Critical Design Review

Submitted To:
Instructor Greg Bixler
GTA Isabel Fernandez

Created By:
Team O

Jacob Dougherty
Kezia Namenyi
Kia Ruffin
Tongshuai Zhang

Engineering 1182
The Ohio State University
Columbus, OH
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Abstract:

The purpose of the AEV project was to research and test the concepts and findings and apply them through evaluated testing in order to design a fully functioning AEV. The performance tests were essential when it came to optimizing the AEV design, as one of the requirements for the performance tests was to look for ways in which data could be used to reflect the performance of the AEV effectively and to justify the decisions that were made in order to improve the designs concept as the goal of completing the final performance test is pursued.

The decisions mentioned above involved problems such as deciding how the battery voltage influences the running distance and time of AEV, which method stops the AEV consistently, which design is the most efficient, and finding a relationship between the distance travelled by the AEV and battery voltage or battery voltage and number of trials. Dreese Data Systems Group O specifically focused on testing battery voltage and how power braking stops the AEV vs coasting, which was important as we decided which method to use to control the coasting distance.

The ultimate goal was to create a functional AEV for the pilot program that has the capability of transporting people between three typical areas in Columbus (Residential Districts (Linden) to Easton and Polaris). All the other goals were related to meeting the different parts for the pilot program that were due at specific times. During Performance Test 1, the AEV stopped at a designed area, waited for seven seconds for the gate to open up, and then continued to go on to the next step. These smaller missions all contributed to the larger goal of being able to move people to different locations, so that these people would be able to access certain goods and services as quickly and accurately as possible by using the smart equipments.

Looking at the bigger picture, there was a need for an advanced energy vehicle because of all of the benefits that it would provide for people, including things like safety, enhanced mobility, controllability, efficiency in time and space, and less pollution to the environment. In order to meet all of these tasks, Team O has been working in collaboration with other teams in Dreese Data Systems with each team focusing on something different. Team O believes that rigorous testing will best optimize the AEV design and thus minimize spending by meeting all the requirements. From the findings of the research and development portion, Team O tends to uses power braking method to solve the problem involving coasting movements for the AEV. The main reasoning behind this is that power braking can give more control over the AEV's stopping potential and then can better control the sliding distance, which leads to the tests being completed in a faster, more efficient, and more productive manner. Also, the time-control method is more reliable than the distance-control method and easy to control.

Table of Contents:

Introduction:

The goal of the AEV design and testing is to create a fully functioning AEV that is able stop at the desired distances in order to go through a gate, connect to a caboose, and return that caboose to where the AEV started. This was done by developing the code and design necessary to complete the tasks given and testing various methods to determine what was the most efficient in terms of cost, time, and energy. The following sections of this report will outline crucial parts to the development of our AEV. First, the experimental methodology section will look at the creation and testing of the AEV. Second will be the results found from our various experiments and trials. Third will be a discussion about the meaning of the results, and lastly there will be a summary of the testing to give an overall conclusion and recommendations. An appendix will follow which will include relevant figures, tables, and drawings of two possible AEV designs in SOLIDWORKS.

Experimental Methodology:

The team was tasked with building an Advanced Energy Vehicle that could perform the specified tasks of transporting people from Linden to Easton and Polaris in the city of Columbus. Before any experiments could be performed, the vehicle had to be assembled. The team was provided with an arduino, a battery, two electric motors, a servo, reflectance sensors, propellers, an “L-shaped” and a “T-shaped” arm, multiple various shaped plastic boards for base construction, wheels, battery supports and multiple various screws, nuts and bolts. In order to complete the Preliminary Research and Development, the team constructed a prototype of the vehicle. While the tests were performed, the team observed how the AEV operated and responded to the code. The team took note of these effects and brainstormed how to make improvements on the design for maximum efficiency and performance. Multiple ideas were created and through the process of concept screening and scoring, a two designs were chosen.

Each of these designs were created from their respective orthographic sketches, which are shown in Figures 3 and 4 (pictured in the Appendix). The first design, Figure 3 (pictured in Figure 03 in Appendix), was used for the Preliminary Research and Development tests. The arduino was in the back and the motors were in the front; this arrangement allowed the vehicle to be balanced which would ensure stability of the vehicle. The team later decided to put the motors in the front instead of the back, because the arduino must be separated from the magnet on the caboose for safety. The battery was strapped to the side of the arm using a zip tie. Although an initial concern was that the battery would add too much weight to the back of the AEV, it proved to add stability and balance the system. This was an important aspect to think about while the team was designing the transportation system because it will be carrying people, and their safety is held paramount to everything else.

While the team was testing the AEV in the Preliminary Research and Development, the team practiced safe procedures to ensure that the AEV did not fall off of the track and the battery did not catch fire. Team members were stationed at the start of the track, the center of the track near the gate, and at the end of the track to retrieve it. These measures were taken so that the vehicle did not get damaged and the company did not incur any fines.

After the team completed the Preliminary Research and Development, the Advanced Research and Development began and the team further analyzed the movement of the vehicle and attempted to isolate any issues that could be remedied. This was done because some inconsistencies were observed in the experimentation process, and the team needed to eliminate these problems. The team tested the battery to see how the experimentation affected the voltage by extension the effect on the motor performance. The team also tested for an efficient braking method whether it be coasting or power braking.

After all testing was complete, the team was ready to begin the performance tests. After the first performance test was complete, it was at this time the team decided to switch the design to the second model (pictured in Figure 04 in Appendix). This modification was made because the vehicle did not have a proper area to attach to the caboose to transport the people, which is the main purpose of the project, The same overall structure of the vehicle was kept the same, with modifications focusing on creating a new base, which would be able to complete the tasks as desired.

Results:

Going into the advanced R&D experiment, two prototypes were selected in order to proceed to the next step for the final design. The first prototype design created by Jacob focused mostly on balancing the weight of the AEV and has been modeled in SOLIDWORKS in Figure 04 in Appendix. While highly effective in stability and ability to create code in a consistent manner when operating on its own, its design became very ineffective when trying to pick up the caboose due to the way which its propellers were positioned. Because of this, a new design was created for the performance testing by Jacob and Zhang, which was graphically modeled in SOLIDWORKS as shown in Figure 03 in Appendix, in order to complete the Performance Tests in a more consistent manner. The new design used larger parts that were crossed over each other with the pickup for the caboose located between the two propellers.

The Concept Screening Matrix and the Concept Scoring Matrix was used to evaluate the strengths and weaknesses of each design. Table 2 details the strengths and weaknesses of each design more specifically. As can be seen, the new design is especially safe whereas Jacob's design has better stability and maintenance. However, as Jacob's design has the greatest total score, his design was selected to move on to the later stages of development and Jacob's design was selected over the others. When tested, this design was able to create similar results with and without the caboose being attached, which was why it was determined that the design shown in Figure 03 in Appendix(Prototype 01) would be used moving forward.

Table 1: Concept Screening Matrix

Success Criteria	Reference	Kia's Design	Kezia's Design	Jacob's Design	Zhang's Design
Stability	0	-	0	0	0
Minimal Blockage	0	+	0	+	+
Maintenance	0	0	0	+	-
Durability	0	-	+	0	0
Safety	0	-	0	+	+
Sum +'s	0	1	1	1	2
Sum 0's	5	2	2	4	2
sum -'s	0	2	2	0	1
Net Score	0	-1	-1	1	1
Continue?	Combine	no	no	yes	no

Table 2: Concept Scoring Matrix

		Reference		Kia's Design		Kezia's Design		Jacob' s Design		Zhang's Design	
Success Criteria	Weight	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Stability	20%	3	0.65	2	0.3	3	0.65	3	0.70	3	0.65
MinimalBlocke	15%	3	0.40	4	0.7	3	0.40	2	0.45	4	0.65
Maintenance	15%	2	0.3	2	0.3	2	0.30	5	0.75	1	0.25
Durabiliy	25%	3	0.80	1	0.20	5	1.05	3	0.85	3	0.75
Safety	25%	3	0.70	3	0.80	3	0.95	2	0.85	4	1.10
Total score			2.85		2.3		3.35		3.6		3. 40
Continue?		No		No		No		Develop		Develop	

Furthermore, the superiority of the chosen design can also be observed through analysis of experimental data collected by Matlab during test runs under the same conditions: identical test track with the same code and the same materials, which conforms to the control variates approach in experiment.

Figure 01 and Figure 02 represent the change in power input by the motors (Watts) over time (seconds).

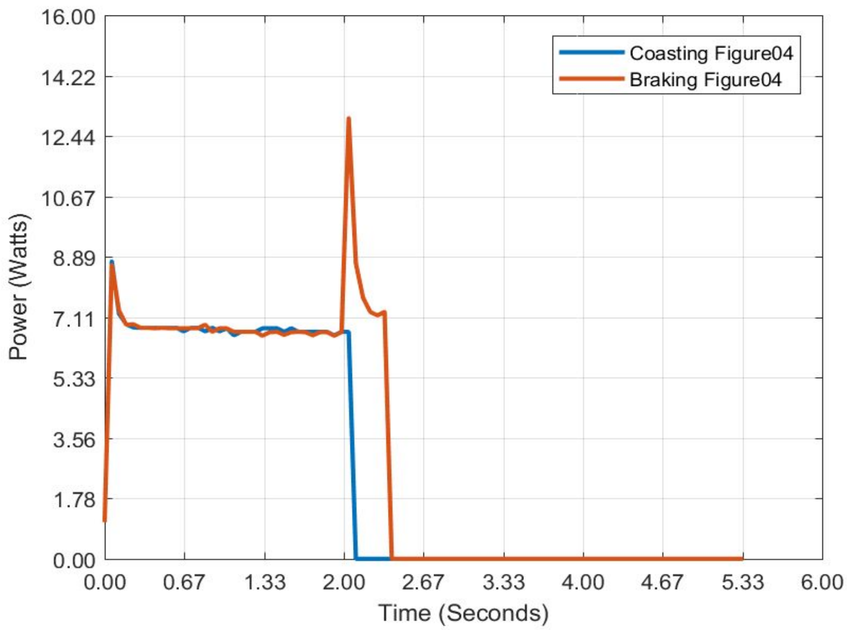

Figure 01: Power (Watts) v. Time (Seconds) -Design1(Jacob/Zhang)

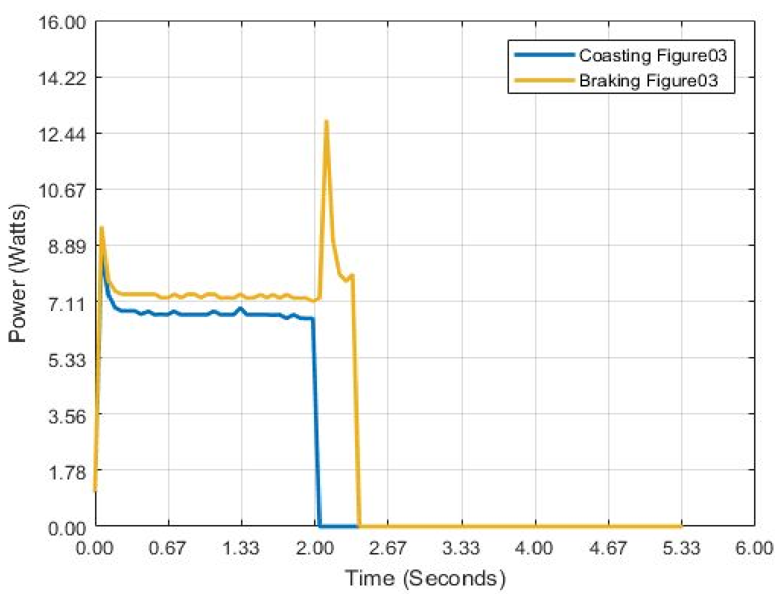

Figure 02: Power (Watts) v. Time (Seconds) -Design2(Jacob)

As can be seen by comparing Figure 01 and Figure 02, Design 1 consumes less power compared to Design 2 which improves efficiency and cost. Also, the graph of Design 1 is more consistent for the same code,which was to be expected as the concept screening matrix shows that Design 1 is more stable and maintainable than Design 1.

Figure 03 and Figure 04 represent the change in power input by the motors (Watts) over distance (meters)

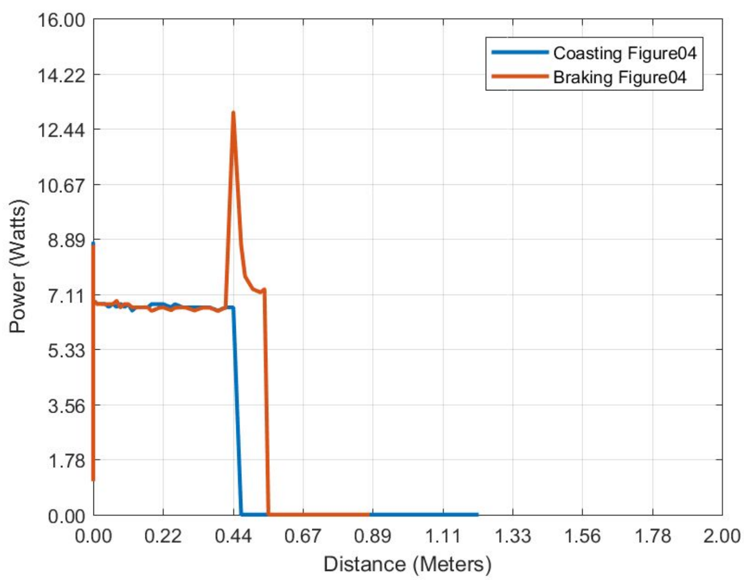

Figure 03: Power (Watts) v. Distance (Meters) -design1(Jacob/Zhang)

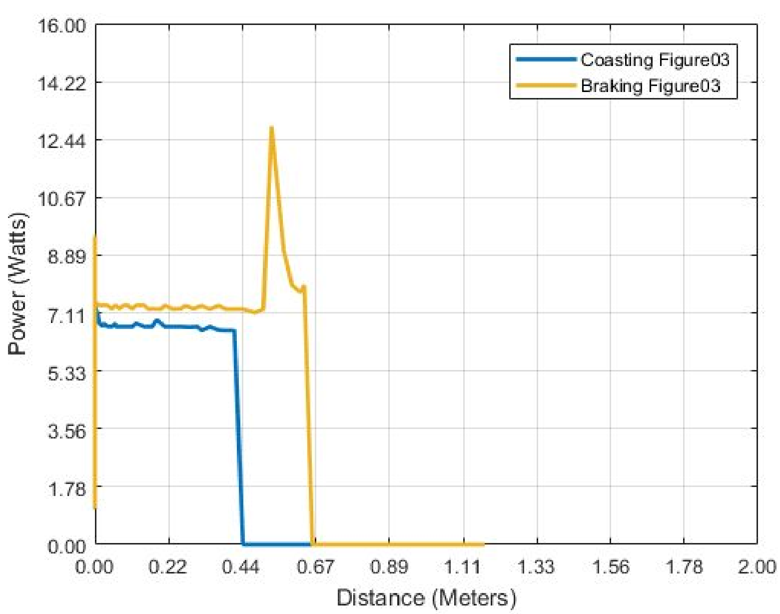

Figure 04: Power (Watts) v. Distance (Meters) -design2(Jacob)

As can be seen by comparing Figure 03 and Figure 04, the sliding distance of Design 1 will come to rest (approx. at 0.89 m compared to 1.16 m), which matches the score of the Table 2- design one is more stable and maintainable hence easy to control with braking method. Therefore, Design 1 was chosen over Design 2.

The final performance tests were the culmination of the rigorous experimentation that the team conducted in order to design the final version of our AEV. Figure 05 below represented the how the power of the motors changes with time for the first performance test. This figure showed that the time-control method could have a good controbility on the AEV - the code made the power of motor change greatly in a tiny time interval, which meant that the AEV could consecutively make different movements without considering too much on the effects of the previous actions. And we could use the brake method instead of the coasting method because we needed to control the sliding distance rigorously to make the AEV entered in the sensored distance at the gate for safety.

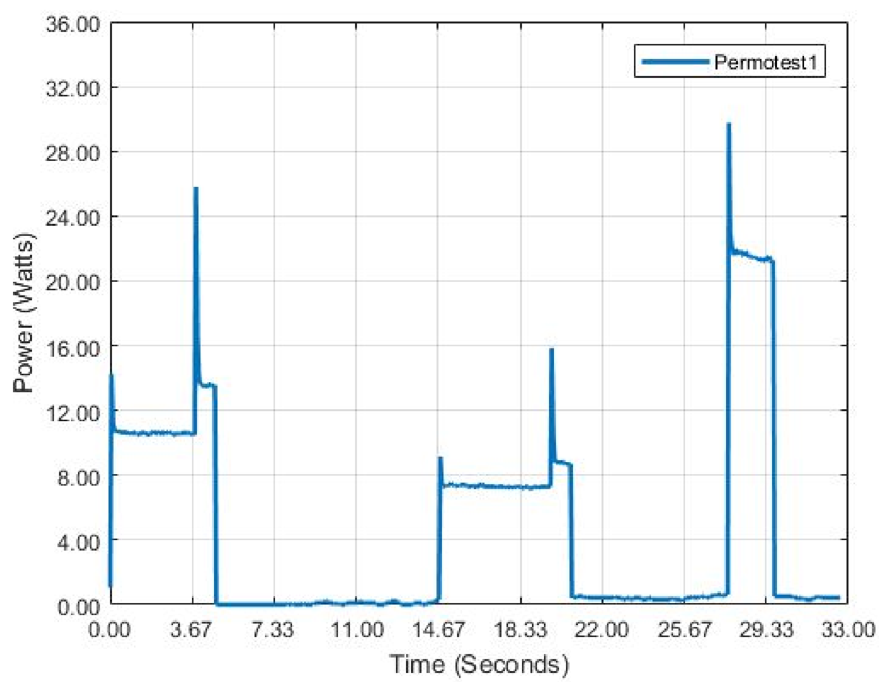

Figure 05: Power vs. Time for Performance Test 01 with time-control method

For the second test (Performance Test 02), we prefered to use the control-time method (goFor() in code) instead of control-distance method (goToRelativePosition() in code) for the same reasons performed in the first performance test. The goal of this test was picking up the caboose after crossing the gate and then making the AEV and caboose (connected together) move reversely a little bit before re-crossing the gate. The team used two types of code to finish this test - the majority of the parts of the two code were the same, the only difference was the final braking distance after the AEV had picked up the caboose traveled a specific distance.

Figure 07 shows the difference of the two code patterns. It can be easily observed that the behavior of the most part of the two runs are almost identical, which not only shows the code patterns owed by both had a stable controbility and repeatability over AEV (even after the AEV picked the caboose), but also verifies that using the braking method and time-control method are more applicable and effective way to control the AEV. For the different part of the figure, the red curve used less motor power to brake the AEV compared with the blue curve. Although the red curve consumed less energy, this is not the best result for the final performance test because it needs to recross the gate for the final test. The red curve made the AEV run out of the sensored distance of the gate, while the the blue curve could stop at the position that lies in the sensored distance of the gate.

Additionally, there is an important factor that should be considered when designing the code for the part that the AEV and caboose travel reversely together as the return on an uphill course. Therefore, we not only need more motor power to generate the forward force but also need enough time to let the AEV pass the uphill, which is why we used the bigger parameter for moterSpeed() method in coding design.

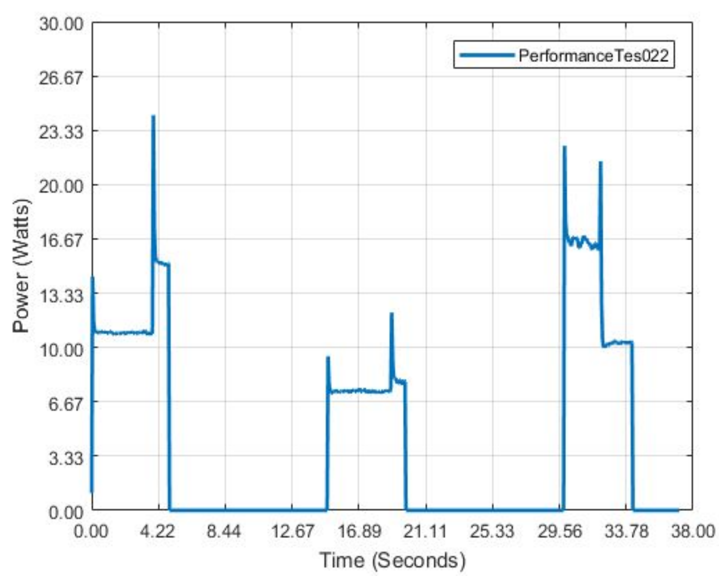

Figure 06: Final code for testing design for Performance Test 02

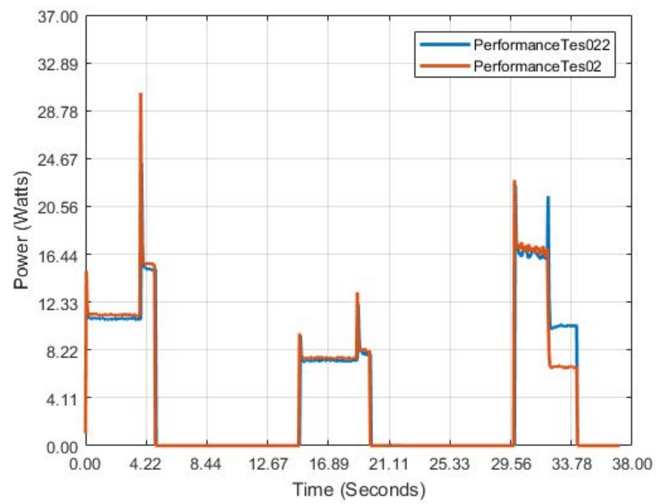

Figure 07: Comparing two patterns of code for Performance Test 02

For the final performance test, we found that result will be more consistent when keeping the change of power of the motors as small as possible especially when calling the power-braking method. Theoretically, it was because the complexity of the system will decrease as the power of AEV only need to make a small shift to change the movement of the AEV, which meant the motion state of the AEV would receive a more controllable(smaller)effect as the variation was small. The Figure 08 and Figure 09 also showed that the two runs were extremely consistent, which was crucial to finish the final test successfully. And the energy consumption was reduced to 232 Joule by reducing the time of goFor method in coding to maximize the energy efficiency, which means we will need less energy and less time to brake the AEV.

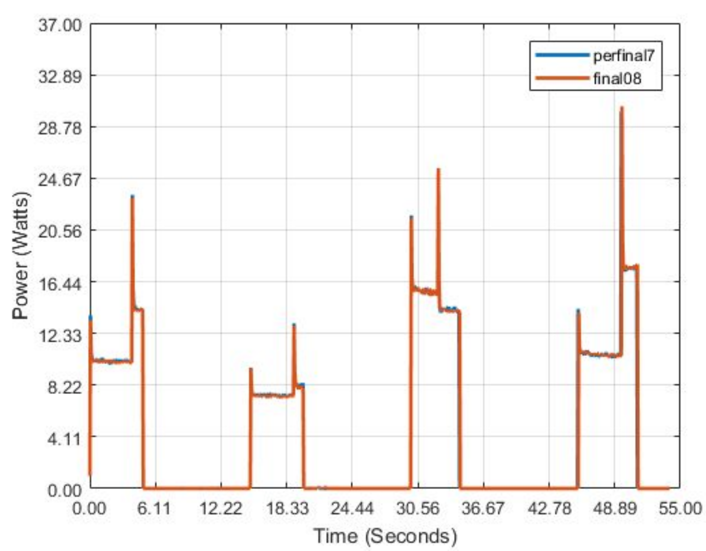

Figure 08: Power(Watts) vs. Time(Seconds)Final for Final Performance Test

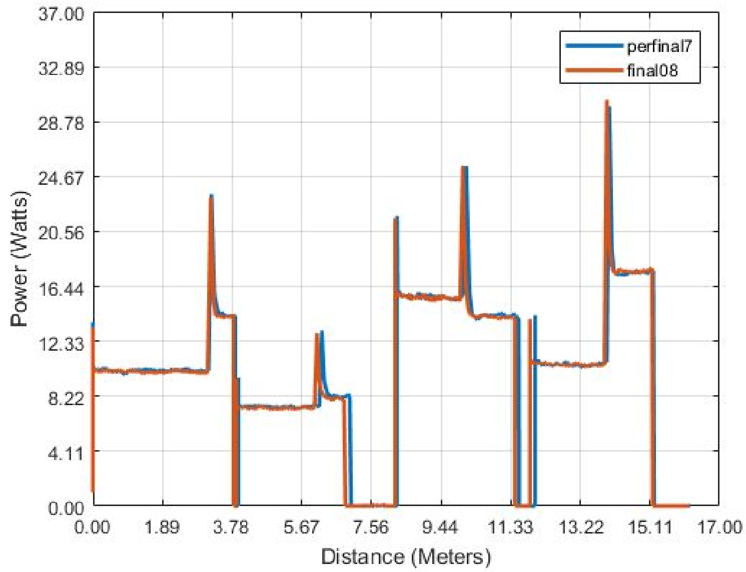

Figure 09: Power(Watts) vs. Distance (Seconds)Final for Final Performance Test

Discussion:

Throughout the various tests done in the preliminary, advanced, and performance test stages, many conclusions were obtained based on the data obtained and observations that were made. In the preliminary stages, an overall understanding of the AEV was developed through each of the exercises. The scoring matrices (shown in Table 1 and 2) were used to help decide which AEV was the best by combining multiple desirable aspects. By focusing on the key aspects of the AEV design, it was determined that Jacob and Zhang's design would be used moving forward, and following more evaluation, it was determined that Jacob's design would be used. The preliminary exercises also gave a better understanding of how to work with the AEV overall. These exercises were an an instrumental part of making the later tests more effective and successful.

In the dvanced research and development stage of testing, the concept of Power Braking vs Coasting as well as Battery Testing were the main focuses. In the Power Braking vs Coasting, the only change in code was whether or not the motors reversed direction in order to "power break". After running these two different types of trials, the data from the AEV was collected and tabulated. These graphs are present in Figures 01 and Figure 02; the difference in code is illustrated in the graphs. While the Power Breaking required more energy, time was saved in this method. It was determined that Power Breaking would be the better choice, because it was more efficient in terms of time and thus cost.

Looking at Figure 01 of Power vs. Time, both of the designs consumed around the same amount of power using the coasting method. The first design used around 7.29 Watts consistently with a spike at around 2 seconds. Design 2 consumed 6.75 Watts of energy consistently with a spike at around 2 seconds. The slope of Design 1 is steeper than Design 2, which shows Design 1 reacts to the braking command more quickly and accurately. For the Power vs. Distance graphs, the two designs behave almost same for the coasting method, but Design 2 consumes less energy. Design 1 has significantly less sliding distance compared to Design 2, approximately 0.89 m compared to 1.16 m. Potential errors may exist because we can not see clearly on Figure 04 what distance is traveled using the coasting method because the Matlab lines interloop. Even so, we can conclude that it is not beyond 1.11 m or it would be displayed in the picture. Furthermore, it may be noted that even though the code used to test the two designs was identical, the power output is steadier and more controlled in the case of Design 1; their graphs are more consistent. This phenomenon may be attributed to the fact that the new design has well-distributed weight and leaves more space between two propellers, which will make the AEV more stable and controllable.

Nonetheless, there were many instances where error could not be avoided.. The biggest error that we had in the group was inconsistent AEV behavior. The code, the track and the battery voltage for the most part was kept constant, however the arduino was not very consistent. The biggest difference between the data collected was in recent Performance Test 1. In the first lab, the team used the same code for the Design 2 ran it seven times. There were four trials that the AEV entered the acceptable range to alert the gate sensor, however there were three times that the AEV did not enter the acceptable range. Trial three and trial six failed to reach the gate sensor at all and trial 1 exceeded the range and hit the gate. Also, when testing the AEV it was found that it was not very balanced on the track. To try and fix this the tema modified the design and moved the placement of the battery to better balance the AEV. This increased stability and lead to greater consistency through the rest of the project.

Figure 10: Distance from the gate vs Trials- Design 2(Jacob)

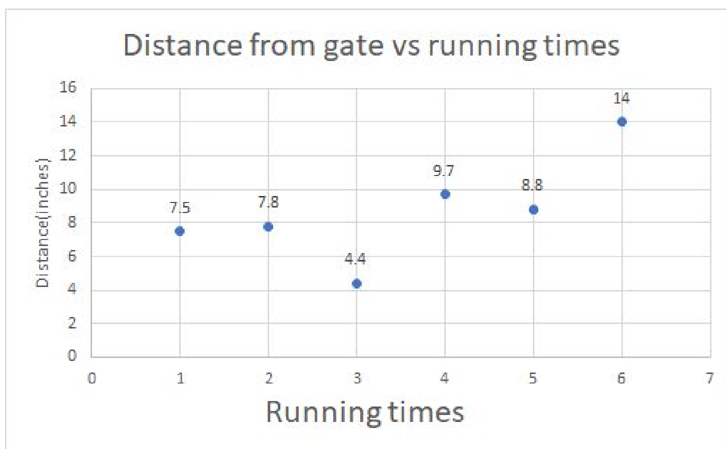

Figure 11: Distance from the gate vs running times with big time interval- Design 2(Jacob)

During the Performance Tests, the group's biggest takeaway from what was completed, was that time-control method was more stable, when compared to the distance control method. The reproductivity and consistency were two crucial factors that determined the final result of tests. The team was met with some troubles on the official Performance Test 01, due to the inconsistency. However, this was explored and overcome as the team prepared for the second and final Performance Test.

The team also found that changes should be made in the arguments of the motorSpeed() method because a big change in regards to the distance because it would affect the accuracy of the result greatly- the time-cumulative effect would cause the total change in distance to be unpredictable bigger than expected as the following the parameter of goFor method (after moterSpeed method) was usually a relatively big time-interval (1.5-8 seconds, the average value is 2.4 second when the parameter of motorSpeed method is not 0). However, it was better to change the arguments of goFor() method when we wanted to make small change of the distance because the total distance would change drastically if we changed the arguments of motorSpeed() - the accumulation effect would have been drastic as even a tiny change (+1 or -1) on the code could cause this.

Conclusion & Recommendations:

Conclusion & Recommendations // Jacob Dougherty:

From the knowledge gained throughout the different levels of testing of the AEV, Team O has been able to work together in order to create an AEV that will be able to complete the desired tasks at an efficient level. This was done by first looking at 5 exercises to learn more about the AEV, and they were able to give a better understanding of how the AEV functions and what would be needed in order to create a design that is not only cost efficient but stable on the track and able to complete the desired tasks. Following this the advanced research was able to tell us more about what would be best for our AEV in terms of power braking or coasting, and also the effect of the battery on AEV performance. It was found that power breaking was the most cost efficient, and that the battery voltage had little to no effect on the results of a trial. Using this information, the testing process of completing the desired task was begun, and it was determined that moving the AEV at a high motor speed towards the gates, followed by a high motor speed in the revere direction in order to stop the AEV was able to create the most accurate results.

Performance testing was able to give a lot of information about the AEV. Through trial and error, it was determined that the way in which code was written could affect the consistency, which led to the code being written in a way which minimized coasting difference. The design of the AEV was also finalized during performance testing, and the wide base with space between the popellors was able to pull the caboose while remaining stable, leading it to be the best choice of design for the final testing. The problems encountered in the AEV testing process were not something that could be entirely avoided, but were able to be dealt with in order to minimize the error that they cause. Through working to minimize error though the way our design was built and how the code was written, the AEV was overly successful and able to complete e desirred tasks in a short amount time with safety and stability.

Conclusion & Recommendations // Kezia Namenyi:

Through the knowledge we gained from our initial experiments and final testings, we have worked to create an efficient AEV. The initial pre-research and development exercises conducted helped show our team the basics of coding, how the propellers worked, how the reflectance sensors worked, and how power was related to the motor speed of our propellers. Using this information, we compared two different AEV designs, searching for the most efficient AEV based on the understanding we had thus far. Focusing on power braking, coasting, and battery testing, we began our research and development phase. Through our research and development we discovered coasting was more efficient than power braking as it consumes less energy. We also discovered the battery does not affect test runs as much as we originally expected, even though the voltage may decrease with additional test runs.

Using the information we gathered through our research, we coded our AEV to complete Performance Test 1. Incorporating coasting over power braking came easy, and proved to be consistent for the first day of testing. The second lab, the code did not work, so we modified our code to include more power braking. Subsequent testing has shown us that, although with power, power braking is less efficient, it is more reliable for our performance tests. Looking forward to Performance Test 2, we realized part of the design for our AEV would not leave room for the propellers to spin once the caboose was picked up. We will continue to modify our code and design to create the most efficient and consistent AEV.

Conclusion & Recommendation // Kia Ruffin:

Many tests and experiments were executed to help guide and expand the team's knowledge regarding the Advanced Energy Vehicle. While the team was completing these tests, the observations and data collected helped the team to create the most safe and efficient vehicle. The preliminary research introduced the team to the fundamental functions of the AEV, including the balance of the AEV and its stability on the rails, and the coding in regards to the motor power and how that related to the speed and how it responded on the track. The data collected throughout this research helped guide the team through the advanced development. This included monitoring the battery voltage to see if it affected the performance, as well as juxtaposing power braking and coasting to see which method proved to be the most effective and efficient. Through analysis and observation, the team concluded that the number of runs the AEV completes, and the distance the vehicle travels has a negligible effect on the performance. The team also decided that power braking is a far more efficient method of braking. This method also allows the AEV to be more consistent, which is important for the performance tests.

The first performance test tasked the team with creating a code that would allow the AEV to approach the gate, pause and pass through. With the data acquired from the preliminary and advanced research and development, the team utilized power braking to complete Performance Test 1. Everyday the team returned to experiment with the vehicle, the code had to be modified.

Unfortunately, the AEV stopped too short, and it did not reach the gate on the first performance test. Considering that the AEV had successfully performed the required tasks to complete the performance test four times prior, the team assumed that it was a random error. However, this event showed the team that the arduino is inconsistent and better code needed to be written to minimize error. At this time the team also transitioned to the second and final design. This change was made so that the AEV could have space to successfully retrieve the caboose. Using these improvements and modifications, the team was able to successfully complete the second performance test and the final performance test. The second performance test went very well and the team received full marks on this run. This task was a little more difficult to complete considering that the code had to adjusted to accommodate the weight of the caboose and the team was not familiar with how the caboose would respond to the code. However, the team was able to complete the requirements and it made it easier to move on to the final performance test. Combining all of the skills and knowledge that the team acquired from the duration of the project, the team was able to successfully code the vehicle to pick up and drop off the caboose.

Conclusion & Recommendation // Tongshuai Zhang:

For now, the team have created an efficient AEV design based the Preliminary R&D and Advanced R&D experiments. It is known how the Arduino codes works, the propeller works, how power was related to the motor speed of our propellers. Then, we mainly came up with two prototypes of design and conducted two testing- power braking-coasting test, and battery testing to compare the performance of the two designs with collected data by Matlab and find the most efficient operations to control the AEV. Through our research and experiment, we discovered coasting was more energy-efficient than power braking as it consumes less energy. But the power braking can have better control of the AEV. Because the energy difference between two method are not very big and it is crucial to control the sliding distance which happens many times in the future experiment, we will choose power braking as the main method to control the AEV when involving the sliding distance. Also, we discovered the the battery voltage does not affect the distance significantly, even though the voltage may decrease with every additional test runs.

Through the information we gathered in our research and experiments, we coded our AEV to complete Performance Test 1. Incorporating coasting over power braking came easy with less energy, we use more power on motorspeed for coasting method while using the less power on motorspeed for braking method and proved to be consistent for the first day of testing. The second lab, the code did not work, so we modified our code to include more power braking. Subsequent testing has shown us that, although the power braking is less efficient, it is more reliable for our performance tests because the AEV has extremely accurate sliding distance limitations. For Performance Test 2, the team realized part of the code would not leave enough time for connecting perfectly the caboose was picked up, so we change the code slightly to extend the time after the AEV took the brake.

For the final performance test, the team didn't do perfectly as the AEV hit the block in the final travel path. Although the team didn't have enough time to optimize the code, but it should resolve this problems if the AEV could brake after it finish the path of downhill. This is because the AEV would still acquire a large amount of momentum if the AEV stops at any position in the downhill pathway. After the lab, the team improved the code that would brake the AEV after the downhill path and tested that code. Because of this change, the AEV rans perfectly and the energy consumption is reduced by 32 Joules although the official test chance had used more. Furthermore, the team could still make the AEV more efficiently by optimize the parameter of motorSpeed and goFor method in code to maximize the energy efficiency- using as less as energy move forwards so that the code could decrease the energy of making the brake, which reduced the cost effectively.

References:

(1) “MCR and Deliverables” Document “Carmen- Carmen Engineering 1182 Autumn 2018
(2) “Final Cost Sheet” Document - Carmen Engineering 1182 Autumn 2018
(3) “Preliminary R&D”- Carmen Engineering 1182 Autumn 2018
(4) “Advanced R&D”- Carmen Engineering 1182 Autumn 2018

Appendix:

Table 1: Schedule addresses roles, tasks, and timeline.

Tasks	**Start Date**	**End Date**	**Due Date**	**Percentage Completed**
Performance Test 02	03/23	03/28	03/28	100%
Decide the Code for the AEV for Final Test	03/28	04/09	04/09	100%
Final Performance Test	03/28	04/13	04/13	100%

Final CDR	04/13	04/20	04/20	100%
Oral Presentation and Summary of Research	04/10	04/18	04/18	100%

Table 2: Each group number' s role in tasks

Tasks	**Jacob**	**John**	**Kezia**	**Kia**
Performance Test 02	Construct AEV to prototype	Tester	Construct AEV to prototype	Tester
Decide the Code for the AEV	Write code	Write code	Tester	Tester
Final Performance Test	Modify AEV	Tester	Modify AEV	Modify AEV
Final Testing and Running of AEV	Tester	Tester	Tester	Tester
Oral Presentation and Summary of Research	Approach	Functionality	Intro	Ending

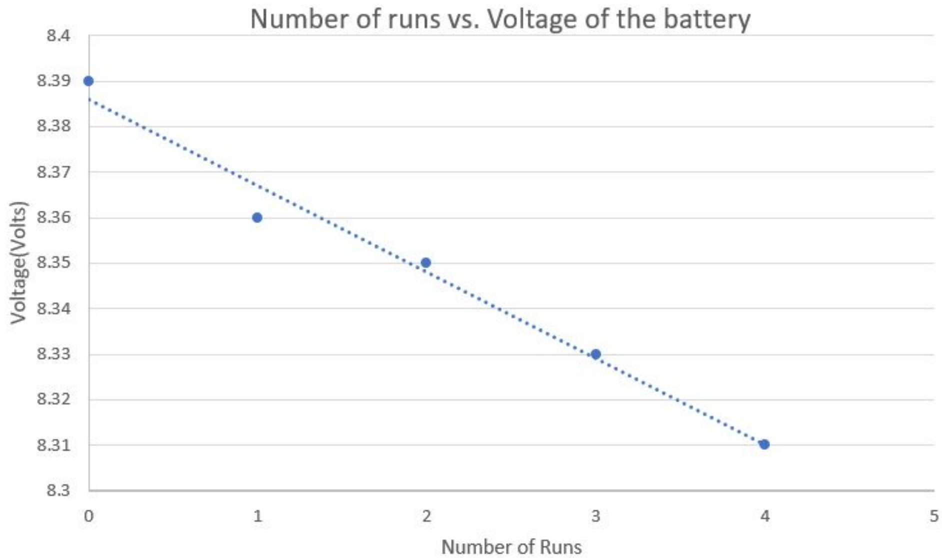

Figure 01: Battery Voltage(Volts) v. the Number of Run

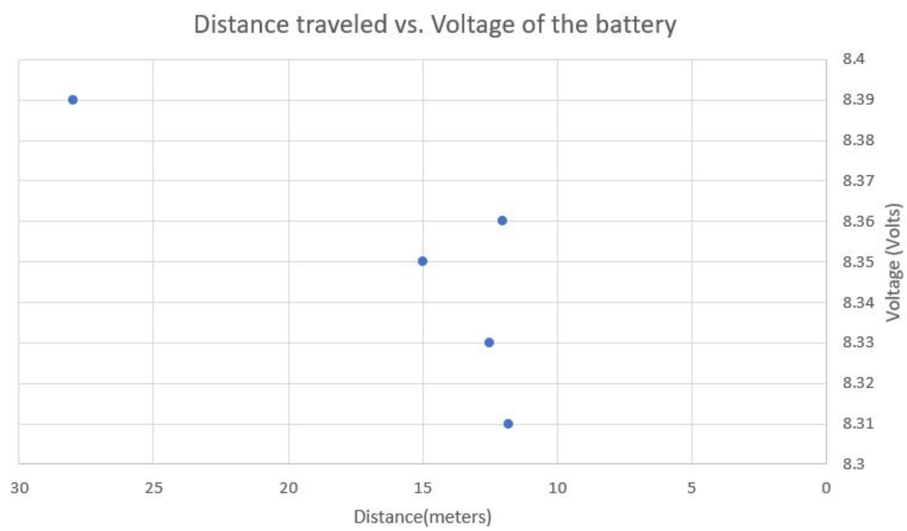

Figure 02: Distance Traveled(Meters) vs. Battery Voltage(Volts)

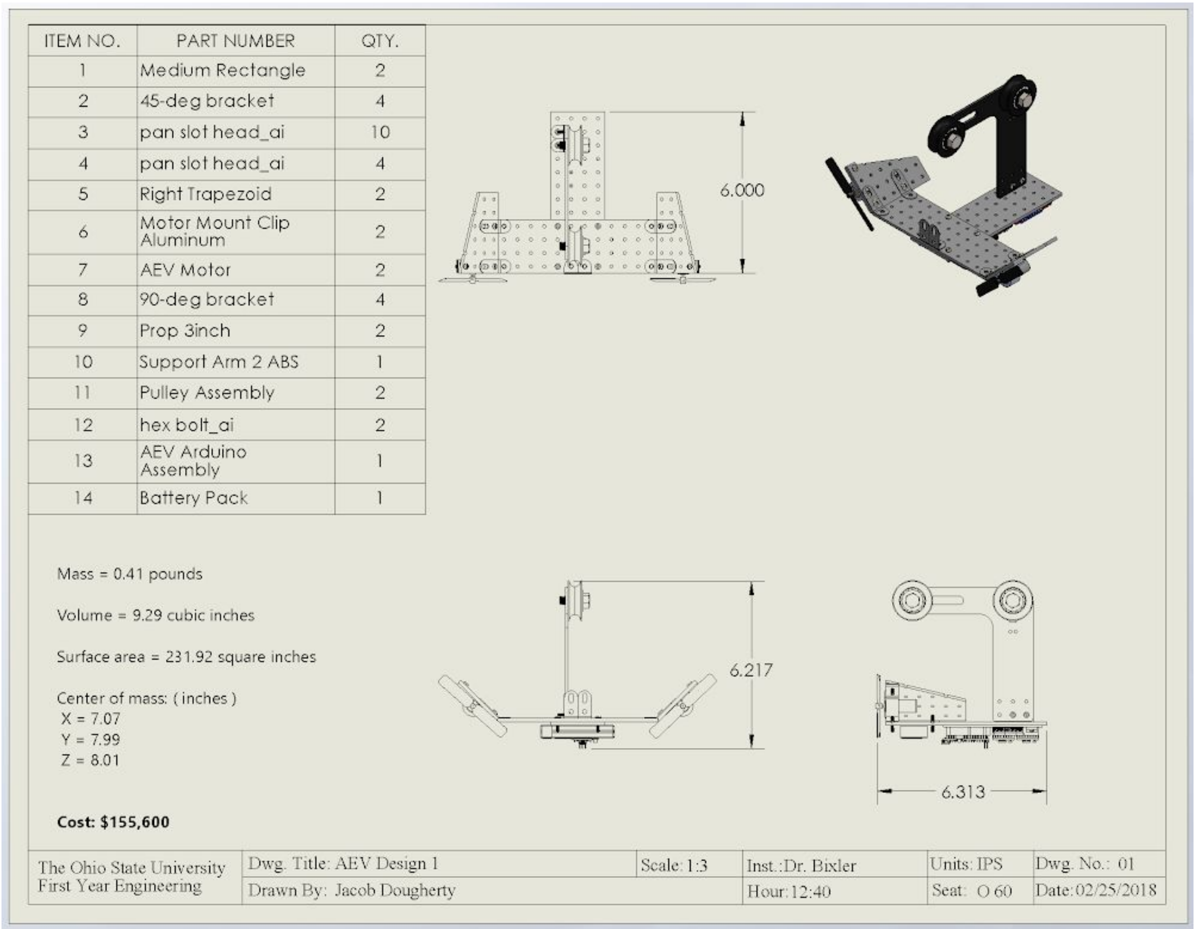

Figure 03: Solidworks Drawing Design (By Jacob and Zhang, Prototype 01)

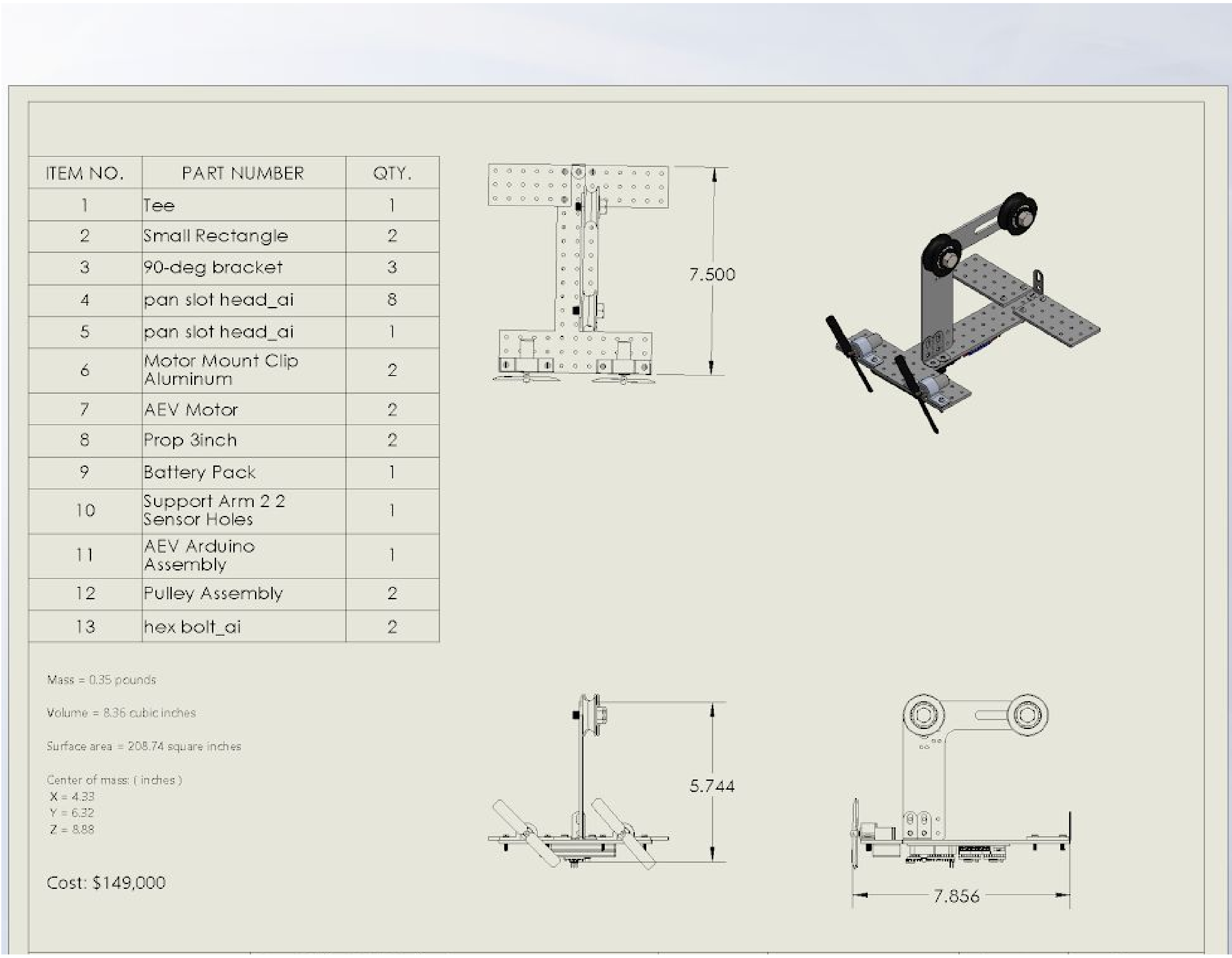
ITEM NO.	PART NUMBER	QTY.
1	Tee	1
2	Small Rectangle	2
3	90-deg bracket	3
4	pan slot head_ai	8
5	pan slot head_ai	1
6	Motor Mount Clip Aluminum	2
7	AEV Motor	2
8	Prop 3inch	2
9	Battery Pack	1
10	Support Arm 2 2 Sensor Holes	1
11	AEV Arduino Assembly	1
12	Pulley Assembly	2
13	hex bolt_ai	2

Figure 04: Solidworks Drawing Design 2(By Jacob Prototype 02)

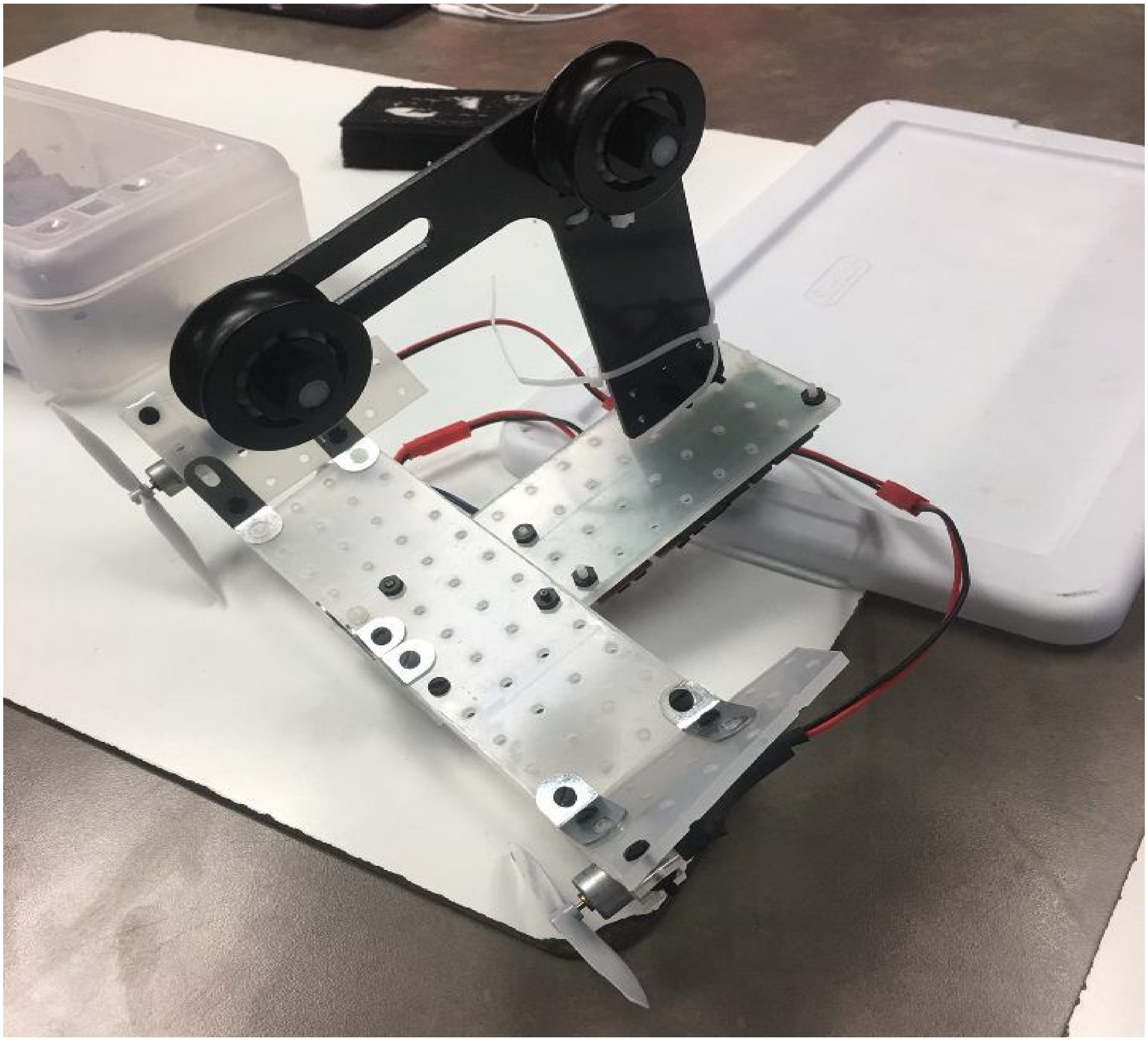

Figure 05: Final AEV Design Photo