Critical Design Review

Submitted To:

Inst. Kadri Parris

GTA Jin Yang

Created By:

Team I

Alex Tetzloff

J.P. Salopek

Dan Heavern

Jeffrey Horowitz

Engineering 1182

The Ohio State University

Columbus, OH

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Executive Summary

Throughout the course of the Advanced Energy Vehicle project, the lab team progressed from initial design to rapid prototyping, to concept screening and scoring, and finally to performance testing. Each lab along the way led to a new advancement in our solution to the task at hand. The task before the team, laid out in the mission concept review, was to rescue an R2-D2 unit using as little energy and time as possible. In doing so, the AEV was required to go forwards and backwards, be able to stop within a certain distance, and adjust to varying track lengths from room to room.

The overall goals of the AEV project were not only to design an efficient AEV that can retrieve the R2-D2 unit successfully but for the team to better understand the design process. The team learned how to complete concept screening and scoring in order to quantify the values of each team member's designs in an effort to combine the best aspects of all the designs. The team often learned better techniques for use of the AEV through trial and error on the track

The team found from the performance tests that the highly efficient code that involved no braking from the AEV was unreliable and inconsistent. This was deduced as the code would be run multiple times from the same starting position, yet it would yield different results for each run. Because of these inconsistent results, the team modified this code, adding a small amount of braking to the code. This slightly increased the energy used by the AEV, though it increased the consistency of its performance.

Table of Contents

Introduction

The AEV project in Engineering 1182 is a project that demonstrates how the engineering team has learned and developed their skills in order to run an Advanced Energy Vehicle. Team I has learned how to run the AEV on the track and now they have started meeting three times a week to improve how the AEV completes its mission as explained in the Mission Concept Review. The AEV project is based off of a Star Wars theme. The AEV is a model of a Rebel monorail system on a low-energy planet that needs to retrieve the droid R2-D2 from a loading dock across the planet. The AEV will pick up the droid with a magnet and then return back to its original destination. All of this transportation needs to be Energy efficient so it is up to the engineering team to design the best AEV that will complete the task. Due to all of the many tasks that need to be completed for the group to finalize the AEV, tasks have now been split up for each team member to complete in a timely fashion.

The AEV was tested many times by the team of engineering students throughout the semester in order to construct an efficient and functional vehicle. Throughout all of the labs completed in the semester, the team of students worked together to make the AEV functional. Each lab contributed more information for the students to use and each week the team pieced together a more functional AEV.

Experimental Methodology

Throughout the labs, performance tests one, two and three were completed. For these performance tests, two designs were compared for their ability to complete the mission. it was important to complete discrepancies regarding designs initially so then the code could be modified to optimize the best design, in order to get the best possible result. For the initial performance test, the two designs that were being compared had small differences, though the differences in balance and consistency were present enough to show that the second AEV design, called "Airplane" (Figure 3) was the superior of the two, and would be the best possible design to use in all of the performance tests.

The setup for the performance tests had the AEV make use of overhead tracks in room 224 and room 308 in Hitchcock Hall. The AEV was assembled using an Arduino control board and 3030 pusher/puller propellers. The two preliminary designs were tested on the completion of the task described in the Mission Concept Review. The task included the AEV starting from stop at the beginning of the track, and coming to a full stop at the gate. The AEV then waits seven seconds and leaves as the gate opens. The AEV then travels to the R2-D2 unit, connects via a magnet on the front of the R2-D2 unit, beginning its return after the R2-D2 unit is connected. The AEV, with R2-D2 in two, arrives again at the gate where it pauses for another seven seconds until the gate once again opens. The unit then travels back to the starting position where it comes to a stop for the final time.

The first performance test focused mostly on the design of the AEV, while the following performance tests had the team refining the code for the best possible performance on the track. The team used these performance tests to create additional codes that would help the AEV accomplish the task with more efficiency and consistency.

Results and Discussion

The team progressed a long ways from the 5 brainstormed design sketches back in Lab 01. 2 of the sketches were designed with simplicity and the other two were more sophisticated. After scoring our predictions of how the specific designs would perform on the track, the team decided to incorporate all of the good ideas from each sketch into one AEV. Thus, the “A-Wing 2” was created.

The design worked great, however it was heavy compared to other AEV’s. When Lab 08 came around and the team had to compare two AEV’s, The more simplistic “Airplane” was chosen for examination. It scored the highest on the scoring matrix of all the other designs. The “Airplane” design had flat wings and less brackets. The “A-Wing 2” design had the wings up at an angle, but had more brackets. When put to the test, It was found that the Airplane was lighter, more energy efficient, quicker, more balanced around turns, and more consistent when completing the objective. Thus, the “Airplane” design overrode the previous design so that the AEV could be optimized.

Now that the design was optimized, the code had to be optimized around it. The design did not change after Lab 08, other than fixing the battery’s location on the AEV with screws for maximum balance. Thus,the team built the code around the AEV to maximize efficiency and work well with the design.

The “Airplane” design is displayed orthographically in Figure 1 and the “A-Wing 2” design is shown orthographically in Figure 2. The “Airplane” design is displayed orthographically in Figure 3 and the “A-Wing 2” design is shown orthographically in Figure 4.

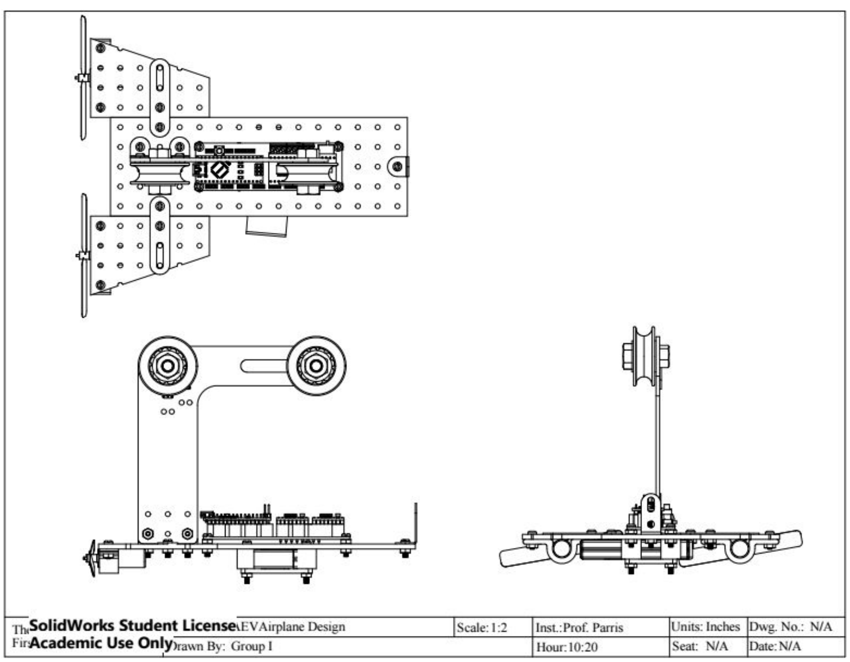


Figure 1: This is the “Airplane” design, which was the final design chosen for the mission

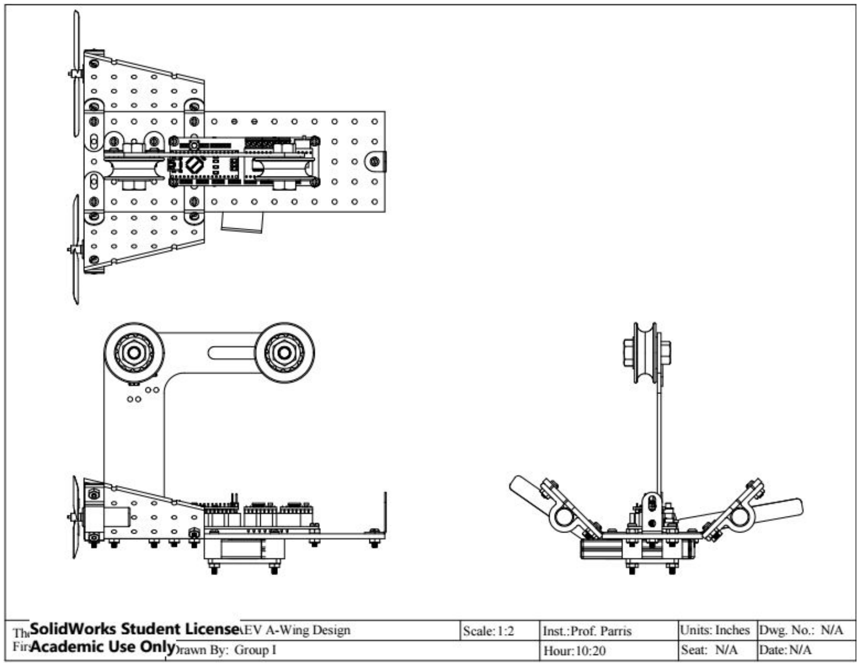
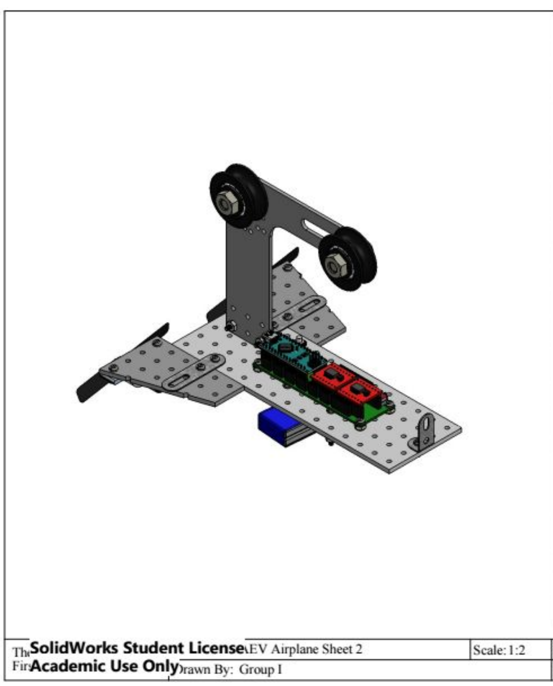


Figure 2: This is the "A-Wing 2" design, which was abandoned after Lab 08



ITEM NO.	PART NUMBER	QTY.
1	AEV Arduino Assembly	1
2	Large Rectangle	1
3	90-deg bracket	3
4	Pulley Assembly w-reflective tape	2
5	Pulley Assembly	2
6	AEV Motor	2
7	Support Arm 2 2 Sensor Holes	1
8	Right Trapezoid	2
9	Battery Pack	1
10	Battery Spacer	4
11	SL-PHMS 0.112-40x0.375x0.375-S	13
12	MSHXNUT 0.112-40-S-S	25
13	Motor Mount Clip Aluminum	2
14	HBOLT 0.3125-18x0.875x0.875-S	2
15	MSHXNUT 0.3125-18-S-S	2
16	Prop 3inch	2
17	Battery Pack Clamp Plate Narrow	1
18	Preferred Narrow FW 0.094	4
19	SL-PHMS 0.112-40x0.5x0.5-S	4
20	Rotation Sensor Board	2
21	SL-PHMS 0.112-40x1x1-S	4
22	flat bracket	2

Figure 3: The "Airplane" design is shown isometrically above

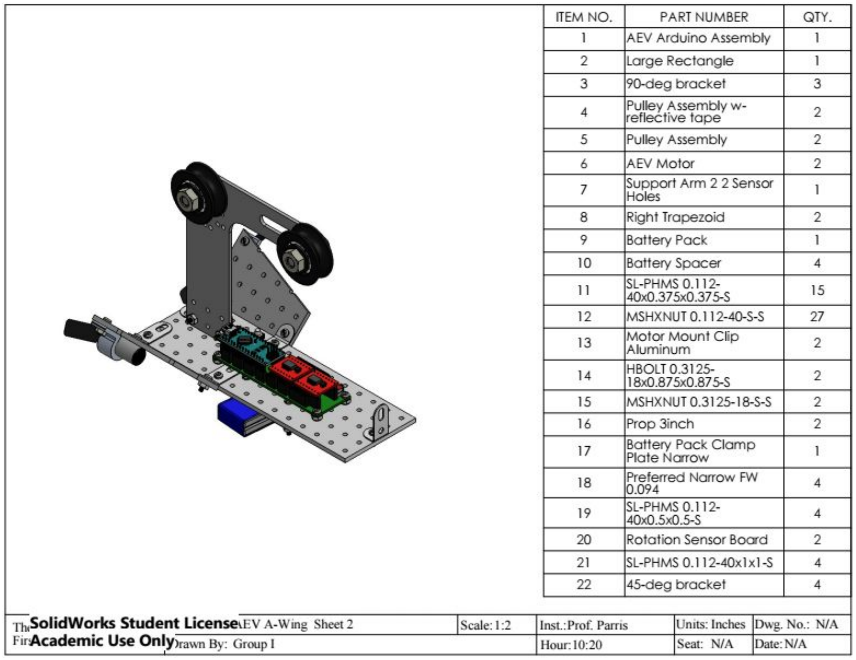


Figure 4: The "A-Wing 2" design is shown isometrically above

The concept screening and scoring matrices were essential to finding the right design for the AEV. The matrices form Lab 03 for the original brainstormed designs are shown below in Tables 1 and 2.

Table 1: Concept Screening Matrix

Success Criteria	A-Wing	Star Destroyer	Airplane	Design D	A-Wing 2
Balanced Around Turns	+	-	+	0	+
Minimal Blockage	+	+	-	-	+
Center-of-Gravity Location	-	-	+	0	+
Maintenance	0	-	0	-	0
Durability	0	0	0	0	0
Cost	-	0	+	0	-
Enviromental	+	+	+	+	+
Sum +'s	3	2	4	1	4
Sum 0's	2	2	2	4	2
Sum -'s	2	3	1	2	1
Net Score	1	-1	3	-1	3
Continue?	Combine	No	Combine	No	Yes

Table 2: Concept Scoring Matrix

		A-Wing		Star Destroyer		Airplane		Design D		A-Wing 2	
Success Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Balanced	15%	4	0.6	1	0.15	4	0.6	3	0.45	4	0.6
Minimal Blockage	15%	4	0.6	4	0.6	1	0.15	1	0.15	4	0.6
Center-of-gravity location	15%	1	0.15	1	0.15	4	0.6	3	0.45	4	0.6
Maintenance	10%	3	0.3	1	0.1	3	0.3	1	0.1	3	0.3
Durability	10%	3	0.3	3	0.3	2	0.2	3	0.3	3	0.3
Cost	25%	2	0.5	3	0.75	3	0.75	3	0.75	1	0.25
Environmental	10%	4	0.4	4	0.4	4	0.4	4	0.4	4	0.4
Total Score			2.85		2.45		3		2.6		3.05
Continue?		Combine		No		Combine		No		Develop	

As shown above, the two highest scoring designs were the “Airplane” design and the “A-Wing 2” design. Therefore, they were chosen to be the team’s prototypes in data analysis testing. The “Airplane” design ended up working the best.

The cost of the AEV was a big factor in the design of the AEV. The team used strategies to eliminate unnecessary components to maximize cost effectiveness. For example, The team did not utilize the servo brake. This eliminated weight and cost. By switching the designs, addition brackets were eliminated and lowered the cost. The team did not utilize 3-D printing. This saved a decent portion of money and not to mention, did not mess with the AEV’s performance. The team did not use decorations to on the design of the AEV because it would have raised cost, weight, and inconsistency. The team put high priority on the cost of the AEV because in many ways, raising the price decreased performance.

The performance tests push the team great lengths into perfecting the AEV. It gave the team time to recognize the strengths and weaknesses of the AEV and what could be improved upon. One item that was improved upon was the battery location. Due to how the AEV was originally constructed, the battery had to be placed in just the right spot to balance the AEV. The team had noticed that when the battery was inserted every lab, it was in a slightly different position than the previous lab. This affected the AEV’s performance from lab to lab even though the same code was being run. So the team installed screws on where the AEV was meant to be to hold it fixed and consistent between labs. Thus, a consistent code could be made that would work without manipulation between labs. This was crucial to the team’s success.

The performance tests also helped the team optimize the code. The team originally wanted to use as much coasting as possible with no brakes by reversing the motors. During the performance tests, this method was found to be way too inconsistent. So, a minute amount of braking was used to save energy and increase performance. The team still ended up using the least amount of energy of all the groups in the class.

The group decided back in lab 5 that the 3030 propellers would be utilized on the AEV because of the data found. The 3030 propellers for pusher and puller were found to have a higher efficiency percentage over the advances ratio compared to the 2510 motor. The team wanted to consume the least amount of energy possible when completing the mission and 3030 propellers were found to be efficient. The graph for the propulsion efficiency vs. the advanced ratio for the 3030 propeller and 2510 propeller are shown below in Figures 5 and 6 respectively.

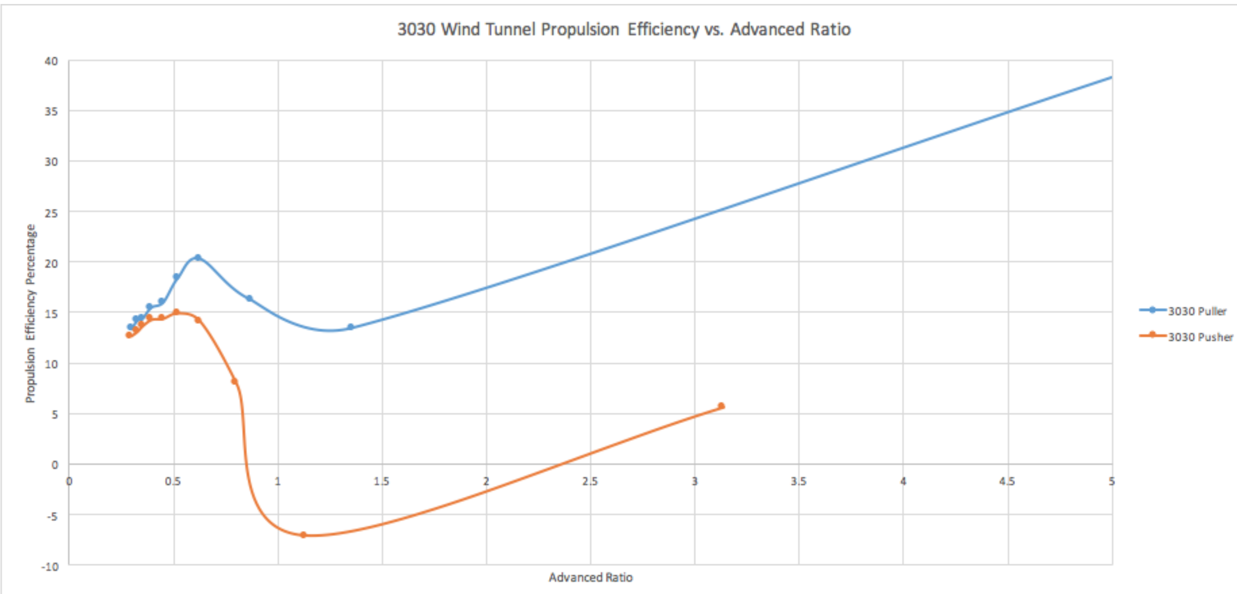


Figure 5: Propulsion Efficiency vs. Advanced Ratio plot for 3030 propeller

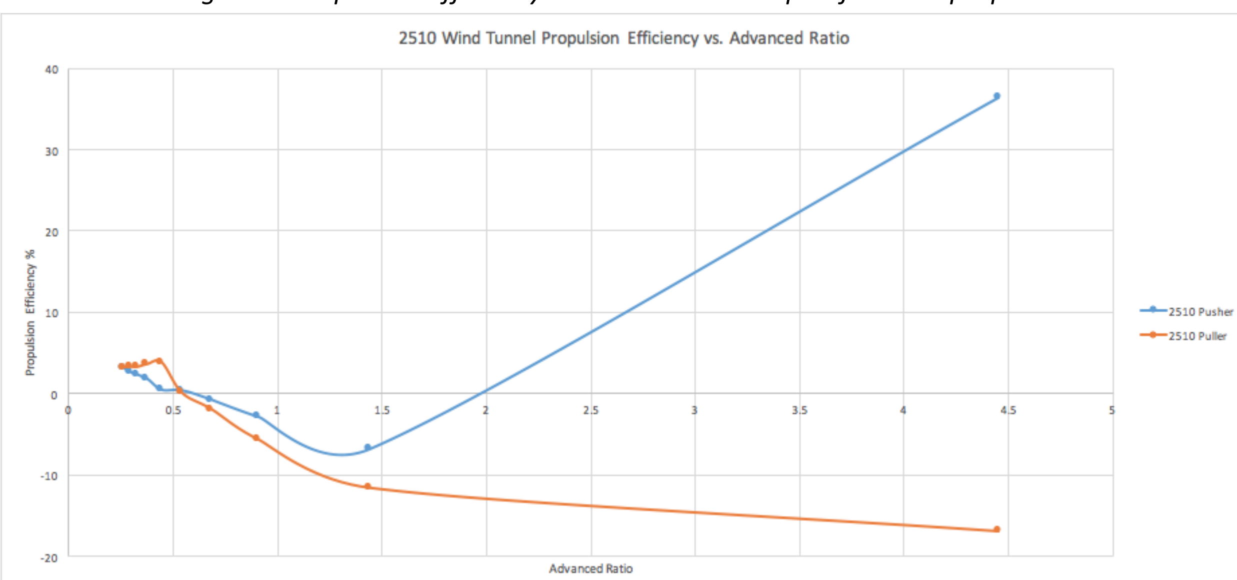


Figure 6: Propulsion Efficiency vs. Advanced Ratio plot for 3030 propeller

The 3030 propellers were also slightly larger than the 2510 propellers. Thus, when spinning, the 3030 propeller gave more thrust, which was helpful to the team's coasting approach on the track.

Performance Test 1 help the team compare the designs of the AEV with data analysis, rather than predictions. So the team used this lab to compare the "A-Wing 2" and "Airplane". Before even looking at the data of their performances on the track, the team observed significant differences between the two models. The "Airplane" was more balanced around turns, more consistent, and lighter than the "A-Wing 2". With these observations alone, the "Airplane" was chosen to be the design because completing the mission is more important to the group that energy efficiency. It was added bonus to find that the "Airplane" utilized a lot less energy than the "A-Wing 2" after using the data analysis tool. The percent power vs. time graphs are shown for the Airplane and A-Wing 2 in Figures 7 and 8 respectively.

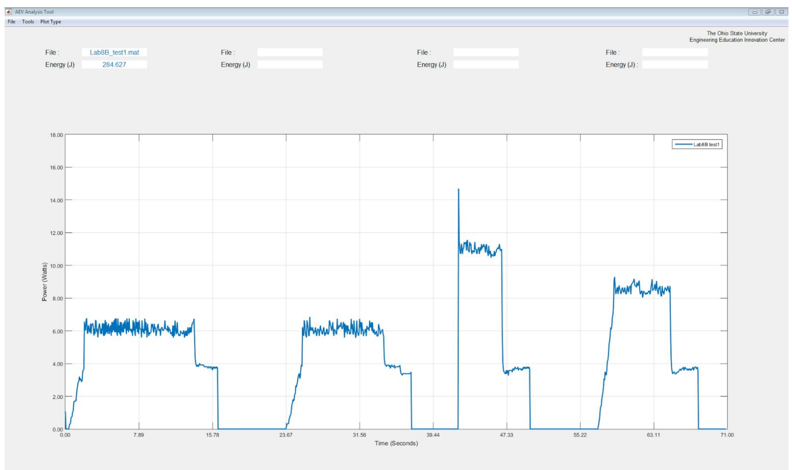


Figure 7: Time vs Power graph for Airplane design

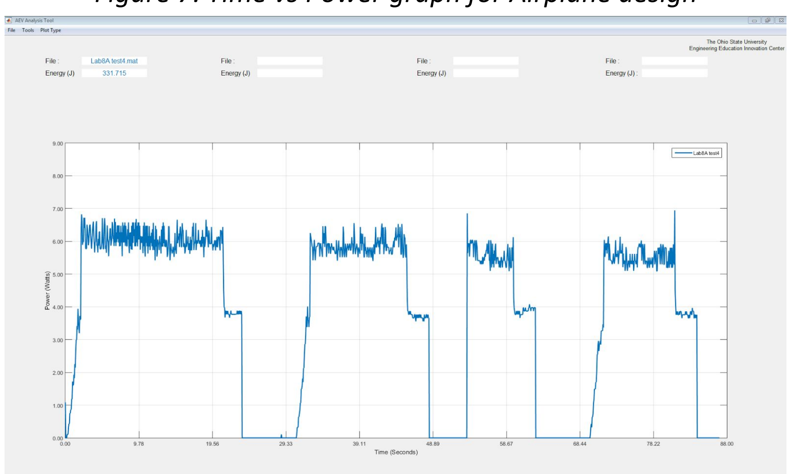


Figure 8: Time vs. Power for A-Wing 2 design

The Airplane design used 47 less Joules than the A-Wing 2. This was a determining factor to the group, which pushed them to change designs.

The performance was further broken down with the line by line energy usage of the code. The breakdown for the Airplane is displayed in Table 3 and the breakdown for the A-Wing 2 is shown in Table 4.

Table 3: Energy and Phase breakdown for Airplane

Phase	Arduino Code	Time in Seconds	Energy (Joules)
1	celerate (4,0,25,2)	2	3.3
2	motorSpeed(4,25)	11	51.3
3	motorSpeed(4,20)	3	11.1
4	motorSpeed(4,0)	7	0
5	celerate (4,0,25,2)	2	3.3
6	motorSpeed(4,25)	10.5	47.8
7	motorSpeed(4,20)	3	11.1
8	motorSpeed(4,0)	5	0
9	motorSpeed(4,45)	4.3	64.1
10	motorSpeed(4,20)	3	11.1
11	motorspeed(4,0)	7	0
12	celerate (4,0,25,2)	2	3.3
13	motoSpeed(4,40)	5.2	67.2
14	motorSpeed(4,20)	3	11.1
		Total Energy	284.6

Table 4: Energy and Phase breakdown for A-Wing 2

Phase	Arduino Code	Time in Seconds	Energy (Joules)
1	celerate (4,0,25,2)	2	3.3
2	motorSpeed(4,25)	19.5	81.6
3	motorSpeed(4,20)	3	11.1
4	motorSpeed(4,0)	7	0
5	celerate (4,0,25,2)	2	3.3
6	motorSpeed(4,25)	13	59.7
7	motorSpeed(4,20)	3	11.1
8	motorSpeed(4,0)	5	0
9	motorSpeed(4,45)	6.2	68.9
10	motorSpeed(4,20)	3	11.1
11	motorspeed(4,0)	7	0
12	celerate (4,0,25,2)	2	3.3
13	motoSpeed(4,40)	9	67.2
14	motorSpeed(4,20)	3	11.1
		Total Energy	331.7

After viewing this chart, it was clear to see why the Airplane design performed better than the original design. The A-Wing 2 took longer to complete the course due to instability on the track and a heavier load. Thus, the thrust was required for a greater amount of time to go the same distance. Therefore, it was more energy inefficient than the Airplane design.

The team made the right decision by selecting the "Airplane" design as the final design for the AEV. It scored the second highest in the scoring matrix and tied for first on the screening matrix. Also, it utilized significant portions of less energy. Lastly, it was much more consistent and time efficient than the original design as discussed above.

The team observed many things during final testing. At the beginning of class, the AEV was working well on the way to the R2D2, but not on the way back. It was overshooting the gate. To fix the problem, the team first tried to increase the braking power. This made the AEV perform closer to the desired outcome, but still was a little inconsistent. It would overshoot or undershoot the gate the gate on the way back. Then, the team tried to increase the time of the braking. This got the team even closer to the desired outcome, but still a little too inconsistent for comfort. So, the team finally increased the speed on the way back and the reversing motor point on the track. This final adjustment made the AEV very consistent. However, the first time a TA came to watch the AEV perform the mission, it failed. Without changing the code one bit, the very next run worked to perfection, although the AEV had a slight collision with the foam at the end. Despite this malfunction, the team received full points for the performance.

Compared to the rest of the class, the team's total score was 6th in the class of 18 groups. This was a decent placing. However, the team was confused how this could happen since it place first in the class in many other areas. For example, the team was first in the class in distance/energy and energy/mass ratios. Also, the team scored the lowest energy usage with 167 J. However, the AEV was the third heaviest in the class. The team was very impressed with efficiency and ecstatic to have the lowest energy usage in the class. The team had ample time to accomplish this goal and did so with success.

There were many places where error could potentially occur during testing. One possible error was that AEV did not perform the same under the same conditions every run and this would affect results. There may have been a little less or more air resistance during each trial. This affects the speed that the AEV approaches the gate with and can cause it to stop short of the goal. More differences in the conditions of the AEV were present because of transportation. In order for the AEV to fit in its box, it had to be taken apart. It could have been put together slightly differently each time, affecting its balance and performance on the track. Another potential error was the battery running out of power. The battery would slowly lose energy over the course of the lab and cause the AEV to perform with less thrust, causing the team to have to modify the code in favor of more power from the engines. This made it difficult for the team to have a consistent code, as it always had to be changed depending on the charge of the battery in order to ensure completion of the mission on that given day. Another potential error was that the R2D2 was sometimes positioned in different places and this caused the vehicle to hit the R2D2 with much force sometimes and other times, be unable to make contact with it. Finally, the sizes of the tracks between room 224 and 308 varied, which caused alterations of the results of the AEV's performance. The team had to create unique codes for each rooms track, so progress that was attained in one room could not be translated to the other room.

The team's theory was that a coasting AEV with short bursts of energy is more efficient than one with constant low power. Also, a lighter AEV with more balance would perform more consistently than an AEV without these characteristics. The theory was found to be true when on testing day the AEV was very consistent and balanced. Not to mention, the coasting approach with no braking used 135 J, the coasting approach with mild braking was 167 J and the initial code, with no coasting and maximum brake usage was 305 J. Thus, the theory was supported. The coasting approach saved over 150 J of energy over the course of the mission. This is shown in Figure 9.

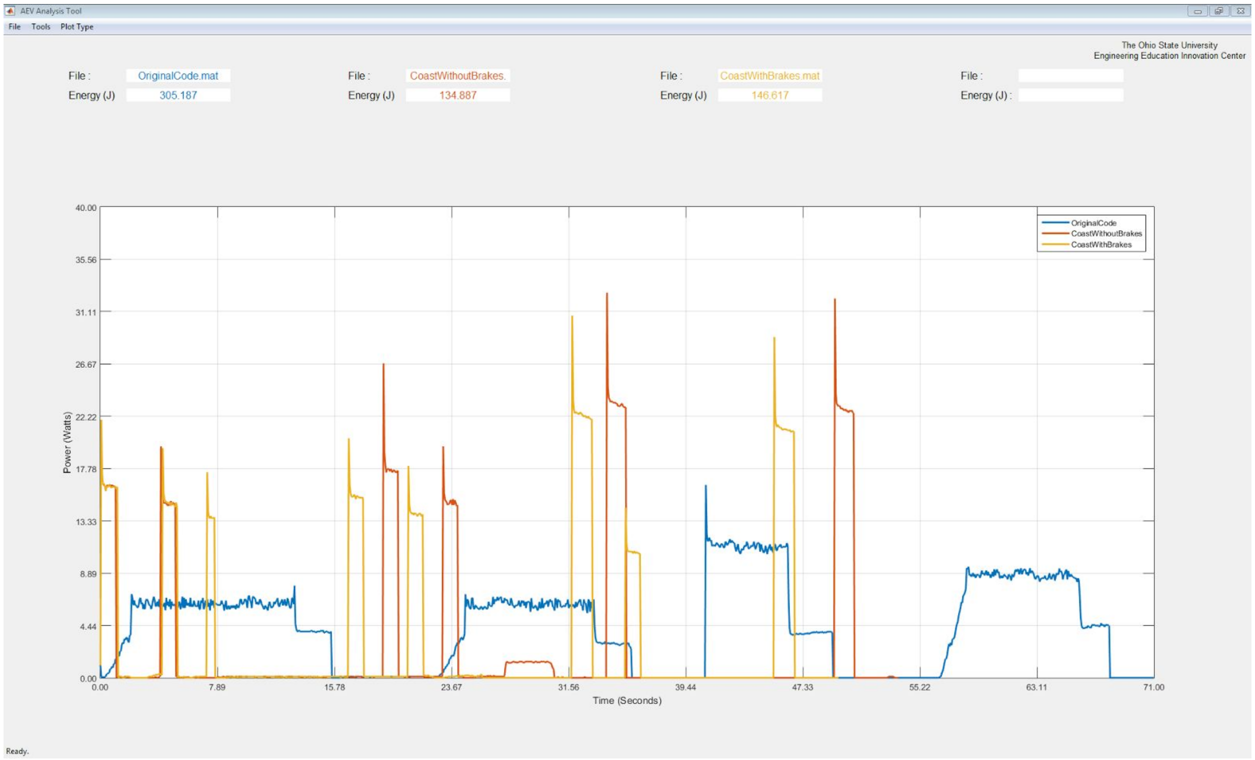


Figure 9: The energy usages of each of the codes created by the team

The AEV used a slight bit more energy than anticipated on testing day. The AEV used 167 J on testing day, but still managed to be the lowest energy usage in the class. This is shown in Figure 10.

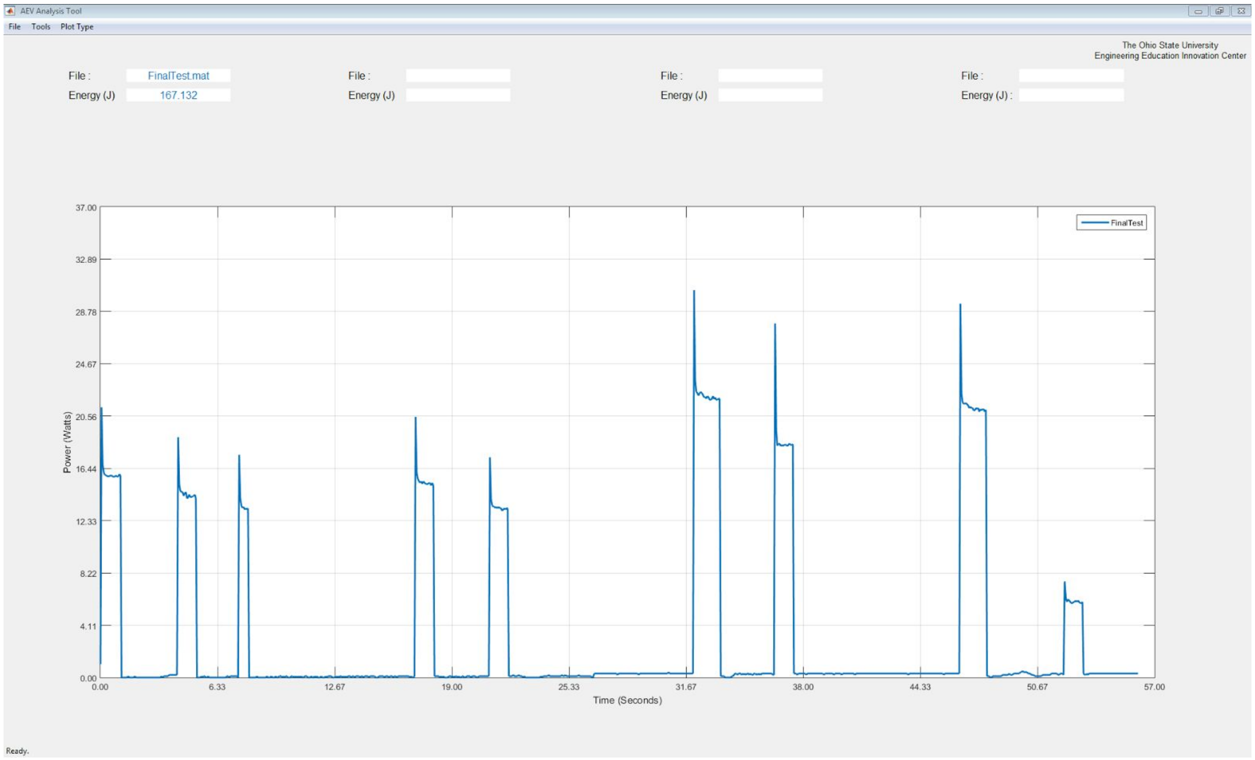


Figure 10: The time vs power plot for the AEV final test

Conclusion & Recommendations

The team had much success with the AEV, learning the values of hard work, careful programming and ingenuity in design. The coding for the AEV had to be done precisely, and because of its inconsistent performance from a variety of factors discussed earlier, it also required much patience and consistent effort from the team. No portion of final testing was left incomplete. The team finished all of the testing for the AEV with a class to spare for more work on the video project.

The team managed to do well in the final performance test, as the AEV completed its task of collecting the R2-D2 unit and stopping at the appropriate positions in front of the gates for the appropriate amount of time, returning safely to the initial position. It used the smallest amount of energy of all the other AEVs in the class (Figure 10). This led to the AEV also having the highest energy/mass and distance/energy of the class as well. The team was able to nearly half the initial amount of energy used, through careful programming. The codes that involved bursts of the AEV motors were difficult at first for the team to be successful with, and also yielded inconsistent results. Adding braking to the 135 joule code did take away from its overall efficiency, though the raise in consistency was well worth the sacrifice.

The final design of the AEV may not have adhered to the Star Wars theme, though it was stable enough on the track to produce acceptable performances (Figure 3). Structural integrity was maintained because the wings were mounted directly in line with the AEV main body, so only one bracket for each wing was sufficient. The final design of the AEV included no new parts printed from the 3D printer. The team believes this is best, as the assembling of the AEV itself was efficient, allowing the team the distinct advantage of having more time than groups that 3D printed a part to finesse the code for a better performance for final testing. The fact that the team did not include a newly designed part also showed their ability to work only with materials given, and solve problems with limited resources.

Error present from inconsistency of the coasting code with no brakes was resolved by adding a reversing of the motors at the expense of some 30 joules of saved energy. Though this made the AEV slightly less efficient, it raised the consistency of each performance on the track. Error present from the constant disassembly of the vehicle for transportation was resolved by taking care in each reassembly of it. The team used the code for room 224 for final testing, as a majority of classes and labs were held there, giving the team a "home-field advantage." Issues that stemmed from inconsistent placement of the R2-D2 unit were resolved by having a team member stationed at that position to move the R2-D2 to the correct position for each trial.

The team would recommend that more care should be taken regarding the charge levels of the lithium-ion batteries provided. The charge of the battery provided for the team on a given day often predicted how difficult and tedious programming would be for that day. With a battery that was low on power, the team would have to make numerous changes to the code to ensure that the AEV would not come up short at the gates. If the team received a battery with more charge the next class, the team would find that the AEV would overshoot every obstacle, and have to further modify the code to suit the more powerful battery. There was also no way for the team to observe whether a battery was low on charge until the code was run and it was determined whether the AEV went too far or too short on the track. It would greatly improve the testing of codes if batteries were charged during and between classes in order to provide groups with fully charged batteries to test their AEVs.

References

1. "AEV Lab Manual." Retrieved from https://eedcourses.engineering.osu.edu/sites/eedcourses.engineering.osu.edu/files/uploads/1182/AEVLab/AEVDocuments/LabManual/AEV_Lab_Manual_Rev_2015_08_07.pdf

Appendix

Table 1: Team Schedule

No.	Task	Start	Finish	Due Date	Alex	J.P.	Dan	Jeff	% Complete
	Creative Design Process Executive Summary	Jan 19	Jan 24	Jan 26	x	x	x	x	100
	Arduino Programming Basics Executive Summary	Jan 26	Jan 30	Feb 2	x	x	x	x	100
	Screening and Scoring Executive Summary	Feb 2	Feb 7	Feb 9	x	x	x	x	100
	AEV 1 Construction	Jan 25	Feb 9	Feb 11				x	100
	External Sensors Executive Summary	Feb 9	Feb 14	Feb 16	x	x	x	x	100
	System Analysis 1 Executive Summary	Feb 16	Feb 21	Feb 23	x	x	x	x	100
	System Analysis 2 Executive Summary	Feb 23	March 1	March 1	x	x	x	x	100
	AEV 2 Construction	Feb 9	March 20	March 21	x			x	100
	AEV 1 Testing	March 21	March 22	March 25	x	x	x	x	100

	AEV 2 Testing	March 22	March 25	March 25	x	x	x	x	100
	Weekly Report	March 27	March 27	March 28	x	x	x		100
	Solidworks Models	March 27	March 27	March 28				x	100
	PDR	March 27	March 27	March 28	x	x	x	x	100
	Performance Test 2 Memo	March 25	April 2	April 5	x	x	x	x	100
	Performance Test 3 Memo	April 4	April 10	April 11	x	x	x	x	100
	CDR	April 11	April 21	April 22	x	x	x	x	100

Figure 1: Airplane Orthographic Views

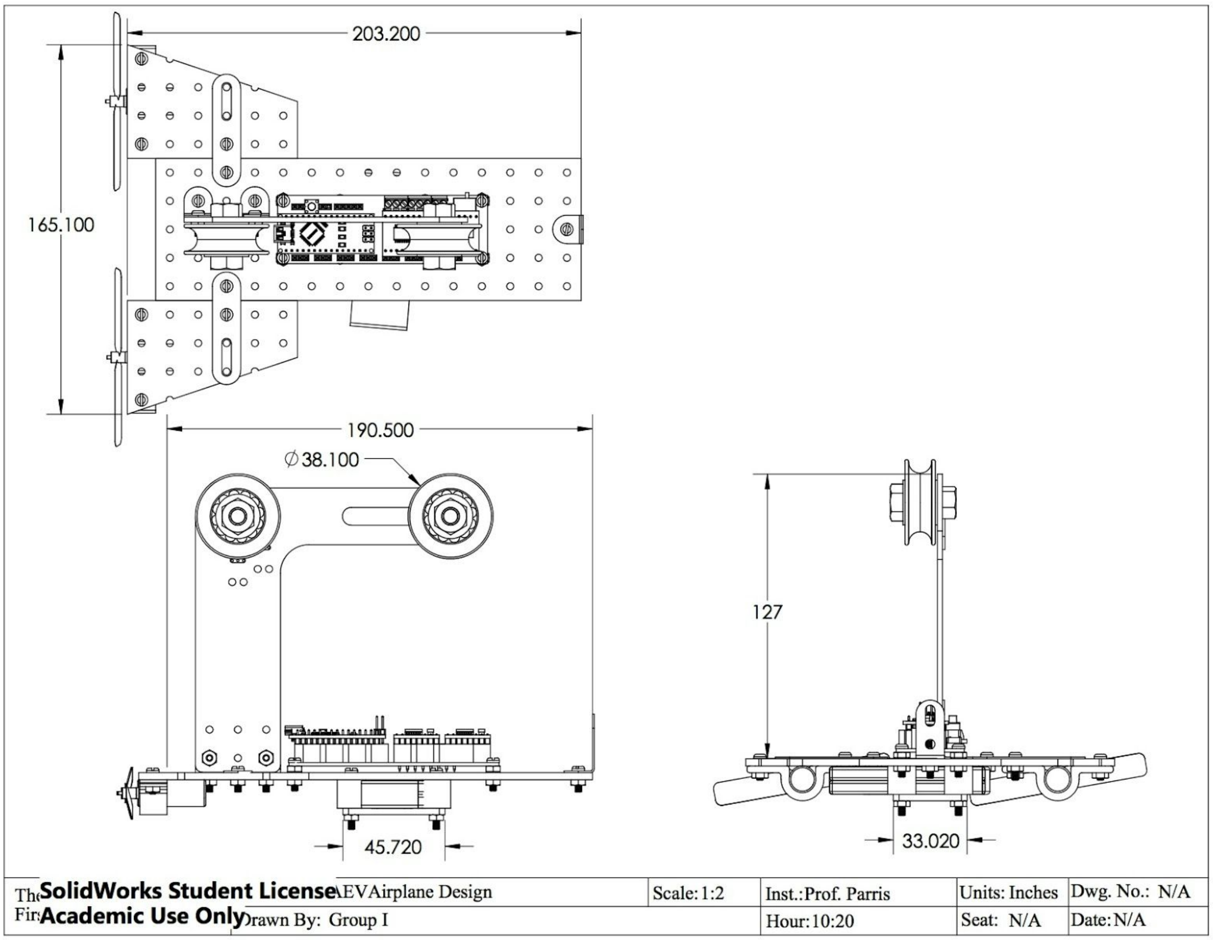
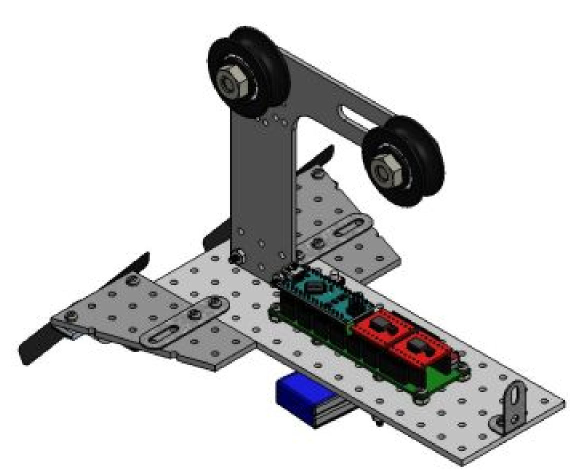


Table 2: "Airplane Costs"

Part	Price
Arduino	$100.00
Electric Motor (2)	$19.98
Wheels (2)	$15.00
Battery	$10.00
Angle Brackets (5)	$4.20
Count Sensor (2)	$4.00
Count Sensor Connector (2)	$4.00
L-Shaped Arm	$3.00
Bulk Screws and Nuts	$2.88

2.5” x 7.5” Rectangle	$2.00
Trapezoid (2)	$2.00
Screw Driver	$2.00
¼” Wrench	$2.00
Battery Supports (2)	$2.00
Motor Clamps (2)	$1.18
Propeller (2)	$.90
TOTAL:	$175.14
TOTAL WEIGHT:	271 grams

Figure 2: Airplane Isometric View



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8	Right Trapezoid	2
9	Battery Pack	1
10	Battery Spacer	4
11	SL-PHMS 0.112-40x0.375x0.375-S	13
12	MSHXNUT 0.112-40-S-S	25
13	Motor Mount Clip Aluminum	2
14	HBOLT 0.3125-18x0.875x0.875-S	2
15	MSHXNUT 0.3125-18-S-S	2
16	Prop 3inch	2
17	Battery Pack Clamp Plate Narrow	1
18	Preferred Narrow FW 0.094	4
19	SL-PHMS 0.112-40x0.5x0.5-S	4
20	Rotation Sensor Board	2
21	SL-PHMS 0.112-40x1x1-S	4
22	flat bracket	2

Th	EV Airplane Sheet 2	Scale: 1:2	Inst.:Prof. Parris	Units: Inches	Dwg. No.: N/A
Fir	rawn By: Group I		Hour:10:20	Seat: N/A	Date:N/A

Figure 3: A-Wing Orthographic Views

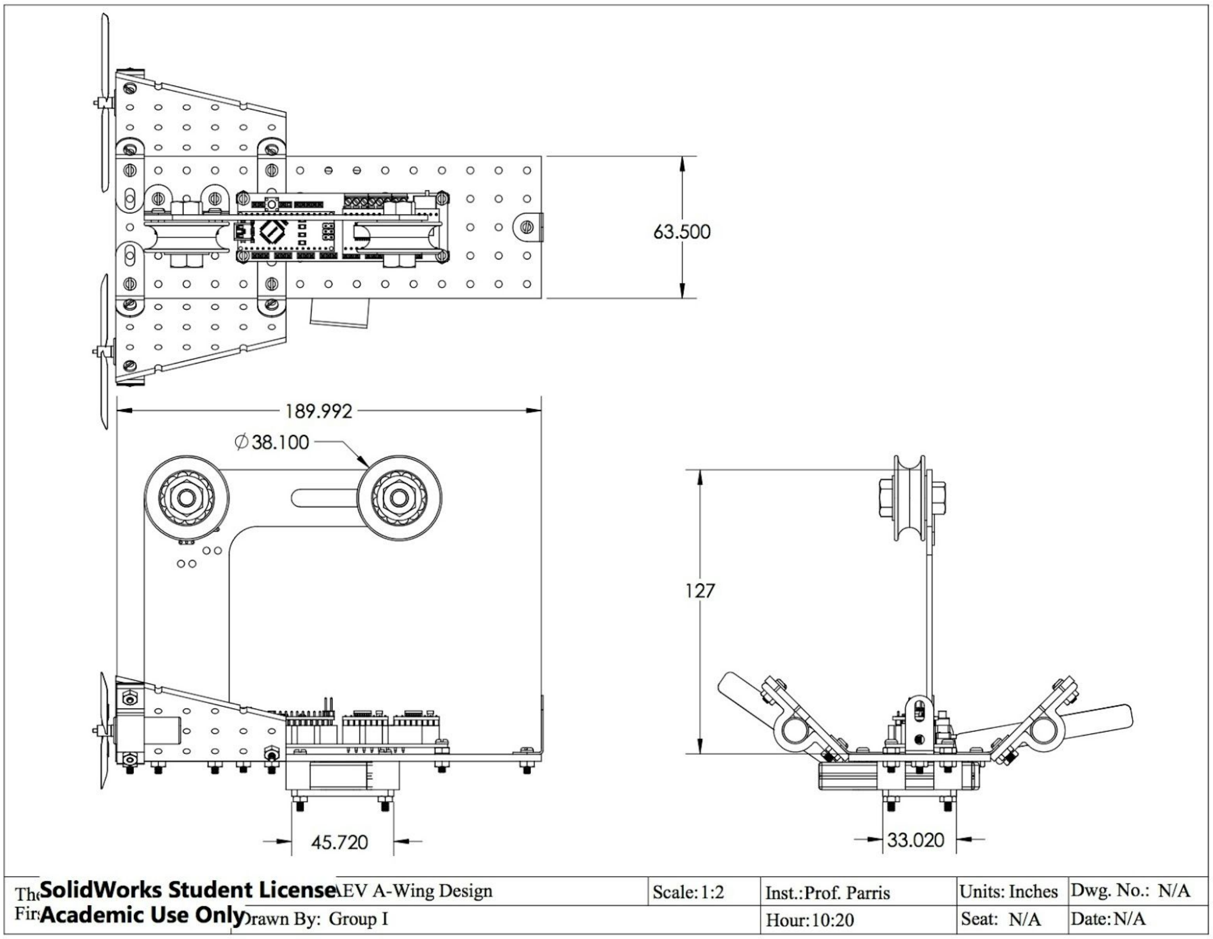
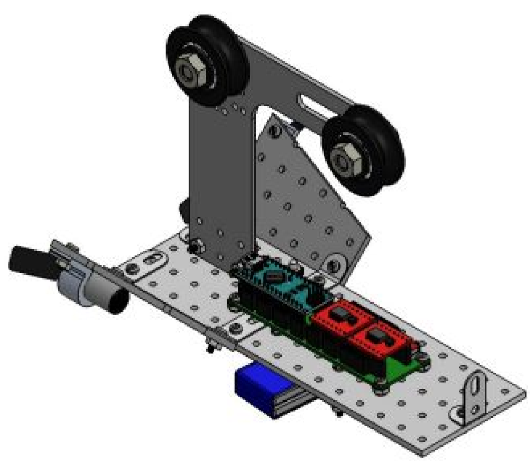


Table 3: "A-Wing Costs "

Part	Price
Arduino	$100.00
Electric Motor (2)	$19.98
Wheels (2)	$15.00
Battery	$10.00
Angle Brackets (7)	$5.88
Count Sensor (2)	$4.00
Count Sensor Connector (2)	$4.00
L-Shaped Arm	$3.00
Bulk Screws and Nuts	$2.88

2.5” x 7.5” Rectangle	$2.00
Trapezoid (2)	$2.00
Battery Supports (2)	$2.00
Screw Driver	$2.00
¼” Wrench	$2.00
Motor Clamps (2)	$1.18
Propellor (2)	$.90
TOTAL:	$176.82
TOTAL WEIGHT:	301 grams

Figure 4: A-Wing Isometric View



ITEM NO.	PART NUMBER	QTY.
1	AEV Arduino Assembly	1
2	Large Rectangle	1
3	90-deg bracket	3
4	Pulley Assembly w-reflective tape	2
5	Pulley Assembly	2
6	AEV Motor	2
7	Support Arm 2 2 Sensor Holes	1
8	Right Trapezoid	2
9	Battery Pack	1
10	Battery Spacer	4
11	SL-PHMS 0.112-40x0.375x0.375-S	15
12	MSHXNUT 0.112-40-S-S	27
13	Motor Mount Clip Aluminum	2
14	HBOLT 0.3125-18x0.875x0.875-S	2
15	MSHXNUT 0.3125-18-S-S	2
16	Prop 3inch	2
17	Battery Pack Clamp Plate Narrow	1
18	Preferred Narrow FW 0.094	4
19	SL-PHMS 0.112-40x0.5x0.5-S	4
20	Rotation Sensor Board	2
21	SL-PHMS 0.112-40x1x1-S	4
22	45-deg bracket	4

Th **SolidWorks Student License**	EV A-Wing Sheet 2	Scale: 1:2	Inst.:Prof. Parris	Units: Inches	Dwg. No.: N/A
Firs **Academic Use Only**	rawn By: Group I		Hour:10:20	Seat: N/A	Date: N/A