Summer 8-17-2017

JME 4110 Seed Aerodynamics

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Joint Engineering Program

University of Missouri–St. Louis ▪ Washington University in St. Louis

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This is a report discussing the analysis and results of a wind tunnel that was created to find the terminal velocity of a variety of seeds.

JME 4110
Mechanical Engineering Design Project

Seed Aerodynamics

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Vladimir Sidorov

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1 INTRODUCTION

1.1 VALUE PROPOSITION / PROJECT SUGGESTION

Seed drop terminal velocity tester. Some seeds significantly interact with the air as they drop from a plant. To get some basic data, design a device that tests the terminal downward velocity.

1.2 LIST OF TEAM MEMBERS

1. Kristin Gonzalez
2. Vladimir Sidorov

2 BACKGROUND INFORMATION STUDY

2.1 DESGIN BRIEF

Through our research we found that the moisture of the seed significantly changes the terminal velocity of a seed. Design a system that records the terminal velocity of a seed falling from a plant.

2.2 BACKGROUND SUMMARY

There were two solutions we found to be very similar to the problem at hand. One report was published by the British Ecological Society. In this report they described the creation of “a new apparatus to measure the rate of fall of seeds” (Askew, A.P., et al. A New Apparatus to Measure the Rate of Fall of Seeds. 1997, pp. 121–125, A New Apparatus to Measure the Rate of Fall of Seeds.). The process of using this apparatus is extremely similar to our idea. Here the seed is dropped into an enclosed box where there are two horizontal and parallel, fan shaped laser beams to catch the seed at 2 different points to then get the speed in which it is falling. The next publication that was found to be similar to our chosen topic was an article from Maxwell Scientific Publication Corporation. In the study that was conducted for this article, they analyzed the physical and aerodynamic properties including the terminal velocities of different seeds. The authors of this article did so by creating an apparatus using a blower, valve, plenum chamber, air flow straight, and an air velocity measurement unit. (S. Gürsoy and E. Güzel, 2010. Determination of Physical Properties of Some Agricultural Grains. Research Journal of Applied Sciences, Engineering and Technology, 2(5): Page No: 492-498.) An example of each of these published apparatus’ can be found on the following page.

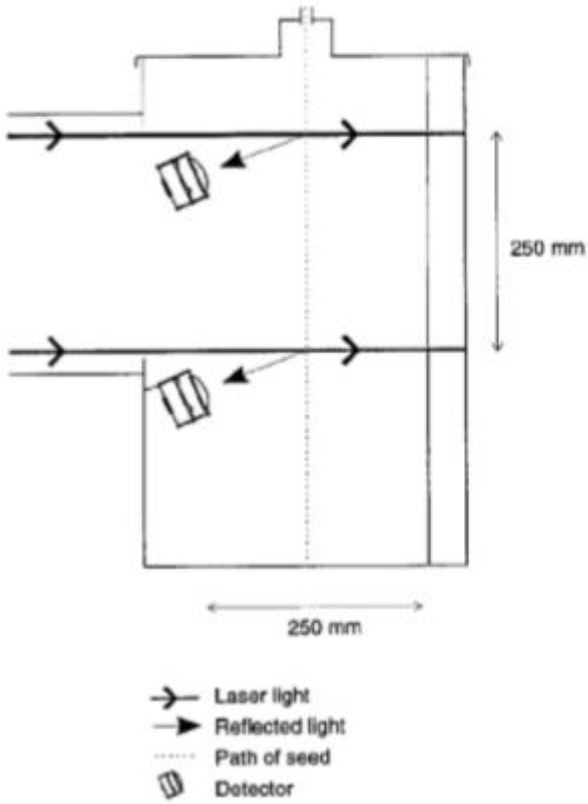


Fig. 1 British Ecological Society Apparatus

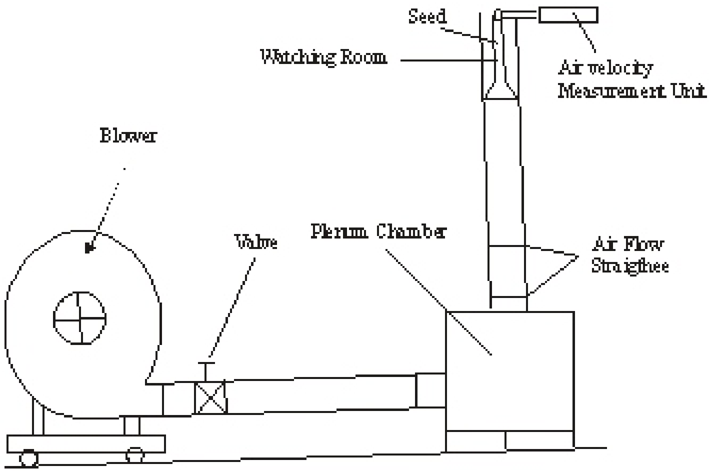


Fig. 2 Maxwell Scientific Publication Corporation Apparatus

3 CONCEPT DESIGN AND SPECIFICATION

3.1 USER NEEDS AND METRICS

3.1.1 Record of the user needs interview

1. What is it, specifically, about the other designs that you do not like for the machine that you would want in your lab?
I think at the moment there aren't other designs for comparison so it's a little hard to answer this question, although I think I mentioned that I'm not very happy with my own idea of a human with a stopwatch, since I don't think the measurements will be very repeatable.

2. What is your preference on the size of the system? (e.g. something that can fit on a table or something that would take up 2 floors)
It would be ideal if it could fit in the lab, so either on a lab bench or on the floor. The ceilings are high though, so it could be up to 7 or 8 feet tall, if it's narrow. The lab is pretty crowded so we can't handle a giant piece of equipment.

3. As far as the noise of the system would you be okay with something at about the noise level of a vacuum cleaner or would you prefer something less noisy?
The noise level of a vacuum cleaner would be OK, although less noisy would be even better. If it was as loud as a vacuum cleaner we'd have to be careful about how often and how long we run it since the lab is an open space with lots of people in it. However, there is a constant low level of machine noise (freezer compressors, often centrifuges) so it doesn't need to be silent - maybe about as loud as a dishwasher would be ideal.

4. Would you want something battery powered or plugged into an electrical outlet?
Plug in would be fine and probably cheaper to run since we wouldn't have to be buying batteries.

5. Would you want something that can test multiples of the same seed at the same time?
Testing multiple seeds at once would be fine, although I would want some way to get velocity for an individual seed. If you were to go this route we'd have to discuss the design a bit to see what kinds of measurements you would be getting.

6. As far as loading the seeds in the system would you want it to be a human doing that or having it be an automated task?
Again it depends on the design. We'd be testing many different types of seeds from different species of grasses, so at some point in the process the human would have to load something. However, it could be analogous to a seed drill in which different types of seeds are loaded into bins by a human and then the drill automatically places them in the ground.

7. Is there anything that you would not want to see as part of the design? If so, please give examples.
In terms of the design, I'd go for something fairly robust and conceptually simple - i.e., I would not want to have so many parts and controls that it needed to be calibrated frequently or was easily broken. If this tool works we will be testing seeds from about 200 different species of grasses so optimizing it for each species is probably not going to work.

8. Is there anything that is not asked of us but would be desirable for this system?

As I mentioned to the other group, if there were way to send the measurements directly to a computer it would be ideal although obviously not central to the function of the machine.

3.1.2 List of identified metrics

1. Place on lab table
2. Less noise than a vacuum cleaner
3. Automatic data recording
4. Less than 10 parts
5. Number of test runs

3.1.3 Table/list of quantified needs equations

Table 1: Quantified Needs Metrics Table

Terminal Velocity Device		Metric									
		Height	Width	Length	Noise Level	Qty Moving Parts	Accuracy	Speed of Rerun	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	**Need**	**1**	**2**	**3**	**4**	**5**	**6**	**7**			
1	Place on lab table								0	0.6	0
2	Less noisy than a vacuum								0	0.4	0
3	Automatic Data Recording								0	0	0
4	Less than 10 parts								0	0	0
5	Number of test runs								0	0	0
Units		ft	ft	ft	dB	Integer	Integer	Runs	**Total Happiness**		**0**
Best Value		3	1	1	50	1	1	48			
Worst Value		10	4	4	75	10	5	5			
Actual Value											
Normalized Metric Happiness											

3.2 CONCEPT DRAWINGS

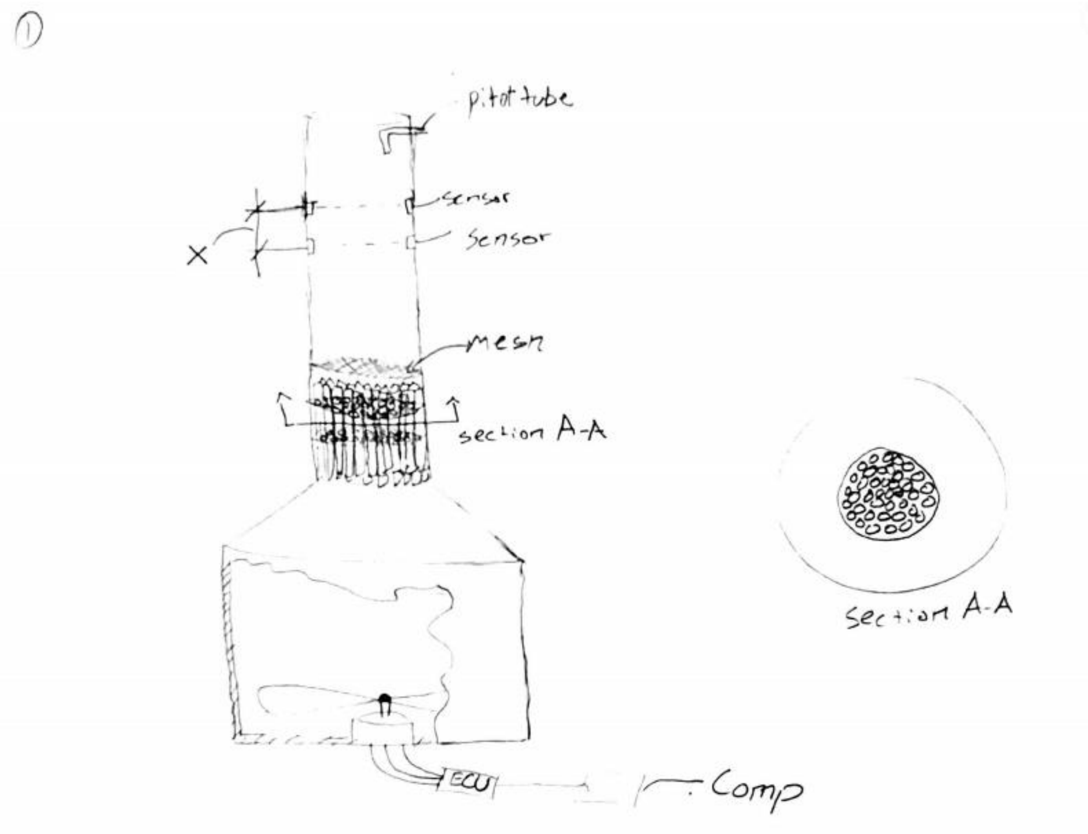


Fig. 3 Concept 1 Design

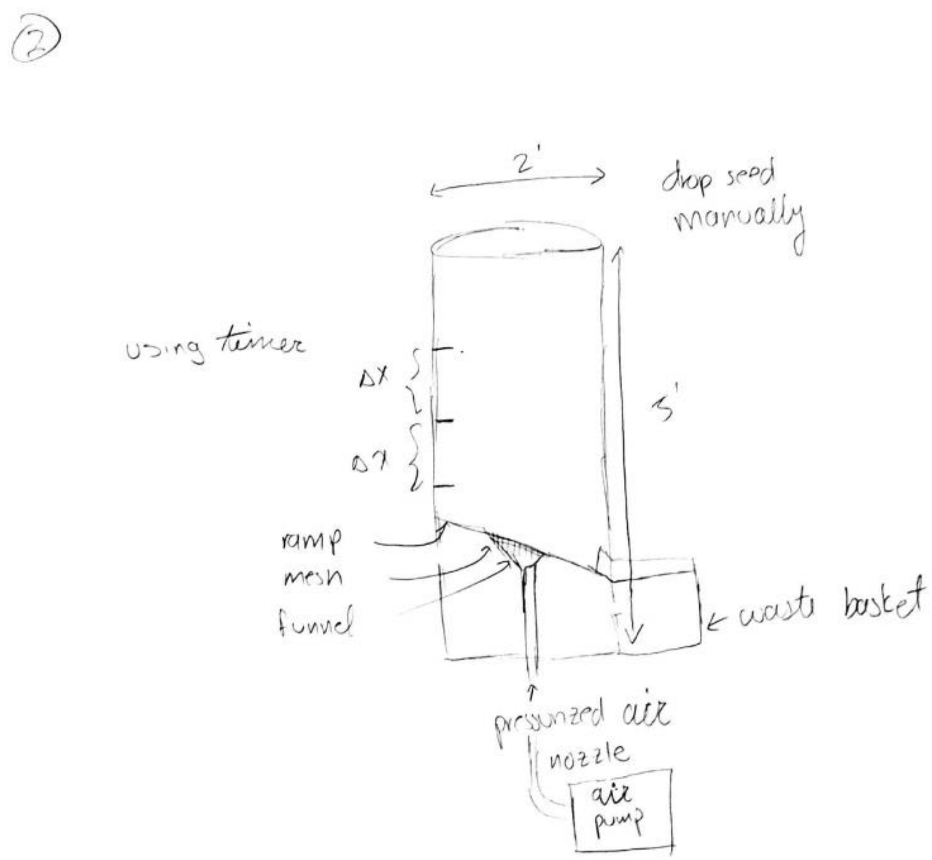


Fig. 4 Concept 2 Design

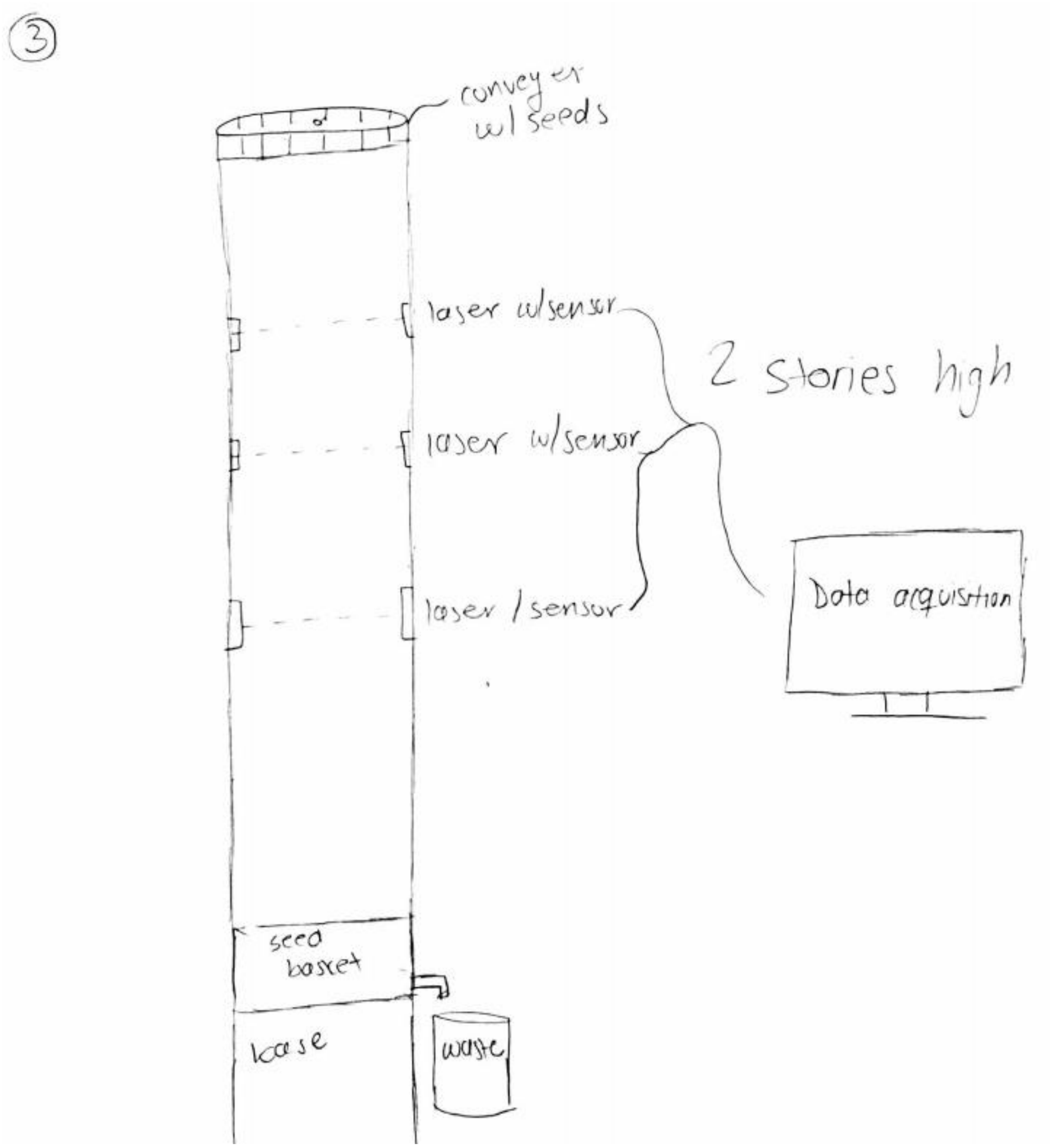


Fig. 5 Concept 3 Design

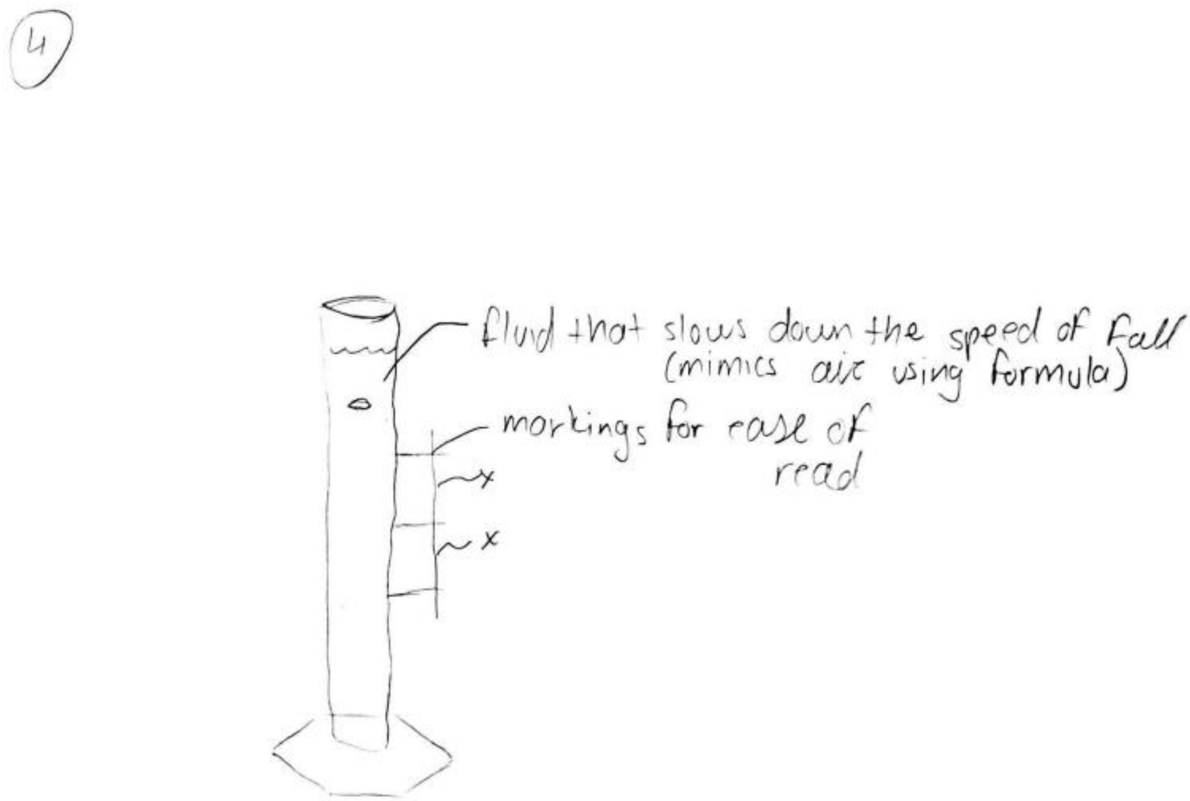


Fig. 6 Concept 4 Design

3.3 A CONCEPT SELECTION PROCESS

3.3.1 Concept scoring (not screening)

Table 2 Concept 1 Metrics

Terminal Velocity Device		Metric									
		Height	Width	Length	Noise Level	Qty Moving Parts	Accuracy	Speed of Rerun	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Valu
	Need	**1**	**2**	**3**	**4**	**5**	**6**	**7**			
1	Place on lab table	0.5	0.25	0.25					1	0.3	0.3
2	Less noisy than a vacuum				1				0.6	0.25	0.15
3	Automatic Data Recording						1		0.75	0.2	0.15
4	Less than 10 parts					1			1	0.1	0.1
5	Number of test runs							1	0.81	0.15	0.1215
6									0	0	0
7									0	0	0
8									0	0	0
Units		ft	ft	ft	dB	Integer	Integer	Runs	**Total Happiness**		**0.8215**
Best Value		3	1	1	50	1	1	48			
Worst Value		10	4	4	75	10	5	5			
Actual Value		3	1	1	60	1	2	40			
Normalized Metric Happiness		1	1	1	0.6	1	0.75	0.81			

Table 3 Concept 2 Metrics

Terminal Velocity Device		Metric									
		Height	Width	Length	Noise Level	Qty Moving Parts	Accuracy	Speed of Rerun	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Valu
	Need	1	2	3	4	5	6	7			
1	Place on lab table	0.5	0.25	0.25					0.69	0.3	0.207
2	Less noisy than a vacuum				1				0.2	0.25	0.05
3	Automatic Data Recording						1		1	0.2	0.2
4	Less than 10 parts					1			1	0.1	0.1
5	Number of test runs							1	0.81	0.15	0.1215
6									0	0	0
7									0	0	0
8									0	0	0
Units		ft	ft	ft	dB	Integer	Integer	Runs	Total Happiness		0.6785
Best Value		3	1	1	50	1	1	48			
Worst Value		10	4	4	75	10	5	5			
Actual Value		5	2	2	70	0	1	40			
Normalized Metric Happiness		0.71	0.67	0.67	0.2	1	1	0.81			

Table 4 Concept 3 Metrics

Terminal Velocity Device		Metric									
		Height	Width	Length	Noise Level	Qty Moving Parts	Accuracy	Speed of Rerun	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Valu
	Need	1	2	3	4	5	6	7			
1	Place on lab table	0.5	0.25	0.25					0.5	0.3	0.15
2	Less noisy than a vacuum				1				1	0.25	0.25
3	Automatic Data Recording						1		0.75	0.2	0.15
4	Less than 10 parts					1			1	0.1	0.1
5	Number of test runs							1	0.81	0.15	0.1215
6									0	0	0
7									0	0	0
8									0	0	0
Units		ft	ft	ft	dB	Integer	Integer	Runs	Total Happiness		0.7715
Best Value		3	1	1	50	1	1	48			
Worst Value		10	4	4	75	10	5	5			
Actual Value		20	1	1	0	1	2	40			
Normalized Metric Happiness		0	1	1	1	1	0.75	0.81			

Table 5 Concept 4 Metrics

Terminal Velocity Device		Metric									
		Height	Width	Length	Noise Level	Qty Moving Parts	Accuracy	Speed of Rerun	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Valu
	Need	1	2	3	4	5	6	7			
1	Place on lab table	0.5	0.25	0.25					1	0.3	0.3
2	Less noisy than a vacuum				1				1	0.25	0.25
3	Automatic Data Recording						1		0	0.2	0
4	Less than 10 parts					1			1	0.1	0.1
5	Number of test runs							1	0	0.15	0
6									0	0	0
7									0	0	0
8									0	0	0
Units		ft	ft	ft	dB	Integer	Integer	Runs	Total Happiness		0.65
Best Value		3	1	1	50	1	1	48			
Worst Value		10	4	4	75	10	5	5			
Actual Value		3	1	1	0	0	5	5			
Normalized Metric Happiness		1	1	1	1	1	0	0			

3.3.2 Preliminary analysis of each concept’s physical feasibility

Concept 1: This concept will consist of a pitot tube to check the velocity of the air running through the mechanism, a fan, a small motor, two sensors connected to lasers, a mesh with thin connected tubes under it to displace the air appropriately, software to run the acquired data into a computer to record the data and separate the seeds accordingly. This concept is feasible but we would need the thin tubes to straighten the airflow to be manufactured and the base of the system that will hold the power supply and motor will also need to be manufactured. These parts may be expensive to purchase due to the motor, fan and pitot tube needed. What will make this concept difficult is how we will get the data recorded onto the computer. Either we will purchase the software, which can become very costly, or we will write the codes using C++ but will have to learn how to properly code to get the system to do what we need.

Concept 2: This concept will have a 2-foot-wide acrylic tube where the seed will be manually dropped in. There will be a platform placed at an angle with a wired mesh incorporated into it to displace the air and make sure the seeds will not fall through and get into the pressurized air tube. There will be a mechanism that is like a funnel attached to the pressurized air tank to make sure the air is moving outward and not just in one direction or area. The platform is put at an angle to have the seed just slide down into a waste basket when it is done being tested. Lasers will be used to measure the terminal velocity of the seeds, which will be much more accurate than a human testing this with a timer and lines on the tube. The issues that one will run into with this concept are the noise level and if the lab even has pressurized air provided. The pressurized air tank may reach too high of a noise level that may not be allowable in the lab setting this machine will be placed into. Because this machine will need a person to stand there and manually drop the seed in as well as manually input the data the rerun time will be very long and not what Toby would like to see. It will not have any moving parts but acquiring the mesh alone may be difficult to get a mesh that is fine enough to not let the smallest of seeds through but also let the air properly flow through it. Therefore, this concept is not very feasible.

Concept 3: This concept is using a different idea where we have a large lab setting that allows for a 10-foot-tall apparatus. There will be a conveyor belt at the top to automatically drop each side. The conveyor will most likely just be an automatic fish feeder of sorts that will be timed and this way the person that will need to refill it will know exactly when to go and refill the machine with seeds to keep the testing going. This machine will have lasers with sensors that will be connected to a computer that will have a software to record the data. The challenges with this will be finding where the seed will reach terminal velocity to know where to place the three lasers and their sensors and how to write out the software that is needed for this system. This system is very feasible but the height is something that Toby would prefer to not have. She would prefer the machine to fit on a lab table and not be 2 stories high.

Concept 4: This last concept will be the slowest when it comes to reruns. The idea here is to use a fluid that mimics air and then have a person standing there to time when it reaches each marked point on the tube. The fluid will slow down the speed of the fall to make it easier for the person to catch the seed at the right points, but will still not be as accurate as a laser. One will be able to acquire the true terminal velocity by using a formula. This concept is neither feasible nor logical to use. The rerun time alone should push someone away from this idea; one must empty out the tube and refill it every time someone wants to run a test on a seed. It may be simple but not efficient.

3.3.3 Final summary statement

The concept that is chosen to be our preliminary design for this project is Concept 1. This concept meets the requirements for the height, width, length and quantity of moving parts. It then partially meets the requirements for the needed noise level, accuracy and speed of reruns. It gets a score of 2 and not 1 when it comes to accuracy because we are taking into consideration the systematic error that can occur with the sensors or coding that will be on the computer. The noise level is not a perfect 50 dB because of the motor that will be placed into the base to rotate the fan. One cannot reach 48 reruns because this mechanism requires someone to manually drop the seeds in. The other 3 concepts were not chosen for their own specific faults. The 2nd concept was not chosen because of the size and noise level. The noise of the pressurized air tank and the air being spit out of the tube will be well above the needed 50 dB. It is also 2 feet taller and 1 foot wider and longer than needed for the space it will be placed. The 3rd concept was not chosen due to how tall it was going to be and how difficult it would have been to build a 20 foot machine and to have Toby find a lab space to fit this large machine. The 4th concept was not chosen because it was not going to be accurate due to the high possibility of human error and the amount of time that would be wasted on restarting a new test for each seed having to refill and empty the fluid in the tube.

3.4 PROPOSED PERFORMANCE MEASURES FOR THE DESIGN

There were several aspects of the design that were used to measure the needed performance. Having a machine that is small enough to fit on a lab table along with having something that is quieter than your average vacuum cleaner were the two main performance measurements we had going into the manufacturing process of this design. Two other aspects we paid attention to were the time it would take for each rerun of a set of seeds as well as the capability to have the system automatically record the data on to a spreadsheet.

3.5 REVISION OF SPECIFICATIONS AFTER CONCEPT SELECTION

After selecting Concept 1 for our design of this apparatus we decided there needs to be an area in either the base or in the tube that can be opened up to remove the seeds that were tested on to make the removal process faster and the testing process more efficient. In order to make the design much simpler the base will just be a regular square box instead of a handmade box made of wood and with angle pieces. In order to get the terminal velocity of the seed there will be an anemometer in the tube recording the wind speed. The anemometer that will be purchased includes computer software that transfers the recordings from the Anemometer straight to the computer and graphs it out per test set. A person will only be needed to drop the seed in and click start and stop on the computer. To control the speed of the motor an extension will need to be added to their internet browser called BetaFlight, which will allow one to increase and decrease the rpms of the motor. The lasers part of the concept will be removed due to being too expensive for this assignment.

4 EMBODIMENT AND FABRICATION PLAN

4.1 EMBODIMENT/ASSEMBLY DRAWING

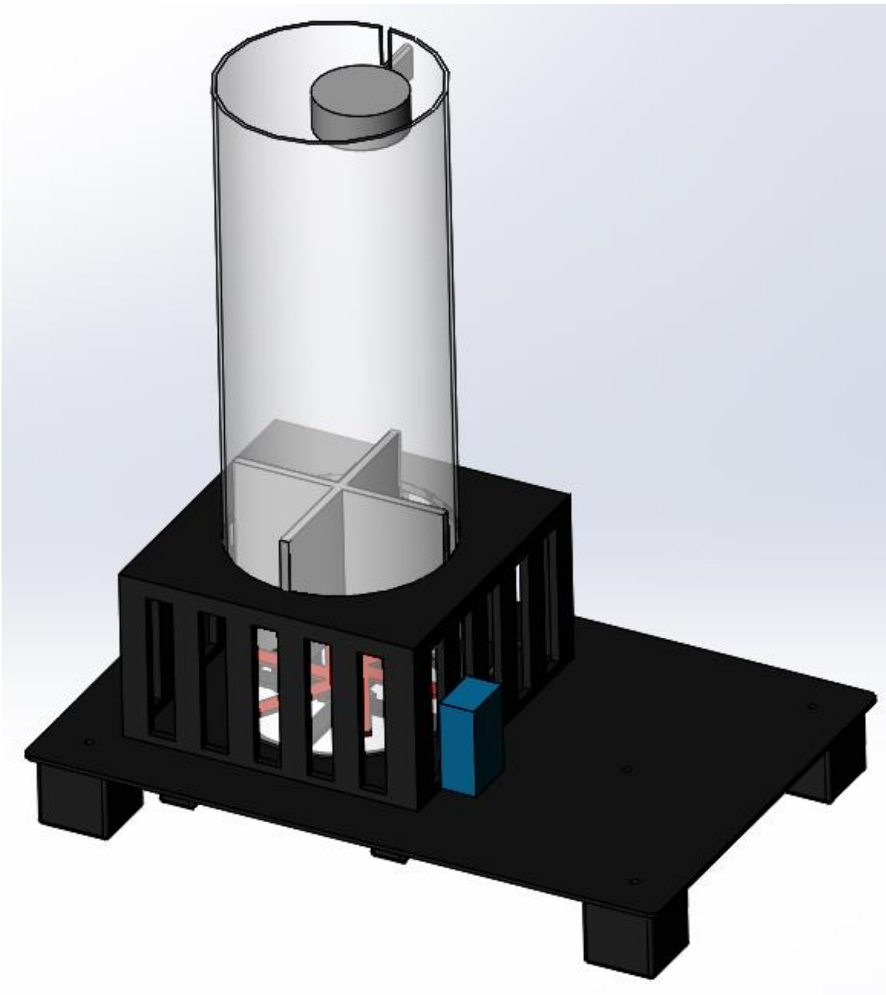


Fig. 7 Assembly Drawing

4.2 PARTS LIST

Table 6

Find No.	Name	Material	Part No.	Qty
1	Base Plate	Aluminum		1
2	Motor	I.S.	RS2205 2300KV	1
3	Propeller	Plastic	6045	1
5	Tunnel	Clear PVC	8585K58	1
6	ESC	I.S.	ESC 20Amp	1
7	Flight Controller	I.S.	Naze32	1
9	Battery	Lithium Ion	1550mAh	2
10	Enlcosure	Woden Box	N/A	1
11	Mesh (36"x84")	Nylon		2
13	Anemometer	I.S.	HP-856A	1
14	Wooden Blocks	Wood	N/A	2
15	Threaded Rod	zinc	N/A	1
16	USB Cord		N/A	1
17	100 ct straws		N/A	6
22	Lock nut		N/A	1
23	Clamp	1040 SS	N/A	1
24	Spade Bit		N/A	1
25	Machine Screw	Zinc	N/A	1
26	Washers	Brass	N/A	1
27	Machine Screw Nut	Zinc	N/A	1
28	Double sided Tape		N/A	1
29	Battery Charger		N/A	1
			Total:	30

4.3 DRAFT DETAIL DRAWINGS FOR EACH MANUFACTURED PART

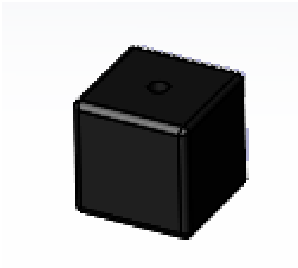


Fig. 8 Base Legs

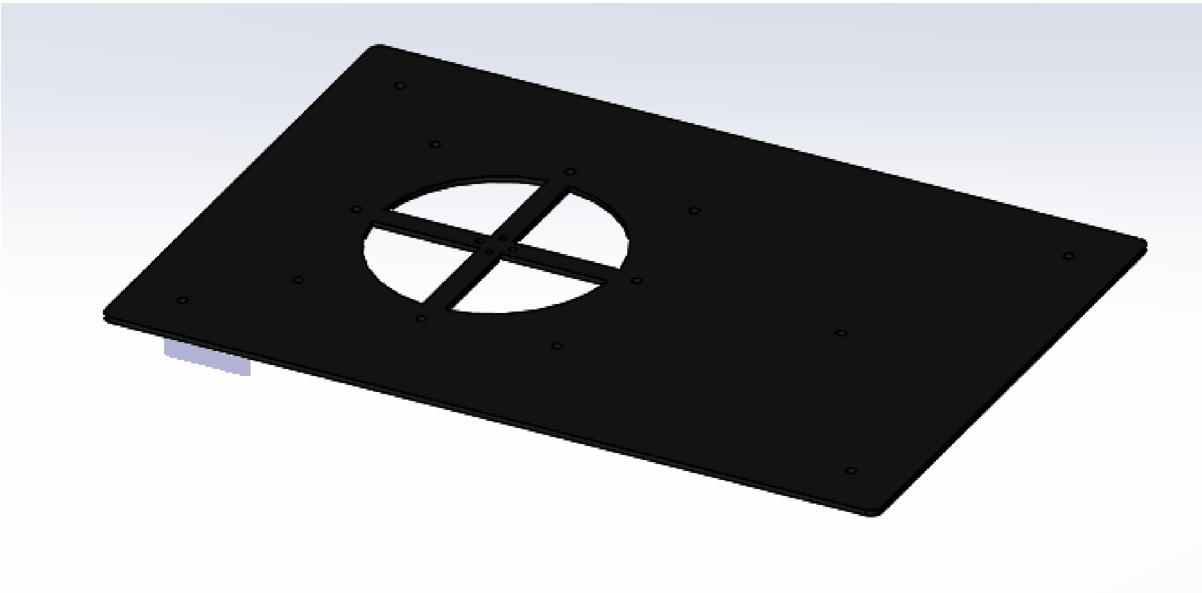


Fig. 9 Base Plate Drawing

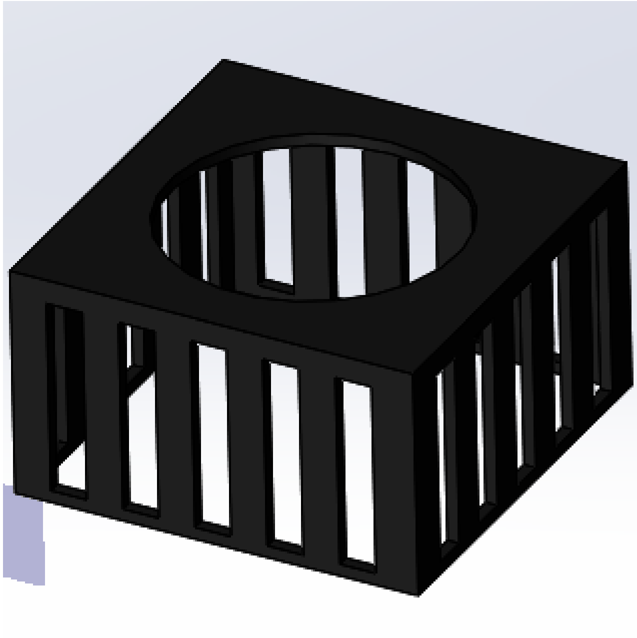


Fig. 10 Wind Tunnel Base Drawing

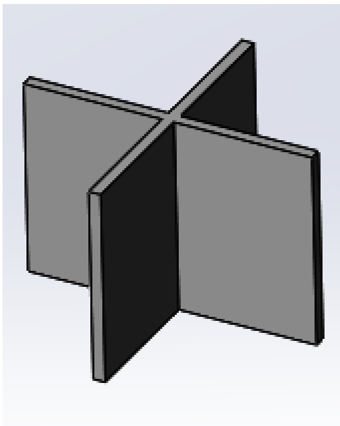


Fig. 11 Air Straightener Drawing

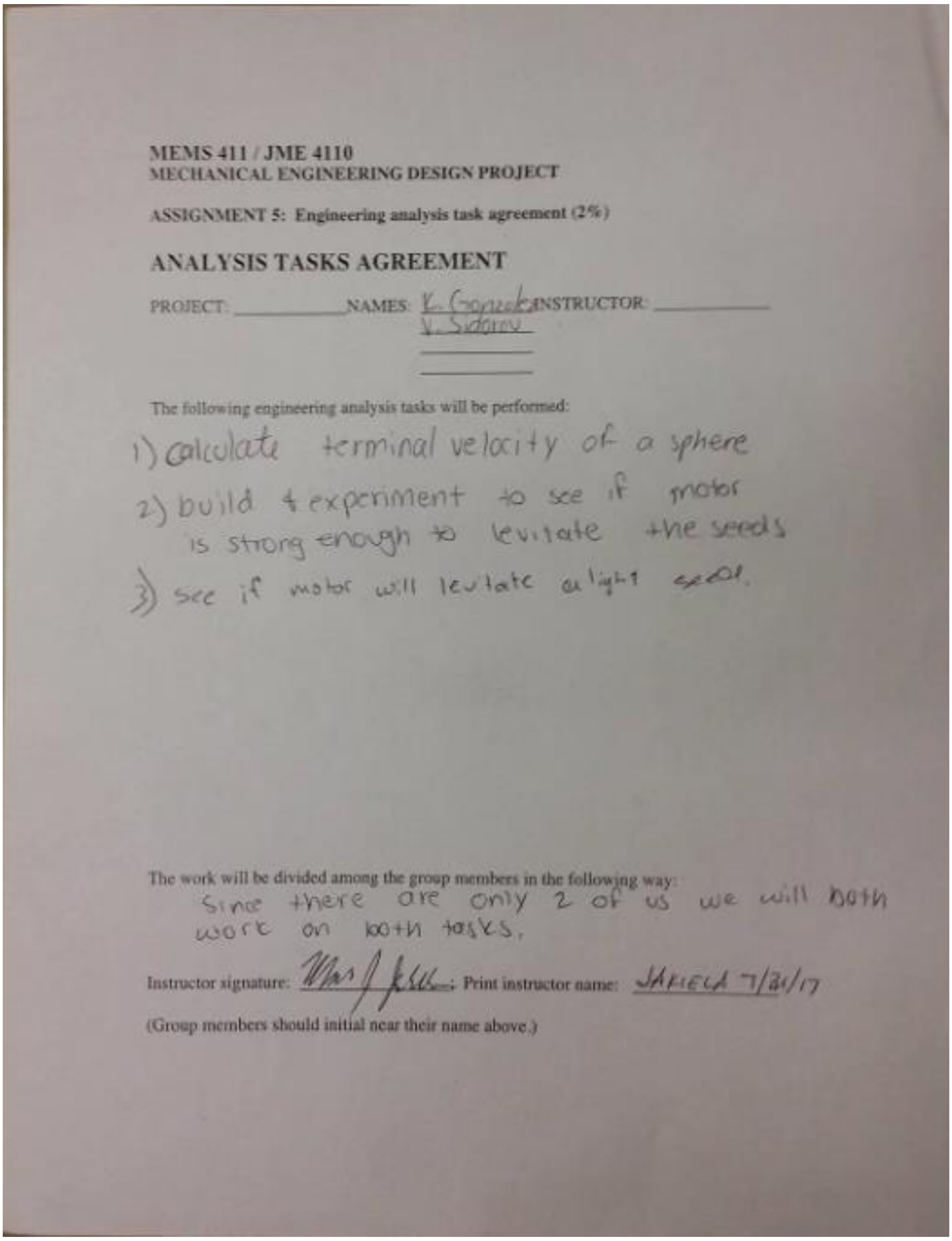
4.4 DESCRIPTION OF THE DESIGN RATIONALE

We chose an aluminum plate as the base for this mechanism instead of wood for several reasons. These reasons include that we are able to thread holes in the base to install the components, it is heavy enough that it will not tip nor slide easily and it will be durable therefore hard to damage and will last a long time. We chose a brushless and strong motor to verify that this mechanism will last a long time in the lab and will be powerful enough to lift any size seed that is put into the wind tunnel. We chose a 6 inch propeller because we wanted to have a big enough wind tunnel for any size seed and to prevent a seed from hitting the sides of the tunnel as much as possible. Having a 6 inch propeller in a 6 inch tunnel will create an even airflow. The 3 bladed propeller was chosen to make a more evenly distributed airflow. A 6 inch diameter clear tunnel that is 2 feet tall was chosen because 2 feet is enough to stabilize the seed in the air and not have the seed bouncing around the sides of the tunnel. The clarity is just to make sure the person keeping the data can see where the seed is and if it has reached its terminal velocity. A 20 Amp Electronic Speed Controller (ESC) was chosen because we needed a powerful battery to run the motor. Therefore, a 20 Amp ESC was chosen to prevent the motor from burning out. The Naze32 was chosen because it can resist a 3 cell 11.1V battery. This specific flight controller was chosen because it is a proven technology out in its field. This 2200 mAh 3S 20C battery was chosen because it would give enough power to run the motor properly and have plenty of experimental runs before needing to be recharged. The enclosure was designed to be an 8”x8” wooden box to be big enough to fit all the components and have them out of sight so they are not accidentally damaged. It being made of wood will make the mechanism light enough to be able to move around and the enclosure to be easily lifted if there are any issues with the components within it. There were several different type of mesh out in the field between the material and hole dimensions alone. We chose a nylon mesh with fine holes to verify the seeds will not be able to fall through and hit the propeller. The nylon was chosen because the holes in the aluminum mesh were not as fine and could possibly fit a very small seed through it. We chose the air straightener to be made of cardboard instead of aluminum or some other metal due to the ease of fabrication and there really is no need to make this component extremely durable because no one or anything will be in contact with it. Although, it is an important component that plays a large role it does not need to be built using extremely sturdy material. This anemometer was chosen because it was good quality for the price it was purchased at. The price range for this piece can range anywhere from $20 to $600 and for now we do not need anything extremely precise in measurement that spending $50 for one should do the job for what we need it for.

5 ENGINEERING ANALYSIS

5.1 ENGINEERING ANALYSIS PROPOSAL

5.1.1 Signed engineering analysis contract



MEMS 411 / JME 4110
MECHANICAL ENGINEERING DESIGN PROJECT

ASSIGNMENT 5: Engineering analysis task agreement (2%)

ANALYSIS TASKS AGREEMENT

PROJECT: ________ NAMES: K. Gonzalez, V. Sidorov INSTRUCTOR: ________

The following engineering analysis tasks will be performed:

1) calculate terminal velocity of a sphere
2) build & experiment to see if motor is strong enough to levitate the seeds
3) see if motor will levitate a light seed.

The work will be divided among the group members in the following way:
Since there are only 2 of us we will both work on both tasks.

Instructor signature: [signature] Print instructor name: JAKIELA 7/31/17

(Group members should initial near their name above.)

Fig. 12 Signed Engineering Analysis Contract

5.2 ENGINEERING ANALYSIS RESULTS

5.2.1 Motivation

The reasoning behind these points of analysis is that we needed to know exactly how much wind speed we would need to lift a seed. Knowing the wind speed would then tell us the amount of power output needed from the motor. Once this was determined we could then test out the motor with the three blade propeller. Testing to verify the motor was strong enough to lift the seed was germane to the project. Without it being able to lift the seed we would've had to start the design again and find a different motor or propeller and keep testing until it worked.

5.2.2 Summary statement of analysis done

There were only a few aspects to analyze as we began to finalize our apparatus. We had to calculate the terminal velocity of a sphere to get a better idea of how much wind speed would have to take place in the clear tube to lift one of the seeds and to show us if the motor that was purchased will be too strong. We then had to build and experiment to see whether the motor could levitate each of the sample seeds that were given to us. The biggest aspect of this portion of the analysis was to decide whether the motor was too strong when it came to the lighter seeds where it could just throw it out of the tube.

5.2.3 Methodology

The calculations were done using the equation for the terminal velocity of a falling sphere. The equation is as follows:

$$V_t = \sqrt{\frac{4gd}{3C_d}\left(\frac{\rho_s-\rho}{\rho}\right)},$$

where V_t is terminal velocity, g is gravitational acceleration, d is diameter, ρ is fluid density, ρ_s is solid density and C_d is the drag coefficient of a sphere (0.47).

After doing the calculations we then began to build the apparatus. Once the Naze32 Flight Controller was set up and connected to the ESC which was then connected to the motor we installed the propeller. We then placed the motor at the bottom of the tube and dropped in one of each seed to test whether the motor was strong enough or too strong to levitate each seed that was provided.

5.2.4 Results

After calculating the terminal velocity of a sesame seed using the equation for a sphere we found the terminal velocity to be 26.44 m/s which converts to 59.14 mph. After doing these calculations the motor was purchased and installed into the base of the apparatus. After testing several different seeds we found that the motor was able to lift each of the seeds but would lift them too high up.

5.2.5 Significance

Knowing that the seeds that are going to be tested within this wind tunnel are a lot smaller and liter than a sesame seed we knew that the motor would be more than strong enough to levitate the seeds. The motor was definitely strong enough but was almost too strong because it could not levitate the seed at a constant height. The seed would either fly out of the tunnel or drop. This is a huge issue considering the whole point of this design is to be able to see when the seed reaches terminal velocity.

That is the point where the seed stops accelerating in the air and stays at a constant volume and the speed the wind is at is the seed's terminal velocity at that point.

6 RISK ASSESSMENT

6.1 RISK IDENTIFICATION

There were several technical and financial risks that came with this project. The technical risks consisted of having a motor too powerful or not powerful enough, having a short tunnel that would not give the seed enough time to reach terminal velocity, anemometer not being accurate enough and not having wood be allowed in the lab space. Then there came the financial risks. The anemometer and tunnel were among the most expensive pieces of equipment. Considering what we needed to do with both we needed to find a clear tunnel and a high quality anemometer all under $100 each. This definitely was not an easy task and the worry was that getting the cheaper ones we would be going down in quality of our project.

6.2 RISK ANALYSIS

Before purchasing the motor we calculated what the terminal velocity of a sesame seed would be using the equation given in section 5.2.3. Knowing that the wind speed must be about 50 mph to make the sesame seed reach terminal velocity we looked through our narrowed down list of motors and calculated which motor would reach that wind speed. We also knew that the seeds we would be testing out were going to be smaller than a sesame seed so we knew if a motor can reach a wind speed of up to 50 mph we were in good shape. Having the right motor and propeller combination is what deteriorates the risk of the tunnel being too short to give the seed the time to reach terminal velocity. After testing out the three blade propeller we realized that the wind in the tunnel was too choppy and that a propeller with more blades was definitely needed. The anemometers that were found online during our research all ranged from about $20 to $600. Due to our budget being $500 we stuck with the $50 anemometer and hoped it would be accurate enough. We tried to go off of the reviews of the product, but you will never know what is true until you actually try it. We actually paid a little extra to be able to get the anemometer that comes with a software that automatically uploads the wind speeds onto a spread sheet and that goes towards our metrics of needing the data put in automatically. After researching codes and standards of your standard laboratory we found that as long as the wooden enclosure was painted properly it would be ok to put into a lab setting.

6.3 RISK PRIORITIZATION

The biggest risk for this project is getting the wrong propeller and motor combination. This is why heavy research was done to verify the chosen motor and propeller can levitate and keep a seed a constant height. The next risk was having an anemometer that followed some of the negative reviews and would not function at all. Not having an anemometer to tell the wind speeds would make it near impossible for the person running the tests to get the terminal velocity of the seed. Therefore we purchased the anemometer the earliest to test it out just in case it was going to need to be returned. Being that we knew we would not reach $500 the budget was not the highest on our priority list of risks.

7 CODES AND STANDARDS

7.1 IDENTIFICATION

Through our research we found that there was a general standard that pure wood in a lab setting was not allowed. Per OSHA standards the motor can only reach 90 dBa to be permissible in the lab and around others. AIAA-R-092-1 identifies the recommended practice for wind tunnel testing. ASTM-D5096 is the standard test method for determining the performance of a cup anemometer or propeller anemometer. AIAA-S-071 is the assessment of experimental uncertainty with application to wind tunnel testing.

7.2 JUSTIFICATION

Wood that is not treated in some way cannot be allowed in any chemical or biological lab setting because if anything spills over the wood will absorb it and potentially make it a hazardous area to be in. The motor being at about 90 dBa or more can cause hearing damage to those around the machine and potentially make the company lose employees. AIAA-R-092-1 is needed to determine the proper procedures to run the system and get the results that are needed. ASTM-D5096 is needed to determine where on the wind tunnel the anemometer will be placed so the customer will get the most accurate wind speed reading. AIAA-S-071 is needed to understand the tolerances that should be expected from the wind tunnel.

7.3 DESIGN CONSTRAINTS

7.3.1 Functional

AIAA-R-092-1 brought to our attention that we needed a specific way to have the customer run their experiments with this apparatus. ASTM-D5096 will help us choose whether to have the anemometer 2 inches down from the top or in the center of the tunnel.

7.3.2 Quality

AIAA-S-071 is a standard that will help us choose between two different anemometers that were both fairly priced but different in specifications.

7.3.3 Manufacturing

When deciding on the base one needed to decide whether to make the base out of sheet metal or to make it out of wood and just paint the wood to treat it. As far as the noise of the motor one needed to consider the way the base plate, motor and stands were put together to adjust the noise level and consider what material each item is made of.

7.3.4 Legal

Per the OSHA noise standard one must choose whether the noise levels get too high that safety equipment may be needed for the ears to prevent a lawsuit for hearing loss.

7.4 SIGNIFICANCE

AIAA-R-092-1 provides one with activities to help direct and cultivate a balanced successful testing system. AIAA-S-071 gave us the go ahead to purchase the $50 anemometer due to the assessment that was made in this code of experimental uncertainty with application to wind tunnel testing. ASTM-D5096 will force us to put the anemometer at a specific height from the propeller within the wind tunnel. When building the base for this project we had to spray paint the wooden box black to treat the wood before installing it onto the base plate to prevent anything from falling onto it and being absorbed into the wood. We needed to add rubber and foam pads throughout the base plate and under the motor to prevent the metal from vibrating and exceeding the noise level that is needed for this project. Due to the motor making so much noise ear pieces would be required to verify the customer will not damage their hearing capabilities.

8 WORKING PROTOTYPE

8.1 PROTOTYPE PHOTOS

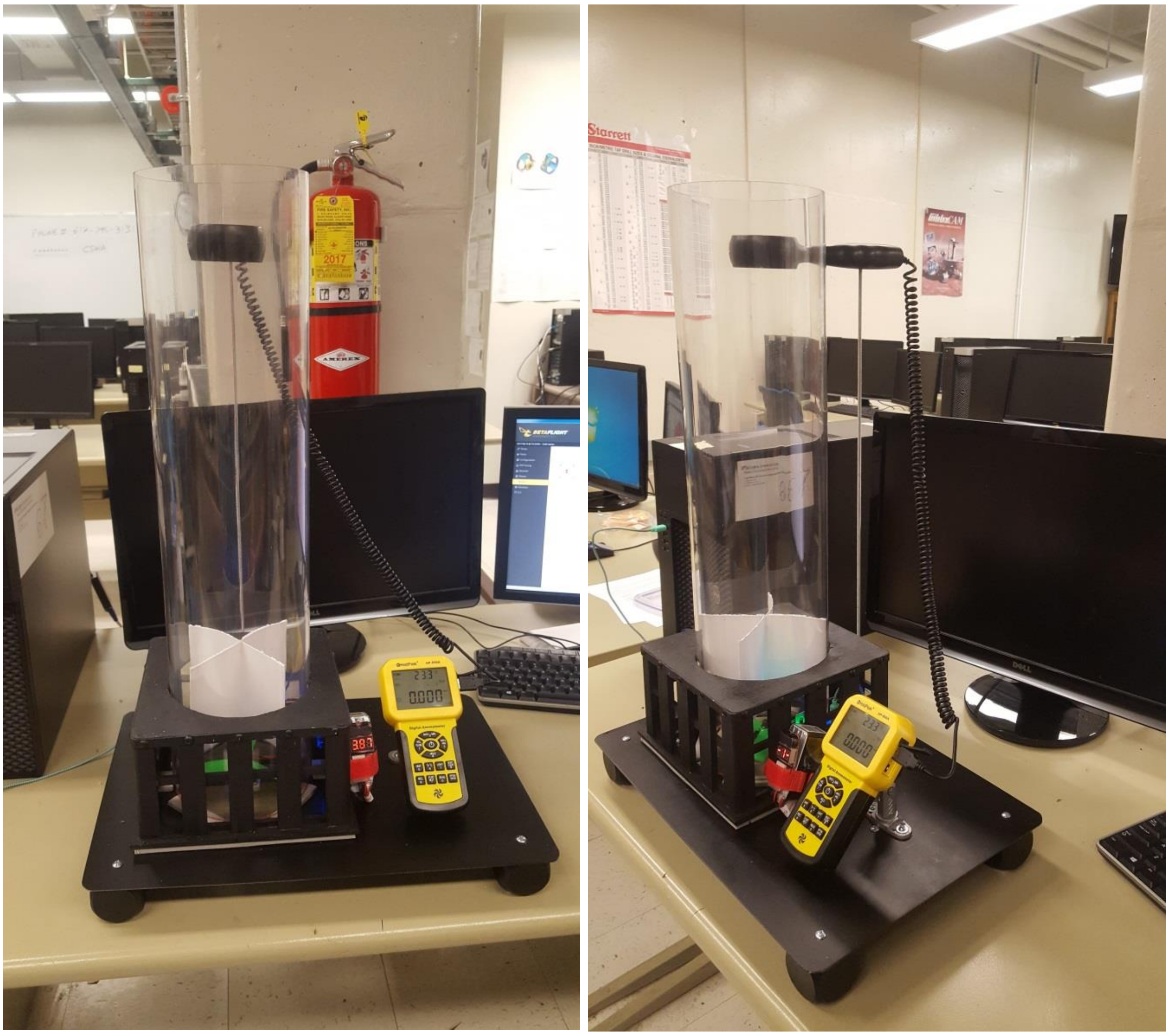


Fig. 13 Front and Right View of Prototype

These two images depict our final prototype that will be presented at the Danforth Science Center. On the left is the front view that shows a head on view of the tunnel, wooden base, anemometer and reading device, battery and LCD screen that shows the voltage of the battery. Through the cracks of the base one will see the propeller and the rest of the air straightening material. On the right is the right side view of the apparatus that gives a better view of the full anemometer as well as the rod that is screwed into it to hold it perpendicular to the tunnel. One can also see the mechanism that is holding the wind speed reader at an upright angle to make it easier on the person experimenting to be able to see the screen. One may also be able to notice the foam placed between the wooden base and metal base plate to prevent any sort of vibration between the two rigid objects.

8.2 WORKING PROTOTYPE VIDEO

https://youtu.be/dpi7ftR7rdI
https://youtu.be/n0y_n5kJ6iQ

8.3 PROTOTYPE COMPONENTS

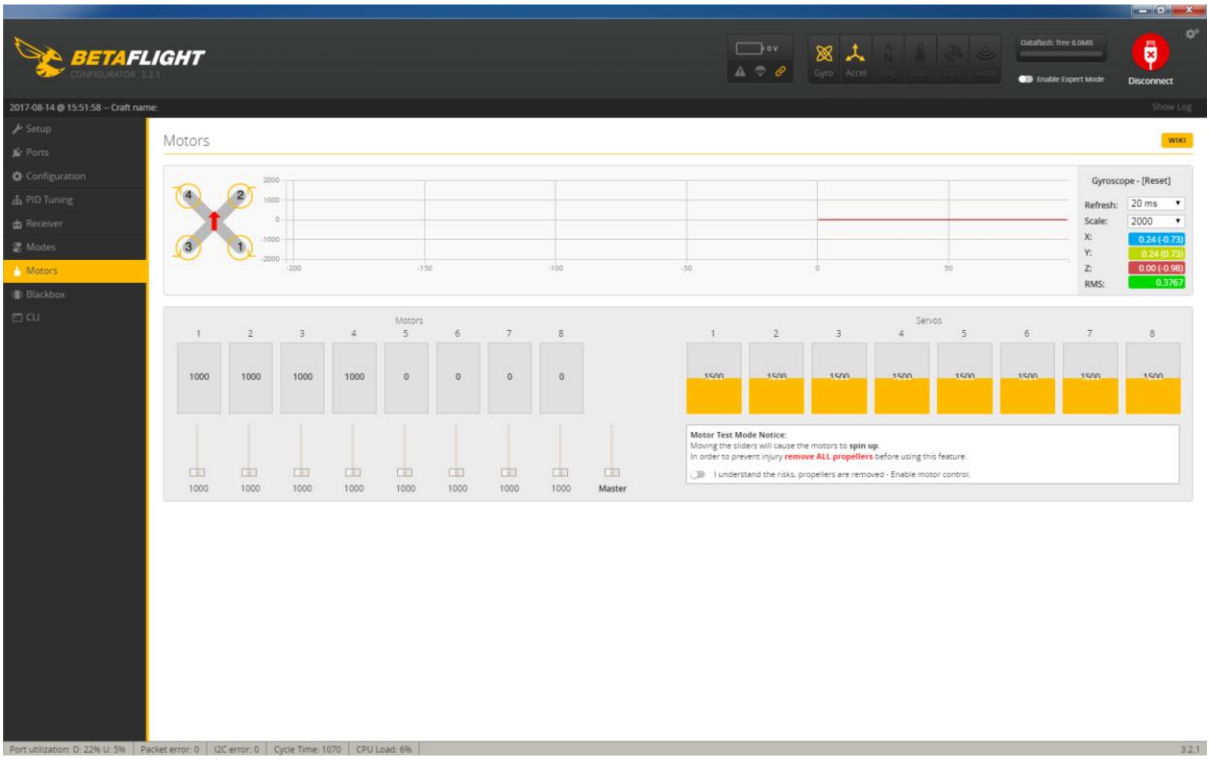


Fig. 14 Motor Speed Control Software

The above picture depicts the software that will be used to control the speed of the motor as the tests are being run. The motor speed can be increased and decreased either by pressing the up and down key on the keyboard or by dragging the button up and down with the mouse. The knob that one will be controlling is the one at the very end that says "Master" on it. Generally we did not need to go above 1400 to get the heaviest of seeds up in the air.

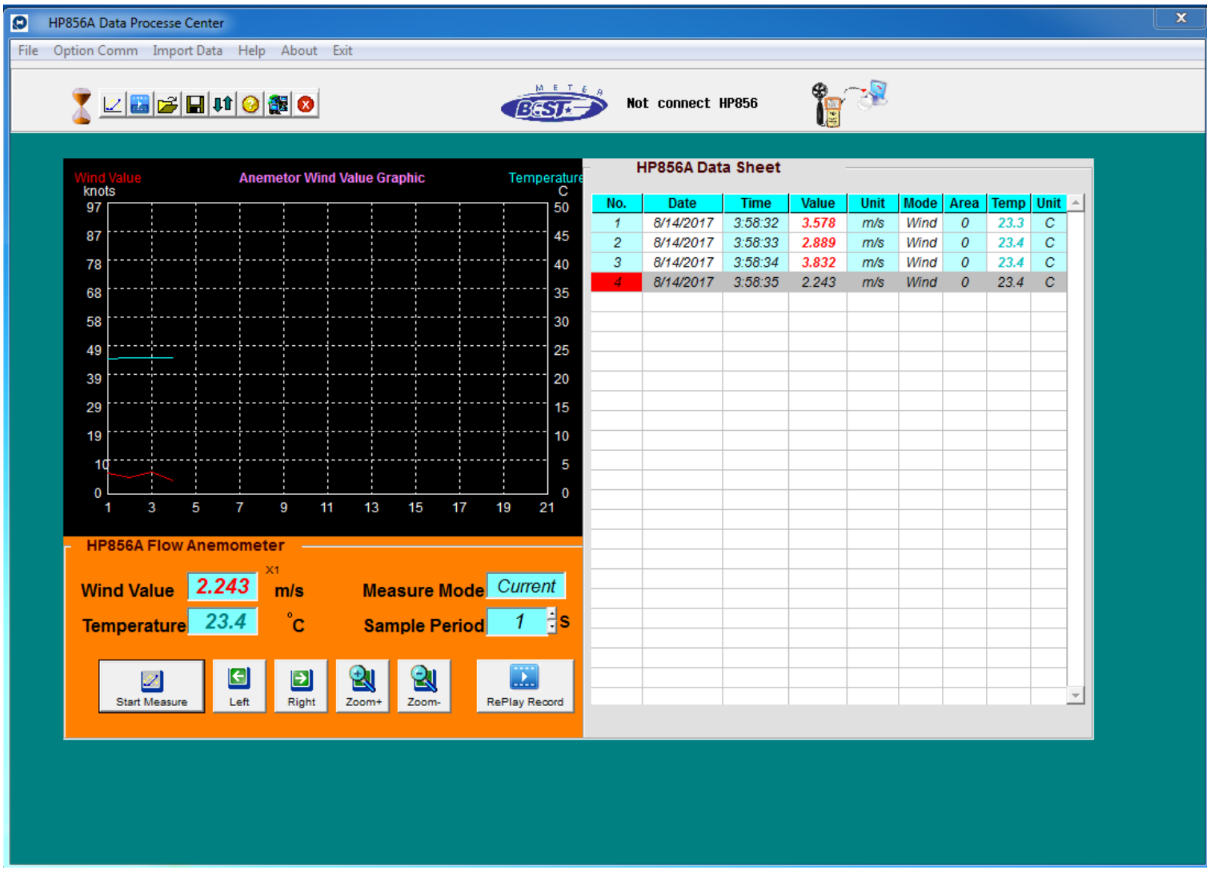


Fig. 15 Anemometer Spreadsheet

The anemometer that was purchased came with a CD that had software on it to attain to capability of automatically uploading the data without needing someone to manually have to put it in. On the right are all the data points which include the date, time, period number, wind speed, and temperature in the tunnel. On the left it shows a graph of how these values are changing throughout the run time along with the wind speed in that moment and temperature. The sample period can be changed depending on how long of a gap the customer wants between test points. The data obtained here can then be exported to an excel sheet where the data can be further analyzed.

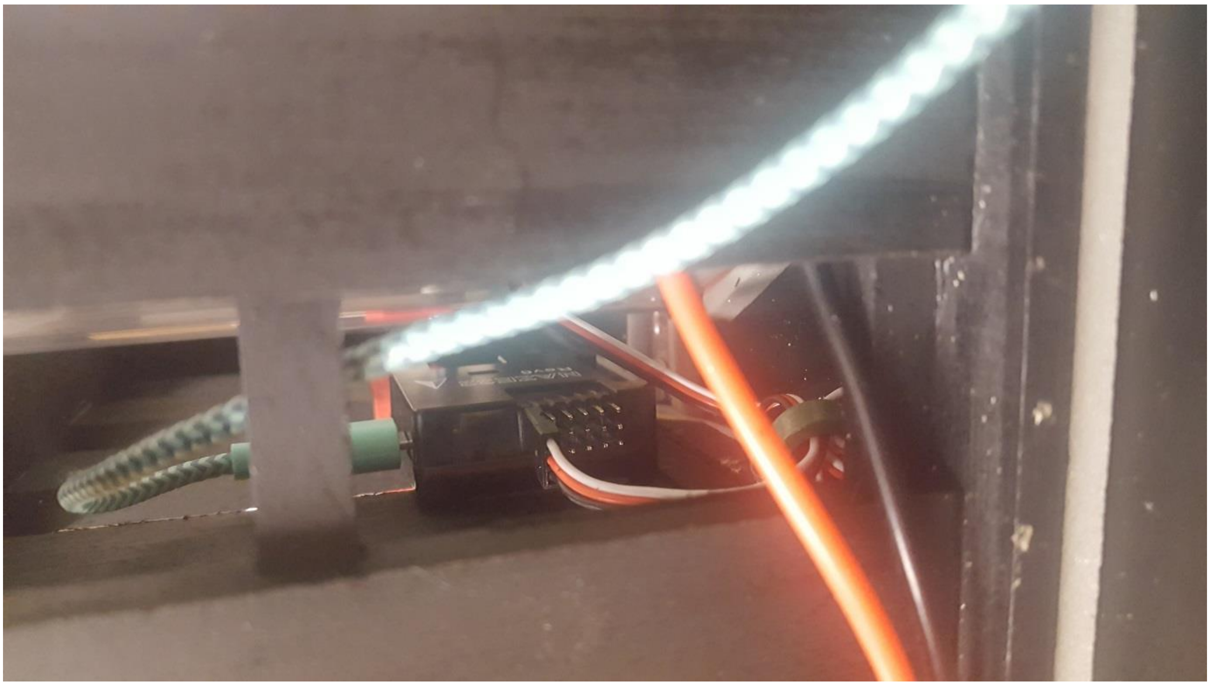


Fig. 16 Flight Controller with wires to connect to ESC

This is a depiction of the flight controller that connects to the computer and gives the command to the motor to increase or decrease its speed. Without this component the Beta Flight software would have been useless. The electronic speed controller (ESC) has a wire running to this component to receive commands from it to control the speed of the motor.

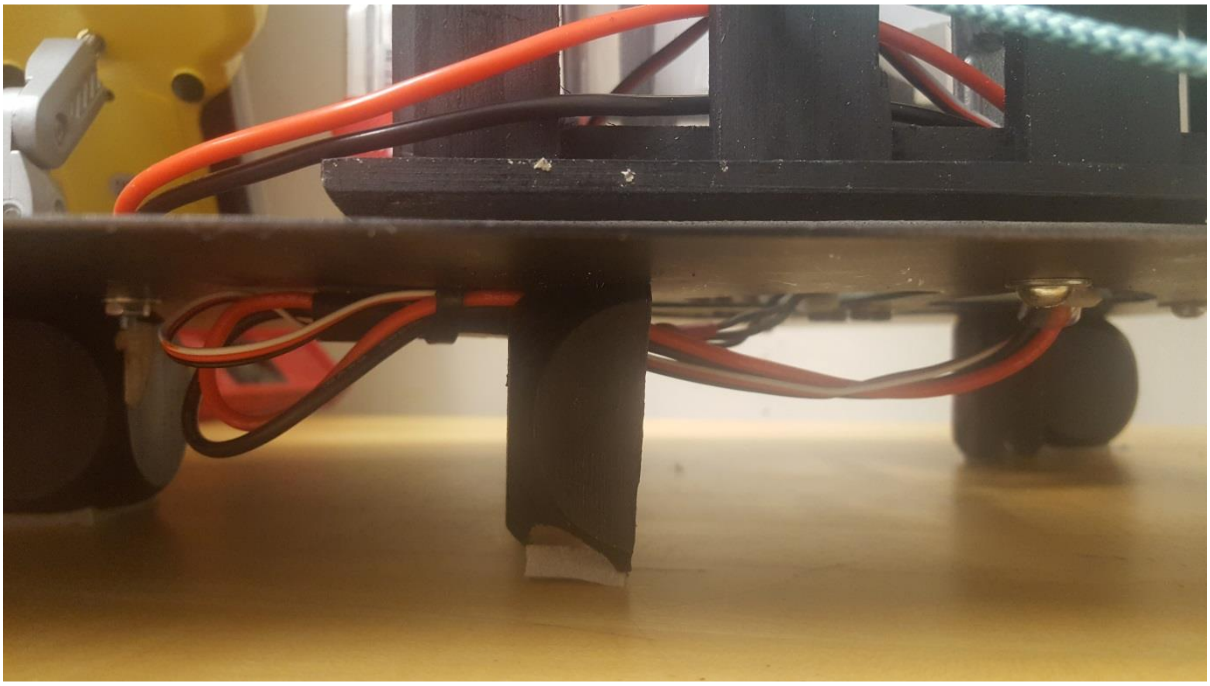


Fig. 17 ESC and wires running to electrical components

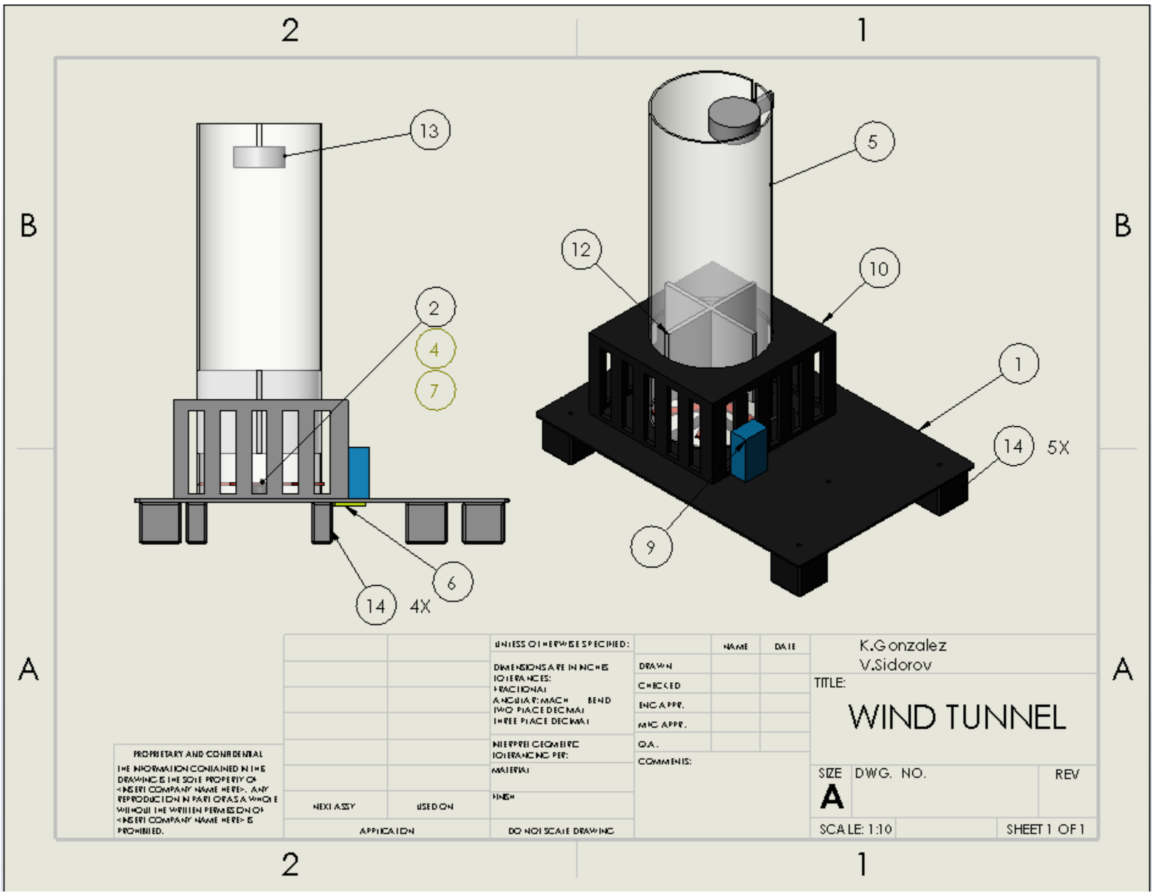
Below the plate one will see the ESC attached and the wires that run up to the motor, battery and flight controller. The ESC is used to send commands to the motor to either increase or decrease in speed. It is also the way the motor gets the power to operate due to the fact the ESC is the only component connected to the battery.

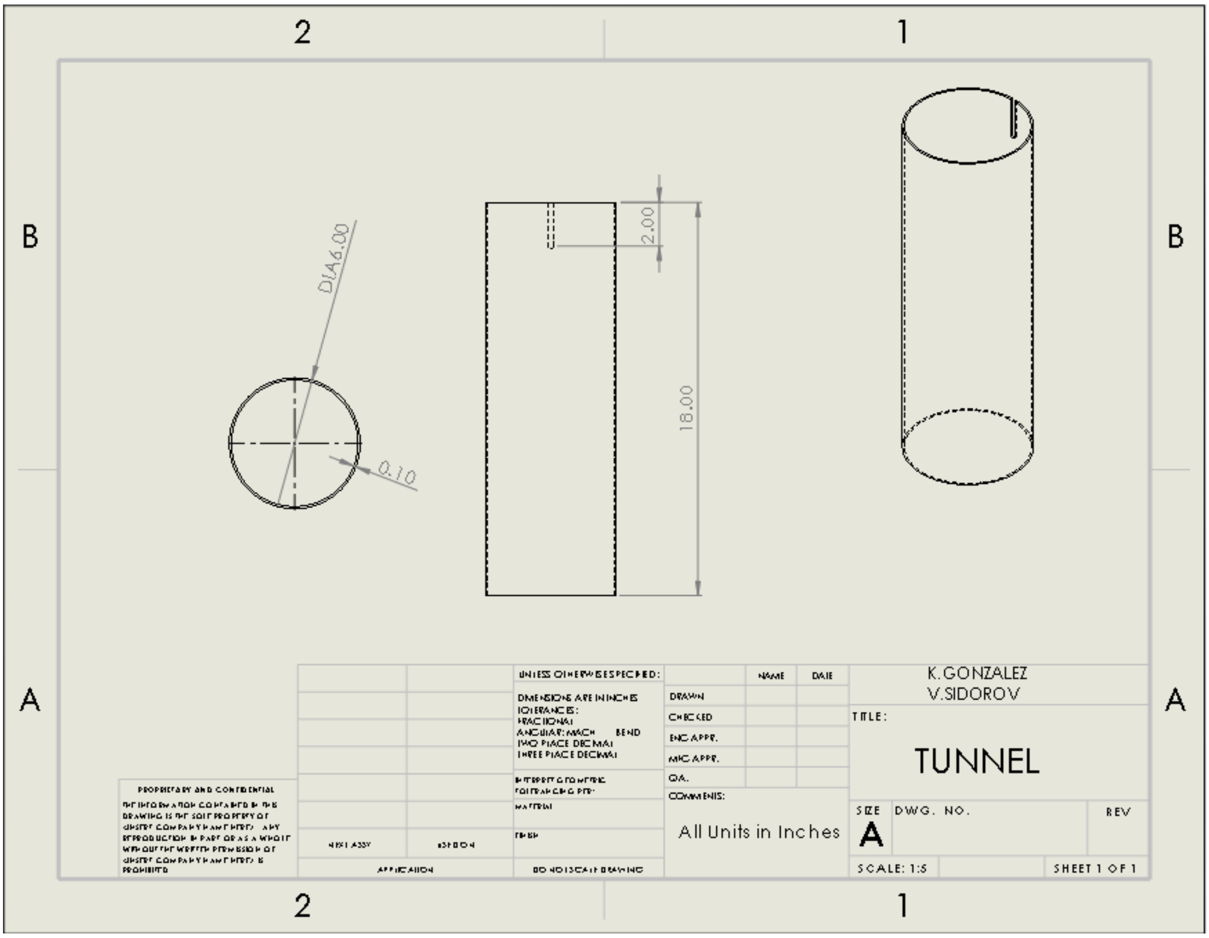
9 DESIGN DOCUMENTATION

9.1 FINAL DRAWINGS AND DOCUMENTATION

9.1.1 Engineering Drawings

See Appendix C for the individual CAD models.





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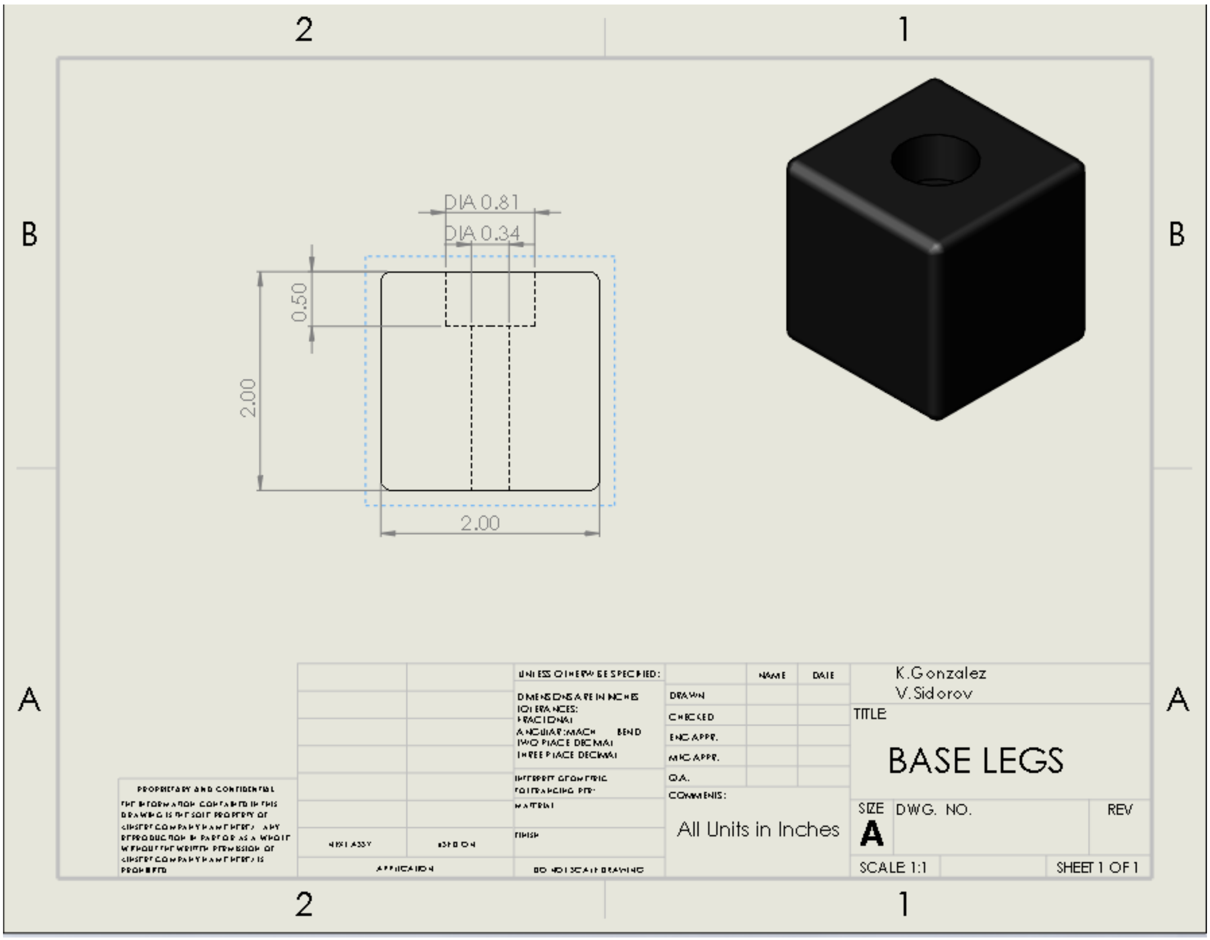
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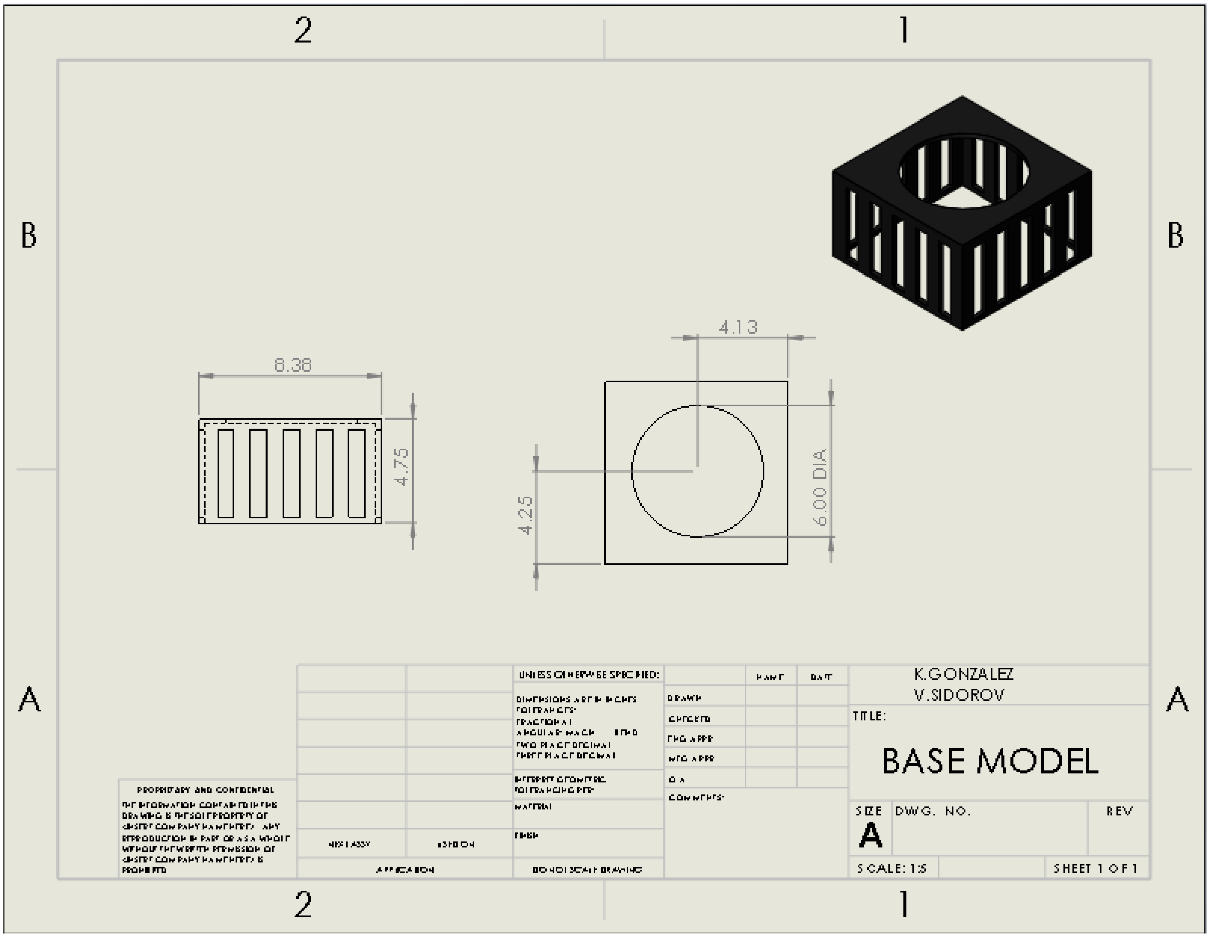
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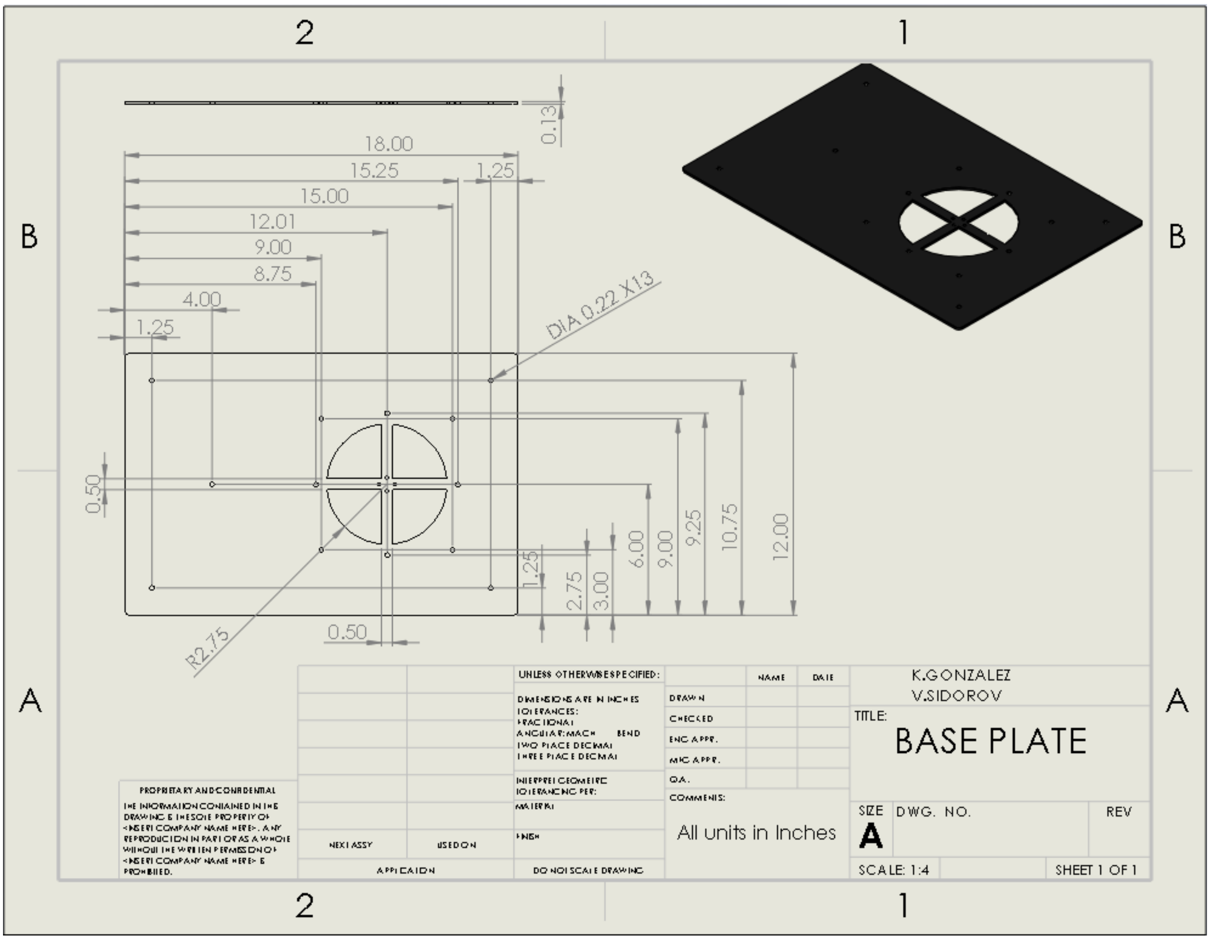

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9.1.2 Sourcing instructions

Find No.	Name	Description	Material	Part No.	Store/Manufacturer	Price per unit	Qty	URL
1	Base Plate	Area to mount all components	Aluminum		Lowe's	$15.78	1	
2	Motor	To spin the propeller	I.S.	RS2205 2300KV	Emax	$21.99	1	
3	Propeller	To create wind in the tunnel	Plastic	6045	Raycorp	$16.99	1	https://www.amazon.com/gp/product/B01N1U2473/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1
4	Hex Blade	To make the wind less choppy	Plastic	5040	Xsoul	$10.99	1	https://www.amazon.com/gp/product/B01G5669KW/ref=oh_aui_detailpage_o02_s00?ie=UTF8&psc=1
5	Tunnel	Contains air into one concentrated area	Clear PVC	8585K58	McMaster-Carr	$76.56	1	
6	ESC	Tells motor how fast to rotate	I.S.	ESC 20Amp	ARRIS	$13.99	1	https://www.amazon.com/gp/product/B00UL3O2BO/ref=oh_aui_detailpage_o00_s01?ie=UTF8&psc=1
7	Flight Controller	Commands ESC	I.S.	Naze32	Afro	$20.99	1	https://www.amazon.com/gp/product/B01CU4SJKQ/ref=oh_aui_detailpage_o00_s01?ie=UTF8&psc=1
8	Battery Monitor Alarm	Tells user when battery is getting low			Virhuck	$6.99	1	https://www.amazon.com/gp/product/B072JSLP66/ref=oh_aui_detailpage_o08_s00?ie=UTF8&psc=1
9	Battery	To power the system	Lithium Ion	1550mAh	Tattu	$22.30	2	https://www.amazon.com/gp/product/B013I9S89E/ref=oh_aui_detailpage_o03_s00?ie=UTF8&psc=1
10	Enlcosure	Keep ESC and Flight Controller from being damaged	Woden Box	N/A	Hobby Lobby	$7.99	1	
11	Mesh (36"x84")	prevent seeds flyind through to motor or out of tunnel	Nylon		Home Depot	$9.73	2	
12	Air Straightener	Straigtens wind and to gain accurate reading of seed		N/A	School	$0.00	1	
13	Anemometer	Tells wind speed in tunnel	I.S.	HP-856A	HoldPeak	$49.99	1	https://www.amazon.com/gp/product/B00XTWEKAW/ref=oh_aui_detailpage_o09_s00?ie=UTF8&psc=1
14	Wooden Blocks	To give a gap between the surface and base plate	Wood	N/A	Hobby Lobby	$4.99	2	
15	Threaded Rod	Holds up the anemometer perpendicular to the tunnel	zinc	N/A	Home Depot	$2.18	1	
16	USB Cord	Connects the Flight Controller to the computer			Target	5.48	1	
17	100 ct straws	Initial Air straightener			Walmart	$0.98	6	
18	Heat Shrink Tube	To prevent circuit from shorting			Walmart	$2.97	1	
19	Loctite	Prevent motor from vibrating and unscrewing bolts			Walmart	$5.93	1	
20	Bullet Connectors	Motor needed bullet connectors to connect to ESC			Mark Twain Hobby Center	$7.56	1	
21	XT60 connector	ESC needed connection to the battery			Mark Twain Hobby Center	$3.98	1	
22	Lock nut	Needed for threaded rod to prevent from unscrewing			Home Depot	$1.18	1	
23	Clamp	To hold tunnel in place	1040 SS		Home Depot	$2.17	1	
24	Spade Bit	Drill holes in the feet			Home Depot	$4.17	1	
25	Machine Screw	Hold feet to plate	Zinc		Home Depot	$5.24	1	
26	Washers	Hold feet to plate	Brass		Home Depot	$1.18	1	
27	Machine Screw Nut	Hold feet to plate	Zinc		Home Depot	$1.18	1	
28	Double sided Tape	Hold flight controller and ESC			Home Depot	$9.84	1	
29	Battery Charger	Charge batteries			SKYRC iMAX	$62.99	1	https://www.amazon.com/gp/product/B017Y2G4Y2/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1
					Total:	$438.23	37	

9.2 FINAL PRESENTATION

https://youtu.be/WrhDdxzMCGE

10 TEARDOWN

11 APPENDIX A - PARTS LIST

Find No.	Name	Material	Part No.	Qty
1	Base Plate	Aluminum		1
2	Motor	I.S.	RS2205 2300KV	1
3	Propeller	Plastic	6045	1
4	Hex Blade	Plastic	5040	1
5	Tunnel	Clear PVC	8585K58	1
6	ESC	I.S.	ESC 20Amp	1
7	Flight Controller	I.S.	Naze32	1
8	Battery Monitor Alarm			1
9	Battery	Lithium Ion	1550mAh	2
10	Enlcosure	Woden Box	N/A	1
11	Mesh (36"x84")	Nylon		2
12	Air Straightener		N/A	1
13	Anemometer	I.S.	HP-856A	1
14	Wooden Blocks	Wood	N/A	2
15	Threaded Rod	zinc	N/A	1
16	USB Cord		N/A	1
17	100 ct straws		N/A	6
18	Heat Shrink Tube		N/A	1
19	Loctite		N/A	1
20	Bullet Connectors		N/A	1
21	XT60 connector		N/A	1
22	Lock nut		N/A	1
23	Clamp	1040 SS	N/A	1
24	Spade Bit		N/A	1
25	Machine Screw	Zinc	N/A	1
26	Washers	Brass	N/A	1
27	Machine Screw Nut	Zinc	N/A	1
28	Double sided Tape		N/A	1
29	Battery Charger		N/A	1
			Total:	37

12 APPENDIX B - BILL OF MATERIALS

Find No.	Name	Material	Part No.	Store/Manufacturer	Price per unit	Qty
1	Base Plate	Aluminum		Lowe's	$15.78	1
2	Motor	I.S.	RS2205 2300KV	Emax	$21.99	1
3	Propeller	Plastic	6045	Raycorp	$16.99	1
4	Hex Blade	Plastic	5040	Xsoul	$10.99	1
5	Tunnel	Clear PVC	8585K58	McMaster-Carr	$76.56	1
6	ESC	I.S.	ESC 20Amp	ARRIS	$13.99	1
7	Flight Controller	I.S.	Naze32	Afro	$20.99	1
8	Battery Monitor Alarm			Virhuck	$6.99	1
9	Battery	Lithium Ion	1550mAh	Tattu	$22.30	2
10	Enlcosure	Woden Box	N/A	Hobby Lobby	$7.99	1
11	Mesh (36"x84")	Nylon		Home Depot	$9.73	2
12	Air Straightener		N/A	School	$0.00	1
13	Anemometer	I.S.	HP-856A	HoldPeak	$49.99	1
14	Wooden Blocks	Wood	N/A	Hobby Lobby	$4.99	2
15	Threaded Rod	zinc	N/A	Home Depot	$2.18	1
16	USB Cord			Target	5.48	1
17	100 ct straws			Walmart	$0.98	6
18	Heat Shrink Tube			Walmart	$2.97	1
19	Loctite			Walmart	$5.93	1
20	Bullet Connectors			Mark Twain Hobby Center	$7.56	1
21	XT60 connector			Mark Twain Hobby Center	$3.98	1
22	Lock nut			Home Depot	$1.18	1
23	Clamp	1040 SS		Home Depot	$2.17	1
24	Spade Bit			Home Depot	$4.17	1
25	Machine Screw	Zinc		Home Depot	$5.24	1
26	Washers	Brass		Home Depot	$1.18	1
27	Machine Screw Nut	Zinc		Home Depot	$1.18	1
28	Double sided Tape			Home Depot	$9.84	1
29	Battery Charger			SKYRC iMAX	$62.99	1
				Total:	$438.23	37

13 APPENDIX C – COMPLETE LIST OF ENGINEERING DRAWINGS

https://drive.google.com/drive/folders/0B1pTL5auTk9JMHpOVW9tV1hWVUU?usp=sharing

14 ANNOTATED BIBLIOGRAPHY

Askew, A.P., et al. A New Apparatus to Measure the Rate of Fall of Seeds. 1997, pp. 121–125, A New Apparatus to Measure the Rate of Fall of Seeds.

This article explains the findings of two scientists who created an apparatus to measure the rate of fall of seeds. It was very useful to this project because it gave an insight into what components to use and what to look for to create a successful and cost effective product.

Levey, Cheryl. “Standards.gov.” NIST, National Institute of Standards and Technology, www.nist.gov/standardsgov.

This website has all of the standards both domestic and international and was used to find codes and standards that would create constraints on this apparatus. Due to the information found on this website several changes had to be made to the design of the apparatus.

S. Gürsoy and E. Güzel, 2010. Determination of Physical Properties of Some Agricultural Grains. Research Journal of Applied Sciences, Engineering and Technology, 2(5): Page No: 492-498

This article has a broader approach to the data they are trying to get from seeds. Here they are trying to obtain physical properties of seeds which include their terminal velocity. This was also used when brainstorming different ways to make an apparatus that works properly and gets the measurements that are needed.