CDR Draft

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Executive Summary

The goal of the Advanced Energy Vehicle project was to build background information on engineering skills such as arduino coding, Solidworks, and vehicle assembly in order to design and run a safe and efficient mode of transportation for the people who are travelling between Linden,Polaris and Easton. In order to achieve a successful AEV, preliminary research and design labs were completed to test different codes and designs and make sure the reflectance sensors were working. Next, advanced research and design labs were completed to expand the knowledge about battery voltage and braking methods. Finally, a final design was settled on and performance testing was conducted. Along the way, in depth meeting notes, progress reports, and committee meetings were recorded to monitor the progress of the project. Upon the completion of all these steps, there will be a safe and effective mode of transportation across the City of Columbus.

From the preliminary labs, multiple results were found. First, it is important to run the reflectance sensor test to make sure the sensors are working, especially when using the absolute and relative position commands. Next, it is better to use a more simple design because it will cost less, weigh less, and overall be more effective. Also, the most important considerations when planning the design of the AEV are safety, efficiency and consistency. There were also important results that came from the advanced research and design labs. From the battery testing lab, although not to the extent that was originally expected, it was shown that battery voltage decreases a little bit after each test run, so it is important to make sure the battery is always charged. From the power braking versus coasting lab, there were only slight differences in the two braking methods. Power braking and coasting both had about the same braking distance, but power braking used slightly more power and was not as consistent (higher standard deviation). Lastly, the performance tests began after the completion of the labs. The first performance test was successful in the end by stopping at the stop sign for seven seconds then proceeding through once the gate opened. Along the way, there were some troubles with the reflectance sensors, which were being used for the “goToAbsolutePosition()” command and there were some errors caused by decreased power from the battery.

In the future, group P recommends tieing up the wires so that they do not get in the way of the propellers and affect the test runs, making sure the battery is fully charged before testing so that there is no inconsistency in power and distance travelled due to low voltage, and running the reflectance sensor test before testing to make sure that the commands in the code that involve tick marks work. Group P also recommends that the simplest design be used because it will reduce cost, maintenance, weight and efficiency. If all of these recommendations were to be followed, the AEV’s performance, safety and efficiency will be maximized. Consequentially, the Smart City of Columbus will be greatly improved and the people of Columbus will have a safe and efficient mode of transportation across the city.

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Introduction

As a solution to the Smart City of Columbus's new plan to make Columbus a safer, travel friendly and more futuristic city, an Advanced Energy Vehicle was built and programmed to travel across the rails of Columbus back and forth from Linden, Easton and Polaris in order to transport the citizens to their destination. In order to complete this task, research and labs were completed to build background information about the different parts of the AEV such as Arduino coding, design ideas and reflectance sensors, then research and labs were done to further expand on some problem areas from the first set of labs, such as battery voltage and braking method. Finally, using the results and conclusions from all of the research and design labs, performance tests were run to perfect the operation, design and safety of the AEV.

In this document, important procedures, results, and recommendations from the research labs and testing will be shared that enhance the entire AEV research and design process. First, the procedures for the preliminary labs and advanced labs will be explained, then the approach to the performance testing will be explained. Next, the results from all of the labs and testing will be conveyed using tables and figures to make the data easier to comprehend. This display of results will lead to the discussion, which is where the data will be analyzed and connected to the theory of the experiments. Sources of error will also be introduced in this section. Through analyzing the data, it will be possible to make inferences and look at patterns across the spectrum, then compare that to the original plan for how the project is supposed to turn out. Finally, conclusions and recommendations will be made by each member of Team P. Each person should provide a summary of the process, conclusion about the AEV, how the error can be addressed, and recommendations for each procedure.

Experimental Methodology

The preliminary research and design lab section consisted of five labs. In the first lab about programming basics, the propellers were mounted on the motors, then the motors, arduino,and battery were all connected and placed on the mount. The arduino power switch was off when connected to the battery. Next, the AEV sketchbook was downloaded and the Arduino IDE was opened. The sketchbook was set up so that the Arduino codes can be written and easily transferred to the Arduino board. Once the program was set up, a basic code was written then uploaded by plugging the usb cord into the computer and the AEV and finally, it was tested so that the team becomes familiar with how the codes and arduino system works. In this lab, the mount was used to hold the aev upright, the battery was used to give power, and the motors were used to make the propellers and AEV move. The arduino coding system was used to tell the arduino what to do.

In the second lab, the reflectance sensors were added to the sample model of the AEV that was on Carmen. The reflectance sensor manual was used to ensure that the reflectance sensors were secured by zip ties and plugged in properly. The reflectance sensor test was performed to make sure that the reflectance sensors were registering the tick marks accordingly. A program was then written using the absolute position command. The program was uploaded to the AEV, then the test was run and monitored by a GTA/UTA to make sure everything is going smoothly. In this lab, the reflectance sensors were used to measure the distance travelled so that the absolute position command could be used.

In the third lab, multiple designs were tested and compared. First, each individual team member designed a sample AEV, drew a picture of it with orthographic views, and recorded its approximate size, weight and bill of materials before coming to labs. In lab, all of the designs were compared and compiled into one team sketch with a drawing, size, weight,and bill of materials. The good aspects of each individual design should be carried over into the team design. In this lab, the only equipment that was used was the AEV design.

In the fourth lab, the Design Analysis Tool was utilized. First, the team design from the third lab was built, then the DAT was downloaded from a zip file on Carmen and installed on MATLAB. The AEV analysis software was then explored to see what tools can be used and what graphs can be made. Next, a simple scenario was coded, uploaded and tested. Finally, the Arduino data was downloaded using the data analysis tool and the graphs of different types of data were analyzed and compared. In this lab, the Data Analysis Tool was used to test the performance of the AEV and whether is is effective, which is useful when comparing designs.

In the fifth and final lab, the concept screening and scoring matrices were introduced. First, five pieces of criteria were brainstormed that the team thinks is the most important for the AEV. Next, concept screening and scoring matrices were completed for the five designs from lab three. In the concept screening matrix, each design was rated by +’s/0’s/-’s foreach piece of criteria, then the scores were compared and the team determined which designs should move on. In the concept scoring matrix, a weight was given to each piece of criteria based on how important it was, then the designs were graded by using a point system. In the end, the team should choose which design is the best and build that AEV design.

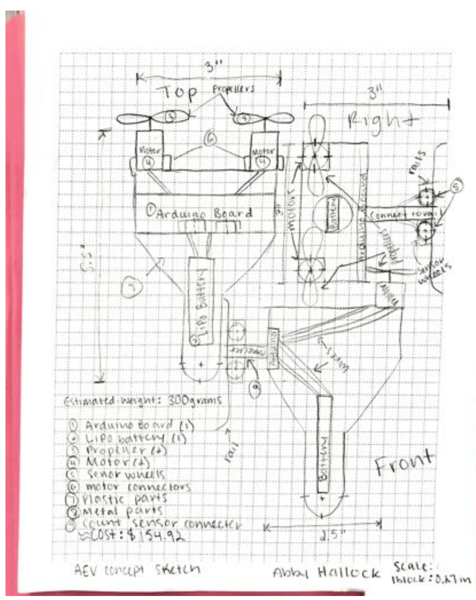
In the advanced research and design lab section, there were two labs that were performed. The first lab was battery testing. A battery was obtained and a code that simulates an actual test run was written and uploaded. The DAT was used to record distance travelled on the straight track as well as the voltage across the run. Multiple runs were tested with the same battery and the voltage patterns were discovered. The second lab was power braking versus coasting. Two codes were written; one that uses the brake code and one that does not. Multiple runs were tested for each code and the distance was measured with the DAT as well as the final and initial distance to be able to compare the braking distances of both methods.

Results

There were some setbacks, as well as positive things, regarding the performance of the AEV and electric motors in lab 1. In our first try of scenario 1, the propeller was placed too tight on the electric motors, so the propeller did not even begin to rotate. After we adjusted it, the propeller worked well. In scenario 2, propellers and motors worked well. In scenario 3, propellers and motors all worked well. However, because we made mistakes when we assembled the AEV, one of the propellers hit the plastic board once it started rotating and broke. Some adjustments to the AEV design were helpful when considering future designs.

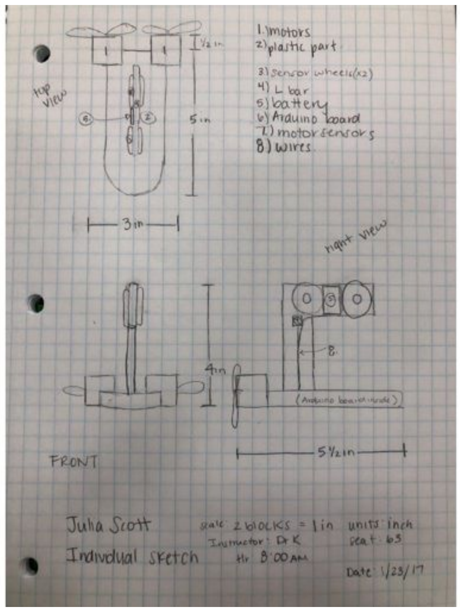
In lab 2, some new Arduino codes were explored. The commands goToRelativePosition() and goToAbsolutePosition() could be a limit to the success of the AEV. The commands could be an issue when trying to find the exact number of marks the AEV should move. Also, the brake command does stop the blades right away, but it might take a while for the actual AEV to come to a full stop due to momentum. The reverse command would have the same issue as the brake command when reversing the entire unit. These issues will also be taken into consideration when coding in Arduino for future AEV testings.

Figure 1: Design A



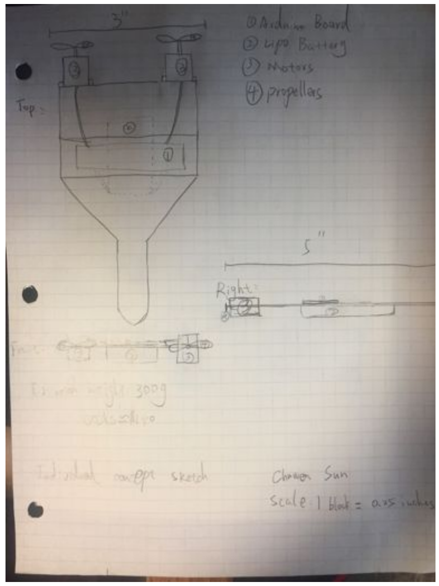
In lab three, many designs were considered with many different reasons for placement of features. Abby chose her design based on safety and stability. Abby choose to place her propellers connected to the motors at the back of the AEV. This allows for the propellers to move freely and not getting in the way of the motors and allows to propel the vehicle forward. Abby placed the Arduino in the middle for easy access to all of the wires and connections. The battery is at the front end so it can still connect to the Arduino board but it is out of the way of everything else. Sticking straight up would be the L bar connecting the sensors. The sensors measure the distance the AEV travels across the rails. The sketch made would keep everything that is necessary for the AEV separate and organized in order to successfully complete the task.

Figure 2: Design J



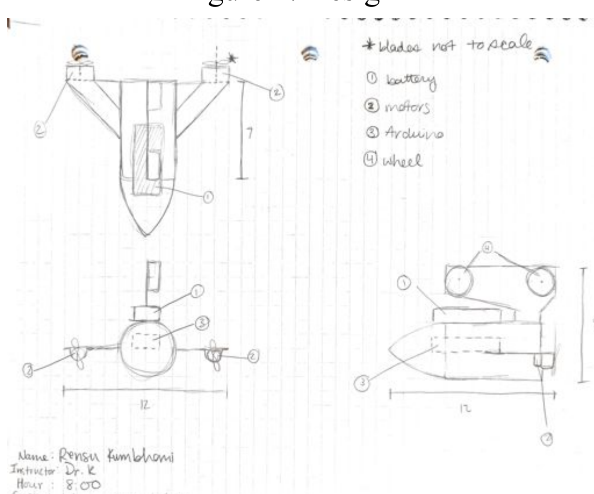
Julia choose her design based on efficiency and safety. The base is a shape of a submarine. The nose of the AEV comes to a subtle point. WHile, the propellers are on the direct back of the AEV to move the AEV forward. The batter and wires are all between the wheels on top of the track. This allows for more passengers to get on and of the AEV. It would also make it easier for maintenance to fix the AEV is something goes wrong as it is all in the same place. Julia estimates the weight to be about 300 grams and the cost to be about $160.00.

Figure 2: Design C



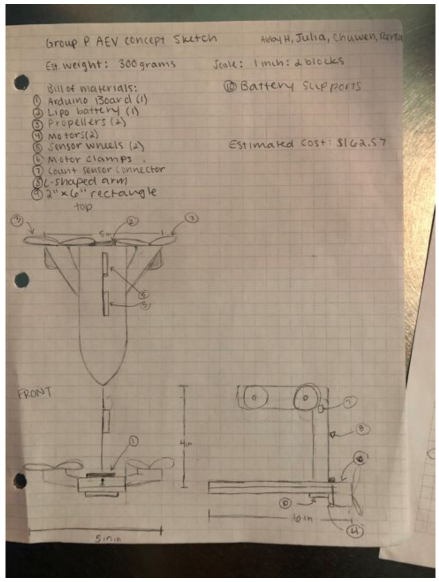
Chuwen's AEV design was based on durability, stability, and efficiency. Chuwen placed the Lipo Battery under the plastic board and placed the Arduino board on the plastic board. By doing some curve and holes about the plastic board, an engineer could connect the Arduino board and battery through the plastic board. This will allow for the company to save space and make the AEV more stable with the plastic board. Chuwen estimates the weight to be about 300 grams and cost about $155.00.

Figure 4: Design R



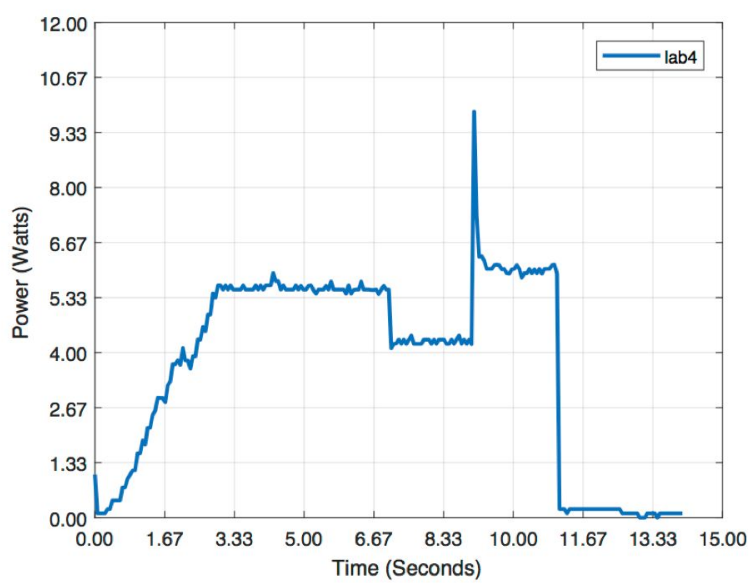
Rensu choose her design to resemble an airplane. By resembling an airplane it would minimize air resistance and drag. Rensu gave the body a pointed nose and wings in the back. Rensu placed the Arduino inside the AEV and the battery on top. The propellers and motors are attached to the wings and placed towards the rear of the AEV for safety reasons. Rensu did realize after designing it might have been a better idea to place the Arduino in a different compartment. Rensu estimates the weight to be 500g and cost about $160.00.

Figure 5: Team Design



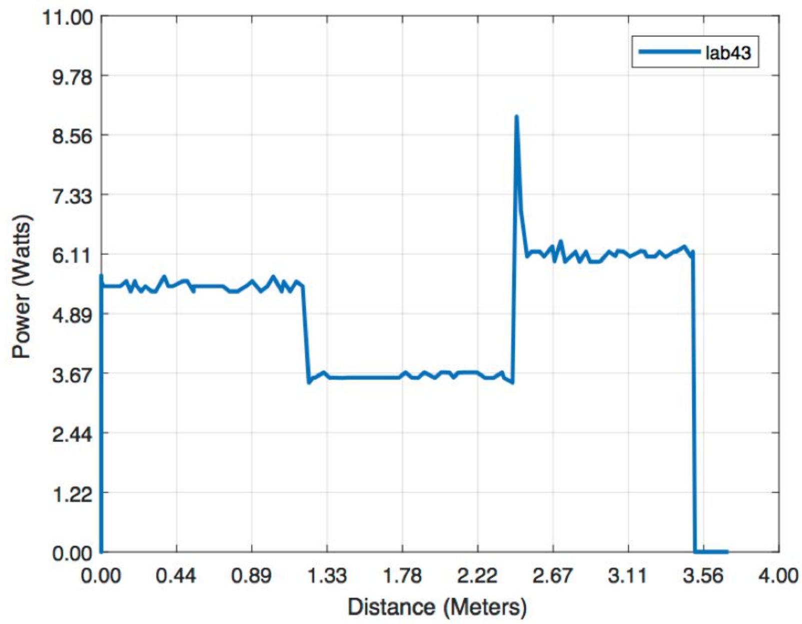
The team decided to make an efficient design based on safety and stability. The team sketch weighs about 400 grams. The cost to build the AEV is about $160.00. The decided to combine everyone's sketch in some way. The propellers are in the back on the AEV closely aligned with Chuwen’s and Rensu’s design. The battery is located on the back side of the AEV resembling a wall so passengers do not fall off the AEV when it is moving. The wires and motor sensors will be in/ wrapped around the L bar like Julia’s and Abby’s design.The team tried to incorporate a good aspect of everyone’s AEV.

Figure 6: Power vs. Time



Above is a graph of Power versus Time of the AEV. As the graph is increasing, from 0 to 3 seconds, the motors are accelerating from 0% to 25% power. The plateau that occurs for approximately 4 more seconds represents the motors at a constant 25% power. Then when the graph suddenly decreases, the motors' power is being decreased to 20%. They stay at this power for about 2 seconds. The spike represents when the motors reverse, and the line coming out of the spike is when the motors are at a constant speed of 25% again for another 2 seconds. The sudden drop is when the motors are braking to a stop.

Figure 7: Power versus Distance



The graph above was also made using the data analysis tool and represents power versus distance. When the motor is powering up from 0% to 25%, the AEV moves approximately 1 meter. As the power decreases to 20%, it moves another 1.5 meters. As the motors reverse the direction of the propellers, it moves just a fraction of a meter forwards before switching directions. As soon as the motors are back up to a power of 25%, the AEV moves another meter in the opposite direction before the motors brake and come to a stop. The AEV has moved about 3.5 meters over the whole test run.

Figure 8: Concept Screening Matrix

Success Criteria	Design A	Design J	Design C	Design R	Team Design
Stability	0	0	+	+	+
Durability	-	-	-	0	+
Maintenance	0	+	+	-	0
Safety	0	+	+	-	0
Efficiency (cost/energy)	0	+	-	0	-
Sum +’s	1	2	2	1	2
Sum 0’s	3	1	1	3	2
Sum -‘s	1	2	2	1	1
Net Score	0	0	0	0	1
Continue?	Combine	Combine	Combine	Combine	Yes

Figure 9: Concept Scoring Matrix

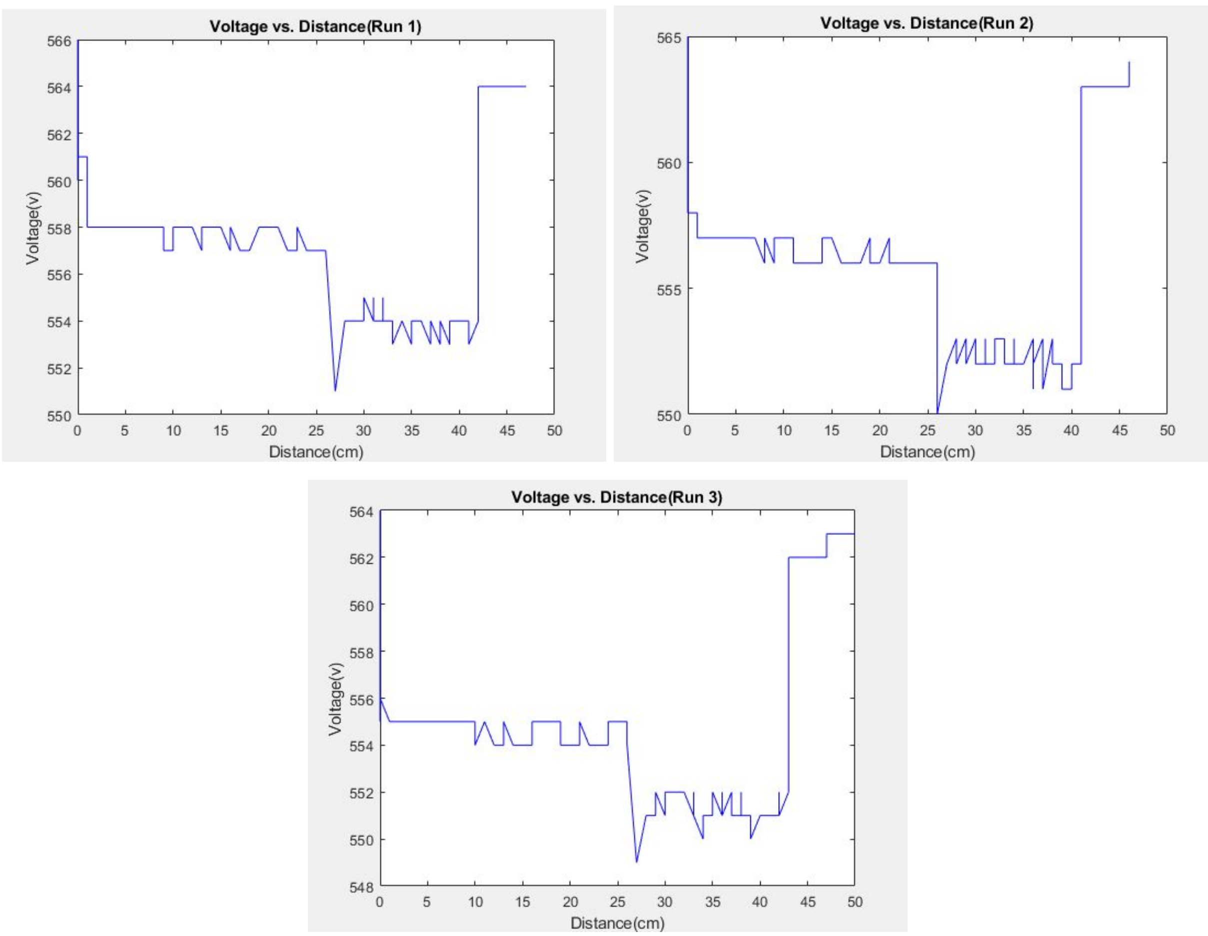
Success Criteria	Weight	Design A		Design J		Design C		Design R		Team Design	
Stability	25%	3	.75	3	.75	4	1	4	1	4	1
Durability	15%	2	.3	2	.3	3	.45	2	.3	4	.6
Safety	30%	3	.9	4	1.2	1	.3	3	.9	3	.9
Maintenance	10%	4	.4	1	.1	3	.3	3	.3	3	.3
Efficiency	20%	2	.4	4	.8	2	.4	2	.4	2	.4
Total	100	-	2.7	-	3.1	-	2.4	-	2.9	-	3.2
Continue?	-	No	-	Yes	-	No	-	No	-	Yes	-

The criteria for the concept screening and scoring matrices were chosen based on the safety of the AEV in the lab and in the real-life situation. The stability of the AEV is the balance or the vehicle's strength to stand when on the rails, whereas the durability is how well the AEV is able to withstand wear, pressure and/or damage. Durability also comes with another factor, which is maintenance. This is how often parts of the AEV will need to be fixed, put back on, or cleaned. Efficiency has two aspects- cost and energy. The goal is for the AEV to be energy efficient, which means it used the least amount of energy and does not waste any, and the AEV should also be cost efficient, which means the cost of all the parts should be minimized, while the design of the AEV is still maximized. Lastly, and most importantly, is the safety of the AEV and the people who are going to be travelling on it. This means that the AEV follows all considerations in the lab manuals, nothing is falling off (safe in lab environment), and the physical design of the AEV would be safe for customers to ride in.

There were pros and cons to each of the five concept sketches made by team P. Design A is not very durable and can break easily, but it is fairly safe and efficient. Design J is highly safe and efficient, but not very durable, so there would be a lot of maintenance involved. On the other hand, Design R has wings that create stability and safety, but it is not as energy and cost efficient. Design C is balanced and not too hard to keep in-tact, but falls low on the highly important safety rating. The Team Design is overall the best design with high stability and durability when on the rails, but could definitely improve on the cost efficiency and safety, which is something that can always be improved upon. Since Design J and the Team Design have the highest ratings on the concept screening and scoring tests, we will be using these two designs as the ones we will test going forward in the project. This lab made it easy to pick out which criteria are most important when designing the AEV and gave us a better idea of what aspects should be incorporated into our design going forward.

In the battery testing lab, the voltage of the battery was measured across multiple runs and across each individual run. We concluded that the power of the battery does go down slightly after each run, but not nearly to the extent that was expected.

Figure 10: Voltage vs. Distance- three runs



The set of figures above represents a graph of the battery's voltage versus the distance that the AEV has traveled, measured by the tick marks. The line on this graph is like a step that is going down, kind of resembling a negative slope, which means that during the run, the voltage of the battery was slightly decreasing as the AEV was running. The voltage spikes back up at the end, which means that the voltage did not drop a drastic amount after each run, but rather took the energy to get the AEV started, then gave it back at the end.

The battery testing lab will help us moving forward because we will be more confident when figuring out the perfect code when trying to simulate the AEV situation. We will know how the Arduino codes work and how the AEV responds to them. We will also take into account that the battery voltage is dropping, so we will try to conserve energy when making our AEV and code, but we will also realize that the rate at which the battery voltage drops is very low, so running out of battery power will not be a concern. If we had more time to research and test this topic, we would have tested different batteries to see if our results were consistent for all batteries because having only one set of data could create some errors.

In the coasting versus power braking lab, the braking distance (total distance- forward distance) was examined for a code with braking and a code that just ends without braking. Unlike our original assumptions, we have concluded that there is not much of a difference in braking distance between the two methods; there are only slight logistical differences. Data was taken to support our conclusions.

Figure 11: Mean and Standard Deviation for Braking Techniques

	Coasting	Power Braking
Standard Deviation	5.52	5.43
Mean (braking distance)	80.91	95.93

The mean value for power consumption for coasting is 21.75 J and the mean value for power braking is 21.67 J. These two values are very similar, but the power used for power braking is slightly more, so this means that more energy would be conserved if the coasting method were to be used.

Figure 12: Average Distance Required the AEV Needs to Stop Before the Gate

	Coasting	Power Braking
Inches	46.77	39.44
Meters	1.19	1.00

Both the power braking and coasting methods provided similar results for average braking distance as well as power consumption, which are two of the most important data numbers taken from this lab. The averages for both values were extremely similar. From this info, we concluded that our AEV could utilize either method of braking and we would see similar, if not the same, results. If we had more time to research this topic, we would add in the servo motor for braking because both of the methods we tested had pretty long of braking distances. Also, some error could have arisen from using different batteries for the two methods, so to get more consistent data we would like to gather results using the same battery and then compare the methods.

Discussion

Prototype 1 most closely replicates an airplane. The wings are an equal distance from the center of the plane to propel the AEV forwards. The battery and arduino board are located in the center the board to replicate an airplane's cabin. Prototype 2 is very similar to Prototype 1 but in Prototype 2, we directed the propellers the opposite direction. Team P wanted to use coasting as it gave off more power in the AEV. So by Team P rotating the direction of the propellers, it allowed for the AEV to more controlled by Team P and we could use mainly coasting with the addition of power braking to slow the AEV down more after it passes the first sensor.

Refer to appendix B for prototypes 1 and 2.

The four designs evolved into the two prototypes by combining everyone's major part. Chuwen had the idea of creating an airplane, Abby had the idea of the propellers facing backwards. Julia had the idea of placing the battery and Arduino board centrally. Rensu had the idea of creating wings. The “wings” are formed from the cross base with the propellers attached to either end. When Team P first test Prototype 1 it was harder to control the AEV because when the AEV wa told to Power break of a certain time the AEV started to accelerate backwards. So by flipping the propellers it allowed for the AEV to slow down from the drag but it was not enough force to make the AEV go backwards. Team P is now focused on Prototype 2 and how do make Prototype 2 more successful.

Refer to figures 8 and 9 for concept screening and scoring matrices.

When the motors were attached to front edge of the wings in Prototype 1, the propellers had to pull AEV, since they were located in the front. With this design, the team noticed some struggle with the AEV trying to pick up speed and be put into motion in the beginning. For the design in Prototype 2 of our AEV, the motors were flipped so the propellers were facing the rear of the AEV and were aligned with the back edge of the wings. As soon as a test run was completed, the team made similar observations. Everyone agreed that that the AEV moved smoother and a small amount quicker than Prototype 1 had during its test run.

In Prototype 2, since the propellers are now pushing the AEV instead of pulling, the team has noticed the battery powering the motors and propellers last longer than when using Prototype 1. The team had thought the differences would not have been as significant as they were and believed it would make little to no difference in how the AEV performed.

The two tests that Team P decided to perform were Battery Testing and Coasting vs. Power Braking. For Battery Testing, the team had hypothesized that the drop in power through several test runs of simple code would show significant amounts of decrease in the power. Surprisingly, the difference in power was miniscule between test runs. The findings were very beneficial due to the fact that it gave us important knowledge that could improve our final code for the AEV and also reassured the team that low-battery shouldn't be an issue over small periods of time.

The second test Team P completed was the Coasting vs. Power Braking test. The group had hypothesized that power braking would be more effective when compared to the concept of coasting. The results actually showed that both methods moved very similarly when coming to a stop and were very consistent between test runs. No team member expected the results to be nearly identical.

There were same trends that we found from our data, but in other cases we were unable to see a pattern from looking at the data. As for the data of Battery Testing lab, the voltage dropped a significant value when the distance of the AEV was at 25 centimeter during each run; however, other than this, all 3 runs share random patterns of voltage, which shows lack of trends on the graphs and for the battery voltage data in general. This allows the group to know that the voltage will be unstable and unpredictable when the vehicle running, so the battery must always be taken into consideration as a limitation when testing the AEV.
As for the data of Coasting vs. Power Braking lab, the final distance of the stopped AEV, both in coasting and power braking, fluctuated between 120 centimeters and 140 centimeters, which means that their braking distances were about the same. After analyzing this data, we can now infer that the two braking methods share the same efficiency because their braking trends are very similar.

The difference of starting positions of AEV on the track is another potential source of error. When doing experiments, it is not easy for the group member to measure the starting position of vehicle accurately every time. As a result, this can cause error in the data for distance. For example, in the Coasting vs. Power Braking lab, starting conditions of AEV will be slightly different in every trial, which could cause fluctuation in the braking distances. The shape changes of the track is a potential source of error. When completing a big amount of AEV testings, the track will not stay at the same shape because they are all different, which can cause instability of group P's data such as causing different power needed in the Coasting vs. Power Braking lab.Some other sources of error could be from the wires hitting the propellers and slowing the AEV down, difference in battery voltage that can affect how the code runs for the AEV, and errors with the reflectance sensors due to incompletion of the reflectance sensor test.

There were both some contradictions and similarities in our labs when comparing the results to what would theoretically happen. For example, in the battery testing lab, we expected the voltage to drop much more after each run. We thought that the voltage would drop a couple tenths out of 8-10 volts after each run, but instead it only dropped a couple hundreths after each time we tested a run. Another example of differing results came from the coasting versus power braking lab. Originally, Team P thought that coasting would have a lot larger of a braking distance than power braking, but in the lab we found that the average braking distances were 80.91 ticks and 95.93 ticks, which is a lot closer than we realized. As for the design, the theoretical results were the same as the experimental results. We found that the design with the propellers facing forward pulling the air is less efficient than the design with the propellers in the back pulling the air, which is what we expected to happen.

Conclusions & Recommendations

In the preliminary research and design labs, Arduino coding was introduced, the reflectance sensors were added and tested, a group design was compiled, the data analysis tool was practiced, and criteria for the AEV was prioritized. In the advanced research and design labs, the battery voltage patterns were studied and braking methods were compared. Group P decided to prioritize safety and efficiency, so a simple, aerodynamic and stable design was configured. It was found that there is slight drop in voltage after each run, so the battery must always be charged. Group P found that there is little difference between power braking and coasting other than slight difference in standard deviation of braking distance and slight difference in voltage usage.

These labs have showed me how to use arduino coding and the large range of error that can occur while programming and testing the AEV. There are many different things that go into the AEV working properly- the battery, motors, arduino, wheels, and sensors have to all be connected properly. Specifically, the design must be simple in order to get the best results, and the reflectance sensors must be in perfect place in order to work. Also, coasting can cause a large range of deviation and inconsistency when doing performance tests.We have chosen to do a very simple design with a cross base, motors on bottom and coming off the back, and a t-shaped arm. The simple design is more efficient because it is lighter and costs less to make, which would use less power and funding. The cross base allows everything to be spread out but not too spread out that it is not aerodynamic. The motors being on the back and bottom allows for more air circulation and it pushed the air rather than pulls. The t-shaped arm is more stable, so the AEV is less shaky. When testing this design compared to our other designs, it used less power from the battery and it was more consistent in braking distance.

We can fix battery error by having a more stable source of battery that drops less power after each run,and by making sure the battery stays fully charged. We can fix wire errors by tightening them and securing them and making sure they are out of the way of the propellers and anything else they can affect. Lastly, we can run the reflectance sensor test before each test to make sure that the sensors are properly functioning.In future lab testing, we would have liked to test the servo motor because it would give a more effective mode of braking and it would be more consistent than coasting and power braking. We would also want to do more battery testing to figure out how to adjust the code as the voltage drops during performance testing.

References

1. MCR & Deliverables document.
2. Reflectance Sensor Manual
3. Technical communications guideline
4. pR&D labs document
5. aR&D labs document

Appendix A- Schedule

Abby Hallock is the PR of the team. She divides up the Reports and Website Updates. She is incharge of submitting the final copies of everything the team needs to submit. Julia Scott is the HR of the team. She is incharge of the schedule and project management. Before testing, Julia builds the AEV for Rensu to input the code. Rensu is incharge of inputting the code and debugging the code if an error occurs. Rensu brings the AEV to Lab every day. Chuwen records that date found in the labs. The team is usually ahead of schedule until Performance Test 1. We struggled with getting the AEV in between the sensors but finally we got the AEV in the sensors on the third trial. Team P plans to find a better way to more accurately get the AEV in between the sensors for Performance test 2. Team P is now ahead of schedule and will be ready to test for Performance test 2 on March 28th. Team P splits up the work evenly and everyone is expected to check everyone's work and put forth their best effort for the team's success. Every task is completed 100% each time.

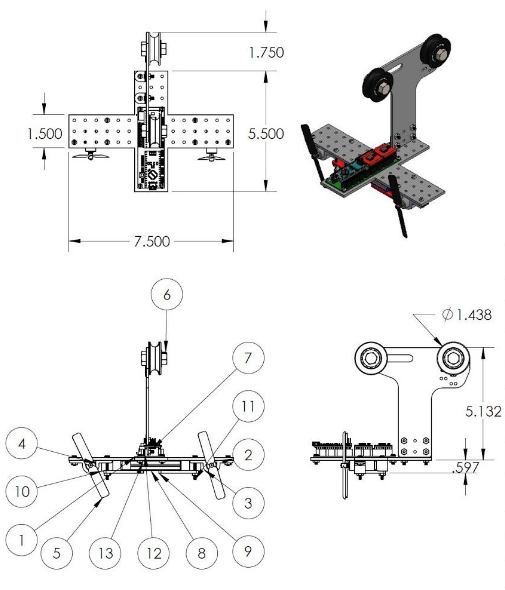
TEAM P SCHEDULE SUBJECT: AEV Project Schedule CLASS: 8:00 AM

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN
WEEK 1	Jan 8	9	10 Meet Team P members	11	12	13/14 Meet to discuss Website Update 1
Due:						
WEEK 2	15 Finished with Website Update ang Meeting Minutes by 8:00PM	16 Submit Website Update 1 & Meeting Minutes	17 Start pR&D Day1	18	19	20/21
Due:			Website Update 1 Meeting Minutes			
WEEK 3	22	23	24 pR&D Day 1 finish and pR&D Day 2 started	25	26	27/28 Meet to divide Progress Report and discuss AEV Project
Due:						
WEEK 4	29	30	31 Finish pR&D	Feb 1	2	3/4 Meet and Discuss Challenges with Progress Report
Due:						
WEEK 5	5 Finished with Website Update & Progress Report 1 by 8:00PM	6 Submit Website Update 2 & Progress Report 1	7 Start R&D	8	9	10/11
Due:			Website Update 2 Progress Report 1			

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN
WEEK 6	12 Julia created Prototype 1 for AEV	13 Create Grant Proposal Script and slides to present	14	15	16	17/18 Meet To discuss How committee meeting went ~ 30 min
Due:		Submit Slide	Committee Meeting 1 Grant Vote			
WEEK 7	19 Start Writing Progress Report	20	21 Finish R&D 2 Begin Updating Website	22	23	24/25
Due:			aR&D quiz			
WEEK 8	26 Divide the Progress Report	27	28 Submit the R&D presentation	MAR 1	2	3/ 4 Meet to discuss Progress Report & concerns with AEV
Due:			Website Update	R&D Presentation		
WEEK 9	5 Finish Progress Report by 8:00PM	6 Revise and Edit Progress Report	7	8	9	10/ 11
Due:			Progress Report 2			
WEEK 10	12 Spring Break	13 Spring Break	14 Spring Break	15 Spring Break	16 Spring Break	17/ 18
notes						

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN
WEEK 11	19	20 Divide up CDR	21	22 Finish CDR by 8:00PM	23 Revise and Edit Progress Report	24/25 Meet and discuss next few weeks due dates Divide up Progress Report 3
Due:			Performance Test 1		Submit CDR	CATME Eval. #2
WEEK 12	26	27 Finalize AEV for Performance Test 2	28 Prepare for Committee Meeting	29	30	31/1
Due:			Performance Test 2	Committee meeting		
WEEK 13	APR 2	3 Finish Progress Report 3 by 8:00 PM	4 Revise and Edit Progress Report 3	5	6	7/8 Discuss Oral Presetnation
Due:				Progress Report 3		
WEEK 14	9 Make Final changes to AEV for final Performance Test	10	11 Fix issues with code for Final Performance Test	12	13	14/15 Meet to finalize Oral Presentation
Due:		Final Oral Presentation		Final Performance Test		
WEEK 15	16 Revise and Edit Final Website Submission	17 CDR done by 8:00 PM for revise and editiing	18 Submit: -CDR -Website Update	19	20	21/22
Due:		Oral Presentation		CDR Website Update Team Evaluations		
WEEK 16	23	24 Reading Day	25	26	27	28/29
Due:						

Appendix B- SolidWorks

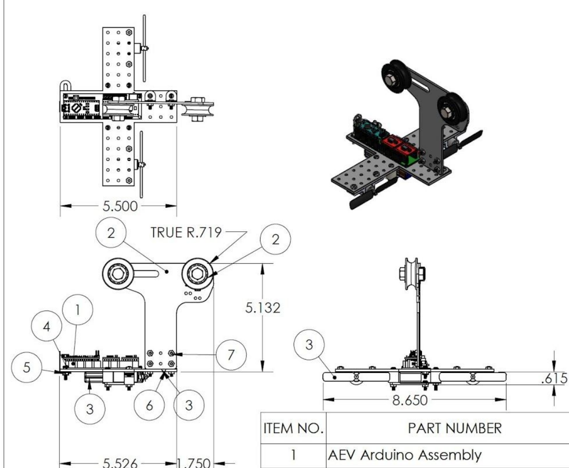


Estimated Weight: 0.34 pounds
Estimated cost: $159.14

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	90-deg bracket	Aluminum	2
2	Cross	Plastic	1
3	Motor Mount Clip Aluminum	Plastic	2
4	AEV Motor	Steel/ Aluminum	2
5	Prop 3inch	Plastic	2
6	Arm Bar	Plastic/ Plastic/ Plastic	1
7	AEV Arduino Assembly	Aluminum/ Plastic	1
8	Battery	Aluminum/ Plastic cover	1
9	Battery holders	Plastic	2
10	Battery Spacer	Plastic	2
11	pan slot head_ai	Aluminum	4
12	pan slot head_ai	Aluminum	12
13	machine screw nut hex_ai	Aluminum	16

The Ohio State University First Year Engineering	Dwg. Title: Prototype 1	Scale: 1:4	Inst.: Dr. K	Units: IN	Dwg. No.: 1
	Drawn By: Team P		Hour: 8:00 AM	Seat: 63	Date: 03/22/2018

SOLIDWORKS Educational Product. For Instructional Use Only.



Estimated Weight: 0.37 Pounds
Estimated Cost: $161.24

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	AEV Arduino Assembly	Aluminum/ Plastic	1
2	Arm Bar/ Wheel/ Sensors	Plastic/ Plastic/ Aluminum	1
3	X base/ battery/ propellopors/ motors	Plastic/ Aluminum/ plastic/ Aluminum	1
4	Bolts	Aluminum	3
5	Nuts	Aluminum	9
6	90-deg bracket	Aluminum	2
7	SL-PHMS 0.112-40x0.375x0.375-S	Aluminum	6

The Ohio State University First Year Engineering	Dwg. Title: Prototype 2	Scale: 1:4	Inst.: Dr. K	Units: IN	Dwg. No.: 2
	Drawn By: Team P		Hour: 8:00 AM	Seat: 63	Date: 03/22/2018

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Figures 1 and 2: Prototypes 1 and 2

Appendix C- AEV Final Coding

```
reverse(4);
celerate(4, 0, 35, 4);      %accelerate the motors
motorSpeed(4, 35);        % keep the motors going
goToAbsolutePosition(-206);  % go the number of tick marks to the sensor then shut off motors
reverse(4);                              %power brake
goFor(2);
brake(4);
goFor(7);                                %stop for 7 seconds at gate
reverse(4);
celerate(4, 0 , 35, 3);            %accelerate through gate
motorSpeed(4, 35);
goFor(3);
brake(4);                         %shut motors off and coast into the caboose
```