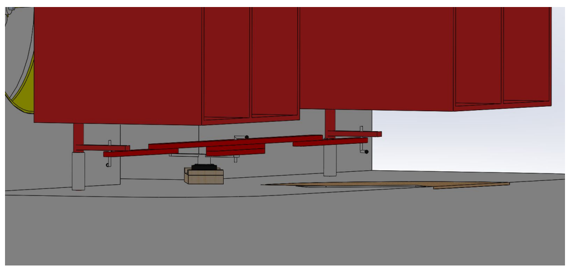


Figure 18: Side view

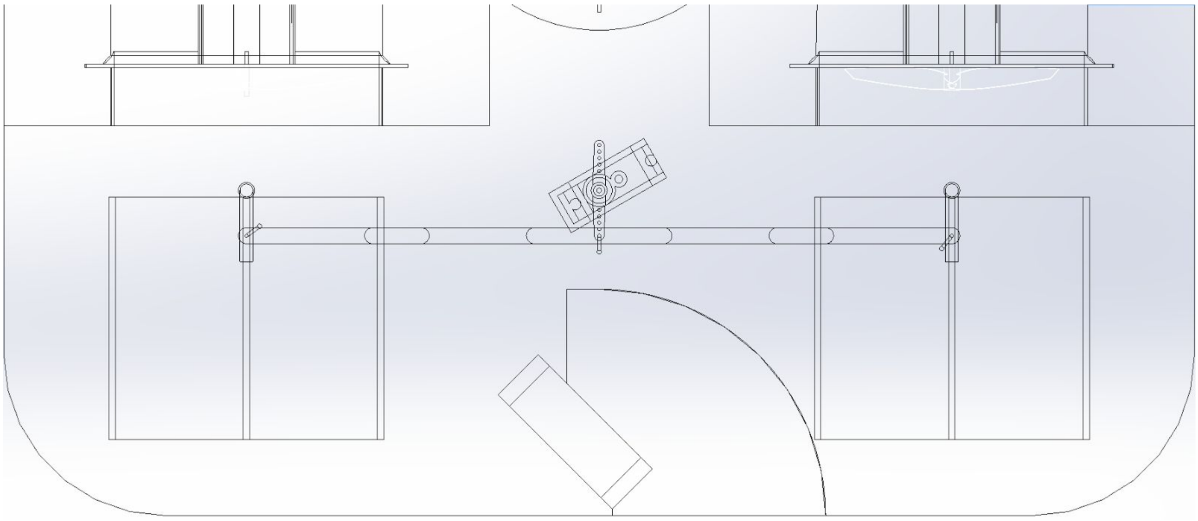


Figure 19: 3D view of whole rudder and rudder rotating mechanism

We designed our rudder rotation to have as large of a radius of rotation as possible. This was done by having a pole extruding from the bottom of the rudders sitting inside of cutouts parallel to the center of the cervo. Two of the rudders are connected together in parallel with the rudder rotating bar. The connection between the rudders and rudder rotation bar allows for the rudders to rotate at the same angle as the plastic top of the servo. The servo is controlled with a standard RC controller by using a receiver. The rudders can rotate until the rudders are almost touching the fan housing.

3.2.3 Dropping Mechanism

A necessary component of this project is the ability for our hovercraft to precisely drop multiple payloads. We looked at many different solutions for this difficult task. We wanted to make our dropping mechanism consistent, quick, and accurate. We had to take into consideration method of movement, location of dropping as well as limitations with the components we were given. After much discussion and analysis, we decided to go with the design shown below in figure 20.

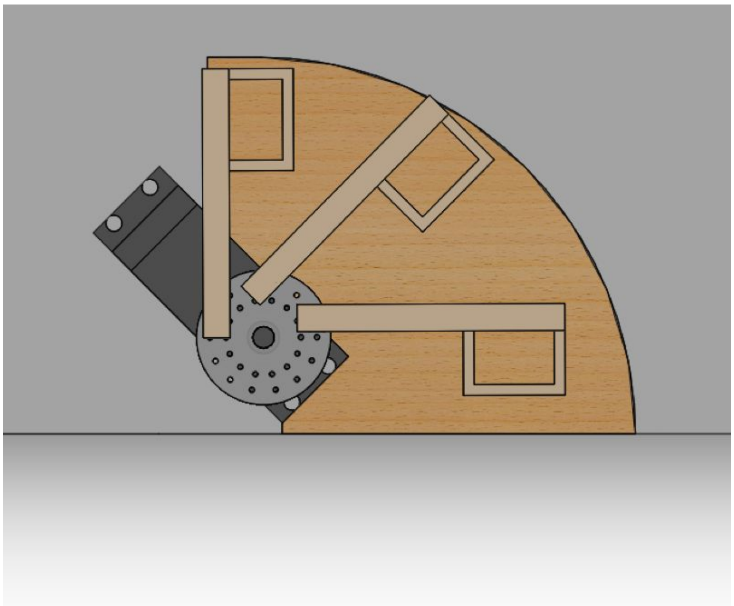


Figure 20: Model of dropping mechanism

In order to create a dropping mechanism up to our standards, we formulated our ideal design , which uses a servo motor for the rotation. We were only given one servo motor, which is responsible for our rudder mechanism, so we had to purchase a secondary servo motor which is pictured above. The dropping mechanism is situated on the back of the hovercraft; we made this design decision because dropping the components off of the back of the craft allows for us to keep going in a straight line. Also, since our rudders are situated on the rear of the craft, it's very similar to having rear wheel steering. This allows for very precise adjustments to make sure that the drop point is situated directly above where we want to drop. We also needed a way to control the dropping mechanism without touching the hovercraft. Since out remote control is responsible for rudder rotation and thrust speed, there is no space to control the dropping mechanism. Our solution was to buy a bluetooth arduino adapter, and to control it with a third party device. We then designed an application for android smartphones which allows the used to easily drop off payloads one at a time. This works great with our design and allows for quick and easy payload dropping. This application is discussed in further detail in the electrical section of the report.

After some testing, we found issues with the accuracy of our dropping mechanism. Since the dropping mechanism is on top of the hovercraft, once it is inflated there is a 4.5 cm drop distance for the parts to fall. While we were performing final testing of the hovercraft, we had issues dropping our components consistently enough. The payload would hit the ground and frequently bounce or roll as far as three inches away. Our design solution can be seen in figure 21.

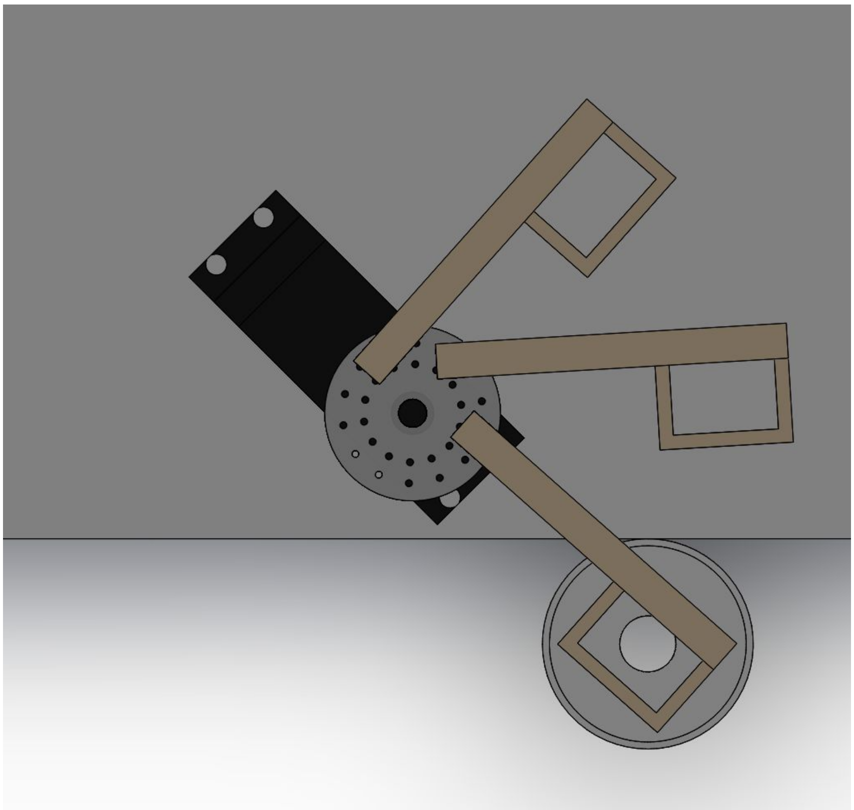


Figure 21: Dropping mechanism with cone attachment

We attached a paper cone to the back of the dropping mechanism right where the payloads are released. This payload consistently drops into the cone, which slides down and stops directly underneath it. We have had immense success with this design, as it minimized our radius of uncertainty from about three inches to almost zero. This is the final iteration of our dropping mechanism, and it has worked for us almost flawlessly, meeting all of our design requirements. It is consistent, very quick and easy to control, and extremely accurate.

3.3 Electrical

The electrical design encompasses several important RC features for the hovercraft to operate successfully. These features include the lift fans, thrust fans, steering system, and dropping mechanism. Each feature will be individually described with respect to the electrical design below. In addition, our selected and alternative electrical design solutions will be discussed and illustrated in detail.

3.3.1 Fan and Rudder Wiring

Our propulsion, lift, and steering system are powered separately by two rechargeable 9.6V battery packs with a current delivery of 2.2Ah. The two lift fans on the bottom of the hovercraft have their own dedicated 9.6V battery to power them. They were initially connected in parallel as shown in our preliminary design in figure 22, however this caused issues with the motors shutting off intermittently due to the divided current. As a solution, we connected the fans in series, which supplied a steady and equal current to each fan, therefore eliminating the issue. The lift fans used no form of speed controller or variable resistor to limit the power supply, as we determined in our lift calculations that constant maximum power would be the best option - only a circuit switch was used to turn the lift fans on or off.

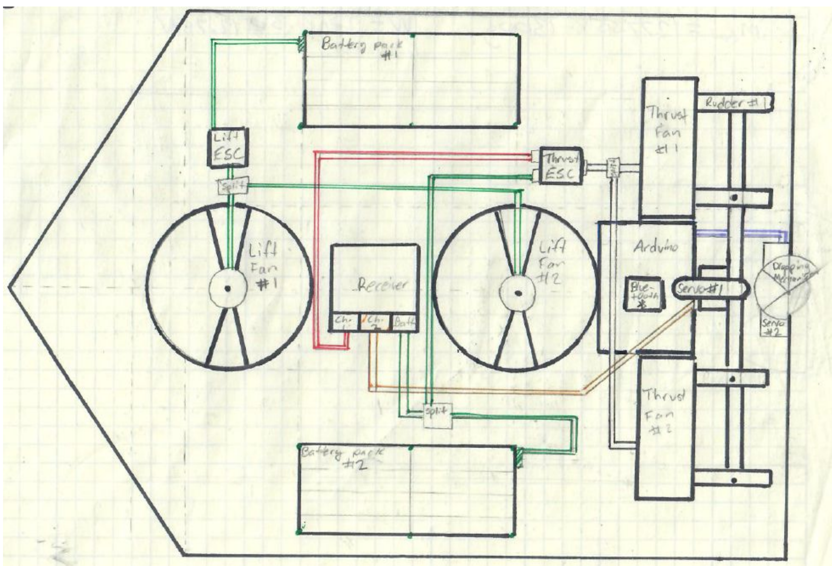


Figure 22: Preliminary design drawing of the propulsion and steering system

For the thrust fans and rudder system, an electronic speed controller (ESC) was used in controlling the power supply to the motors. The speed controller contains three ports: power supply, receiver, and motor. The battery pack is connected to the power supply port of the ESC, which then runs into the receiver and motor separately. The thrust fans are connected in parallel and are wired to the motor port of the ESC. The receiver is then connected to the receiver port of the ESC and is the device that receives signals from the RC controller for the manipulation of the thrust fan power and servo rotation. The rudder control motor (the servo) is connected solely to the receiver, and is powered by the receiver itself - which gets its power via the battery port on the ESC. The final layout of the fans and rudder circuitry can be seen in the schematic diagram in figure 23.

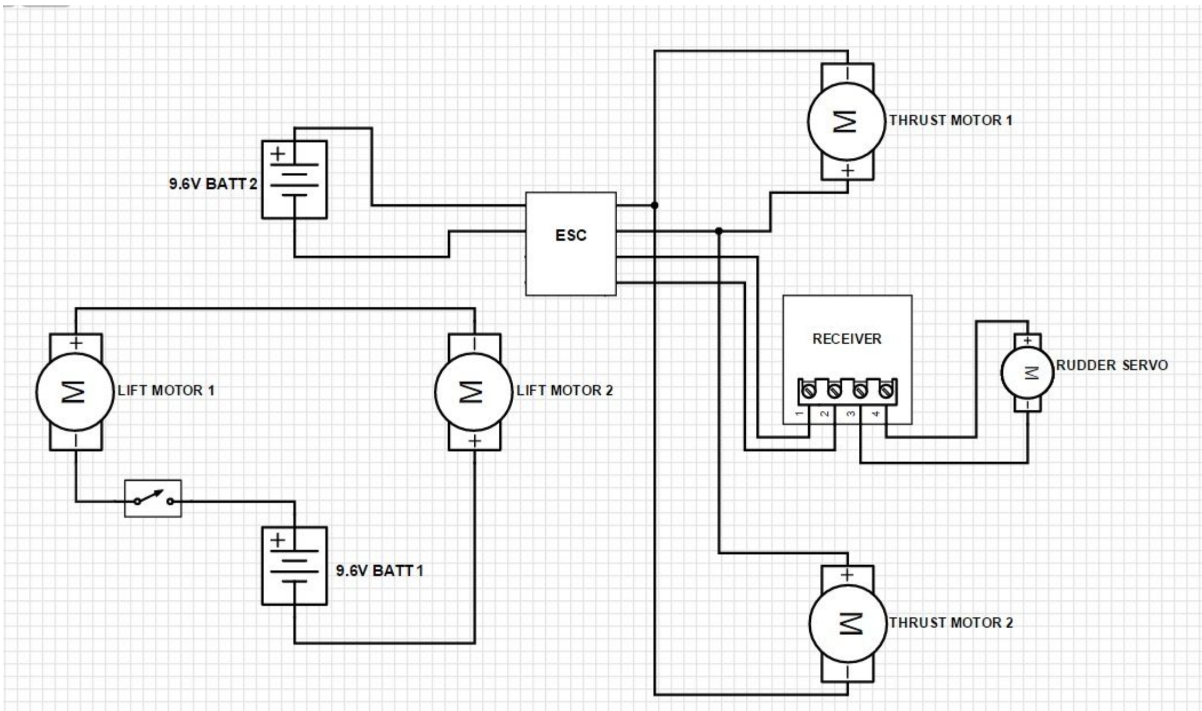


Figure 23: Schematic diagram of the final fan and rudder electrical design solution

3.3.2 Bluetooth and Arduino

For the dropping mechanism, we decided to use an extra servo that controls rotation from 0 to 180 degrees. We created an android application using free MIT App Inventor software followed by a Youtube tutorial which taught us how to create it (Mert Arduino and Tech, 2016). Then, we install the application to an android phone. This application can command the servo to rotate 45, 90, or 135 degrees by simply tapping labelled buttons or sliding a tab from the left to the right across the screen as seen in figure 24. We limited the maximum rotation in the app to 135 degrees because it was the furthest our dropping mechanism could rotate without colliding into the servo itself. With an HC-05 bluetooth module connecting to the Arduino, the servo was able to receive the commands from the smartphone. The Arduino uses the input code shown in figure 25. It is adapted from a Youtube tutorial as well. The code firstly defines the variables for bluetooth signals, which connects the bluetooth with default Rx and Tx on the arduino board. Below in figure 24, the app we created using MIT App Inventor is shown as a screenshot from a smartphone.

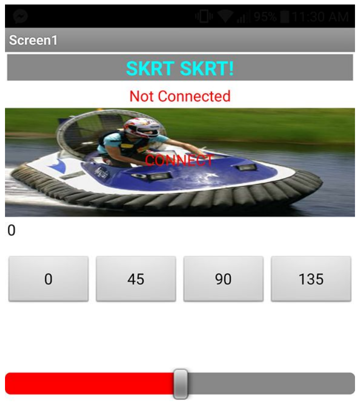


Figure 24: Smartphone app for dropping mechanism control

The set up section, the Software Serial allows change any arduino board pin to serial pin. It also uses 'if' statement to allows the program to compile. If the bluetooth is on, the bluetooth starts to receive the position of the servo and then send command signals to the position of the servo. The servo rotates an angle as the requested angle from the bluetooth that is controlled by the application on an android phone. See figure 25 below for the Arduino code for the bluetooth servo mechanism.

```
#include <SoftwareSerial.h>
#include <Servo.h>
Servo myservo;

int bluetoothTx=10;//bluetooth tx to 10 pin
int bluetoothRx=11;//bluetooth rx to 11 pin

SoftwareSerial bluetooth(bluetoothTx,bluetoothRx);


void setup() {
  myservo.attach(9); // attach servo to pin 9

  Serial.begin(9600);
  bluetooth.begin(9600);

}

void loop() {
  if(bluetooth.available()>0)
  {
    int servopos=bluetooth.read();//save the received number to servopos
    Serial.println(servopos);//serial print servopos current number received from bluetooth
    myservo.write(servopos);//rotate the servo the angle received from the android app
  }

}
```

Figure 25: Arduino Code for Bluetooth Servo. Adapted from Mert Arduino and Tech (2016).

The variables for bluetooth is set to pin 10 and 11 on the arduino so we connect them. The servo is connected to pin 9 so it is same as the code. The servo and bluetooth both are connected to the ground on the arduino. The VCC pin of the bluetooth connects to 3.3 voltage on the board. The servo connects to the 5 voltage on the board. See figure 26 below for the wiring and connection with the bluetooth and the Arduino.

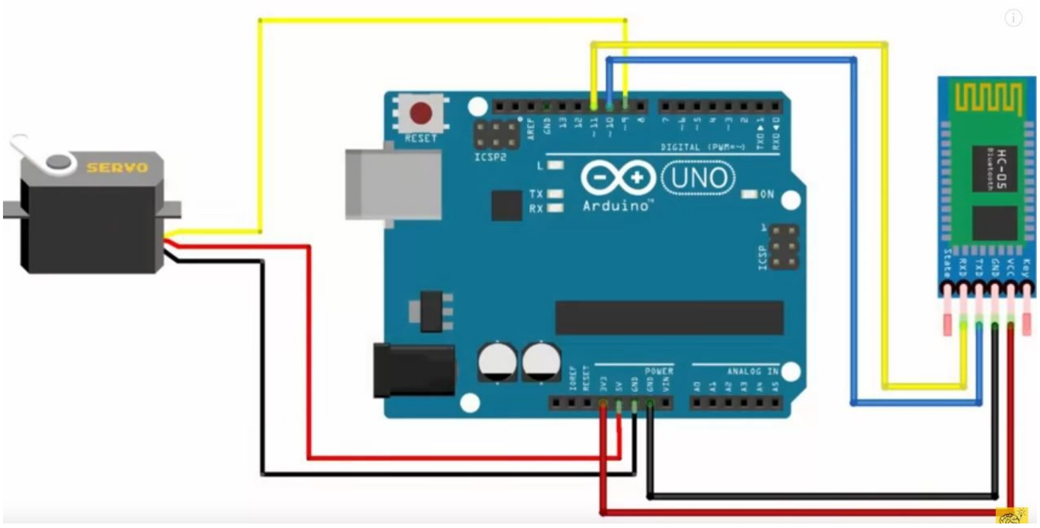


Figure 26: Wire Connection for Bluetooth Servo (Mert Arduino and Tech, 2016).

4.0 Analysis

The selected models and weight distribution analysis will be described in detail in the sections below.

4.1 Selected Models

Through the span of this project our team has come up with three different types of complete designs. Our first design was made before materials have been available and was modified to account for cost. Built to be cheap many extra parts were removed leaving only the use of two fans, one for the lift and one for the thrust. This however did not work out as we calculated the loss of extra materials makes the ability to move slowed down to the point where this design was not efficient at all. Second we moved onto a design that is much closer to how our final design looks (see figure 27). This design has a much wider base and uses two lift fans and two thrust fans. Using rudders to control the directional movement and having a servo operate as a dropping mechanism this design had much more potential. The wood frame was light and had lots of space for components as well as extra weight. Continuing from this design we finally move to our final product, which is strongly based on its predecessor. With similar fan placement and rudder system only a few parts were changed, such as the base material, dropping mechanism and shape of the rudder. The base material was converted into styrofoam as it upholds the lightweight body and is easier to mold and shape. The dropping mechanism changed into a more accurate and simpler to use design that will help the pesticide drops be placed in specific sections if needed.

4.2 Weight distribution

For a hovercraft to successfully hover in a horizontal plane the weight off all the components must be properly distributed. To accomplish this goal our group organised a system of steps. The first step made was to mark a grid on the structure to indicate the mass distribution of the hull (see figure 27). The grid lines are marked with accompanied length in inches.

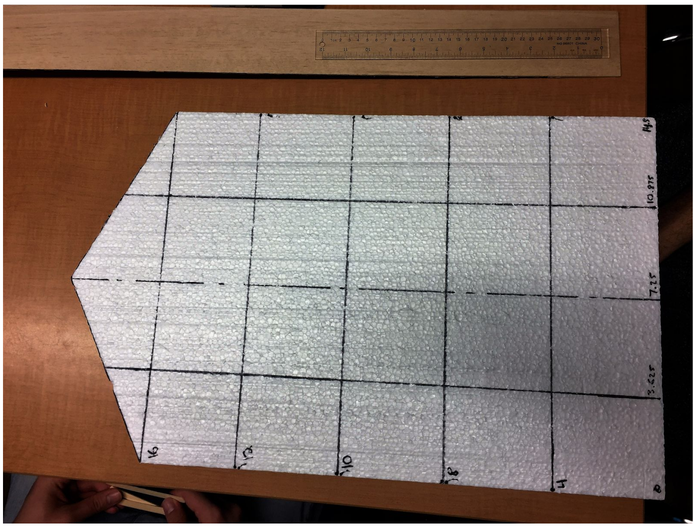


Figure 27: Preliminary hull design

Using the grid lines the lift fans were strategically placed in the centerline of the hull, leaving enough space for the rutter and dropping systems. We decided to place the lift fans in the hull before allocating the positions of the other components since they can be moved around to balance the weight. The placement of the thrust fan supports and rudder system was determine by making sure both sides of the centerline of the hull is symmetrical. As long as the components are symmetrical with respect to the center line, the moments due to the weight will cancel each other out along the width of the hull. Once the electrical components and the skirt was attached, we started to test the lift fans to see how the distribution was along the length of the craft. Initially it was found that the hovercraft was back heavy due to the rudder system and thrust fan supports being near the rear. To counteract this moment, we placed the two batteries closer to the nose of the hull and added 6 washers weighing 200 grams in total directly on the front. With this placement of the components the hovercraft was at equilibrium along its length and width resulting in no movement when idling.

5.0 Engineering tools used

Described below is some of the calculations used in our analysis stage and the applicable of them to the project.

5.1 Lift Analysis

In the lab 2, while conducting a hull experiment we recorded results from the pressure map to identify the required power needed to generate enough lift off the ground from the fans (Crawford, 2017). The objective of this laboratory is to utilize our collected data to analyze the mathematical relationships between the fan's generated thrust, and its electrical inputs. It is our goal to use these experimental calculations to create an optimal hovercraft design with respect to the propulsion system. To estimate the supporting weight including the weight of hovercraft we must calculate using the following equation that generates upward reaction force due to the fans. $W = (P)(A)$, where W is the force that the mass of the hovercraft creates due to the acceleration of gravity, P is the pressure developed underneath the hull by the displaced air, and A is the area projection of the hull that the pressure is acting on. We found the estimated maximum lift was calculated to be 2.75N per propeller. We used this data to determine whether we will be using 2 fans in the initial brainstorming stage. This was considered to try and achieve the inexpensive design which is one of our main objectives. Another finding is that the lift force is more intense when the hull is closer to the ground as the projected air has less distance to propagate. Without the presence of a skirt on the hull, the lift will be easily changed with increased clearance as the skirt helps keep the air under the hovercraft. Therefore, the we used skirt to lift reduce the friction between the base of the hovercraft and ground in our final design.

5.2 Thrust Analysis

In the first and second labs, we conducted experiments on the performance of the lift and thrust fans. We collected data for airspeed, thrust, angular propeller speed, voltage required, and current to calculate the thrust coefficient, volumetric coefficient, advanced coefficient for various air speed values, and the power efficiency for the fans (Crawford, 2017). We plotted graphs to determine the relationships in the data which helped us in estimating the maximum velocity of the hovercraft. However, the graphs were incorrect and did not have a peak point where the power and thrust have a maximum efficiency. The reasons could be the unsystematic errors such as human error, physical structure, and/or poor environmental condition. Our team decided to consider other team's finding for the max efficiency. The max thrust produced by one propeller is 1.1N. Based on this value, our team decided to use 2 fans for the thrust to increase the speed.

5.3 Analysis of Arduino system with Circuits

In the third experiment, we learned to use the arduino system and gained knowledge of connection, power input and outputs and any other electrical components. This lab introduced us to a solution to control the input power by using potentiometer and to control a servo by using the arduino system. The required language for arduino system is C language which is similar to the C++ language which we learned in the previous year level. In total, our team wanted to control three mechanisms with the servo motors: lift, thrust and dropping so we tried to write the code based on the knowledge gained in this laboratory. After we gained enough knowledge about the arduino code, we used bluetooth with arduino system for the purpose of convenience.

6.0 Conclusion

The hovercraft design project was an engineering challenge assigned to us by Professor Crawford as a major objective for our APSC 258 course. The primary focus of the project was to create a remote-controlled hovercraft that could hypothetically act as a tool for farmers to use in delivering pesticides to specified locations, and complete the course designed by the professor. After completing the project, we have successfully produced the preliminary report for the initial planning, conducted three experiments that gave us necessary performance data, designed a functional hovercraft that exceeded expectations, and created the final report that describes our whole process thoroughly. As a team, we exercised and further developed our engineering problem solving and collaborative working skills in a challenging but successful project.

A significant challenge in creating our hovercraft was figuring out exactly what materials we needed, and how we could use them. The school provided us with most of the basic components of the hovercraft, however much of our design used purchased items. We often times had to evaluate the current state of the hovercraft and see what materials or devices were needed to be purchased in order to move forward or make improvements. This sometimes led us to burn up some of our budget on things we did not necessarily need. Nonetheless, our team succeeded financially and used almost exactly the $100 limit of the allocated budget.

Below is a list of main components used in our final hovercraft design:

- Styrofoam base and fan housing
- Two wooden rudders
- Trash bag skirt
- Four brushless DC motor fans
- Two High-speed servo motors
- Arduino Uno microcontroller
- HC-05 Bluetooth module
- Mini Self-adhering breadboard
- Two 9.6V battery packs
- Receiver
- Speed controller
- Electrical wiring

Using these materials, we were able to build a hovercraft that met all of our desired functional goals: high speed, precise maneuverability, and accurate delivery. Under our strict budget and scoring set out by the instructor, we decided that these three objectives took precedence over all others. We had to sacrifice weight carriage for speed and maneuverability, because of our 2-lift/2-thrust fan design. Although weight was a factor that we decided to pay less attention to, we were still able to carry much more than our anticipated amount, especially considering the fact that we only had two lift fans.

The following list describes the parameters on which the hovercraft's performance is evaluated on:

- Extra weight carried on top of the hovercraft while completing the testing course
- Time to complete the testing course
- Accuracy of the payload delivery

After testing our hovercraft's performance, we can conclude that these achievements have been reached:

- Be able to carry more than 1kg extra mass in addition to the hovercraft
- Reach a max speed of approximately 0.7 m/s without extra weight, and a max speed of approximately 0.5 m/s with 0.5kg added weight
- Be able to turn on axis in both directions with minimal horizontal movement
- Complete 3 payload deliveries over the course of 20m in under 60s
- Consistently drop payloads with accuracy of 0-1 inch from the desired target

We translated the customers requirements into engineering requirements, and developed the design based on the ideation process. We took advantage of the group working tools and engineering tools so that the design process is clear and organized. The final design meets most of the requirements we set in the ideation process. The subsystems functioned well in our testing phase, and the budget was controlled in a reasonable range.

To broadly summarize our project, we define it as a functionally successful end-product that performed at a higher standard than we had expected. Our design was fairly complex yet simplistic enough to perform all of the basic functions very well. As a group, we are very satisfied with the outcome of our hard work and we hope to compete in the final competition held on Tuesday April 4, 2017. Our final hovercraft prototype can be seen in the figure 28 below.

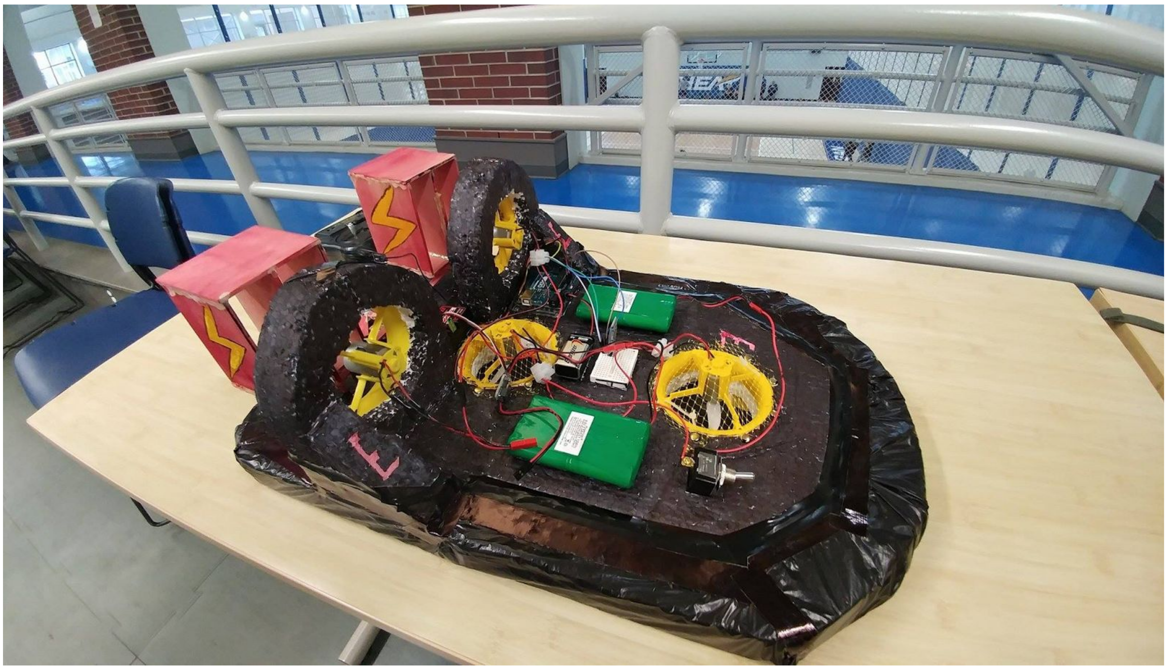


Figure 28: Final hovercraft product

7.0 References (APA)

Crawford, B., B.C. (2017, January 31). *APSC 258 Applications of Engineering Design Project Planning – Gantt and CPM*. Lecture presented at APSC 258 Lecture in University of British Columbia Okanagan, Kelowna.

Weyand, S., S.W. (2017, January 10). *APSC 258: Ideation*. Lecture presented at APSC 258 Guest-Speaker in University of British Columbia Okanagan, Kelowna.

Kkmalu (March 15, 2016). *FT HOVERCRAFT W/ FULL PLANS!.* Retrieved from https://www.flitetest.com/articles/peter-s-hovercraft-with-plans

Mert Arduino and Tech. (2016, Oct 21). *Arduino Tutorial 12 - Servo Motor Control via Bluetooth (with Smartphone)*. [Video File]. Retrieved from https://www.youtube.com/watch?v=gL7b8E_5aYs

Woodford, Chris. (2000/2016) *Hovercraft.* Retrieved from http://www.explainthatstuff.com/hovercraft.html.

Appendix A - Design Drawings

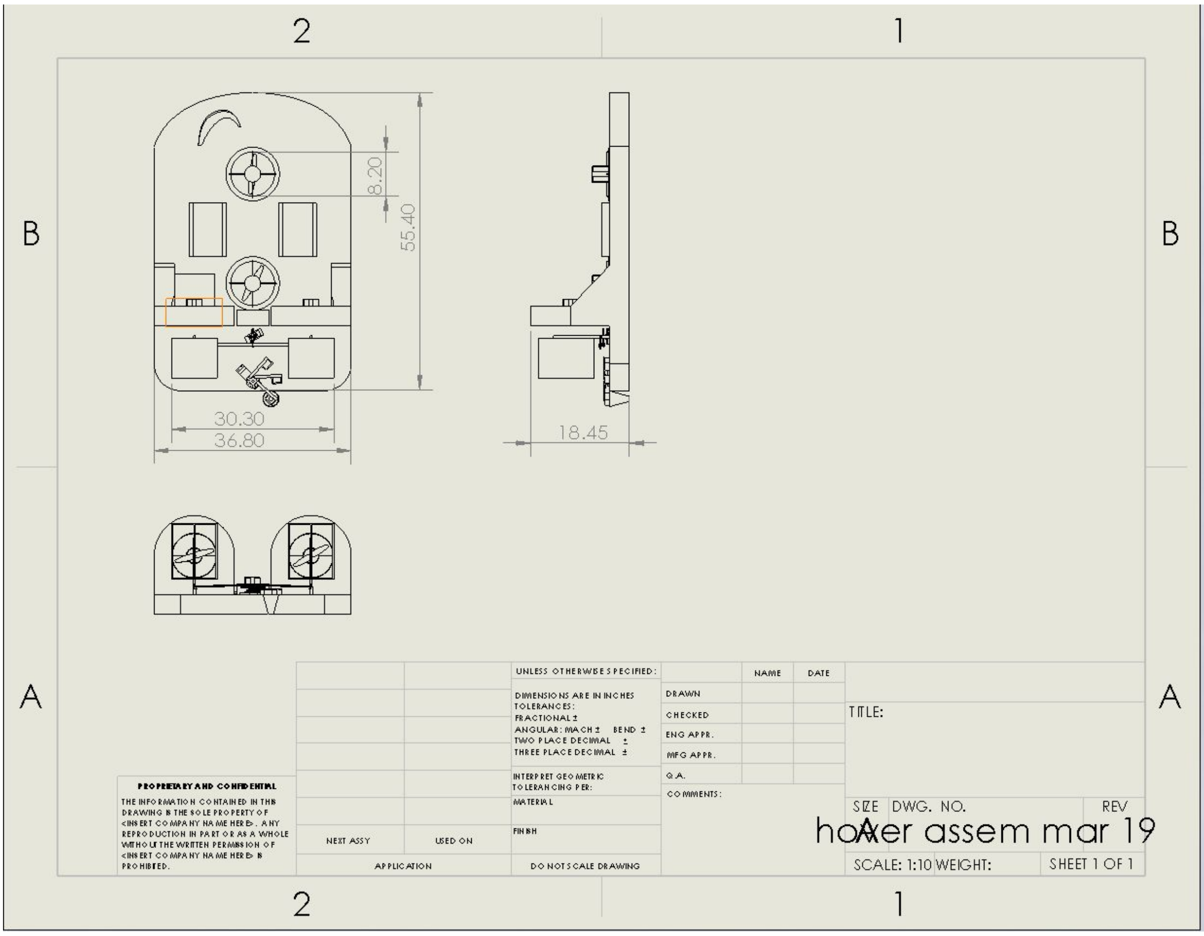


Figure 29: Hovercraft final design drawing

Note. Units in centimeters(cm)

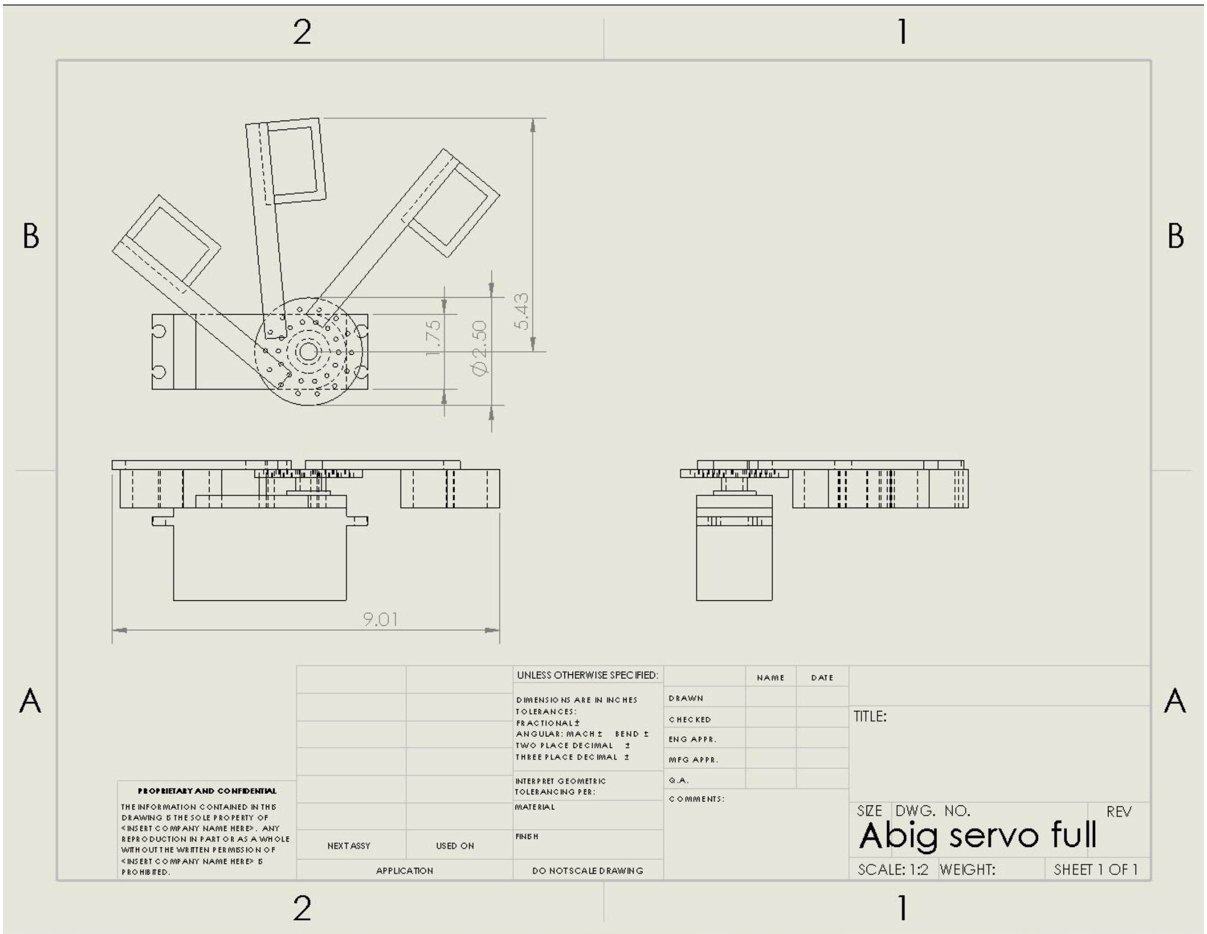


Figure 30: Dropping Mechanism Design Drawing

Note. Units in centimeters (cm)

Appendix B - Design Calculations

Sample Calculations

Clearance = 0mm

$\text{Lift}(W) = PA \Rightarrow A = \frac{\pi}{4}\left(10cm \times \frac{1m}{100cm}\right)^2 = 0.00785m^2$

For position = 1cm → $\text{lift} = 0.01kPa \times \frac{1000Pa}{1kPa} \times 0.00785m^2 = \boxed{0.08N}$

Energy consumed → $P = VI = (8.20V)(2.71A) = 22.222W \times \frac{0.11kWh}{1W} = \boxed{2.44kWh}$

Same calculations for all positions and when clearance = 2mm, 4mm

Estimated Maximum Lift

Clearance = 0mm, Position = 5cm, Pressure $\simeq 0.35kPa = 350Pa$

↳ $\simeq$ Max lift $= 350Pa \times 0.00785m^2 = \boxed{2.75N}$

Estimated Maximum Thrust

From lab# 1, when Propeller angular speed = max and air speed = median, propeller thrust = 1N, max attainable under lab conditions.

Figure 31: Design Calculation

Appendix C - Material Billing

Table 1: Material Billing

Item	Cost ($)
Hot Glue Gun + Glue sticks	$16.00
Styrofoam	$16.00
Popsicle sticks	$1.00
Sand Paper	$6.00
Wiring	$3.50
Bread Board	$6.49
Straws	$1.00

Servo	$13.99
Bluetooth Receiver	$13.99
Zip straps	$2.00
Velcro	$10.00
Total	$90

Appendix D - Meeting Minutes

Table 2: Meeting Minutes

Names	Accomplishments	Date	Time
Peter Braden Alexander Damien Yuan Evan	Delegated tasks for preliminary report, began work on preliminary report	02/16/2017	2 hours
Peter Braden Alexander Damien Yuan Evan	Began brainstorming basic hovercraft design/layout and possible designs for dropping mechanism	02/23/2017	2 hours
Peter Braden Alexander Damien Yuan Evan	Split up the group into specific sections for construction, assessed materials to be used	03/02/2017	2 hours
Peter Braden Alexander Damien Yuan Evan	Extra parts purchasing and selection	03/04/2017	3 hours
Peter Braden	Split lab report 1 into sections, began work	03/05/2017	5 hours

Alexander Damien Yuan Evan			
Peter Braden Alexander Damien Yuan Evan	Team meeting, beginning of construction phase, preparation of coding and wiring, preliminary fan housing design and placement of fans.	03/11/2017	8 hours
Name	**Accomplishments**	**Date**	**Time**
Peter Braden Alexander Damien Yuan Evan	Application of thrust fan and rudder placement, finalization of weight distribution, dropping mechanism placement	03/12/2017	8 hours
Peter Braden Alexander Damien Yuan Evan	Delegating tasks for lab reports 2 and 3, began work on reports	03/13/2017	6 hours
Peter Braden Alexander Damien Yuan Evan	Finalizing of hovercraft design, trial and error stage for skirt design, lift fan power testing and rudder testing	03/18/2017	8 hours
Damien Evan	Hovercraft testing, dropping mechanism Bluetooth testing, final adjustments and repairs	03/22/2017	3 hours
Peter Braden Alexander	Final report preparation,	03/25/2017	4 hours

Damien Yuan Evan	delegation of tasks and prefatory research		
Peter Braden Alexander Damien Yuan Evan	Final report work, formatting, etc.	03/26/2017-03/31/2017	20+ hours combined
Peter Braden Alexander Damien Yuan Evan	Hovercraft testing with makeshift course, final small adjustments made to dropping mechanism	03/28/2017	3 hours
Peter Braden Alexander Damien Yuan Evan	Hovercraft course test in lab section	03/30/2017	2 hours