AEV Critical Design Review Report

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Executive Summary

The AEV project consisted of designing, building, and coding an advanced energy vehicle (AEV) that would run on a monorail track and complete the assigned task. Other goals of this project were to design a vehicle that would focus on energy management, operational efficiency, and operational consistency. This project also developed project management and team working skills and taught more about the design process and project documentation. Each week, the team performed a different lab or test that all contributed towards the design, coding, building, and testing of the AEV. The assigned task was *Star Wars* themed, and the team was challenged to build an AEV that would start in the drop off area, glide on the monorail and stop in front of the first sensor for five seconds, continue on the path and navigate to the cargo area to pick up an “R2-D2”, stop for five seconds to verify all cargo is loaded, return back to the gate, trigger the other sensor, pause for seven seconds, and then continue back to the starting position and final drop off area. The AEV’s mission was to transport R2-D2 units following the destruction of the Death Star. An efficient system was needed because of the limited power source on the remote planets.

During the first week of lab, the team explored the system hardware components and learned how to set up the AEV software as well as program basic commands in Arduino. Future labs involved performing tests to become familiar with the propulsion system efficiency as well as the programming for the external sensors, brainstorming and drafting AEV concept sketches, downloading data from the automatic control system in order to conduct analysis of the AEV after each run, using a concept scoring and screening matrix in order to analyze the various AEV models, running and collecting data from testing the AEV on a straight track, analyzing data in order to determine the amount of friction generated as well as the energy used, designing and testing two different AEV designs using the same code to determine which design would run more efficiently, testing different codes, and reducing the overall energy used. All of the labs gave the team valuable information on the overall AEV design.

The team found that the 3030 puller configuration propellers worked best and that a motor power around 35% proved to have the best efficiency. Performance Test One showed that the design with the battery on the arm used less power. Performance Test Two showed that a code that utilized less coasting proved to be more consistent and accurate. Through Performance Test Three the team learned that although coasting was inconsistent, some could be used in the final code in order to keep the energy efficiency low.

During the final run, the AEV was able to complete the mission with almost complete accuracy. The AEV had an energy to mass ratio of 959 J/kg. Compared to the rest of the class, the team ranked in the top half. The only problem that was encountered was when the AEV had picked up the R2-D2 and was on the way back to the starting position. A light touch had to be given to ensure that the AEV would not touch the gate while stopping. Recommendations to this overall project would include being given more time to perfect the code, having more consistent AEV tracks, and being given parts that were newer and upgraded in order to fix environmental inconsistencies.

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Introduction

The purpose of the Advanced Energy Vehicle project was to create the most cost and energy efficient vehicle for the rebel alliance to transfer R2-D2 units across the land to interceptor aircrafts of a remote planet where energy is scarce. The goal of the project was to design an Advanced Energy Vehicle (AEV) to complete the task of traveling on a track, stopping between two sensors for seven seconds, continuing down the track, stopping to pick up an R2-D2 unit, waiting five seconds with the cargo attached, then to travel back to the gate, waiting for the arm to lift, and finally make it to the drop off area with the cargo intact. The Critical Design Report (CDR) was written to summarize the entire project and show how the final AEV design came to be. Each week in class a different lab would be performed to test different aspects of the AEV. The CDR highlights key points discovered from each of these individual labs and justifies the final design.

The project began with the team building a simple AEV design. The AEV was crafted from a set of given materials, and the team had the option to make a custom laser cut part. Each week different labs were performed in order to improve the structure, code, and energy efficiency of the AEV. These labs include tests to become familiar with the propulsion system efficiency as well as the programming for the external sensors, brainstorming and drafting of AEV concept sketches, downloading data from the automatic control system in order to conduct analysis of the AEV after each run, using a concept scoring and screening matrix in order to analyze the various AEV models, and running and collecting data from testing the AEV on a straight track. Other labs included analyzing data in order to determine the amount of friction and energy generated, designing and testing two different AEV designs using the same code to determine which design would run more efficiently, and the testing of different codes to reduce the energy consumption. All data collected was recorded and will be discussed further in the sections below. At the end of the semester after all testing, the team had a final run where the AEV was graded based on how well it completed the designated tasks. The team also had the chance to participate in the AEV Showcase where they presented the project to a panel of judges. This final Critical Design Report presents what Group L has tested and learned from the semester and showcases the final AEV design.

Experimental Methodology

Many labs were performed in order to create the final AEV design and code. In Lab One, the team mounted propellers on two motors and used the Arduino Sketchbook software to practice programming various calls needed to complete tasks such as adjusting the motor speed or traveling for a certain amount of marks. During Lab Two, the team used a wind tunnel was used to collect information about propulsion efficiency (see Figure 1 below). A power supply was turned on to a wind tunnel that used either a 'pusher' or 'puller' motor configuration. The percent power, current, and thrust scale reading measurements were taken at varying percent power increments. Using the data collected, the propulsion efficiency and the advanced ratio were calculated. By graphing and analyzing this data it was found that the AEV was most efficient at 35 percent power using the 3030 puller configuration, so the team made sure to utilize these propellers in the design.

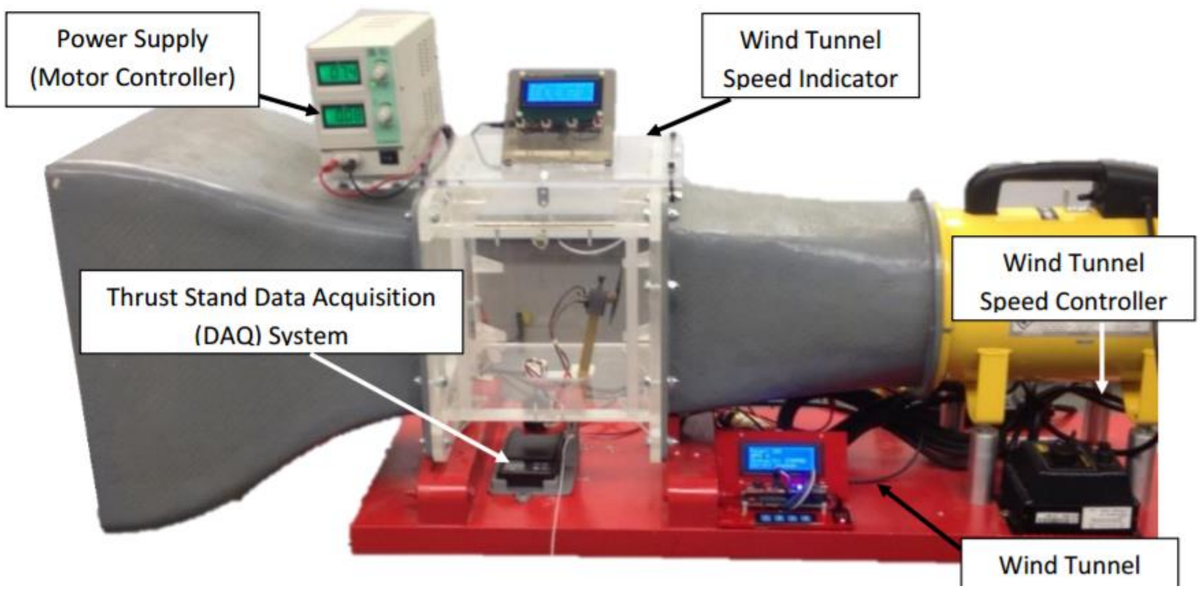


Figure 1: Wind Tunnel Equipment
(Taken from The Ohio State University Advanced Energy Vehicle Design Project: Lab Manual pg.42)

In Lab Three, the team members all created their own AEV designs through a concept sketch. These designs were then analyzed using concept screening and scoring matrices. Within these tests, balance, weight, cost, aerodynamics, durability, flexibility, and style were all scored. The results then led to two designs for the AEV which were then tested. The next few labs after this involved testing the AEV designs on the track and then downloading the data to analyze the performance. During Performance Test One, the two final designs for the AEV were both tested on the track using one set of code. After each run, the data from the sensors was uploaded to the computer from the Arduino. The sensors on the wheel obtain the data which is then uploaded into a MATLAB file to be made into graphs, showing both power versus distance and power versus time on excel spreadsheets. The data was obtained by connecting a USB cord to the corresponding part of the AEV and then opening up MATLAB and running a previously created program. Using this data, the team selected the better of the two AEV designs to test in Performance Test Two. During this second performance test, two sets of code were compared. Two different codes were run and the data was again collected after each run. The codes were compared to see which ran with the least amount of energy. The best code was selected and used in Performance Test Three. Performance Test Three allowed for last minute testing of the AEV before the final test. The code was perfected and tweaked based on the analyzing of many trial runs. The team continued to work towards making the most energy efficient runs.

During the last week of lab, the team completed the final test. The team had two chances to run their AEV on the track and complete all the necessary tasks of traveling to the gate arm, waiting for seven seconds at the sensor, picking up the R2-D2, traveling back to the sensor, passing through the gate, and stopping at the correct point. The AEV ran on the inside track as seen below in Figure 2.

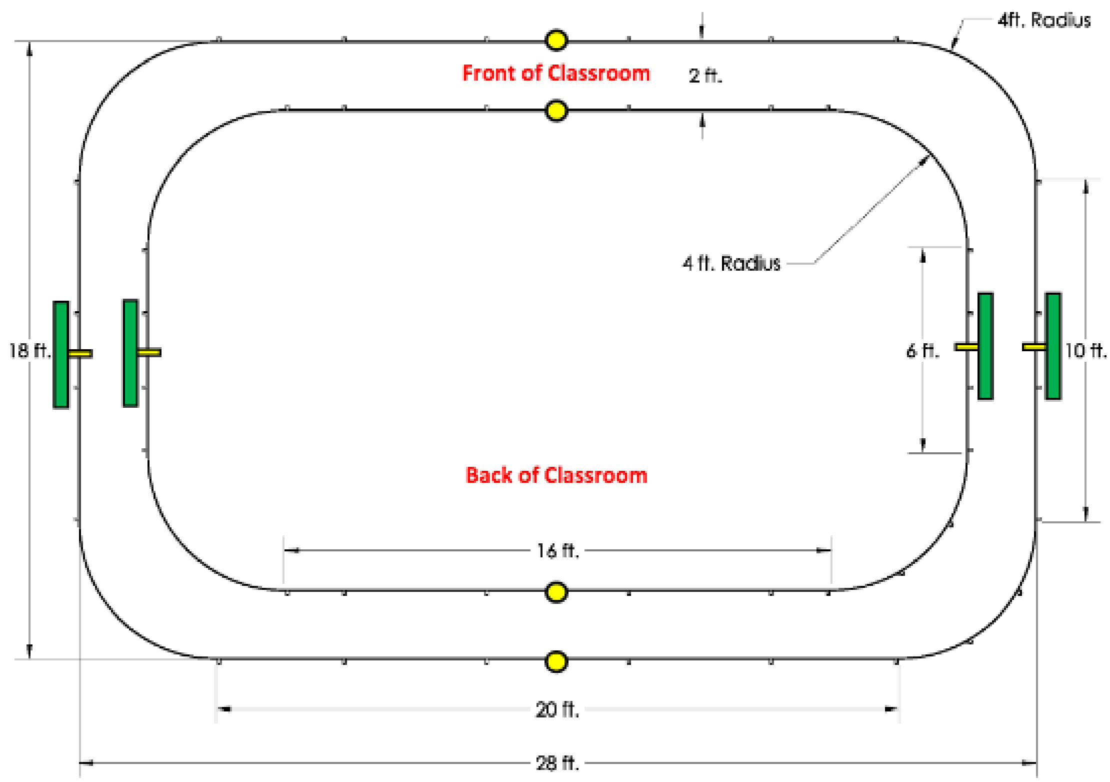


Figure 2: Monorail Network Description

(Taken from The Ohio State University Advanced Energy Vehicle Design Project: Lab Manual pg.16)

After all of the testing, the team's final AEV design included one medium rectangle of plastic, a T-shaped support arm, 16 pan slot screws, 16 machine screw nuts, four 90 degree brackets, an arduino, two hex bolts, two rotation sensor boards, a modified tee, two aluminum motor mount clips, two AEV motors, two three inch props, a battery pack, a narrow battery pack clamp plate, and a pulley assembly with reflective tape. This setup can be seen in Figure 3 below.

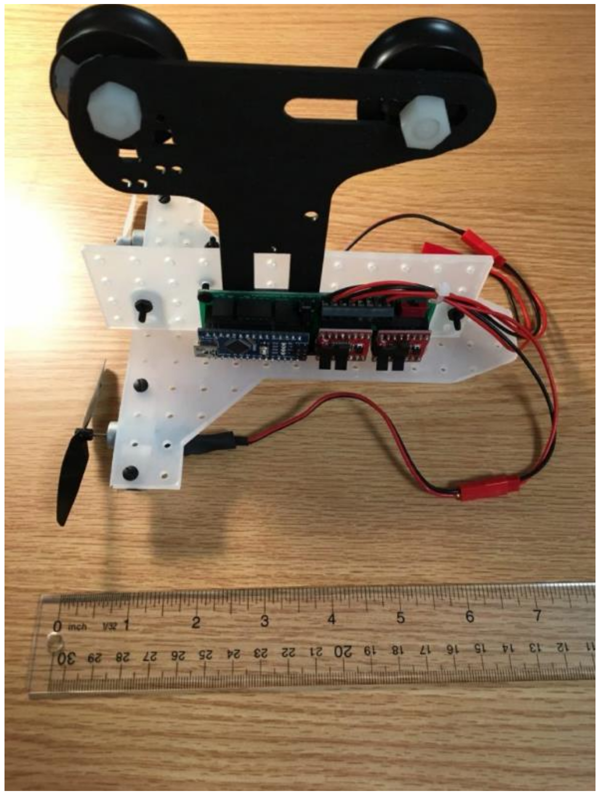


Figure 3: AEV Design Setup

The green rectangular part found in the front of Figure 3 is the Arduino where the team uploaded code. The wheels were attached to the T-shaped support arm and allowed the AEV to glide along the monorail track. The sensors were connected to the support arm near the wheels in order to detect the rotations from reflective sensors on the wheel. These sensors were used to know when to change the AEV speed and reverse the wheel direction. Figure 4 below shows the size of the sensors compared to a quarter. The commands goToAbsolutePosition(d) and goToRelativePosition(d) were used along with the sensors in order to successfully navigate the AEV along the monorail track to complete the mission.

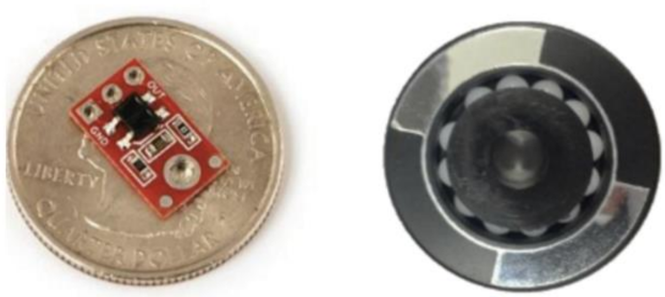


Figure 4: Reflective Sensor (left) and Wheel with Reflective Tape (right)

(Taken from The Ohio State University Advanced Energy Vehicle Design Project: Lab Manual pg.33)

Results

The two prototype designs that were tested during Performance Test One were both based on the same base model. The model was an evolution on a design created in Lab Four with improvements to both the weight and the balance. In both of the designs the T-arm was used to attach the wheels to the body of the AEV. A medium sized rectangular piece was then attached to the arm so that its large sides were parallel to the flat part of the arm. A modified version of the T-block was then attached perpendicular to the rectangle. The motors were attached to the bottom side of both sides of the top of the T block. The Arduino also bolted to the side of the rectangular piece. The difference in the two designs comes from the location of the battery. In the first design, shown in Figure 9 (see appendix), the battery was placed in between the holder plate and the modified T block on the bottom of the AEV on the side opposite of the Arduino. In the other design, shown in Figure 10 (see appendix), the battery was bolted to the rectangular piece on the opposite side of the Arduino. This would end up being the final design selected by the team.

Concept screening and scoring matrices were used to determine which designs were the best overall and what parts of each individual design stood out from the rest.

The concept screening matrix, shown below in Table 1, was used to help decide which concept designs from Lab Three would be the most useful to continue to develop. As compared to the reference AEV design, design three, the one the prototypes mentioned were created from, showed the best combination of positive aspects to negative ones.

Table 1: AEV Concept Screening Matrix

Criteria	Reference Score	Design 1 Score	Design 2 Score	Design 3 Score	Design 4 Score
Balance	0	-	-	+	0
Weight	0	-	-	+	-
Cost	0	0	0	+	+
Aerodynamics	0	+	0	-	+
Durability	0	+	+	+	+
Flexibility	0	+	0	0	-
Style	0	+	+	0	+
Total +	0	4	2	4	4
Total 0	7	1	3	2	1
Total -	0	2	2	1	2
Net Score	0	2	0	3	2
Continue?		Yes	No	Yes	Combine

In the concept scoring matrix, shown below in Table 2, design three was again ranked higher than any other design based upon a weighted list of criteria. The only criterion where design three was scored lower than another design was on durability, a characteristic which was improved upon after Lab Four. Because of design three's identicalness to the final design, the scores given to Design three in Table 2 can also be seen as the scores for the final design.

Table 2: AEV Concept Scoring Matrix

		Reference		Design 1		Design 2		Design 3		Design 4	
Criteria	Weight	Score	Weighted Score	score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Balance	0.2	3	0.6	2	0.4	3	0.6	5	1	4	0.8
weight	0.2	3	0.6	3	0.6	1	0.2	4	0.8	4	0.8
Cost	0.1	2	0.2	3	0.3	3	0.3	4	0.4	3	0.3
Aerodynamics	0.15	3	0.45	4	0.6	2	0.3	3	0.45	3	0.45
Durability	0.15	2	0.3	3	0.45	4	0.6	3	0.45	3	0.45
Flexibility	0.15	3	0.45	3	0.45	2	0.3	4	0.6	2	0.3
Style	0.05	1	0.05	5	0.25	5	0.25	5	0.25	5	0.25
Total Score			2.65		3.05		2.55		3.95		3.35
Continue			No		No		No		Develop		No

The cost effectiveness of the system is one of the most important aspects to be considered when building and producing a good. In order to reduce the cost of the vehicle, the team only used the parts already provided instead of custom making parts which would increase cost. The team also avoided using any extraneous pieces to reduce the materials needed and therefore the cost of the vehicle. The total cost of the team's AEV was $159.30. As seen in the bill of materials, below in Table 3, the bulk of the list is nuts and bolts, the cheapest materials, costing around $3 when in bulk. The most expensive component was the Arduino microcontroller which cost $100, roughly two thirds of the total cost.

Table 3: Bill of Materials

ITEM NO.	PART NUMBER	QTY.
1	Medium Rectangle	1
2	Support Arm 1 2 Sensor Holes V2	1
3	pan slot head_ai	7
4	pan slot head_ai	6
5	pan slot head_ai	4
6	machine screw nut hex_ai	17
7	machine screw nut hex_ai	2
8	90-deg bracket	4
9	AEV Arduino Assembly	1
10	hex bolt_ai	2
11	Rotation Sensor Board	2
12	Modified Tee	1
13	Motor Mount Clip Aluminum	2
14	AEV Motor	2
15	Prop 3inch	2
16	Pulley Assembly	1
17	Battery Pack	1
18	Battery Pack Clamp Plate	1
19	Pulley Assembly w-reflective tape	1

The performance of the vehicle during the final testing was critical in evaluating how effective the strategies implemented by the team were. The full results of the test can be found in Figure 15 in the appendix. A plot of power vs. time of the final run of the AEV is shown in Figure 5. As seen below, the run can be easily broken into phases based on each spike and plateau of the graph.

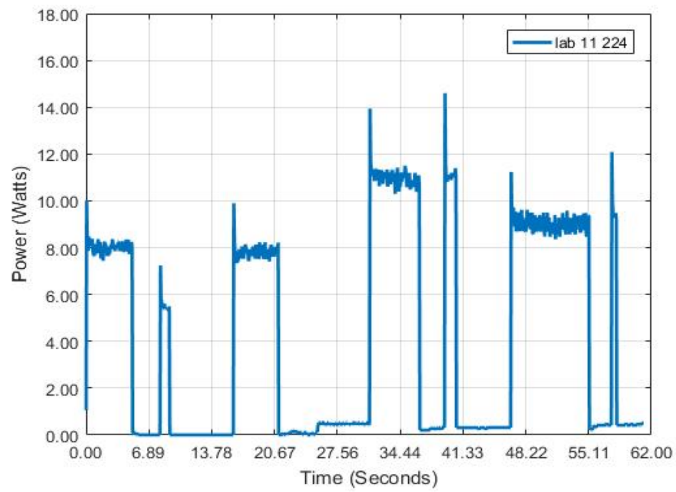


Figure 5: Final Run Power vs. Time

A table showing the breakdown of energy consumed per each of these phases is shown below. From this data in Table 4, it can be seen that the total energy consumption was 251.884 joules. With the mass of the AEV being 260 grams, the energy to mass ratio was 959 J/kg. More importantly, the breakdown table shows when the most energy was consumed by the AEV, during phases seven and eleven, which, logically, occurred when the AEV was pulling the cargo which requires more force and therefore more energy to move.

Table 4: Final Run Phase Breakdown

Phase	Code	Energy Consumed (J)
1	reverse(4); motorSpeed(4,30); goToAbsolutePosition(-190);	37.358
2	motorSpeed(4,0); goToAbsolutePosition(-363);	0.216
3	reverse(4); motorSpeed(4,25); goFor(1.5);	7.766
4	brake(4); goFor(7);	0.294
5	reverse(4); motorSpeed(4,30); goToAbsolutePosition(-595);	35.276
6	brake(4); goFor(10);	0.514
7	reverse(4); motorSpeed(4,45); goToRelativePosition(200);	61.594
8	motorSpeed(4,0); goToRelativePosition(160);	0.469
9	reverse(4); motorSpeed(4,45); goFor(1.25);	15.409
10	brake(4); goFor(7);	0.441
11	reverse(4); motorSpeed(4,45); goToAbsolutePosition(-155);	80.699
12	motorSpeed(4,0); goToAbsolutePosition(-15);	0.402
13	reverse(4); motorSpeed(4,40);	11.445
14	goFor(1); brake(4);	0.000
	Total:	251.884

In comparison with other teams who also tested on the inside track, the energy mass ratio of the team's vehicle was the third best with a score of 959 J/kg (see Figure 11 in the appendix). The two teams that had better scores had energy mass ratios of 950 J/kg and 971 J/kg. The team's energy consumption of 243.9 J ranked in the top half of the class and was not too far from the range of the team with the lowest energy consumption of 190.2 J. The AEV completed the final run in 57 seconds with an initial score was a 36 out of 40 because of one touch in order to prevent the AEV from breaking the second sensor on the return side of the gate. This touch was not completely necessary, but breaking the sensor would result in a zero, so a quick decision was made by a team member to prevent the total loss. The time factor bonus multiplier from our run time was 1.62, bringing the final score to 74.5 points. This result however, placed the team around the middle of the field when compared to the whole class.

Discussion

The purpose of this project was to create an advanced energy vehicle that, when programmed with a specific code, could complete a given task on a track as efficiently as possible. During the first few weeks the team was able to become familiar with each part of the AEV and their functions. The team also observed how various function calls worked. This allowed the team to come up with different and unique models for the AEV that could be tested.

During the third week of lab the team used wind tunnel testing was used to determine the propulsion efficiency. Through extensive testing using various voltage inputs, it was determined that the 3030 propellers would be the most efficient, producing much more pushing and pulling power than the 4545 propellers. This result was expected because the 3030 propellers had a greater surface area than the 4545 propellers, allowing for more movement when wind energy was applied. The 3030 propellers design also allowed it to be efficient when pushing and pulling the AEV. After determining which propeller was the most efficient, the amount of power needed to make the AEV run while wasting the least amount of energy was determined. It was found that the propulsion efficiency peaked at an input power of about 35 percent (see Figure 6 below). This means that applying more or less than 35 percent power to the motors will decrease the efficiency of the vehicle. This value makes sense because it is greater than the minimum motor speed value to get the AEV to move (25 percent motor speed), but not so high that the AEV will fly off the track.

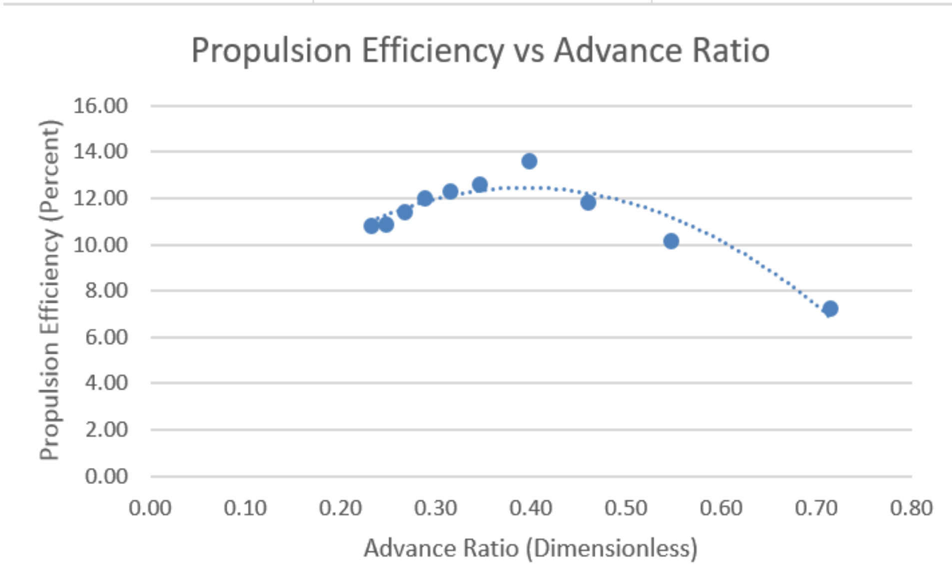


Figure 6: 3030 Propeller Propulsion Efficiency vs. Advance Ratio

Next, the team was tasked with creating four original designs for the AEV, comparing them to a reference AEV using plus, minus, and zero's to represent whether or not the design would perform better, worse, or as well as the reference AEV for that specific criteria. As seen earlier in Table 2, design three had the most plus marks meaning that, theoretically, it would perform better than the other designs. Each criteria was then given a weight based on how important it was to the overall performance of the AEV and each design was given a score out of five for each criteria, shown earlier in Table 3. Balance and weight were the highest weighted criteria while cost was the least weighted criteria. This is because the cost of the AEV does not really affect how the AEV runs. On the other hand, the balance and weight of the AEV are very important factors. If the AEV is unbalanced, it could potentially fall off the track. If the AEV weighs too much, then it will not be efficient. The weighted values were multiplied by the score each design was given and the totals for each design were compared. Theoretically, the higher the value the better the design would perform when compared to the others.

The team next built two different AEV prototypes based off of the results obtained from the concept screening and scoring matrices. In the first design, the battery was placed on the bottom of the AEV. In this design, the weight distribution was not even, causing the AEV to lean to the right because of the Arduino board. Uneven weight distribution caused the AEV to rock and lean to one side, making it difficult to round corners. In the second design, the battery was instead placed on one side of the arm. Although this was a minor change, it appeared to improve the stability and the overall look of the AEV. These two different designs were tested and comparing using graphs of power versus time. The design with the battery on the arm (see Figure 8 below) used slightly less power compared to the design with the battery near the arm (see Figure 7 below).

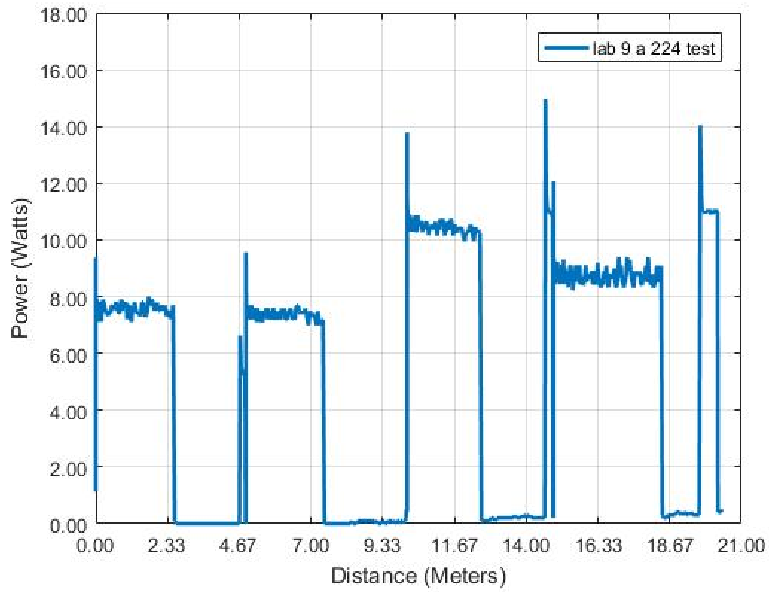


Figure 7: Run Power vs. Distance for the AEV Design 1

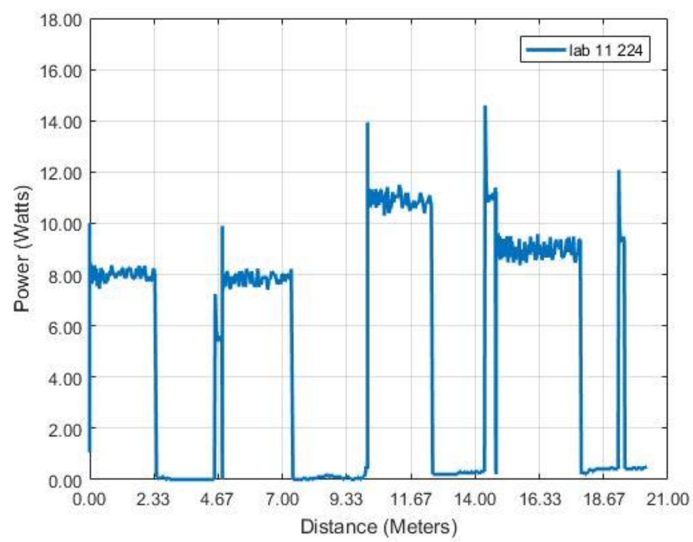


Figure 8: Run Power vs. Distance for AEV Design 2

Beyond the physical structure, cost was another aspect highly ranked when deciding the designs. In order to make it as least expensive as possible, the group decided to not add any parts including laser cut plastic or 3D printed parts. Cost was important because it was something that was easily controlled, guaranteeing a specific outcome whereas the energy of the vehicle was affected by how the vehicle ran. The team's AEV price was also low because the servo motor was not used. This technology would have added a much higher cost to the final expenses. The most expensive part of the AEV was the Arduino. This part could not be removed because it was the main 'brain' and was how the AEV ran.

After selecting the design, the team worked to write and perfect the code. Each week in lab, many test runs were performed in order to tweak the code to get it to run as stated in the mission. During Performance Test Two, two different codes were tested to see which would run more consistently with less energy. Code one utilized coasting to reduce the amount of power used during the runs. Code two eliminated some of the coasting and instead used the commands goToAbsolutePosition(d) and goToRelativePosition(d). It was found that during the lab time, the battery supplied different amounts of voltage. This caused the code that used coasting to be very unpredictable. The team decided to use the code two for the final run because it proved to be more consistent and reliable.

One potential error throughout the lab was the inconsistency of the runs. The team's final code still utilized some coasting as a way of maneuvering down the track. Due to the varying voltages of the battery, the power used to move the propellers was not always the same causing some slight inconsistencies. This error was a major factor that set the team back when it came to preparing for the final test. Although the code was not changing, the AEV would travel a different distance each time. Consistency is very important when it comes to stopping between the two sensors used to lower the gate on the track. The AEV must stop before the second sensor, so having the vehicle go a different distance every run would ruin the possibility of completing the final test successfully. The fact that the sensors were located next to wheels was also a possible source of error. The positioning of the wheels could have caused the counts to be off. When the sensors do not detect the correct wheel count, the commands in the Arduino code such as goToAbsolutePostion and goToRelativePosition no longer could be useful.

During the final test, the team's AEV was able to complete the mission with almost complete accuracy. During the first half of the run, the AEV successfully stopped in front of the gate, picked up the R2-D2, and traveled back to the gate. At the second stop before the gate on the way back to the start, the AEV had to be given a slight touch in order to ensure that the it did not run into the gate while stopping. This problem was likely from the inconsistency during coasting that had also occurred in some of the previous runs. The team was able to regain points when the AEV completed the run in only 57 seconds. The team had an overall energy usage of 959 J/kg. Compared to other groups, seven other groups had lower overall energy levels. Although Group L did not use the lowest energy, the AEV still used less than 1000 J/kg (as seen in Table 7 in the appendix) and ranked in the top half of the class.

Conclusions and Recommendations

The purpose of the AEV project was to allow students to work together in teams to build an advanced energy vehicle that could complete a certain task as efficiently as possible. In order to achieve this goal, many tests needed to be conducted. The wind tunnel test showed which propellers worked best and the power level that there was peak efficiency at. The 3030 propellers were deemed to work the best and it was determined that the AEV would run most efficiently using a power input of around 35%. Different designs for the AEV were also compared and contrasted using concept screening and scoring matrices. After the scoring process, it was decided that the best design was the one that was the most lightweight and balanced. This design, design three, was chosen for further testing. The balance was further increased later on when the design was modified, placing the battery on the top of the AEV across from the Arduino rather than on the bottom. Another factor the team thought about when constructing the final design was the total overall cost of the AEV. One of the ways the team kept the mass of the AEV as low as 260 grams was to construct the vehicle using as few parts as possible. This caused the overall cost of the vehicle to only $159.30. Different codes were tested and implemented and it was determined that although coasting was very energy efficient, it proved to be very inconsistent. The final run used the commands goToAbsolutePostion and goToRelativePosition with minimal coasting.

During the final test, the team's AEV used 251.884 J of power while running the course. Given the mass of the AEV, this gave the vehicle an energy to mass ratio of 959 J/kg. Compared to the class, the team ranked in the upper half (see Table 7 in the appendix). The small sections of code that utilized coasting proved to be very beneficial to the team as they helped reduce the overall amount of energy consumed and kept the energy to mass ratio small. The team worked very well together and always remained very optimistic and positive during the test trials. Since the team worked so well together and was able to write a code that worked in the beginning of the testing, the team had the opportunity to participate in the AEV Showcase. This experience was very beneficial and fun and the team members were able to use their strong technical and communication skills to present to three different judges. Overall, the team worked very hard to produce a superior product that, when tested, completed the task at hand in a timely and efficient manner. There were no major mishaps that hindered the team or caused the AEV to not be able to complete the main bulk of the task.

The team did face a few minor challenges while testing the AEV. One minor challenge the team faced involved time. The team had to test the AEV in both room 224 and room 308, each having slightly different tracks. This caused the team to create two separate codes, one for each room. While this was not very challenging, having to change and fix a code that the team might not have to use for the final run took time away from perfecting the final code. To fix this, the team decided it would be best to focus time in room 224 to testing different kinds of code. Another challenge the team faced involved the battery. Throughout the day, the batteries lost power, leading to inconsistencies with the AEV's performance that the team would have to fix. The team resolved this by running the AEV as few times as possible before doing the finals runs. This conserved the battery's energy and helped the team succeed during the final test. The team also dealt with inconsistencies when writing the code. The first code relied heavily on using coasting in order to increase the vehicle's overall energy efficiency. This coasting would cause a lot of inconsistencies involving how far the AEV traveled during each run. To fix this, the team slightly decreased the overall distance the AEV needed to coast. This increased the reliability of the AEV without decreasing the energy efficiency. The count sensors also caused some trouble for the team early on in testing. They needed to be properly placed near the wheels and in an area of sufficient lighting. When testing, the team made sure the surrounding area was well lit and that the sensors were properly placed flat against the T-shaped arm near the wheel. All of these problems, while time consuming to fix, did not hinder the AEV's performance in the final test.

To improve the AEV project as a whole, the team would suggest less time focused on the design process and more time focused on writing the code. The design process for the group did not take a lot of time, so the team ended up using some of that time to start writing a code for our vehicle. Looking at other groups, it seemed they had a design chosen fairly quickly as well and also took a lot of time to figure out how the code would work. The team would also recommend that the staff buy new equipment for the vehicles. Some of the equipment used was very dated and would not always perform accurately. Throughout the testing, the team needed replacement motors and a replacement arduino. If these two areas of concern were fixed, the team would have had no problem with this project. Overall the project was very well designed and fairly easy to execute without much need for extra instruction or assistance from staff.

References

1. "The Ohio State University Advance Energy Vehicle Design Project" Lab Manual (2016, December 12) Retrieved from https://app.box.com/embed/preview/2gaj9nkdkxyhjwcntvh9ga9elwwzuurn?theme=dark&show_item_feed_actions=yes&show_parent_path=yes

Appendix

Table 5: Team Gnatt Chart

Team Gnatt Chart		Estimated Time	1/20/2017	1/27/2017	2/3/2017	2/10/2017	2/17/2017	2/24/2017	3/3/2017	3/17/2017	3/24/2017	4/7/2017	4/14/2017	4/21/2017	Percent Complete
Task	Teammate Participation														
AEV Lab 01	Alador, Amanda, Connor Kristin	1.5 h	1.5 h												100
AEV Lab 02	Alador, Amanda, Connor Kristin	1.5 h		1.5 h											100
AEV Lab 03	Alador, Amanda, Connor Kristin	1.5 h			1.5 h										100
AEV Lab 04	Alador, Amanda, Connor Kristin	1.5 h				1.5 h									100
AEV Lab 05	Alador, Amanda, Connor Kristin	1.5 h					1.5 h								100
AEV Lab 06	Alador, Amanda, Connor Kristin	1.5 h						1.5 h							100
AEV Lab 07	Alador, Amanda, Connor Kristin	1.0 h							1.0 h						100
AEV Lab 08	Alador, Amanda, Connor Kristin	1.5 h								1.5 h					100
AEV Lab 09	Alador, Amanda, Connor Kristin	1.5 h									1.5 h				100
AEV Lab 10	Alador, Amanda, Connor Kristin	1.5 h										1.5 h			100
AEV Lab 11	Alador, Amanda, Connor Kristin	1.5 h											1.5 h		100
AEV Lab 12	Alador, Amanda, Connor Kristin	1.5 h												1.5 h	100

Table 6: Team Schedule

Performance Test 1	No.	Task	Start	Finish	Due Date	Kristin	Connor	Amanda	Alador	% Complete
	1	Design two different AEV models	3/10/2017	3/21/2017	3/22/2017	X	X	X	X	100
	2	Develop a code to test the two models	3/10/2017	3/20/2017	3/22/2017	X	X	X	X	100
	3	Test the two AEV models and collect data	3/10/2017	3/20/2017	3/22/2017	X	X	X	X	100
	4	Create SolidWorks models of the two designs	3/25/2017	3/26/2017	3/27/2017		X			100
	5	Analyze data and determine which AEV model is better	3/10/2017	3/20/2017	3/22/2017	X	X	X	X	100
Performance Test 2	**No.**	**Task**	**Start**	**Finish**	**Due Date**	**Kristin**	**Connor**	**Amanda**	**Alador**	**% Complete**
	1	Develop two AEV Codes to complete task	3/24/2017	3/27/2017	3/29/2017	X	X	X	X	100
	2	Tweak and edit the codes to run to perfection	3/24/2017	3/27/2017	3/29/2017	X	X	X	X	100
	3	Test the codes with the AEV	3/24/2017	3/27/2017	3/29/2017	X	X	X	X	100
	4	Collect and analze data from each code	3/24/2017	3/29/2017	3/29/2017	X	X	X	X	100
Performance Test 3	**No.**	**Task**	**Start**	**Finish**	**Due Date**	**Kristin**	**Connor**	**Amanda**	**Alador**	**% Complete**
	1	Test AEV with chosen model and code	4/3/2017	4/3/2017	4/10/2017	X	X	X	X	100
	2	Test AEV with lights off	4/3/2017	4/3/2017	4/10/2017	X	X	X	X	100
	3	Test AEV with fan on	4/3/2017	4/5/2017	4/10/2017	X	X	X	X	100
	4	Collect and analyze data from each run	4/3/2017	4/5/2017	4/10/2017	X		X		100
	5	Determine obstacles and plan to overcome them	4/2/2017	4/5/2017	4/10/2017	X	X	X	X	100
Performance Test 4	**No.**	**Task**	**Start**	**Finish**	**Due Date**	**Kristin**	**Connor**	**Amanda**	**Alador**	**% Complete**
	1	Read over code and check for errors	4/10/2017	4/10/2017	4/14/2017	X	X	X	X	100
	2	Find the mass of the AEV	4/10/2017	4/10/2017	4/14/2017	X	X	X	X	100
	3	Run the AEV and record time it takes to complete task	4/10/2017	4/10/2017	4/14/2017	X	X	X	X	100
	4	Analyze results and information	4/10/2017	4/10/2017	4/14/2017	X	X	X	X	100
	5	Possibly run the AEV a second time	4/10/2017	4/10/2017	4/14/2017	X	X	X	X	100
	6	Analyze results and fill out information sheet	4/10/2017	4/10/2017	4/14/2017	X	X	X	X	100

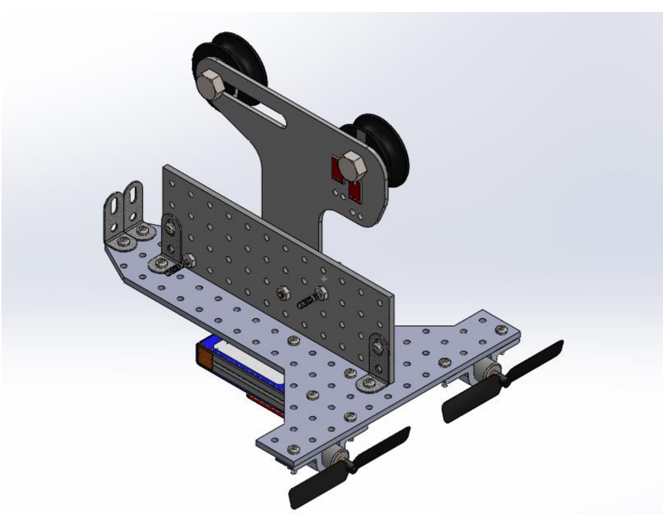


Figure 9: AEV Design 1 Isometric View

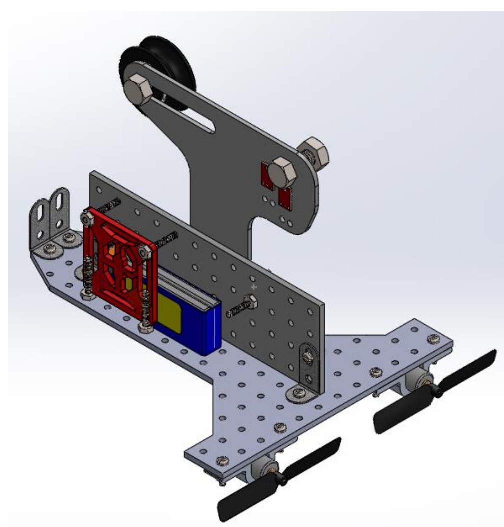


Figure 10: AEV Design 2 Isometric View

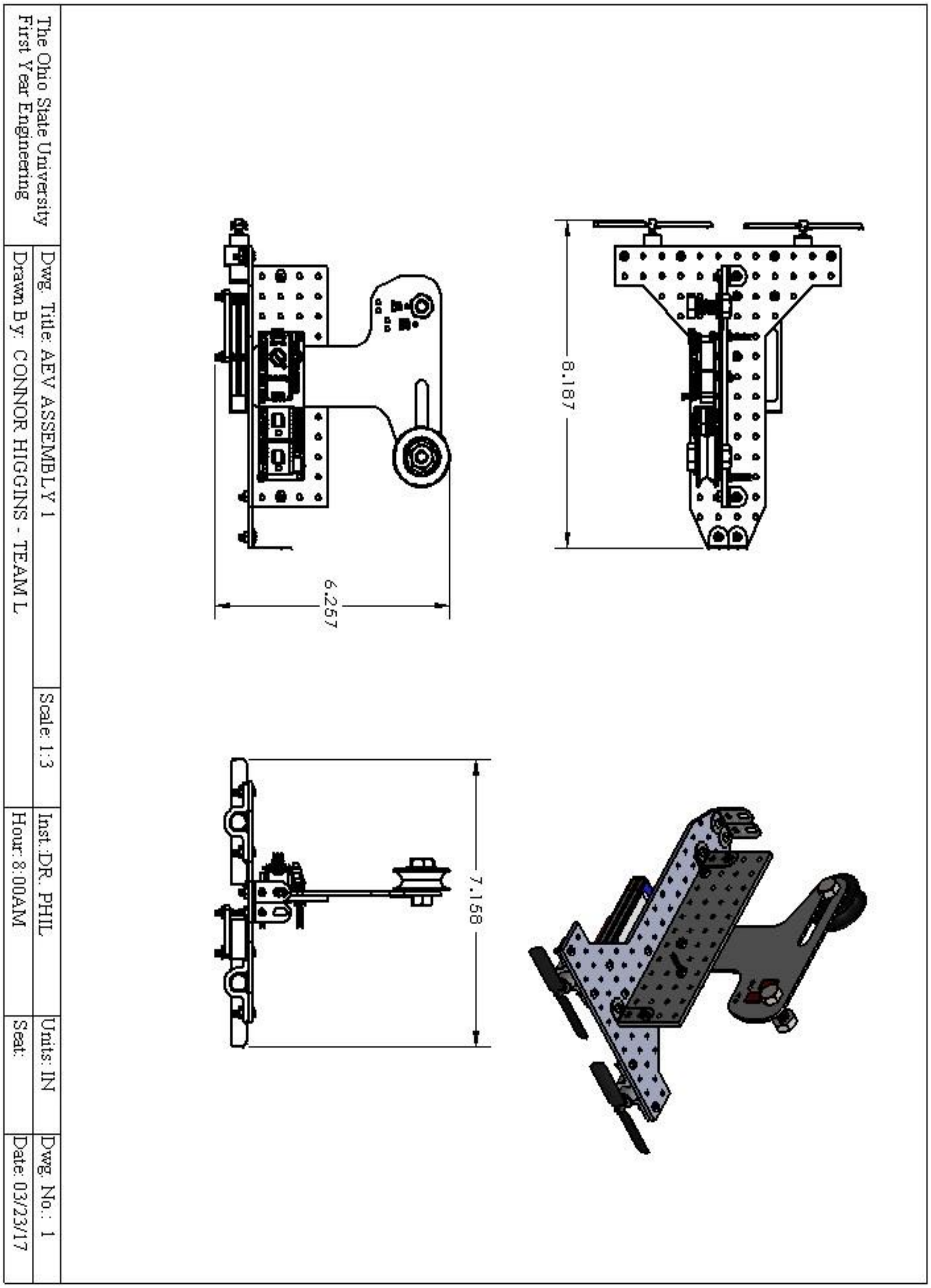
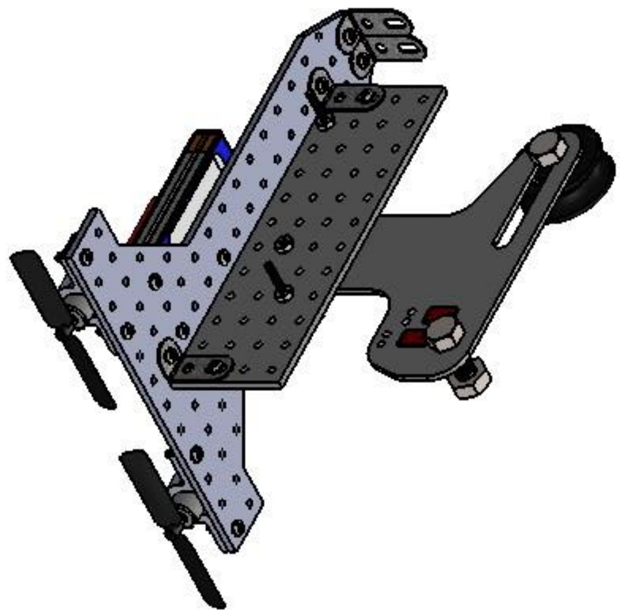


Figure 11: AEV Model 1 Page 1



ITEM NO.	PART NUMBER	QTY.
1	Medium Rectangle	1
2	Support Arm 1 2 Sensor Holes V2	1
3	pan slot head_ai	7
4	pan slot head_ai	5
5	pan slot head_ai	4
6	machine screw nut hex_ai	16
7	machine screw nut hex_ai	2
8	90-deg bracket	4
9	AEV Arduino Assembly	1
10	hex bolt_ai	2
11	Rotation Sensor Board	2
12	Modified Tee	1
13	Motor Mount Clip Aluminum	2
14	AEV Motor	2
15	Prop 3inch	2
16	Battery Pack	1
17	Battery Pack Clamp Plate Narrow	1
18	Pulley Assembly	1
19	Pulley Assembly w-reflective tape	1

ESTIMATED WEIGHT	260g
ESTIMATED COST	$159.30

The Ohio State University First Year Engineering	Dwg. Title: AEV ASSEMBLY 1	Scale: 1:2	Inst.: DR. PHIL
	Units: IN	Dwg. No.: 2	
	Drawn By: CONNOR HIGGINS - TEAM L	Hour: 8:00AM	Seat:
	Date: 03/23/17		

Figure 12: AEV Model 1 Page 2

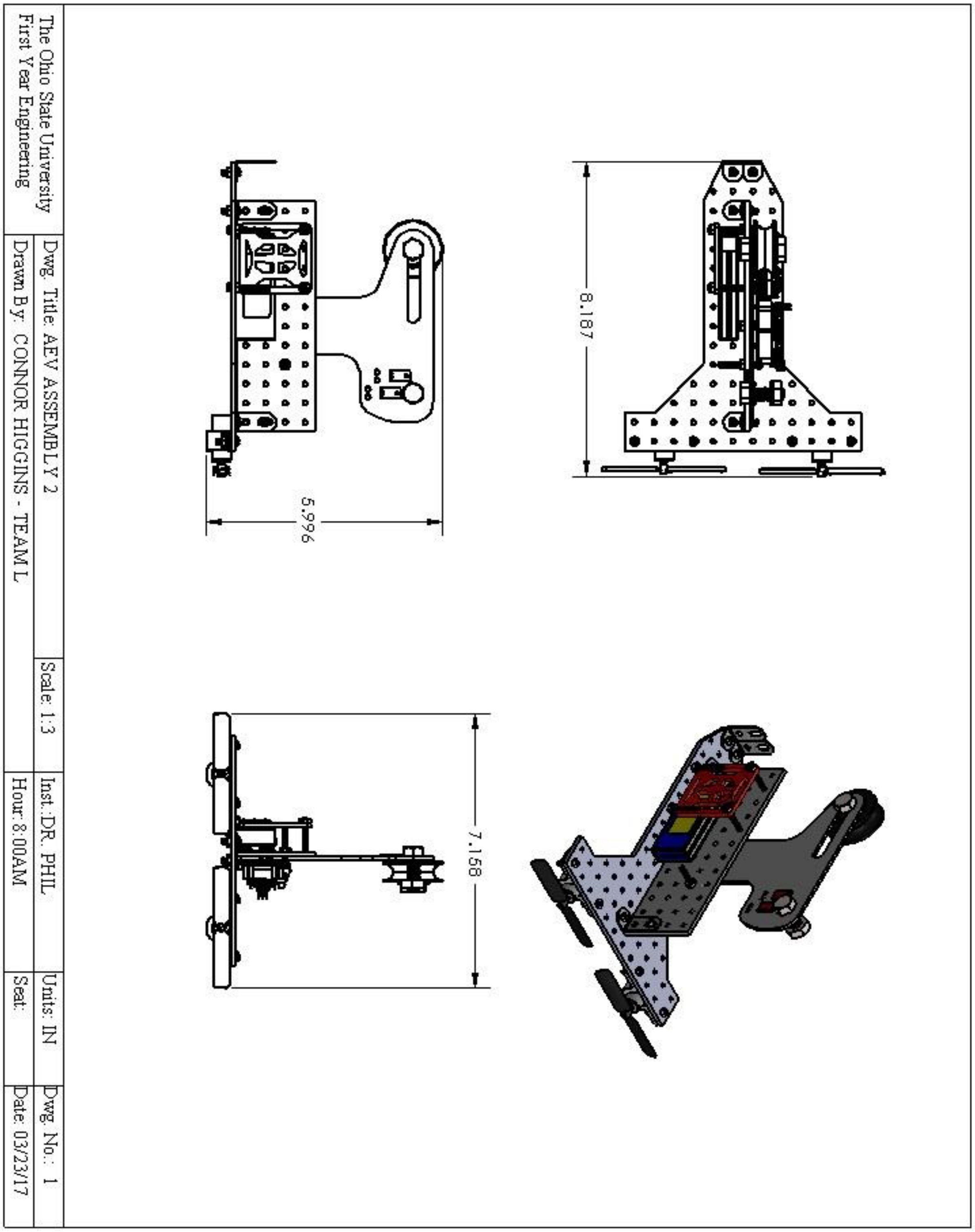
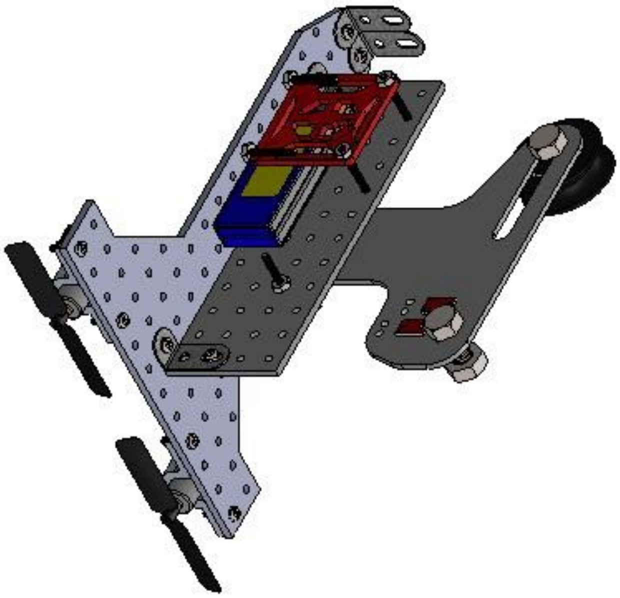


Figure 13: AEV Model 2 Page 1

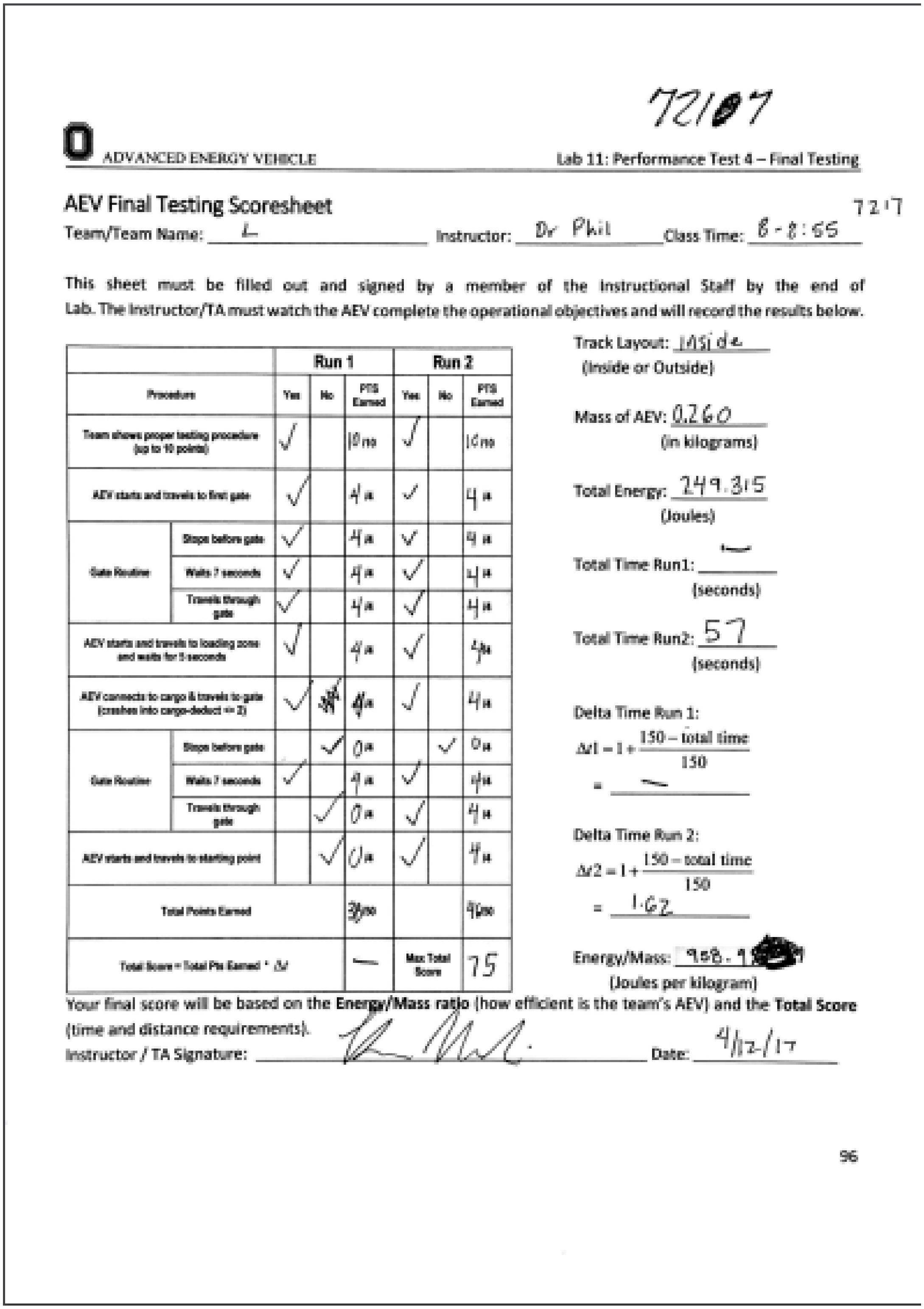


ITEM NO.	PART NUMBER	QTY.
1	Medium Rectangle	1
2	Support Arm 1 2 Sensor Holes V2	1
3	pan slot head_ai	7
4	pan slot head_ai	6
5	pan slot head_ai	4
6	machine screw nut hex_ai	17
7	machine screw nut hex_ai	2
8	90-deg bracket	4
9	AEV Arduino Assembly	1
10	hex bolt_ai	2
11	Rotation Sensor Board	2
12	Modified Tee	1
13	Motor Mount Clip Aluminum	2
14	AEV Motor	2
15	Prop 3inch	2
16	Pulley Assembly	1
17	Battery Pack	1
18	Battery Pack Clamp Plate	1
19	Pulley Assembly w-reflective tape	1

ESTIMATED WEIGHT	260g
ESTIMATED COST	$159.30

The Ohio State University First Year Engineering	Dwg Title: AEV ASSEMBLY 2		
	Scale:1:2	Inst.:DR. PHIL	Units:IN	Dwg.No.: 2
	Drawn By: CONNOR HIGGINS - TEAM L	Hour:8:00AM	Seat:	Date:03/23/17

Figure 14: AEV Model 2 Page 2


72107

ADVANCED ENERGY VEHICLE — Lab 11: Performance Test 4 – Final Testing

AEV Final Testing Scoresheet

7217

Team/Team Name: L   Instructor: Dr Phil   Class Time: 8-8:55

This sheet must be filled out and signed by a member of the Instructional Staff by the end of Lab. The Instructor/TA must watch the AEV complete the operational objectives and will record the results below.

		Run 1			Run 2		
Procedure		Yes	No	PTS Earned	Yes	No	PTS Earned
Team shows proper testing procedure (up to 10 points)		✓		10/10	✓		10/10
AEV starts and travels to first gate		✓		4/4	✓		4/4
Gate Routine	Stops before gate	✓		4/4	✓		4/4
	Waits 7 seconds	✓		4/4	✓		4/4
	Travels through gate	✓		4/4	✓		4/4
AEV starts and travels to loading zone and waits for 5 seconds		✓		4/4	✓		4/4
AEV connects to cargo & travels to gate (crashes into cargo-deduct <= 2)		✓	[illegible]	4/4	✓		4/4
Gate Routine	Stops before gate		✓	0/4		✓	0/4
	Waits 7 seconds	✓		4/4	✓		4/4
	Travels through gate		✓	0/4	✓		4/4
AEV starts and travels to starting point			✓	0/4	✓		4/4
Total Points Earned				[illegible]/50			[illegible]/50
Total Score = Total Pts Earned * Δt				—	Max Total Score		75

Track Layout: inside (Inside or Outside)

Mass of AEV: 0.260 (in kilograms)

Total Energy: 249.315 (Joules)

Total Time Run1: — (seconds)

Total Time Run2: 57 (seconds)

Delta Time Run 1:

$$\Delta t1 = 1 + \frac{150 - \text{total time}}{150}$$

= —

Delta Time Run 2:

$$\Delta t2 = 1 + \frac{150 - \text{total time}}{150}$$

= 1.62

Energy/Mass: 958.9[illegible] (Joules per kilogram)

Your final score will be based on the **Energy/Mass ratio** (how efficient is the team's AEV) and the **Total Score** (time and distance requirements).

Instructor / TA Signature: [signature]   Date: 4/12/17

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Figure 15: AEV Final Testing Scoresheet

Table 7: Overall Class Results for Final AEV Run

ENGR 1182 – AEV Final Test Results

Section 7217

Enter scores in blue fields

T	R	Inside / Outs	AEV Mass (	Total Energy	Run Time	Del	Energy / Mass (J/	Points Earne (out of	Total Score = Points Earned Delta t	Returned Ki
A	1	Outside	0.245	192.5	74.0	1.51	787	42	63.3	Yes
A	2	Outside	0.245	Incomplete	Incomplete	#VALUE!	#VALUE!	8	#VALUE!	Yes
B	1	Outside	0.238	281.6	63.0	1.58	1183	50	79.0	Yes
B	2	Outside	No run	No run	No run	#VALUE!	#VALUE!	No run	#VALUE!	Yes
C	1	Outside	0.240	Incomplete	77.0	1.49	#VALUE!	42	62.4	Still has kit
C	2	Outside	0.240	291.3	64.0	1.57	1214	46	72.4	Still has kit
D	1	Outside	0.180	412.1	90.0	1.40	2289	46	64.4	Yes
D	2	Outside	No run	No run	No run	#VALUE!	#VALUE!	No run	#VALUE!	Yes
E	1	Inside	0.293	190.2	67.0	1.55	649	50	77.7	Yes
E	2	Inside	0.293	185.0	50.0	1.67	631	46	76.7	Yes
F	1	Inside	0.275	202.0	61.0	1.59	734	73	116.8	Yes
F	2	Inside	0.275	200.5	55.0	1.63	729	69	112.0	Yes
G	1	Inside	0.289	321.2	71.0	1.53	1111	46	70.2	Yes
G	2	Inside	0.289	317.8	63.0	1.58	1100	50	79.0	Yes
H	1	Inside	0.255	309.2	56.0	1.63	1213	50	81.3	Yes
H	2	Inside	No run	No run	No run	#VALUE!	#VALUE!	No run	#VALUE!	Yes
I	1	Inside	0.256	357.8	68.0	1.55	1398	46	71.1	Yes
I	2	Inside	0.256	248.5	62.0	1.59	971	50	79.3	Yes
J	1	Inside	0.228	277.5	59.9	1.60	1217	50	80.0	Yes
J	2	Inside				2.00	#DIV/0!		0.0	Yes
K	1	Inside	0.284	Incomplete	Incomplete	#VALUE!	#VALUE!	10	#VALUE!	Yes
K	2	Inside	0.284	269.9	70.0	1.53	950	42	64.4	Yes
L	1	Inside	0.260	Incomplete	Incomplete	#VALUE!	#VALUE!	38	#VALUE!	Has not checked in
L	2	Inside	0.260	249.3	57.0	1.62	959	46	74.5	Has not checked in
M	1	Inside	0.257	309.0	55.0	1.63	1202	46	75.1	Has not checked in
M	2	Inside	0.257	321.0	53.0	1.65	1249	50	82.3	Has not checked in
N	1	Inside	0.241	386.4	54.0	1.64	1603	42	68.9	Yes
N	2	Inside	0.241	355.1	51.0	1.66	1473	50	83.0	Yes
O	1	Outside	0.268	Incomplete	Incomplete	#VALUE!	#VALUE!	10	#VALUE!	Yes
O	2	Outside	0.268	478.8	62.0	1.59	1786	46	73.0	Yes
P	1	Outside	0.244	Incomplete	Incomplete	#VALUE!	#VALUE!	42	#VALUE!	Still has kit
P	2	Outside	0.244	220.2	68.0	1.55	903	30	46.4	Still has kit
Q	1	Outside	0.236	286.0	61.0	1.59	1212	46	73.3	Yes
Q	2	Outside	0.236	309.7	57.0	1.62	1312	50	81.0	Yes
R	1	Outside	0.247	285.7	73.0	1.51	1157	38	57.5	Yes
R	2	Outside	0.247	279.8	70.0	1.53	1133	42	64.4	Yes