Abstract

In this lab, the team's purpose was to use an Advanced Energy Vehicle (AEV) to transport people from Linden to Easton and Polaris. This report contains the introduction to the AEV experiments, the experimental methodology used to conduct the research, experimental data from the AEV and the detailed data from the multiple research, the discussion of the results, and the conclusion and recommendation from the AEV labs. This report will let the reader know the best methods to design an AEV, transport the AEV, and improve the techniques of coding the AEV. These methods for the AEV are essential because the AEV's design affects its movement efficiency, the transporting methods affect the safety of the passengers on board, and the coding techniques determine the efficiency of power consumption.

After the experiments and multiple research, the group concluded that Coasting the AEV to a stop consumed the least power, but it was the least accurate method of stopping the AEV. Power braking provided the more accurate version of stopping but consumed more power. The group decided to use power braking because they prioritized accuracy over power consumption. Additionally, the team conducted the Solidworks simulations research. After the research, the team concluded that reducing the mass of the AEV improves its braking accuracy. The team recommends that the AEV should use power braking method if braking accuracy is prioritized, but coasting is recommended if efficiency of power consumption is the main priority. Lastly, mass study in Solidworks simulations can greatly reduce the weight of the AEV and improve the overall efficiency of the AEV.

AEV Critical Design Review Draft

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Executive Summary

The Advanced Energy Vehicle (AEV) labs required several weeks of Preliminary and Advanced Research and Design (PR&D and AR&D). The lab's goal was to create an inexpensive, fast and energy-efficient way to transport people from Linden to Easton and Polaris. Additional goals were to improve group coordination, manage time efficiently, and learn the process of research and experimentation to solve real world problems. During the preliminary labs, the team learned basic skills for operating the AEV such as writing codes, testing the AEV hardware, brainstorming and experimenting various designs, and staying within the constraints of the labs. The lab consisted of several constraints such as limited materials, fixed battery power output, fixed track shape, maximum budget, etc. The group was given a budget of $500K, with basic materials for the AEV including the track shared with classmates. The designs for the lab were brainstormed to fit the constraints. The designs that failed to satisfy certain criteria such as light weight, stable parts, and minimal cost were removed. Some of these design testing occurred in the AR&D when the team conducted Coasting vs. Power Braking and Solidworks Simulations.

The AR&D's Coasting vs. Power Braking research focused on lowering energy consumption and reducing braking distance. The tests were performed for each braking method until the results became consistent. According to the data, the average braking distance for coasting and power braking were 133.235 in and 123.338 in and the standard deviation were 3.16 in. and 2.71 in. respectively. Coasting traveled an extra 10 inches on average. The average energy consumed for coasting and power braking were 26.934 J and 39.125 J respectively. Coasting consumed about 33% less energy than power braking. Based on this, the group concluded that power braking increases braking accuracy even though it will consume more energy.

The second AR&D was on Solidworks Simulations. The overall goal of Solidworks Simulations was to reduce assembly times when designing AEV models, address weight problems, and conduct a digital motion study for the group's AEV designs. To fulfill these goals, the team conducted mass study and motion study in Solidworks Simulations. The original AEV design weighed 1.21 pounds before conducting the mass study or motion study. The AEV lost 0.89 pounds after the mass study. After the mass study, the team conducted motion study in Solidworks. This study was much more challenging since the user interface for motion study was not well optimized. The motion study's data did not account for friction or air resistance, so the data was not helpful. The animation of the design was a more effective representation of the AEV than the data produced by it. Next step was to apply these findings to the performance tests.

In the first performance test, the group's goal was to move the AEV in front of the gate in the middle of the track. Since the AEV's position could only differ by about 15 marks, the team put emphasis on accuracy and decided to use power braking method to stop the AEV based on the AR&D findings. The reduced AEV weight from the Solidworks Simulations helped lower the power consumption required for the AEV to move the same distance as before.

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Introduction

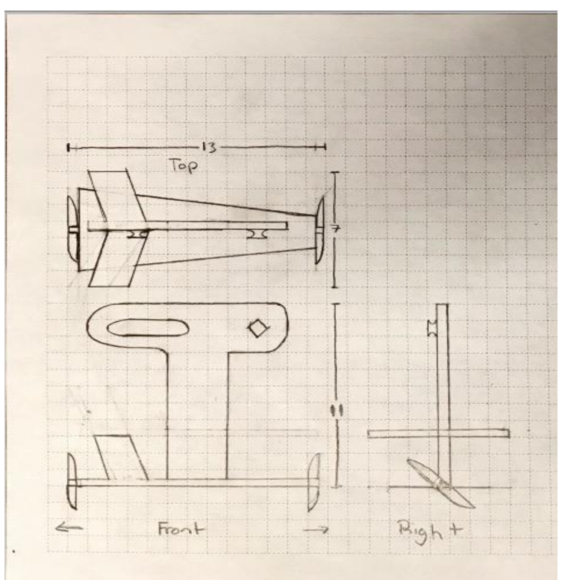
The purpose of AEV project is to design an advanced energy vehicle to transport people from Linden to Easton and Polaris. To increase the efficiency and consistency of the AEV, the team conducted several researches and experiments. During the researches and experiments, the team learned how to use the AEV analysis tool to analyze performance data and make design decisions. This lab report will detail the design process of AEV, summarize the findings of researches and experiments and conclude how these findings benefit team's AEV design. For the sections below, firstly in the "Experimental Methodology" section, the team will introduce what tests and researches the team conducted throughout the labs.

Secondly in the "results" section, the team will present what results the team received in each experiment by analyzing the collected data and concluding several efficient working methods for the AEV. Next, in the "Discussion" section, potential errors will be addressed and data that the team received will be compared to the expected data. Then, in the "Conclusion and Recommendations" section, the team will summarize and conclude what the team accomplished so far, and the future development plan will be provided. Finally, in the "Appendix" section, all the relevant data, plots, codes and SolidWorks drawings are presented.

Experimental methodology

Research 1: Creative Design Thinking

One of the first labs were called the Creative Design Thinking lab. In this lab, team were going to use creative thinking to draft several drawings of the vehicle design. Each member of the team needed to draw their own design, and there would be a collective design based on each one's draft. The AEV kit needed to be prepared for the testing of the designs.



Refer to Design D in Appendix F

Research 2: Arduino Programming Basics

The second lab was called Arduino Programming Basics. In this lab, the teams familiarized with the Arduino coding interface, which was a code language the team used for the AEV. The team explored the syntax and behavior of the given functions and observed how they controlled the vehicle's motors. The materials that the team prepared prior to the lab were the AEV kit, the battery, and the USB cable.

Research 3: Concept Screening and Scoring

The next lab was called Concept Screening and Scoring. In this lab, the team was introduced to matrices used for screening and scoring designs. The team sued these 2 things to compare different designs to a reference design. Additionally, the AEV was required to be finished before this lab. The team prepared the AEV, battery, and USB cable before the lab begun.

Concept Scoring											
		Reference		**Design C**		**Design D**		**Design E**		**Design F**	
Success Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Stability	30%	3	0.9	3	0.9	4	1.2	4	1.2	4	1.2
Minimal Blockage	20%	3	0.6	3	0.6	4	0.8	4	0.8	5	1
Lift	10%	2	0.2	2	0.2	3	0.3	4	0.4	4	0.4
Weight	25%	3	0.75	4	1	3	0.75	2	0.5	3	0.75
Safety	15%	3	0.45	3	0.45	2	0.3	3	0.45	3	0.45
Total Score			2.9		3.15		3.35		3.35		3.8
Continue?		No		No		Develop		Develop		Yes	

Refer to the Concept Screening and Scoring table on Appendix A.

Research 4: External Sensors

The fourth lab was called External Sensors. In this lab, the team familiarized with the external Sensor on the AEV, and the team learned some new functions related to the external sensors. Also, the team learned how to test their external sensors to find was there any error in the external sensor. The materials that the team prepared for this lab were the AEV, battery, USB cable, external sensor, and the servo.

Research 5: Advanced R&D- Costing vs. Power Braking and Solidworks Simulation

During the fifth research, the team started Advanced Research and Design (AR&D). This research was divided into to 2 parts. The first part was called Coasting vs. Power Braking. Braking was an important component in AEV project. In this lab, two ways of braking were available for the AEV-coasting and power braking. Coasting refers to switching off the motors so that the AEV could gradually slow down the speed until it stops completely. Instead of cutting off the power of the motors, power braking reverses the direction of the motors, so an opposing force was applied on AEV to help it stop. Two main factors were considered when testing these two methods, energy consumption and braking distance. The team prepared two codes and conducted a series of testing for each method to determine which style suits team's AEV most.

The second part was called Solidworks Simulation. The team designed two different AEV through Solidworks and used the evaluation tools in Solidworks to study mass, volume and cost of two different designs to analyze which design was better. The things team needed to be prepared for the lab were the AEV, battery, USB cable, and a computer installed with Solidworks.

Research 6: Performance test 1

The latest research that the group accomplished was called the Performance Test 1 (PT1). This test was used to test whether the AEV traveled according to the code provided by the team. In PT1, the AEV simply had to travel to the gate, stop for 7-seconds, and proceed from the gate. The materials that the team needed to prepare for the lab were the AEV, battery, USB cable, and a computer that could edit Arduino code.

Results

During the preliminary labs, the team learned the basic coding to move the AEV from one position and stop. As the team learned more about coding, the accuracy of scenarios on the lab increased. Then, the reflectance sensor test helped the group locate sensor errors. These sensors "sensed" the location of the AEV and it was crucial that they worked as accuracy as possible.

Later, the team also brainstormed several AEV designs. The group started with four designs: Pravesh's design (Design A), Jingming's design (Design B), Feifan's Design (Design C), and Joey's design (Design D). The four designs passed through the concept screening process which evaluates the success criteria of each design and rates them "+", "0", or "-". *The success criteria are displayed on the Concept Screening and Scoring table on Appendix A.* Only designs C, and D were an improvement from the reference AEV. Design C was chosen due to its high stability, minimal blockage, and low weight. Design D was chosen because of its high ratings on all success criteria. These two designs were evaluated by the concept scoring method (a higher resolution version of the concept screening method with percent weight on success criteria and a rating of 1 through 5). *Refer to the Concept Screening and Scoring table on Appendix A.*

After the concept scoring, design C and D were combined to form Design E which was the design tested in Performance Test 1 (PT1). Design F had higher ratings on its success criteria than Design E, but it was in the process of being 3D printed and it was only going to be available in the future performance tests. Designs C and D's movements were analyzed using the same code, so the comparison would be fair. *Refer to Table 1 for basic Arduino codes and energy cost below. For exact codes used, refer to Appendix C (codes 1,2).*

Table 1: Execution time of each command and the total energy cost of that command.

Phase	Arduino Code	Time(s)	Total Energy(J)

1	motorSpeed(4,25);
	goFor(2);
	goToRelativePosition(108);
		0-2	58.7587

2	motorSpeed(4,30); goFor(1)	2-3	13.5746
3	brake(4)	3-3.09	0

Design C was the first design that was successfully tested with less than 5 marks of error. This design was meant to be a simplistic plane design. The plane-like design helped to keep the AEV stable and move at the speed of 10 mph, but its speed changed to 5 mph when the AEV reversed. Design D had a minimalistic jet-like design which was stable, light, and safe. Its narrow design, and sharply tilted wings at 45 degrees increased lift and reduced drag which ultimately lowered the weight and kept the AEV stable. The team does not have a way of testing lift or drag so these are simply assumptions. Under the same conditions and code, Design D travelled at the same speed of 10 mph when moving forward, but its reversing speed was also 10 mph unlike Design C. The placement of the motors on both front and back of Design D contributed to its improved reversing speed. *Refer to Appendix E and F for all the AEV designs. For detailed drawings of Designs E and F with materials, refer to Appendix G and H.*

Design E evolved from designs C and D in terms of its stability, minimal blockage, and safety. Its stability improved because the design was symmetrical which caused placement of the AEV objects to be optimized. Due to Design E's compact shape, it caused minimal issues with blockage. Design E also scored more on safety than other designs because its motors placement was optimal for passenger's safety. *Refer to the Solidworks drawings and Bill of Materials of the designs on Appendix G and H.*

After the testing the designs, the group conducted the AR&D on Coasting vs. Power Braking. The experiments were performed for each braking method until the results became consistent. The testing codes are attached in Appendix C (*code 1,2*). The data are collected and calculated from Power vs Distance and Power vs Time plots (*figures 6-12 on Appendix D*) using AEV data analysis tool. The average braking distance for coasting and power braking were 133.235 in. and 123.338 in. and the standard deviation were 3.16 in and 2.71 in respectively. Coasting traveled an extra 10 inches on average. The average energy consumed for coasting and power braking were 26.934 J and 39.125 J respectively. Coasting consumed about 33% less energy than power braking. Also, based on the t-test, expected percentages of trials that fall within a 3-inch margin of the average for both coasting and power braking were 89.89% and 93.12% respectively.

Based on this, the group concluded that power braking increases braking accuracy even though it will consume more energy. *Refer to the figure below and Appendix D for additional details.*

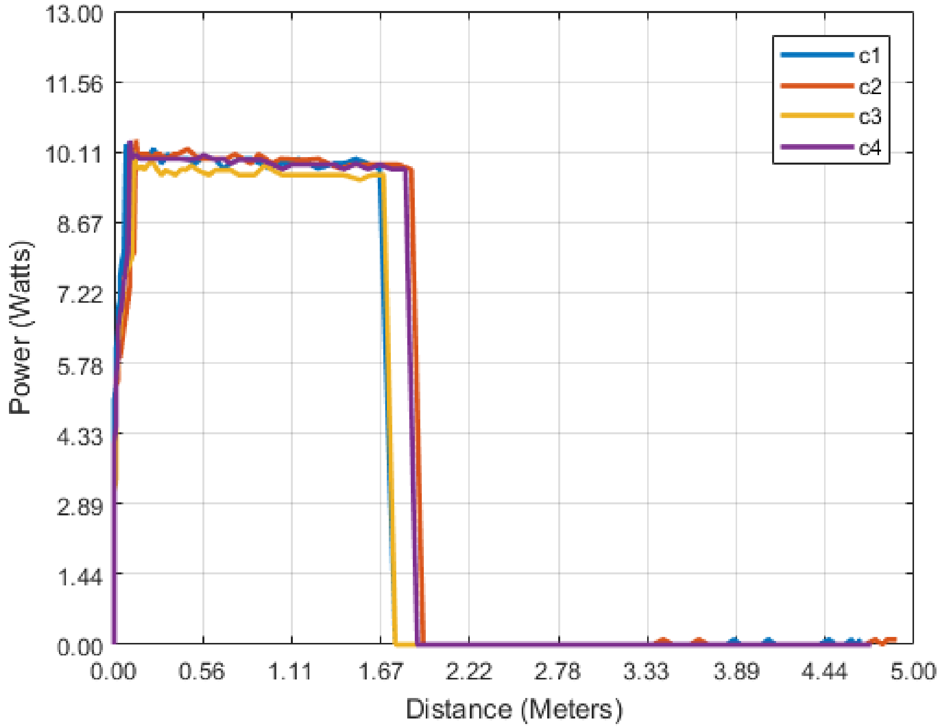


Figure 1. Power(Watts) vs Distance(Meters) Plot (Coasting Test 1-4)

The group also determined if the weight affected coasting or not. Two different weights of 263 grams and 290 grams were chosen to do the comparison. Because the testing code remained the same, the energy consumed almost stayed the same even though the weights were different. The average coasting distances for 263 grams and 290 grams AEV were 133.235 in and 127.573 in respectively. Also, the expected percentages of trials that fall within a 3-inch margin of the average for both 263 grams AEV and 290 grams AEV were 89.89% and 74.17% respectively. The group concluded that increasing weight decreases the coasting distance accuracy. *Refer to Appendix D for details.*

To reduce the weight of the AEV, the group conducted another AR&D research on Solidworks simulations. Solidworks simulations is part of Solidworks (3D modeling software) that conducts several studies to improve the design and efficiency of the model. The team performed the mass and motion study on Solidworks simulations. Before the mass study, the original AEV design weighed 1.21 pounds, had a volume of 10.32 cubic inches, and had a surface area of 226.81 square inches. The new design's mass properties after conducting the mass study are given in *Appendix B*. The AEV lost 0.89 pounds after the mass study. The volume and surface area also decreased. Volume went down by 2.6 cubic inches and the surface area decreased by 28.61 square inches. Since the materials available on Solidworks are not exact materials present in the AEV, the weight difference is about 9% when comparing Solidworks design's mass to actual AEV's mass.

After the mass study, the team conducted motion study in Solidworks. Design F was used for this study. This study was much more challenging for the researcher since the user interface for motion study was not well optimized. Also, many hours of practice were required for the researcher to be proficient with this study. The animation conducted by Solidworks allocated 99% of computer's graphics memory which became a problem for the researcher due to computer latency. However, the video produced was at 60 frames per second after it was uploaded so the latency was only an issue when conducting the study. *Refer to Figure 2 below the upcoming paragraph for AEV Design F's details.*

One of the key takeaways when conducting Solidworks Simulations was to use the placement of the Arduino (microcontroller of the AEV with central processor) as a constraint for AEV designs to produce the least amount of interferences and reduce the combinations of designs. Without using Arduino's placement as a constraint, there were 313 interferences and 212 combinations of designs. However, once the Arduino was placed, the interferences decreased to 20. These new interferences were part of the Arduino object assembly (given by the OSU Engineering department) and not part of the entire AEV. The number of design combinations also decreased to 6 from the previous 212. *Refer to Figure 2 below for the AEV Design F's exploded view. For the bill of materials and detailed dimensions, refer to Appendix G.*

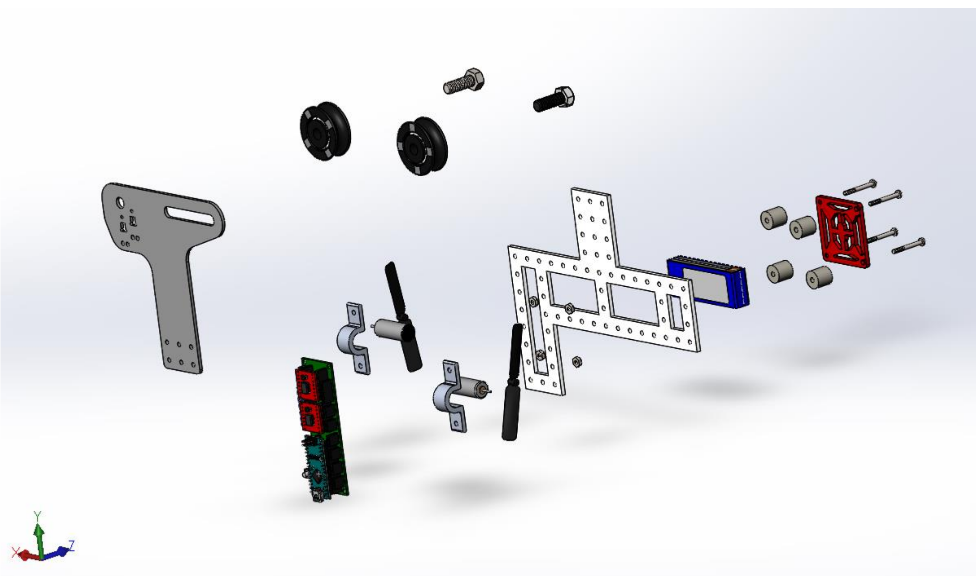


Figure 2. AEV exploded view after implementing the design combinations and conducting mass and motion studies.

After the AR&D findings from both Coasting vs. Power braking and Solidworks Simulations, the group was prepared for Performance Test 1 (PT1). In PT1, the group's goal was to move the AEV in front of the gate located in the middle of the track. Since the AEV's position could only differ by about 15 marks, the team put emphasis on accuracy and decided to use power braking method to stop the AEV based on the AR&D findings. The second AR&D results from Solidworks Simulations helped lower the power consumption required for the AEV to move the same distance as before. During PT1, the team used Design E, the combination of Design C and D as mentioned previously. The group received a perfect score of 16 for their first PT1 run. Before the run, the team improved the AEV's stopping distance accuracy by repeatedly collecting data on the track. The large collection of data improved the consistency of the stopping distance to a difference of 5 marks. Since 5 marks is below the 15 marks error limit, the performance test was successful. The decreased weight from Solidworks Simulations also contributed to the low energy consumption for the AEV. *The figure below shows the power consumption comparison between previous design and the new design after Solidworks Simulations.* The heavier weight is the design before Solidworks Simulations. *For the PT1 data, refer to Appendix I.*

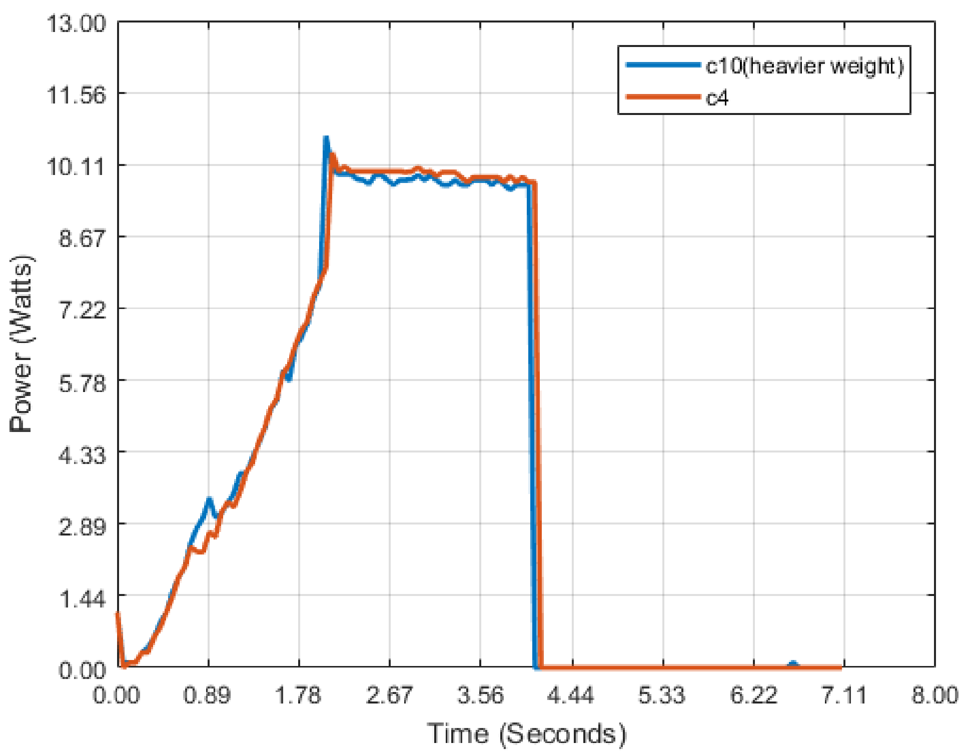


Figure 3. Power(Watts) vs Time(Seconds) Plot (Coasting 260 grams vs 293 grams)

After the completion of PT1, the group focused on Performance Test 2 (PT2). The team will continue to research more accurate methods to stop the AEV besides Coasting and Power Braking. These new methods include changing the codes to use "If" and "While" statements.

The main coder for the team is in the process of learning these new functions to apply in the upcoming PT2. *Refer to Appendix J under week 11 and Appendix K for future schedule.*

Discussion

In the preliminary lab weeks, "fail fast" was the team's motto. The group made mistakes early and learned to solve the problems. In the early labs, the team's coding skills caused several errors when trying to stop the AEV. The AEV stopped 30 marks earlier than the expected distance. The group's theory that the AEV would travel about 6 feet and reverse was not matching with the results. The group realized that the brake method was never being activated based on relative distance, but on a time of 3 seconds. The coder quickly fixed this issue and conducted multiple tests to make sure the problem was fixed.

During the days before the lab, the team members researched AEV designs and concluded that Design C and D should move forward. The group performed the concept screening and concept scoring and found that these designs received the most points in success criteria. *Refer to Appendix A for additional details.* Design C wanted the plane structure to reduce the weight of the AEV. Due to the special shape of the wings, lift would be created when the AEV travelled on the track. And because of the lift, the AEV would become lighter so that it could travel faster. Design D came from a google search: "fastest prop plane". XF-84H Thunderscreech was the top result. This plane had a propeller at the front center and a narrow body. Main wings were sharply angled towards the back of the plane, and a second set of smaller wings elevated from the back of the plane. The team's AEV design matched this concept; the main body had the shape of wings angled sharply back, the Arduino and battery pack formed a narrow center, and a second wing was elevated in the back of the AEV. These designs were chosen based on the theory that sharply angled wings could reduce drag and lower the weight of the AEV which would ultimately decrease the power output. *Refer to the designs on Appendix E-H.*

Lastly the group decided to combine Design C and Design D to create Design E that has a plane-like shape with straight wings. These two designs were chosen due to their stability, weight, and their compactness. The group still needed to improve Design E in terms of battery placement and propeller location which gave the rise to Design F. However, Design F is currently being 3D printed and it is not available for testing.

Besides the design flaws, one of the other errors that the team tried to avoid early was the inaccuracy of the sensors. So, the group conducted the reflectance sensor tests and found no errors with the sensors. However, the sensors were not always 100% accurate. The AEV often stopped at a difference of 5 marks. The team wanted to learn how this inaccuracy could be lowered so they performed the Coasting vs. Power Braking tests in the Advanced Research and Design (AR&D). The goal of this research was to determine whether Coasting or Power Braking was more accurate or more power consuming. Theoretically, the group assumed coasting should consume less power since no energy was being used to counter the force provided by the propellers, but it would also be less accurate since it was harder to predict where a moving object will stop when the coefficient of friction is unknown. Since power braking reverses the movement of the propellers to stop the AEV, it was safe to assume it would take more power than coasting. However, power braking made the movement of the AEV more controlled since it could stop the AEV almost instantly. So, the group assumed that power braking would be more accurate. Then the team performed the experiments to test whether the data matched the theory.

During the Coasting vs. Power Braking experiments, the data was not always error free either. The group found the errors made during the research and reported them accordingly. First, the battery was not changed for power braking tests due to the time limitation and limited battery available. This affected the efficiency of increasing AEV's speed. In the future tests, the group cannot avoid this problem, but the team will do their best to work around it. Second, Small power impulsions happened during braking process of coasting test 1-2. The energy consumed caused by this small power impulsion was almost 0. Even though the real reason had not been clarified yet, the team believed that this was due to the sensor's error. *Refer to Appendix D for details.*

Besides Coasting vs. Power Braking, the group conducted another research on Solidworks Simulations. In Solidworks Simulations, two of the team members conducted mass and motion study on the two AEV designs. *Refer to Appendix B for the results.* Since the AEV lost 0.89 pounds after the mass study, the group found this study helpful. The materials available on Solidworks were not exact materials present in the AEV, the weight difference was about 9% when comparing Solidworks design's mass to actual AEV's mass. However, even if the AEV was 9% heavier with the new weight, the AEV would still be lighter the original AEV.

After the mass study, the team conducted motion study in Solidworks. This study was much more challenging since the user interface for motion study was not well optimized. Since the data produced by motion study did not account for friction and air resistance, the data on *Appendix B* was not helpful. Also, many hours of practice are required to be proficient with this study. The animation conducted by Solidworks allocated an enormous amount of computer's graphics memory which was hard to run in many of the computers the group performed the study on. However, the video produced was smooth after it was uploaded so the latency was only temporary. *The findings of the motion study are provided in Appendix B.*

After performing both the AR&D research, the AEV's accuracy grew worse as the time for the PT1 grew closer. The group hypothesized that the sensors were at fault. The team recognized that the sensors failed the reflectance sensor test and did not respond properly to a simple brake code. The group replaced the sensors before the Performance Test 1 due to these issues. After the reflectance sensor issue was resolved, the data from AR&D helped improved the accuracy of AEV's stopping distance. During the performance test, the AEV was consistent and stopped properly before the gate and passed through the gate after 7 seconds. The team then received a perfect score of 16 for PT1. *Refer to Appendix I for PT1 data.*

Conclusion and Recommendations

The main task for the team's AEV was to travel by the track to pick up a cargo train and return by navigating a timed gate on both journeys while being as efficient as possible. During the Advanced Energy Vehicle project, the team followed the sequence of labs, and a comprehensive designing and testing plan was executed. By utilizing Arduino code programming and AEV data analysis tool, the team was able to improve AEV design's energy-efficiency and consistency gradually during the design process. Many factors had to be accessed to successfully complete team's main task. These included the general structure of the AEV, the braking method that AEV used, as well as the Arduino code.

The team's current AEV design evolved from designs C and D in terms of its stability, minimal blockage, and safety. By using the concept screening and scoring, the team combined the advantages of design C and D and eliminated the disadvantages. Generally, the team's current design had high stability due to the symmetrical structure. Additionally, the current design's motor placement maximally ensured the passengers' safety.

Through the coasting and power braking research, the team found that the power braking method could increase the braking accuracy even though it consumed more energy. Additionally, the team also found that the increasing weight reduced the braking accuracy. Since the team considered the consistency as the main priority, the power braking method was chosen as the braking method for the team's AEV.

The team recommends using code based on distance, not time. Inaccuracy from slight differences in acceleration, top speed, average speed, coasting distance can be minimized by using "goTo" rather than "goFor". This is because the end of one command and the beginning of another command will theoretically end and start at the same location (no matter the differences in acceleration, average speed, etc.). In other words, code based on time is dependent on every part of the code to be consistent in all forms, whereas each command in the code based on distance should be independent of each other. Further, braking accuracy is more consistent with power braking. So, to improve both accuracy and efficiency, the team recommends coasting for a set distance ("goTo") and then include a short-distance braking code (power depends on the speed of the coasting AEV).

The team has yet to create code to improve efficiency as accuracy continues to be an issue. The team has noticed that the accuracy of the sensors changes between each lab. For instance, the code for PT1 was accurate to an inch radius of the desired braking location, whereas this same code had a braking location radius of nine inches. Potentially, more advanced coding techniques can help to minimize sensor error. These coding techniques may include "if" statements and "while" loops. Also, running the sensor test helped to improve accuracy of the sensors. The justification for why this occurred has not been determined, but it is theorized to serve as a calibration for the sensor chips.

Appendix A

Concept Screening and Scoring

Concept Screening							
		Pravesh	Jingming	Feifan	Joe		
Success Criteria	Reference	Design A	Design B	Design C	Design D	Design E	Design F
Stability	0	+	+	+	+	+	+
Minimal Blockage	0	+	0	+	-	+	0
Lift	0	+	0	0	+	-	-
Weight	0	-	+	0	0	0	+
Safety	0	-	-	0	+	+	+
Sum +'s	0	3	2	2	3	3	3
Sum 0's	5	1	2	2	1	2	1
Sum -'s	0	2	1	0	1	1	1
Net Score	0	1	1	2	2	2	2
Continue?	Combine	No	No	Yes	Yes	Combine	Revise

Concept Scoring											
		Reference		Design C		Design D		Design E		Design F	
Success Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Stability	30%	3	0.9	3	0.9	4	1.2	4	1.2	4	1.2
Minimal Blockage	20%	3	0.6	3	0.6	4	0.8	4	0.8	5	1
Lift	10%	2	0.2	2	0.2	3	0.3	4	0.4	4	0.4
Weight	25%	3	0.75	4	1	3	0.75	2	0.5	3	0.75
Safety	15%	3	0.45	3	0.45	2	0.3	3	0.45	3	0.45
Total Score			2.9		3.15		3.35		3.35		3.8
Continue?		No		No		Develop		Develop		Yes	

Stability is the most important AEV criteria because with high stability, other criteria benefit.

Minimal Blockage is also essential so that the AEV does not bump into other materials and slow down

Lift is essential is lowering the weight due to multiple plane-like designs

Lower weight will help the AEV carry cargo easier as well as lower energy cost

Safety is essential for the well-being of the group and the budget for the company

Concept Scoring2	IMPROVED VERSION 2/28/18										
		Reference		**Design E**		**Design F**					
Success Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score				
Stability	30%	3	0.9	4	1.2	4	1.2				
Minimal Blockage	20%	3	0.6	1	0.2	5	1				
Lift	10%	2	0.2	4	0.4	1	0.1				
Weight	25%	3	0.75	2	0.5	4	1				
Safety	15%	3	0.45	3	0.45	3	0.45				
Total Score			2.9		2.75		3.75				
Continue?		No		Yes		Yes					
Design E (First Design on Website)											
Pros: Generates lift, reduces weight											
Cons: High blockage, heavy											
Design F (Second Design on Website)											
Pros: Minimal blockage, light, Compact											
Cons: Does not generate lift, Part placement highly affects stability											

Appendix B

Additional data available on the website below under "Motion Study" and "Mass Study"

https://u.osu.edu/eng1182groupn/solidworks-simulation/

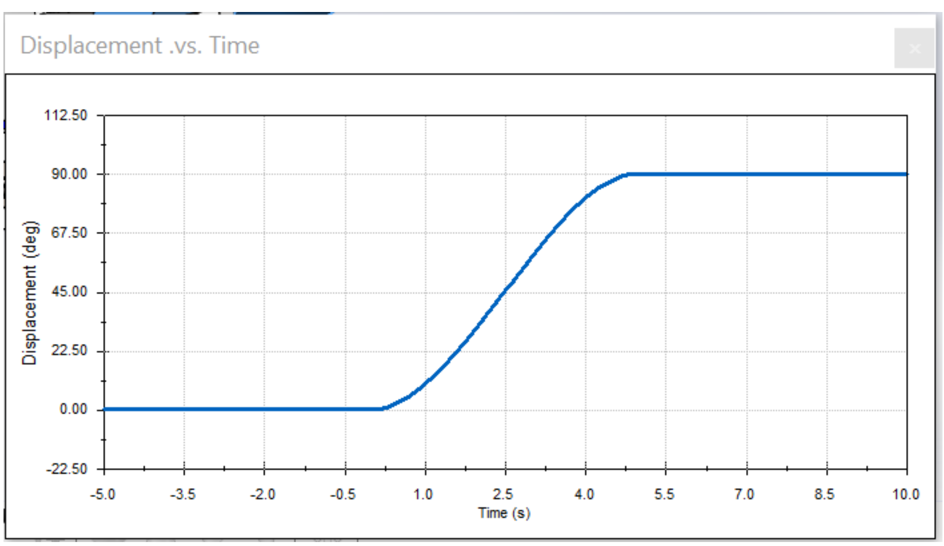


Figure 4. Motion study data for the displacement of the AEV as time increases.

Mass Study Data

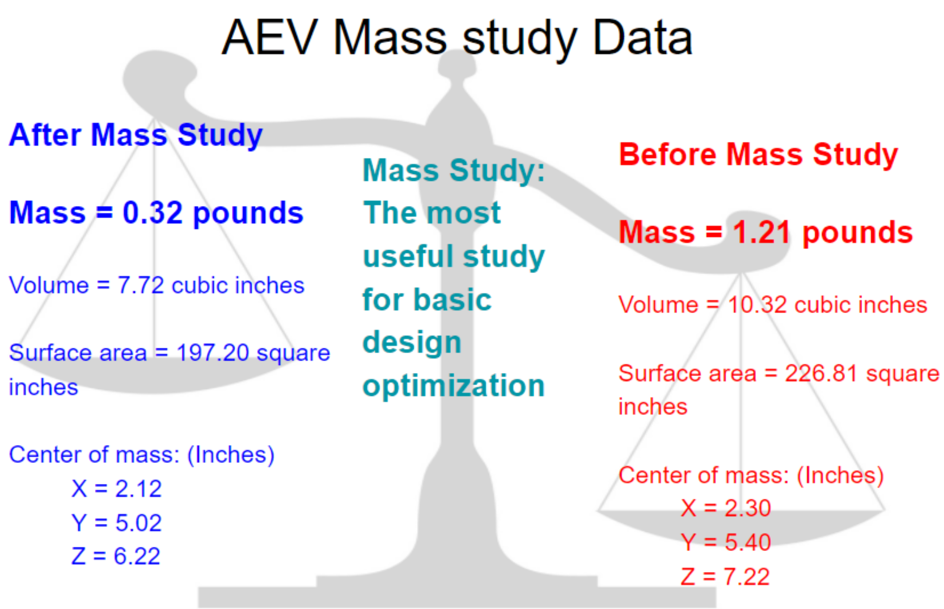


Figure 5. AEV mass study data containing mass, volume, surface area, and center of mass before mass study and after mass study.

Appendix C
Coasting vs Power Braking Codes

```
//accelerate all motors from 0 % power to 40% power in 2 seconds.
celerate(4,0,40,2);
//run at current speed for 2 seconds.
goFor(2);
//brake all motors.
brake(4);
```

Code 1. Coasting Test Arduino Code

Test Code for Power Braking:

```
//accelerate all motors from 0 % power to 40% power in 2 seconds.
celerate(4,0,40,2);
//run at current speed for 2 seconds.
goFor(2);
//brake all motors.
brake(4);
//reverses the polarity of all motors
reverse(4);
//accelerate all motors from 0 % power to 20% power in 2 seconds.
celerate(4,0,20,2);
//run at current speed for 2.2 seconds.
goFor(2.2);
```

Code 2. Coasting Test Arduino Code

Appendix D
Coasting vs Power Braking Data

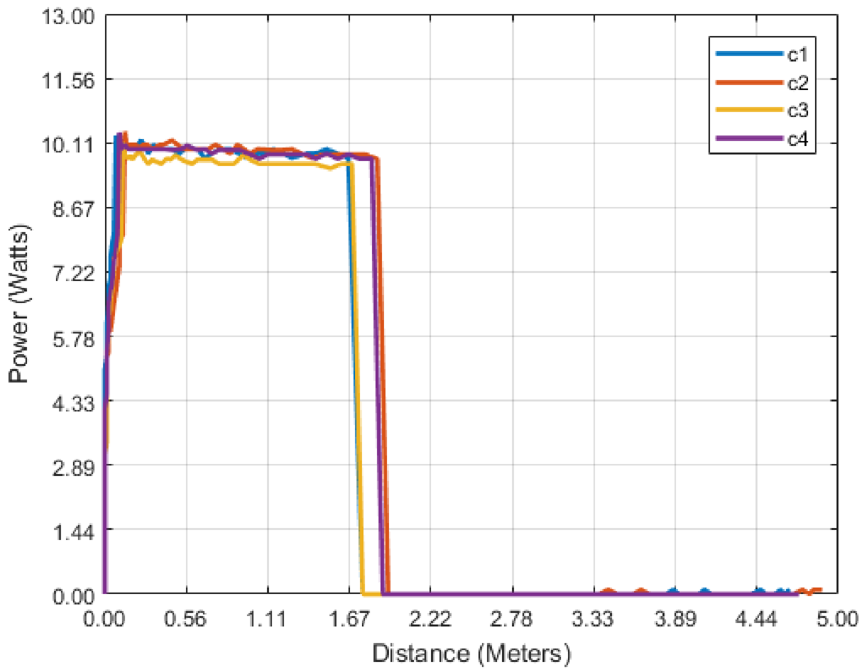


Figure 6. Power(Watts) vs Distance(Meters) Plot (Coasting Test 1-4)

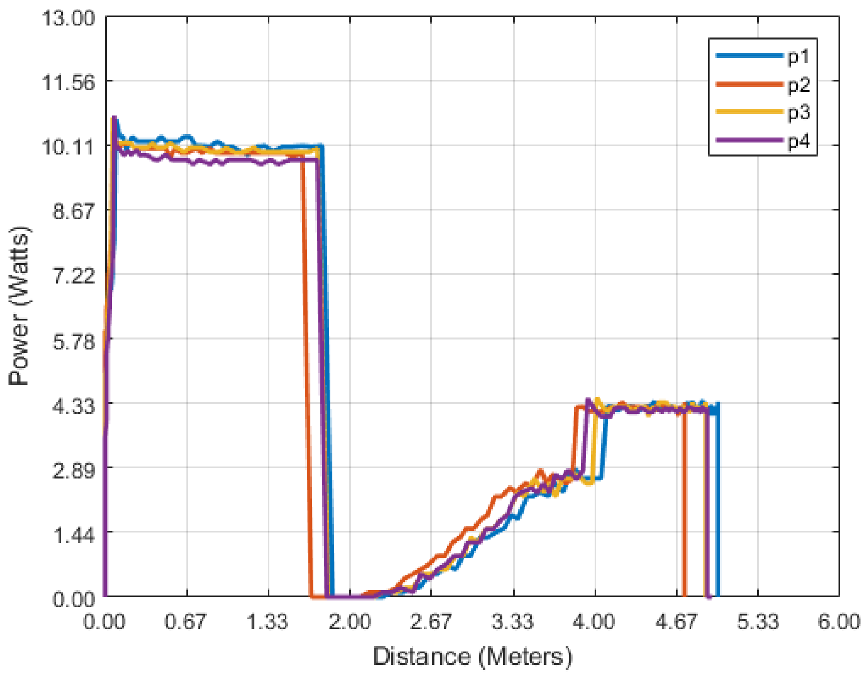


Figure 7. Power(Watts) vs Distance(Meters) Plot (Power Braking Test 1-4)

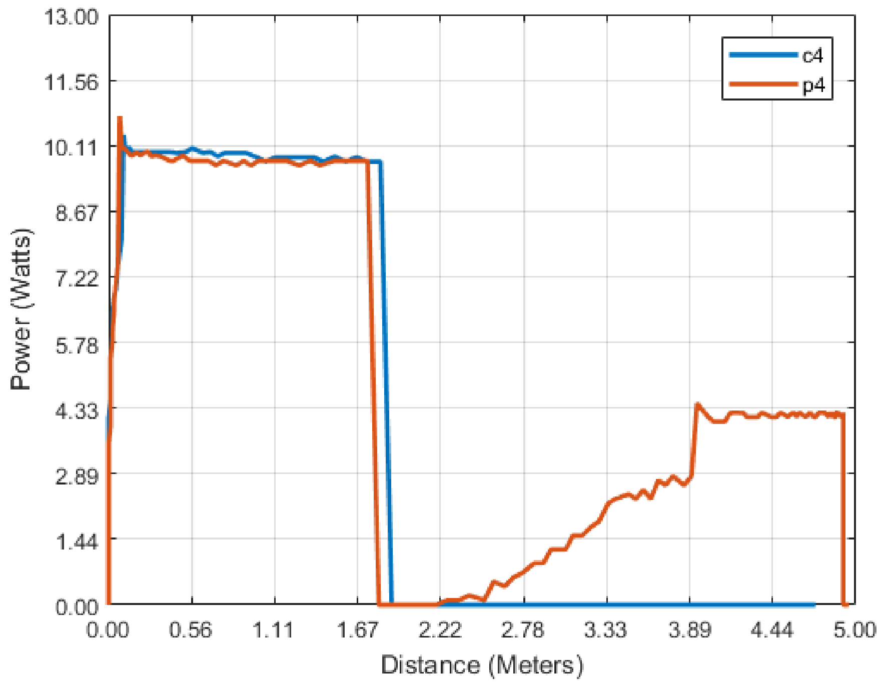


Figure 8. Power(Watts) vs Distance(Meters) Plot (Coasting Test 4 vs Power Braking Test 4)

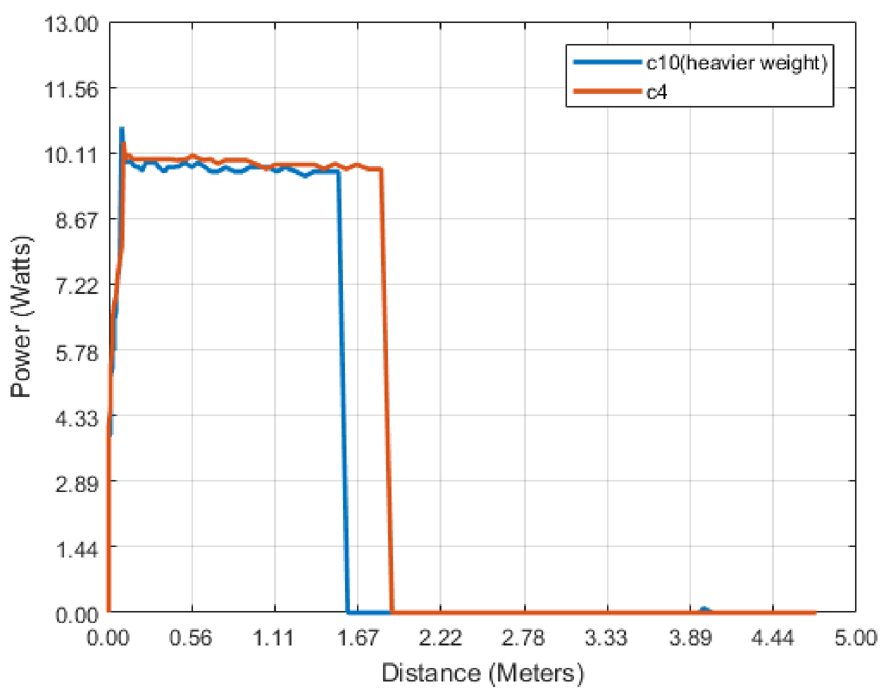


Figure 9. Power(Watts) vs Distance(Meters) Plot (Coasting 260 grams vs 293 grams)

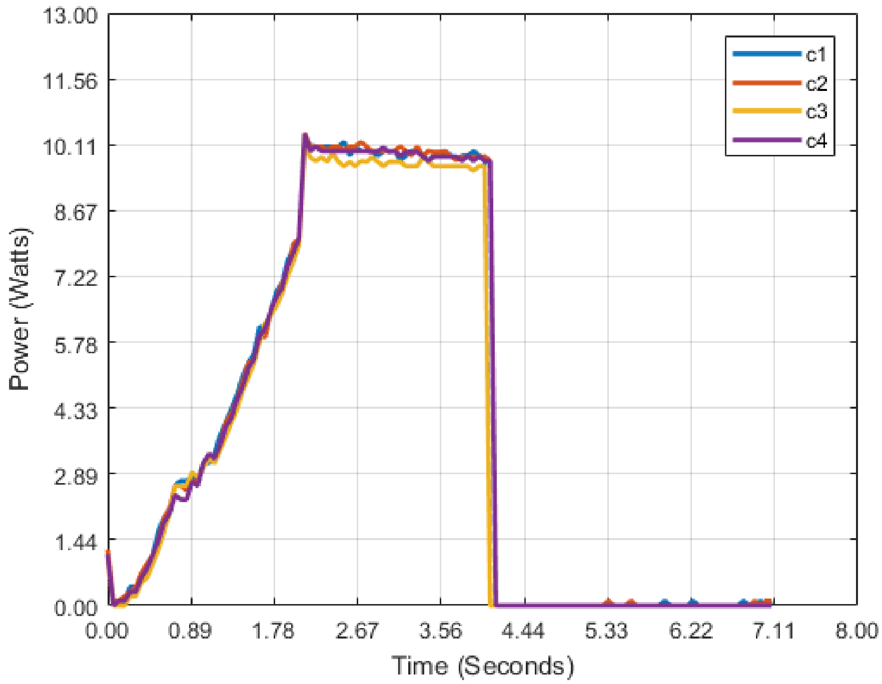


Figure 10. Power(Watts) vs Time(Seconds) Plot (Coasting Test 1-4)

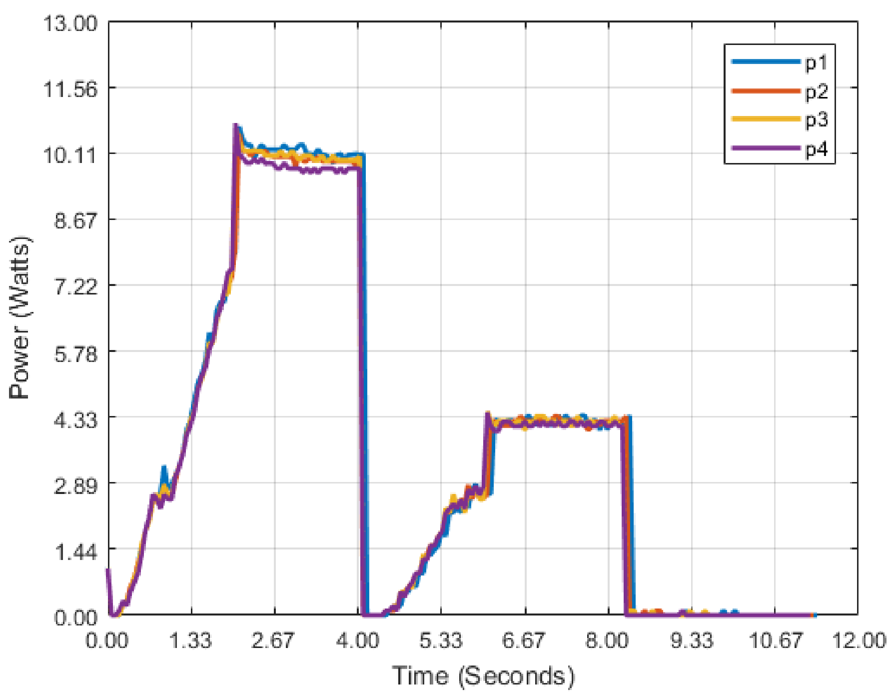


Figure 11. Power(Watts) vs Time(Seconds) Plot (Power Braking Test 1-4)

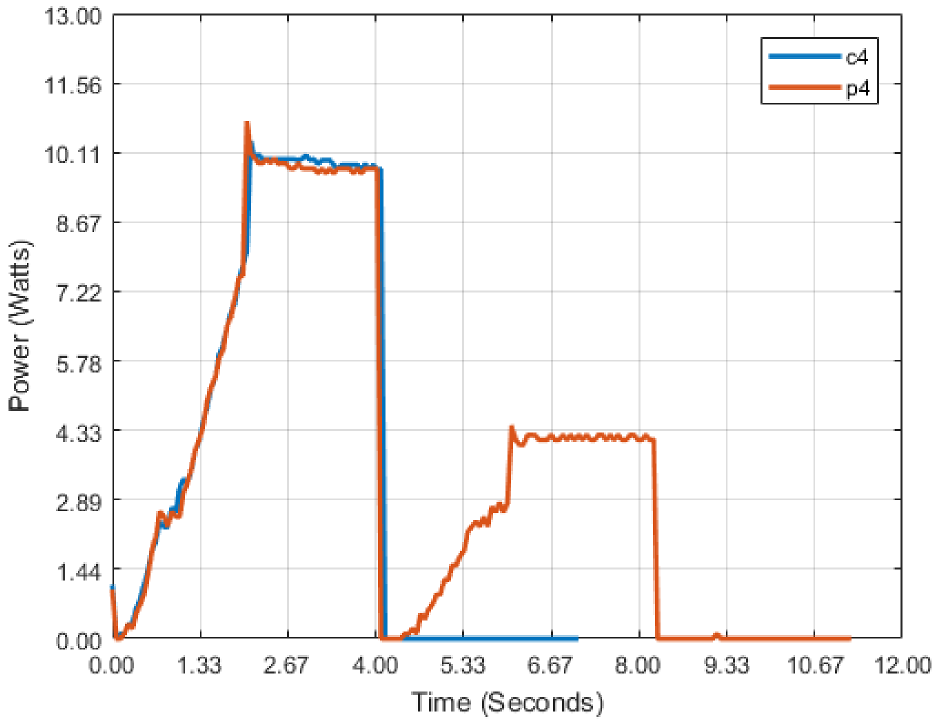
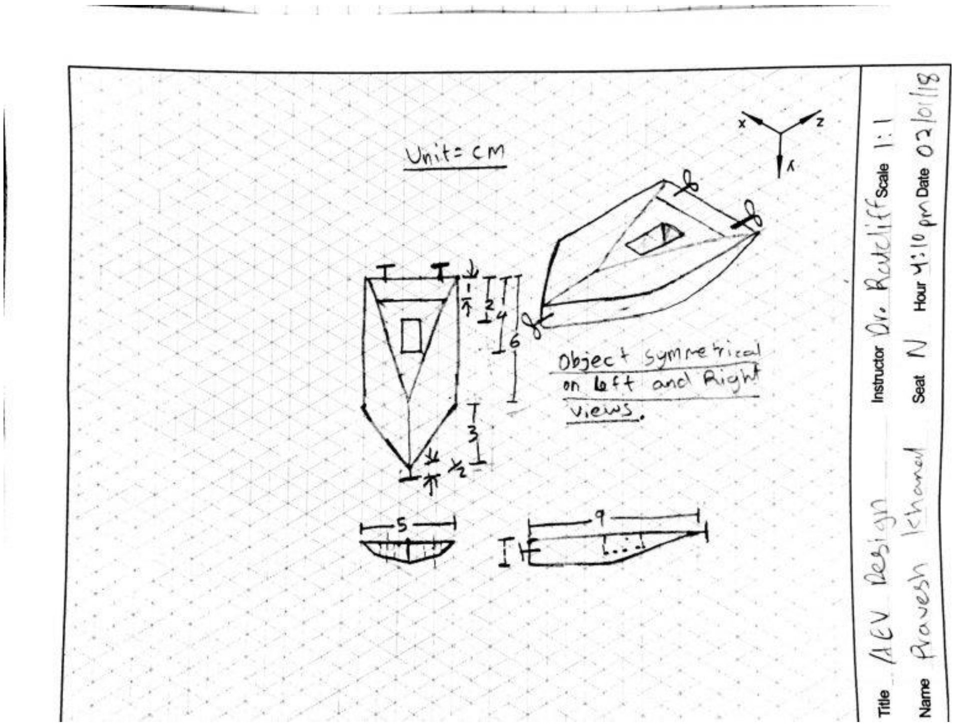


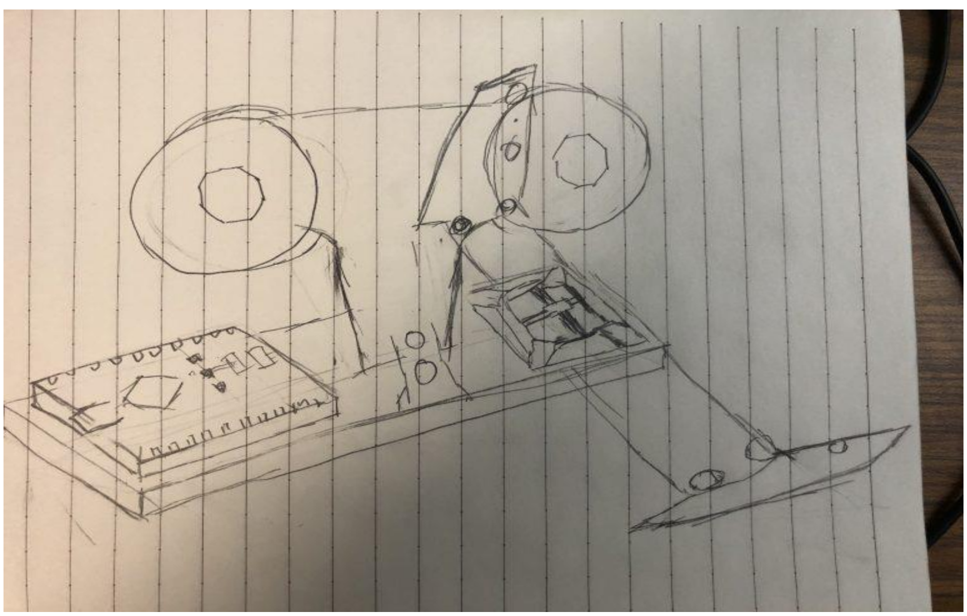
Figure 12. Power(Watts) vs Time(Seconds) Plot (Coasting Test 4 vs Power Braking Test 4)

Appendix E

Design A

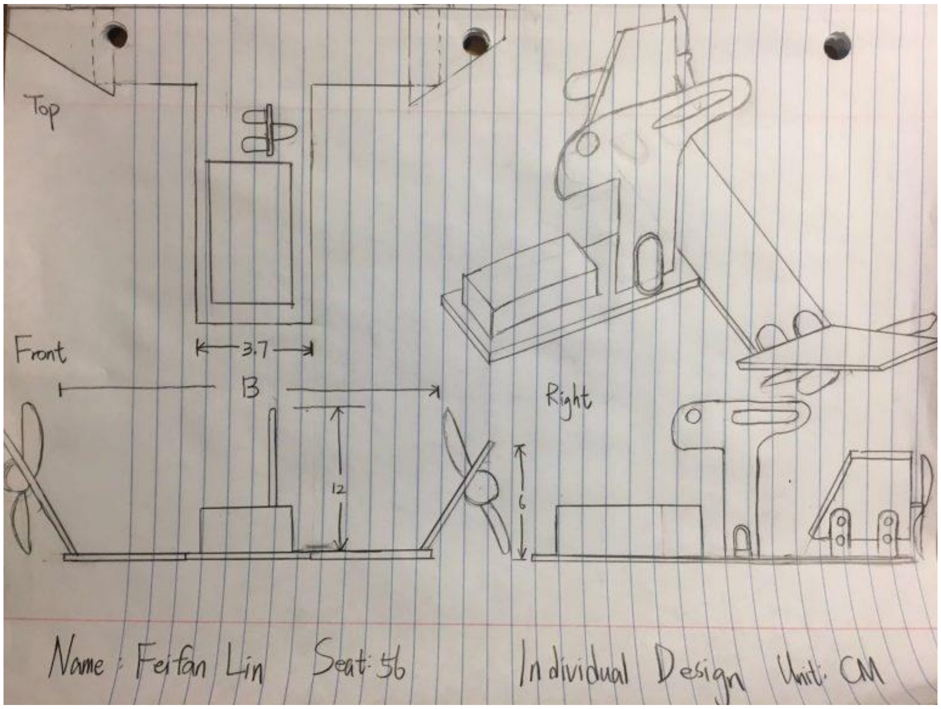


Design B

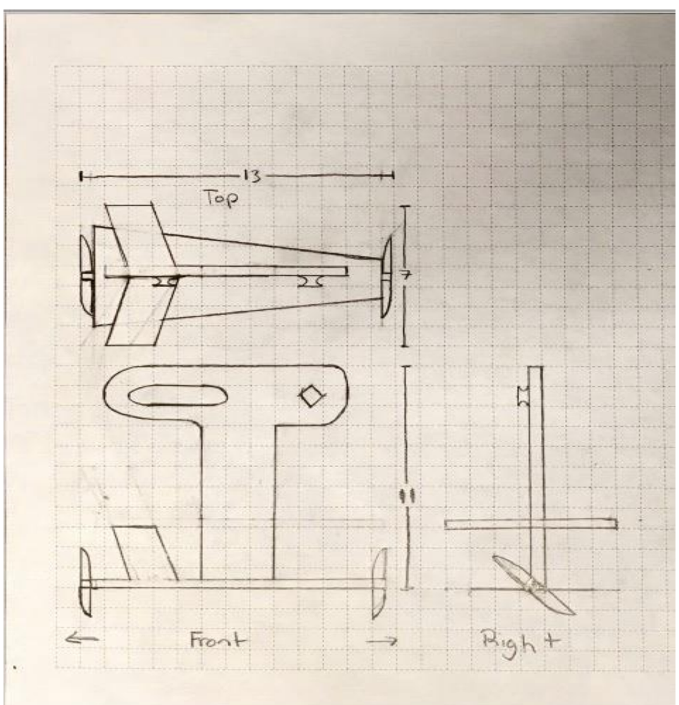


Appendix F

Design C

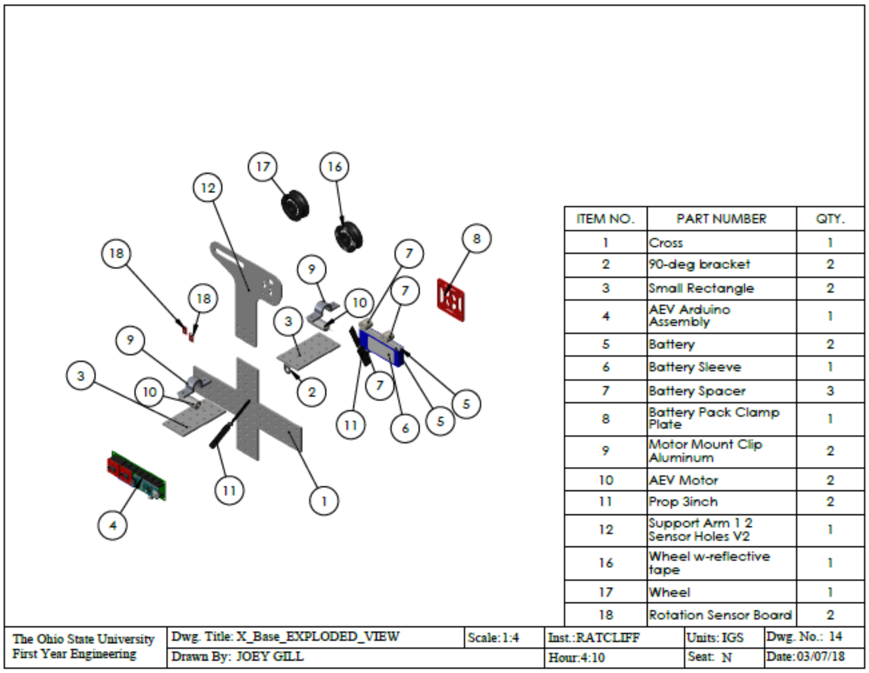


Design D



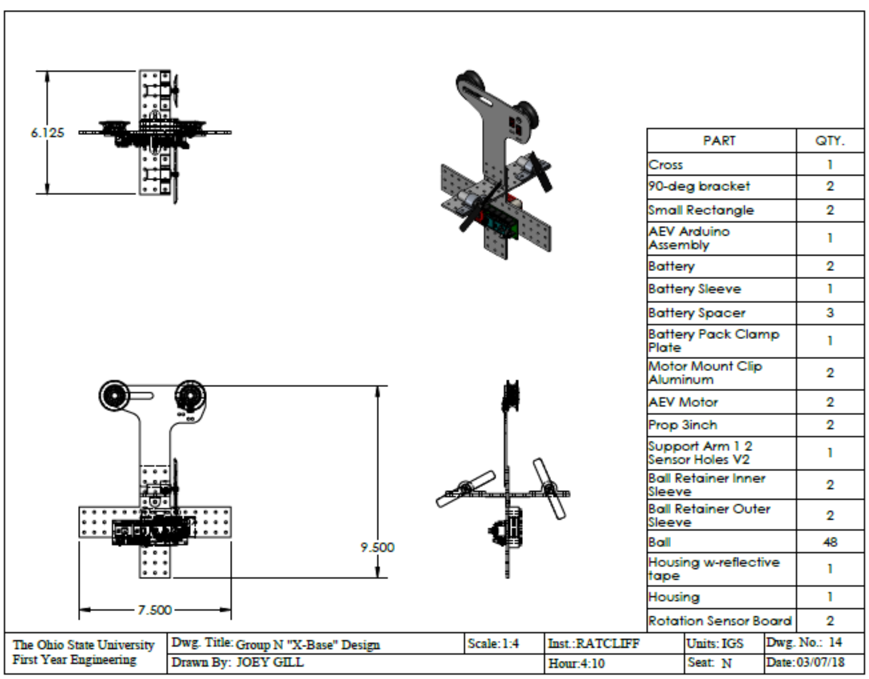
Appendix G

Current AEV: Design E



ITEM NO.	PART NUMBER	QTY.
1	Cross	1
2	90-deg bracket	2
3	Small Rectangle	2
4	AEV Arduino Assembly	1
5	Battery	2
6	Battery Sleeve	1
7	Battery Spacer	3
8	Battery Pack Clamp Plate	1
9	Motor Mount Clip Aluminum	2
10	AEV Motor	2
11	Prop 3inch	2
12	Support Arm 1 2 Sensor Holes V2	1
16	Wheel w-reflective tape	1
17	Wheel	1
18	Rotation Sensor Board	2

Figure 13. Current AEV base. Exploded view with bill of materials.

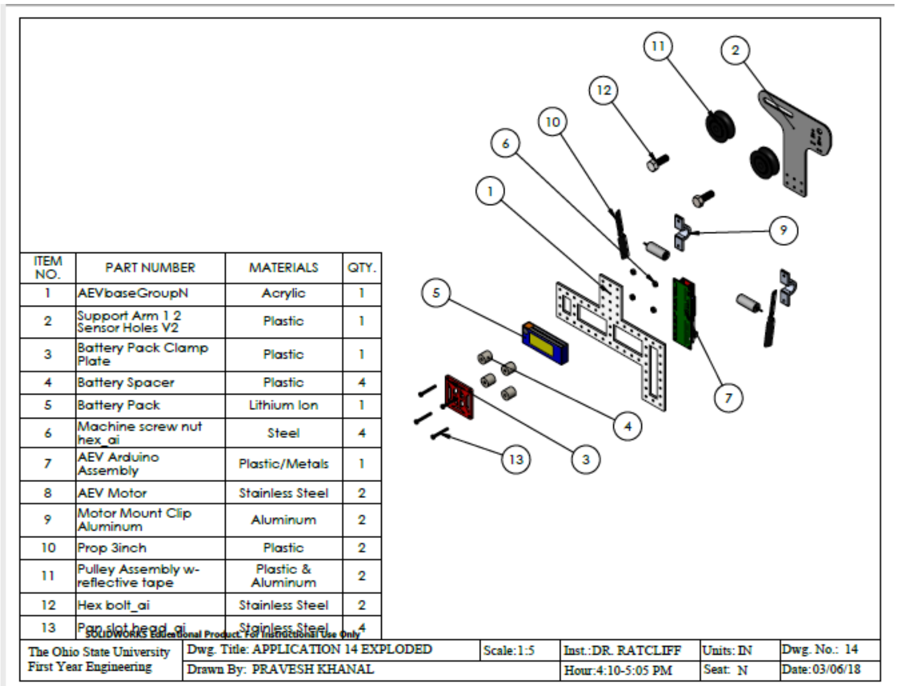


PART	QTY.
Cross	1
90-deg bracket	2
Small Rectangle	2
AEV Arduino Assembly	1
Battery	2
Battery Sleeve	1
Battery Spacer	3
Battery Pack Clamp Plate	1
Motor Mount Clip Aluminum	2
AEV Motor	2
Prop 3inch	2
Support Arm 1 2 Sensor Holes V2	1
Ball Retainer Inner Sleeve	2
Ball Retainer Outer Sleeve	2
Ball	48
Housing w-reflective tape	1
Housing	1
Rotation Sensor Board	2

Figure 14. Current AEV base. Drawing with basic dimensions and bill of materials.

Appendix H

Main AEV: Design F



ITEM NO.	PART NUMBER	MATERIALS	QTY.
1	AEVbaseGroupN	Acrylic	1
2	Support Arm 1 2 Sensor Holes V2	Plastic	1
3	Battery Pack Clamp Plate	Plastic	1
4	Battery Spacer	Plastic	4
5	Battery Pack	Lithium Ion	1
6	Machine screw nut hex_ai	Steel	4
7	AEV Arduino Assembly	Plastic/Metals	1
8	AEV Motor	Stainless Steel	2
9	Motor Mount Clip Aluminum	Aluminum	2
10	Prop 3inch	Plastic	2
11	Pulley Assembly w-reflective tape	Plastic & Aluminum	2
12	Hex bolt_ai	Stainless Steel	2
13	Pan slot head_ai	Stainless Steel	4

Figure 15. Main AEV base. Exploded view with bill of materials.

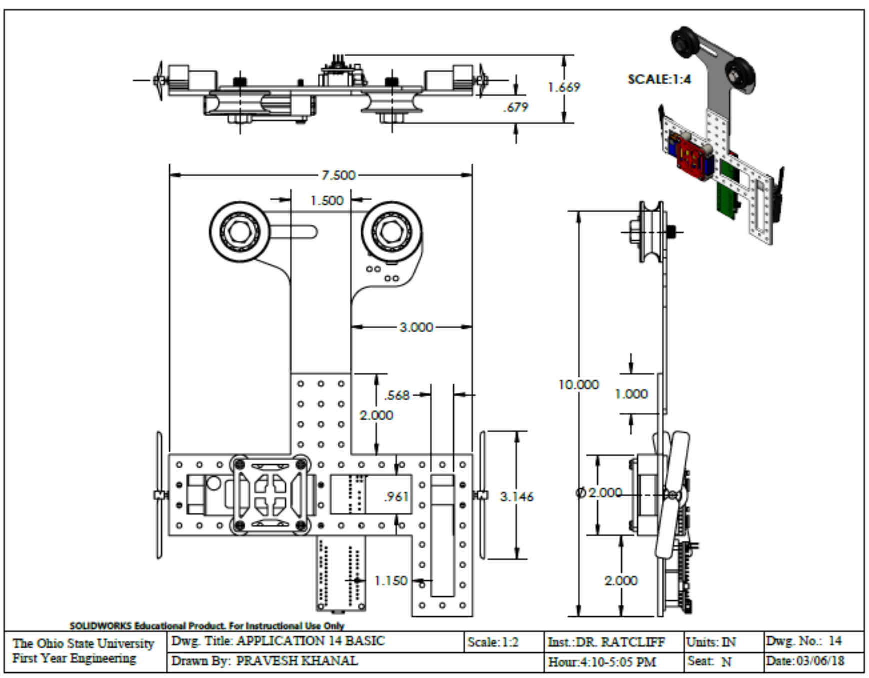


Figure 16. Main AEV base. Drawing with basic dimensions.

Appendix I

Performance Test 1 Data

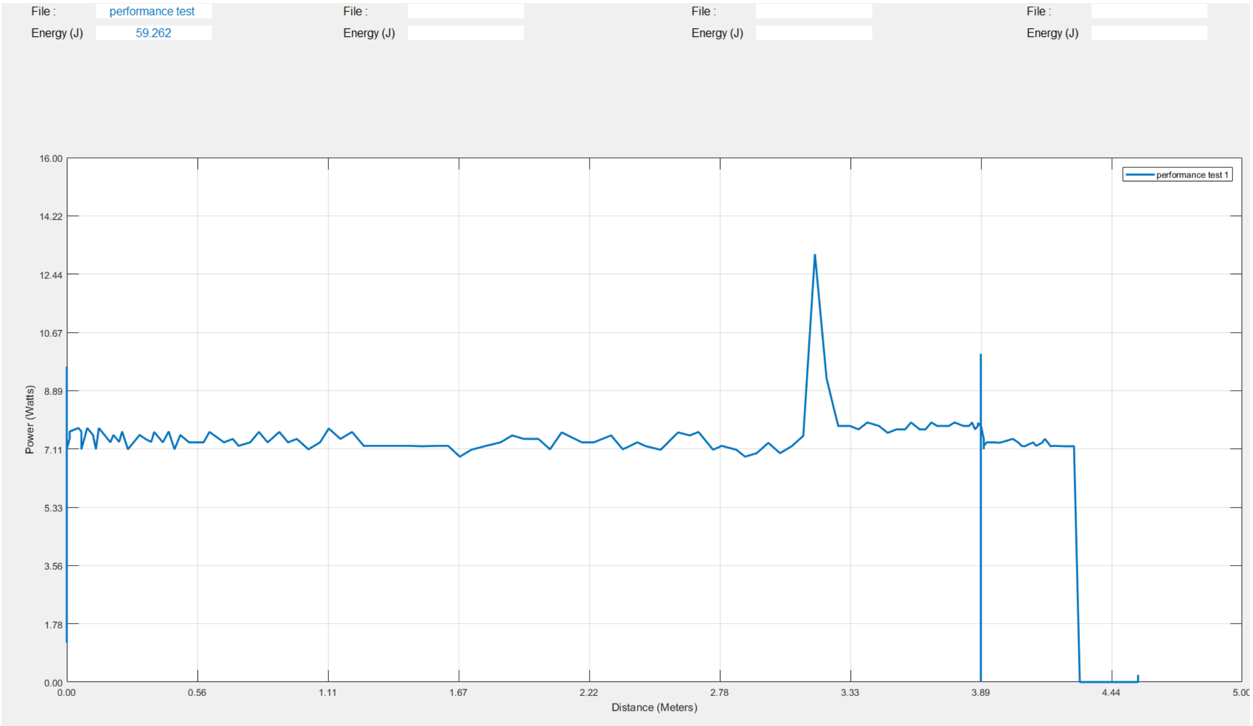


Figure 17. Power(Watts) vs Distance(Meters) Plot (Performance Test 1)

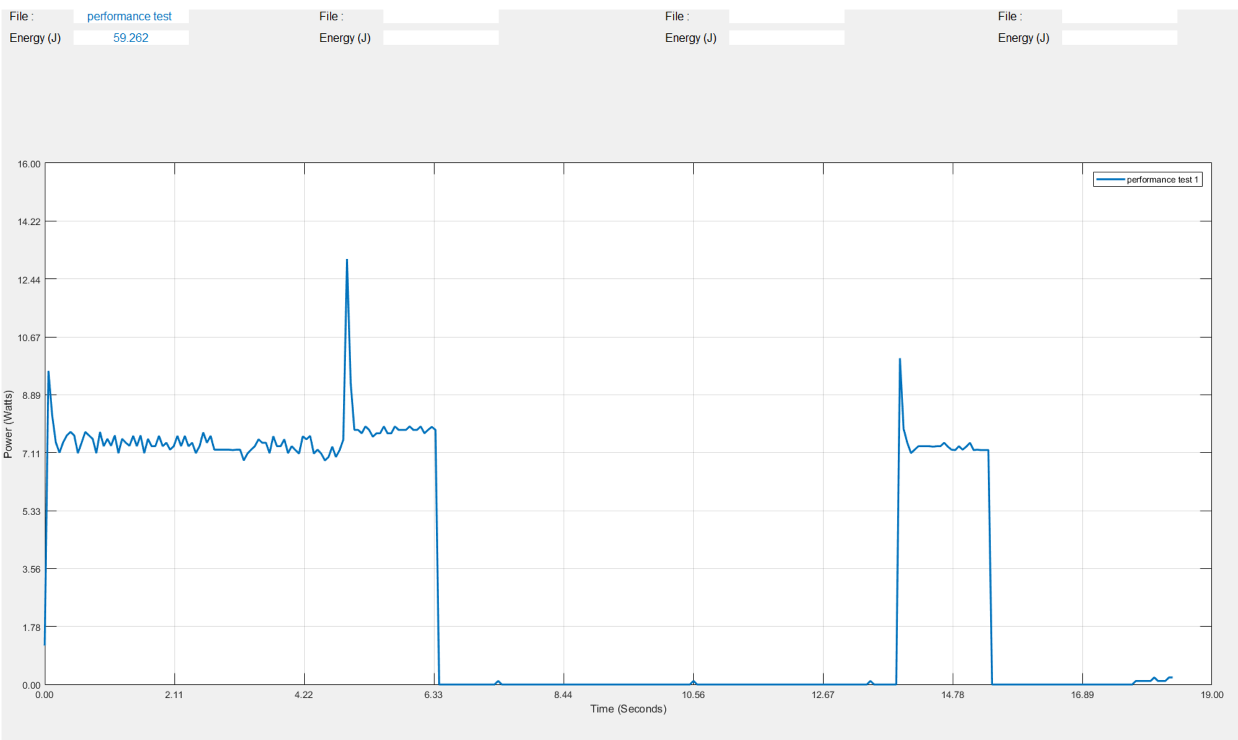


Figure 18. Power(Watts) vs Time(Seconds) Plot (Performance Test 1)

Appendix J

Team Meeting Minutes

Week 5

February

Meetings #10,11

Date: February 8, 2018
Time: 5:30 PM – 9:30 PM (face to face)
Place: Hitchcock 324, 224
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Progress Report and AEV Design

Date: February 9, 2018
Time: 2:55 PM – 5:15 PM (face to face)
Place: Hitchcock 224
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Coasting vs. Power Braking

Objective:
During the week 5 meetings, the group's goal is to finish the Progress report 1 and start Advanced Research and Design.

To do/Action items:
The group attended the 5:30 lab on Thursday to make up lab 2 and lab 4. They discussed details about the AEV design and tested their code during this time. After the make-up lab, the group met in Engineering lab 324 for 4 hours to discuss the progress report and each person's responsibility.

The group researched Coasting vs. Power braking. The group tested two separate codes to determine whether Coasting or Power braking was more energy efficient. The group discussed how wedge-like wings could potentially harm the AEV stopper since it is like catching a knife. The team encountered several problems when uploading the code to the AEV. The AEV was not recognizing the reverse command. The coder, Feifan learned that a brake command did not have a time specified which caused the motor to be powerless and the reverse command was not working. Joey noticed the error and told Feifan to fix the error which ultimately fixed the problem. The team was confident that 50% power would not be too much, but the result showed that the AEV reversed too much.

Initial ideas:
Provide specific roles for each member for Coasting vs. Power Braking. (J.G., F.L. P.K., J.C.)
Each member received a part for Coasting vs. Power Braking.

Review the Advanced R&D topics for the lab. (J.G., P.K.)

Update the website for each part in Committee Meeting 1. (P.K., J.G., F.L., J.C.)

Decisions:
-Finish each assigned role before the submission deadline for upcoming deliverables. (FL, JG, JC, PK)

-Prepare for additional Advanced R&D topics. (FL, JG, JC, PK)

-Plan ahead for the upcoming presentations (PK, FL, JG, JC)

Upcoming tasks:
Prepare for another Advanced R&D topics. (J.G.)

Start the Progress Report 2 deliverables. (P.K.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 6

February
Meetings #12,13,14

Date: February 12, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Grant Proposal Roles

Date: February 15, 2018
Time: 5:30 PM – 9:30 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Committee Meeting 1 and Grant Proposal

Date: February 16, 2018
Time: 2:55 PM – 5:15 PM (face to face)
Place: Hitchcock 224
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Grant Proposal Presentation and Committee Meeting 1

Objective:
During the week 6 meetings, the group's goal is to finish the grant proposal presentation and the committee meeting 1.

To do/Action items:
In the tenth meeting, the group talked about various base designs for the grant proposal. Joey asked the team what we would decide on the number of blades on the propeller. The team also assigned each member a specific part of the grant proposal presentation.

In the eleventh meeting, the group met in the Engineering lab to discuss and finish the committee meeting 1. Pravesh wrote down the team meeting notes and organized the presentation for the grant presentation. Feifan modeled the base as the part being pitched. Pravesh discovered that the current design had a flaw because it lacked a place to attach a magnet. So, the group decided to modify the design to have an attachment at the back of the AEV to hold the magnet.

In the twelfth meeting, the group finalized the grant proposal an hour before the lab in HI 324. Joey presented the grant proposal. The group discussed each part in the committee meeting. Joey and Jingming were responsible for the research and development aspect and Feifan was responsible for public relations. Pravesh submitted the HR portion of the committee meeting online.

Initial ideas:
Provide specific roles for each member for Grant Proposal and Committee Meeting 1. (J.G., F.L. P.K., J.C.) Each member received a part of Committee Meeting 1.

Review the Advanced R&D topics for the lab. (J.G., P.K.)

Update the website for each part in Committee Meeting 1. (P.K., J.G., F.L., J.C.)

Decisions:
-Finish each assigned role before the submission deadline for Committee Meeting 1. (FL, JG, JC, PK)

-Prepare for Advanced R&D topics. (FL, JG, JC, PK)

-Rehearse the presentation for the Grant Proposal (PK, FL, JG, JC)

Upcoming tasks:
Prepare for Advanced R&D topics. (J.G.)

Start the Progress Report 1 deliverables. (P.K.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 7

February
Meetings #15,16

Date: February 21, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Advanced R&D topics

Date: February 23, 2018
Time: 2:55 PM – 5:15 PM (face to face)
Place: Hitchcock 224
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Pravesh Khanal (P.K.)
Topic: Coasting vs. Power Braking and Solidworks Simulation

Objective:
During the week 6 meetings, the group's goal is to finish Coasting vs. Power braking research as well as start a new research for Wind tunnel. If the Wind tunnel is not working, Solidworks simulation is the next option.

To do/Action items:
In the 15th meeting, the group discussed how Solidworks assembly could be used to model AEV designs. This discussion led the group to talk about Solidworks Simulation. The group considered researching Solidworks simulation since it could provide a useful insight into designing the AEV and analyzing its properties.
In the 16th meeting, the group finished Coasting vs. Power Braking and discussed the results with the team. The wind tunnel lab was canceled, so Pravesh and Jingming decided to start Solidworks Simulation for the group's second research.

Initial ideas:
Research Solidworks simulations. (J.G., F.L. P.K., J.C.) Pravesh and Jingming received a part for Solidworks simulations.

Review the Advanced R&D topics for the lab. (J.G., P.K.)

Update the website for each part in Committee Meeting 1. (P.K., J.G., F.L., J.C.)

Decisions:
-Pravesh and Jingming will finish Solidworks simulations and upload the data for the upcoming presentation. (FL, JG, JC, PK)

-Prepare for Advanced R&D topics. (FL, JG, JC, PK)

-Rehearse the presentation for the oral presentation. (PK, FL, JG, JC)

Upcoming tasks:
Prepare for oral presentation. (J.G.)

Start the Progress Report 2 deliverables. (P.K.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 8

February
Meetings #17,18

Date: February 26, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Pravesh Khanal (P.K.)
Topic: Website Update 3 and Progress Report 1 Rewrite

Date: March 02, 2018
Time: 2:55 PM – 5:15 PM (face to face)
Place: Hitchcock 224
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Pravesh Khanal (P.K.)
Topic: Website Update 3

Objective:
During the week 8 meetings, the group's goal was to update the Website with the new Advanced Research & Design data as well as finish rewriting Progress Report 1.

To do/Action items:
In the 17th meeting, the team discussed the aspects of Progress Report 1 that needed improvement. Since the forward-looking portion of the Progress Report 1 was non-existent, the group asked TAs questions on what this portion is supposed to contain.
In the 18th meeting, the group met in HI computer lab 224 to discuss what the Website Update 3 was missing. Since the Website Update required updated team meeting notes, the group had to coordinate with other members to discuss whether the meeting notes were up to date.

Initial ideas:
Upload the Solidworks Simulations data on the website. (J.G., F.L. P.K.) Pravesh decided to upload the data in the website.

Upload the Coasting vs. Power Braking data into the website. (J.G., P.K.) Joey and Feifan will upload these materials.

Update the website for the team meeting notes. (P.K.) Pravesh will update the team meeting notes.

Decisions:
-Pravesh and Jingming will finish Solidworks simulations studies and upload the data on the Website. (JC, PK)

-Joey and Feifan will upload the data from Coasting vs Power Braking on the website. (FL, JG)

-Update the Team meeting notes. (PK)

Upcoming tasks:
Progress report 2 forward-looking portions. (J.G.)

Start the Progress Report 2 deliverables. (PK, JG, FL, JC)

Progress report 2 Solidworks Simulations potion. (PK, JC)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 9

March

Meetings #19,20

Date: March 07, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Pravesh Khanal (P.K.)
Topic: AEV Base Printing and Progress Report 2

Date: March 08, 2018
Time: 4:45 PM – 5:20 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Pravesh Khanal (P.K.)
Topic: Progress Report 2 and Website

Objective:
During the week 9 meetings, the group's goal was to update the Website, send AEV base to be printed out, and finish Progress Report 2.

To do/Action items:
In the 19th meeting, the group still needed to send the AEV base design to one of the TAs to be 3D printed. Right before submitting the design, the group had to alter the design of the AEV on the front part where the motor is located because the magnet placement interfered with the location of the motor.
In the 20th meeting, the group needed to meet and finalize progress report 2 as well as update the meeting notes on the website. Since this is the last meeting note that is being submitted on the Progress Report 2, the group had to double check the meeting notes for any errors.

Initial ideas:
Format everyone's part in Progress Report. (J.G., F.L. P.K., J.C.) Pravesh decided to format the Progress Report.

Implement the Coasting vs. Power Braking data into the report. (J.G., F.L.) Joey and Feifan have completed these materials.

Update the website for the team meeting notes. (P.K.) Pravesh will update the team meeting notes.

Decisions:
-Pravesh will format the Progress Report and number the Appendix accordingly (JC, PK)

-Joey and Feifan will write the Coasting vs Power Braking report. (FL, JG)

-Update the Team meeting notes. (PK)

-Joey will write the future portion of the Progress Report. (JG)

Upcoming tasks:
Progress report 2 submissions. (P.K.)

Prepare for the Performance Tests. (P.K., J.G., F.L., J.C.)

Write code for Performance Tests. (F.L.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 10

March

Meetings #21, 22, 23, 24

Future Schedule

Date: March 09, 2018
Time: 3:55 PM – 5:05 PM (face to face)
Place: Hitchcock 224
Members Present: Feifan Lin (F.L), Joey Gill(J.G), Pravesh Khanal(P.K), Jingming Chen (J.C)
Topic: Accuracy for combined Coasting and Power Braking

Date: March 19, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G), Pravesh Khanal(P.K), Jingming Chen (JC)
Topic: Optimize Speed for Optimal Power Braking / Performance Test 1

Date: March 21, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G), Pravesh Khanal (P.K), Jingming Chen (JC)
Topic: CDR Draft / Optimize Speed for Optimal Power Braking

Date: March 23, 2018
Time: 3:55 PM – 5:05 PM (face to face)
Place: Hitchcock 224
Members Present: Feifan Lin (F.L), Joey Gill(J.G), Pravesh Khanal(P.K), Jingming Chen (J.C)
Topic: CDR Draft and Performance Tests

Objective:
During the week 10 meetings, the group completed Optimal Speed to Optimize Braking accuracy, performance Test 1, and CDR draft.

To do/Action items:
During the 21st meeting, the group tested the accuracy for combined Coasting vs. Power Braking.
In the 22nd meeting, the team conducted experiments to Optimize Speed for Optimal Power Braking.
In the 23rd meeting, the group discussed CDR draft and completed the Optimize Speed for Optimal Power Braking.
During the 24th meeting, the team completed the CDR draft and begun Performance Test 2.

Initial ideas:
Experiment and test Accuracy for combined Coasting and Power Braking. (J.G., F.L.) Joey and Feifan will complete this task.

Optimize Speed for Optimal Power Braking. (J.G., F.L., P.K.)

Update the website for the team meeting notes. (P.K.) Pravesh will update the team meeting notes.

Update the website with the new data from the labs.

Decisions:
-Experiment and test Accuracy for combined Coasting and Power Braking. (FL, JG)
-Optimize Speed for Optimal Power Braking. (FL, JG, PK)
-Update the Team meeting notes. (PK)
-CDR draft should be completed during the week after Spring break (JC, PK)

Upcoming tasks:
Performance Test 1.

CDR Draft. (P.K., J.G., F.L., J.C.)

Write code for Performance Tests. (F.L.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 11

March

Meetings #25, 26, 27

Future Schedule

Date: March 26, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Expected: Feifan Lin (F.L), Joey Gill(J.G), Pravesh Khanal(P.K), Jingming Chen (J.C)
Topic: Performance Test 2/ Committee Meeting 2

Date: March 28, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Expected: Feifan Lin(F.L.), Joey Gill(J.G), Pravesh Khanal(P.K), Jingming Chen (JC)
Topic: Performance Test 2/ Committee Meeting 2

Date: March 30, 2018
Time: 3:55 PM – 5:05 PM (face to face)
Place: Hitchcock 224
Members Expected: Feifan Lin (F.L), Joey Gill(J.G), Pravesh Khanal(P.K), Jingming Chen (J.C)
Topic: Committee Meeting 2/ Progress Report 3
XXX

Objective:
During the week 11 meetings, the group will complete Performance Test 2, Committee Meeting 2, and start Progress Report 3.

To do/Action items:
During the 25st meeting, the group plans to complete Performance Test 2 and start organizing data for the upcoming committee meeting.
In the 26th meeting, the team will finish Performance Test2 if it was not finished on the 25th meeting.
In the 27th meeting, the group will discuss Progress Report 3 and conclude the Committee Meeting 2 in lab.

Initial ideas:
Test the Arduino code for the Performance Test 2. (J.G., F.L.) Joey and Feifan will complete this task.

Discuss the Committee Meeting 2 and provide roles for each member. (J.G., F.L., P.K.)

Update the website for the team meeting notes. (P.K.) Pravesh will update the team meeting notes.

Update the website with the new data from the labs.

Decisions:
-Performance Test 2 will be done by Feifan and Joey. Pravesh will help with spotting the AEV. (FL, JG)
-Start data organization for Committee Meeting 2. (FL, JG, PK, JC)
-Update the Team meeting notes. (PK)
-Update the Website. (FL, PK)

Upcoming tasks:
Performance Test 2.

Committee Meeting 2 (P.K., J.G., F.L., J.C.)

Write code for Performance Tests. (F.L.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Appendix K

Future Schedule

For roles and other details, refer to Appendix J, Week 11 Team Meeting Notes

Table 2: Future schedule for upcoming weeks with percentage completed

Task	Subtasks	Start Date	Due Date	Time	Teammates	Materials	% Complete
Performance Test 2	Write Arduino code for the scenario	3/26/2018	3/28/2018	1 hour	Feifan, Joey	AEV,Battery, Rails	70%
Performance Tests	Collect data and improve accuracy	3/28/2018	3/30/2018	2 hours	Joey, Feifan, Pravesh	AEV,Battery, Rails	50%
Committee Meeting 2	Organize data and assign roles	3/26/2018	3/30/2018	1 hour	All	Computer, Data	10%
Progress Report 3	Collect PT1 Data and assign roles	3/30/2018	4/4/2018	3 hours	All	AEV,Battery, Rails, PC	20%

Appendix L

Website Materials Used in AEV Labs

Mission Concept Review(MCR) and deliverables
https://osu.app.box.com/s/3mal1rsekfbvd5oflbhmbuahawq9oc8p
Preliminary R &D
https://osu.app.box.com/s/ter1ysxfl88vej3wezqleed30cymth1p
Advanced R&D
https://osu.app.box.com/s/8qetsj0dtopzr1m0zljcyaj5fio3c33x
Group N Website
https://u.osu.edu/eng1182groupn/