Critical Design Review Report

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Executive Summary

The purpose of this AEV project was to design an AEV and program it to move around a track and respond to track cues. In addition to the actual creation of the vehicle, it was important that the team developing the design made sure to be as cost and energy efficient as possible due to power limitations on remote planets. One of the team's main goals was to make the AEV as light as possible so that weight would not be an obstacle when programming the vehicle's power usage during movement. The main objective was for the AEV to pick up an R2D2 unit with a magnet and carry it back around the track.

In an attempt to make the vehicle lighter, the group swapped out the base piece from a large rectangle to a T-shaped part and assembled the Arduino, battery, and motors on it. By taping some cardboard and adding a rubber band to the servo, a brake was installed to press up against the track and keep the vehicle in place. The brake made the vehicle more consistent with stopping, especially when it approached the gate.. Performance test 1 showed that the servo brake design was more energy efficient and reliable to complete the MCR. After the design process was completed for the AEV, the programming was the next main concern. The vehicle then was programmed to brake the motors, reverse the motors, cue the servo brake, wait for five seconds, release the brake, and then continue to the end of the track to retrieve the R2D2. Performance tests 2 & 3 showed that using a reverse command before the servo brake was cued was not only more reliable but also more energy efficient. The work completed in performance tests 1-3 was used in the final performance test where the AEV successfully completed the MCR with a low energy usage.

This lab was important to the scientific community because it practiced restraint on cost and energy. It also involved a lot of troubleshooting and changing parameters. The end result of this lab was a flawless run on the track. The AEV began traveling towards the gate, slowed down, then stopped at the sensor before heading to the end of the track. It then picked up the AEV, waited five seconds, then proceeded back towards the gate. After reaching the sensor and waiting for the gate arm to lower, it returned to the beginning of the track, successfully rescuing the R2D2 unit.

Prior to finalizing the AEV design, the team experimented with several different key components, the first being the propellers. The puller 3030 propellers proved to be the most powerful compared to the two other sets of propellers provided after comparing them in a propeller test measuring their power output. In addition to propellers, the team also utilized a different base design before switching to the T-shaped plastic base. This base allowed for the most space with the least amount of excess material, essential in cutting any unnecessary weight from the vehicle.

Some recommendations would be to have started the vehicle with the least amount of material as possible to keep it lightweight. From there, it was easy to add some necessary components to improve the vehicle as it moves. In addition, programming the vehicle in parts and breaking up the track into segments helped with organizing and implementing the actual movement of the AEV. In conclusion, the AEV lab was a success because of the tests run making the vehicle as light and energy efficient as possible. The team's strong attention to detail and ability to make fast, effective changes to the AEV led to an energy to mass ratio of 971 J/kg and a final run energy usage of 220 J.

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Introduction

The objective of the labs was to determine an AEV design that could transport the R2D2 units across the land while also being energy and cost efficient. Another objective of the lab was that the AEV must complete the task within a time limit and follow all instructed rules. In order to come to a conclusion of which AEV would fit better for the task, some goals needed to be met by using design and efficiency. These goals included being able to stop at the gate for a certain amount of time in order to gain access into the cargo area. Another goal was to be able to travel back to the drop off area and safely deliver the cargo. In order to meet these goals both the AEV design and code had to complete multiple tests that collected data about their performance. These tests were then compiled to reach an overall conclusion.

The report was created to demonstrate major trends between design and code efficiency. These trends helped to solve the problem of finding an energy and cost efficient AEV that could travel to pick up the R2D2 units in a timely manner. The following report includes an experimental methodology section where the experimental procedure of the labs is discussed, followed by a results section where the data from the labs is presented. Following the results is a discussion section where the analysis, potential error, and comparison to theory of the report are located. After the discussion section is the conclusions and recommendations that discusses which AEV design and code was chosen and why it is better for the task.

Experimental Methodology

The setup for the labs involved the following materials and equipment: the AEV track, the arduino, the motors, the propellers, the wheel sensors, the servo, Arduino Sketchbook, and MatLab. The AEV track consists of a half oval monorail like track that has a gate in the middle that can only be activated by tripping the first sensor. The following connections were made to the arduino board: the 2 motors, the wheel sensors, and the servo. The arduino board was used to store and transfer code to the other equipment parts, which then runs the AEV on the track.

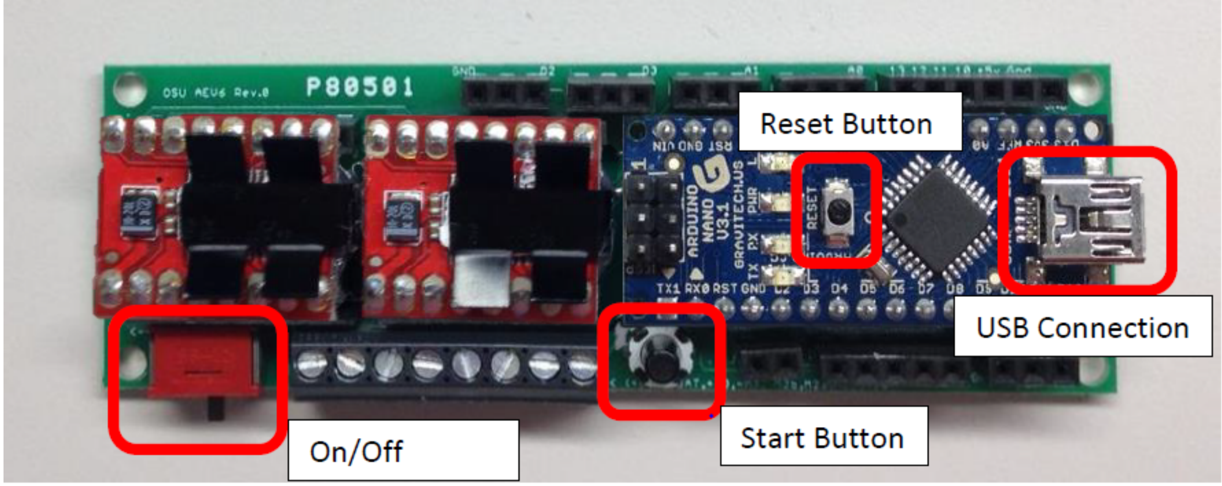


Figure 1: Arduino Board

The motors provided power to the AEV and which allowed the AEV to move forwards and backwards on the track. The propellers were attached to each motor and help the AEV move by either using the push or pull method.

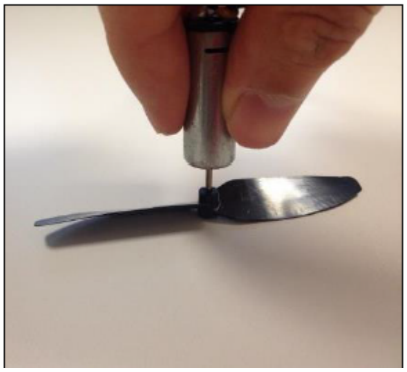


Figure 2: Motor and Propellor Assembly

The wheel sensors were used to measure distances along the track that the AEV had travelled. The wheel sensors worked by counting how many marks had been travelled by the AEV and then completes commands when it gets to a certain number of marks.

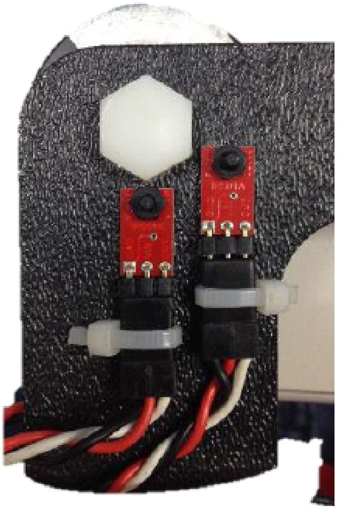


Figure 3: Wheel Sensors

The servo helps to provide a control of angular position. The Arduino Sketchbook was used to write code and then transfer it to the arduino using a USB cable.

The motors and wheel sensors were calibrated by creating and running a set of code, consisting of using the basic celerate, motorSpeed, goFor, brake, and reverse commands, to make sure each part was functioning properly. The calibration of the motors was completed in lab 1 before the AEV was even put on the track. In order to calibrate the wheel sensors a special code called the reflectanceSensorTest() was used, which helped to make sure the wheel sensors were measuring marks properly and that the wheels were travelling in the proper direction. This calibration took place in lab 2 but also occurred in other labs when the wheel sensors weren't working properly. After insuring that all parts of the equipment were functioning properly a code was created using the Arduino Sketchbook. The sketchbook uses the same coding process as a C or C++ program but has specific functions used for the AEV. Once the code was created the AEV was ready to be tested. Using a USB cable the code was transferred from the sketchbook into the arduino controller. Once the arduino was started the code would be executed making it run along the track and perform the tasks written in the code. After each run on the track the AEV was hooked back up to the computer using the USB cable in order to retrieve its data from the run. The AEV reads in the data using EEPROM which stands for Electrically Erasable Programmable Read-Only Memory. The AEV's EEPROM data was collected by downloading the aevDataRecorder file to MatLab. The MatLab file was used to convert the data into parameters that can be easily understood, such as time to seconds, current to amps, voltage to volts, and distance and position to meters. Converting the data into these parameters makes it easier to calculate the power of the AEV at any point in time along it's run. The power was then graphed along with time to calculate the energy used from the AEV, in order to find the energy a midpoint approximation of the Riemann Sum was used.

The process of running the AEV on the track was used amongst multiple different designs. These designs were all tested using the same code in order to be compared against each other. There were two different types of methods that were used to compare AEV designs against each other. The first method was screening which used +, -, and 0 to rank the AEV in different categories. After assigned a value in each category, the categories were totaled up giving the AEV an overall score. Based on the score given, it was decided whether or not the AEV was fitting for the tasks. Another method of test AEV design was the concept scoring, which was similar to concept screening but used numbers inside of +,-, and 0. Each AEV was tested and then ranked in each category. Both methods were using in determining the design of the AEV.

After completing the experimental research of the AEV, the design process entered a cycle of analysis, design decisions, research, and comparison. This cycle worked to test and compare AEV designs, codes, and energy modifications. There were four sets of performance tests that worked to find the final product of the AEV design and code. Each performance test had a different focal point which allowed multiple versions of the design and code to be made and tested against one another to find the perfect AEV. These performance tests proved most useful to the final design because they were all performed with a full track code. This was meaningful because the team could actually see the difference each change made on the AEV as a whole, meaning the design, energy, and repeatability.

Results

One of the first tests the team ran during the course of the AEV project was the wind tunnel test to determine which propellor was most efficient. In figure 4 below, the propellor efficiency vs advance ratio graph was shown which was derived from a wind tunnel test. This graph, from system analysis 1 helped the team decide the correct propellor to use. What was learned from this test was that the 3030 propellor was much more efficient than the 2510 propellor, this was essential in making the correct propellor choice. After the most efficient propellor model was determined, the most efficient motor speed percentage to run the AEV with was determined. According to figure 4, an advanced ratio of 0.4

yielded the most ideal efficiency percentage of approximately 50%. Using the advance ratio formula it was determined that the ideal motor speed percentage was approximately 30. From this data, the team implemented a motor speed equal or near 30.

Regarding the two different concepts tested in performance test 1, the advanced test ratio and wind tunnel test data was applied in the same way to both models because of how similar they were. The advanced ratio as well as any other wind tunnel data would not be affected by the implementation of a servo motor.

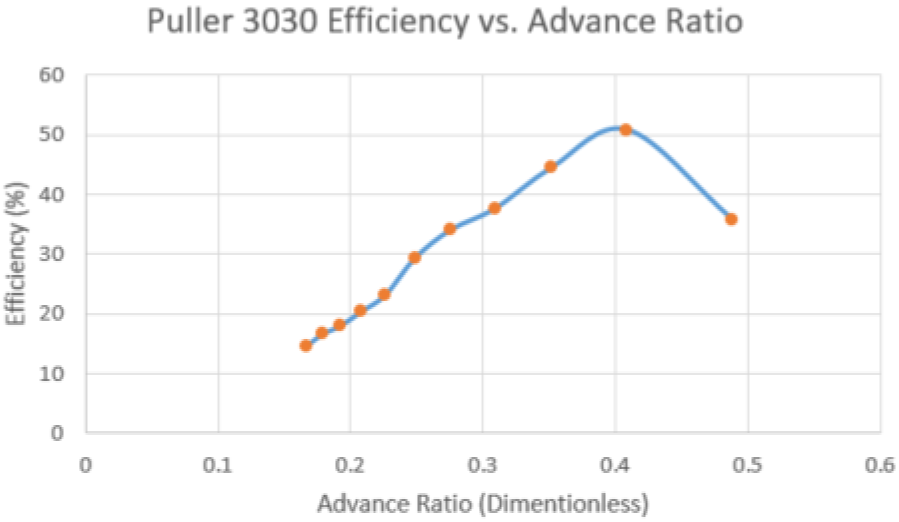


Figure 4: Propulsion Efficiency vs Advance Ratio

Figure 5 below, shows the supplied power vs time for the final run with the servo brake. What was shown were the specific phases of the program the team wrote to run the AEV. The team came to the conclusion that the servo brake route was the way to go after performance test 1 showed that it was more efficient and a more reliable way to stop the AEV. This data was shown explicitly with the amount of energy used for each phase of code in table 1.

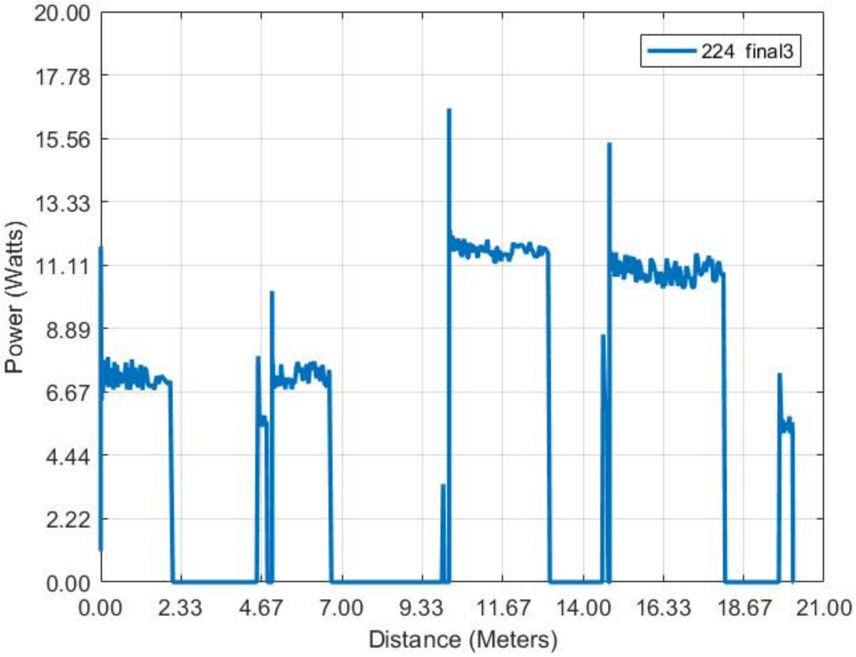


Figure 5: Supplied Power vs Distance, Final Run

In table 1 the breakdown of the different phases of the AEV final run were explained. It was important to understand which component of the graph correlates to what in the actual code. Without that understanding, the team would have a hard time correcting the errors moving forward after the test runs because there would be a lack of data to base the decisions on. What was shown was the energy used for each phase from the final run. This came about through the performance tests the Team ran in PT 1 and 2. This allowed the group to maximize the efficiency of the code and AEV for this final run.

Table 1: Phase break down of Figure 5 and the Arduino Code

Marks	**Distance**	**Energy**	**Description**
0	0	-	The start of the track, beginning of the code
0-145	0-70.86 in	24.47 J	The first section where the AEV accelerates to the first gate
145-365	70.86-178.73	-	Coast into the first gate before it has to slow down
365-388	178.73-189.76	2.84 J	Reverse motors to slow down before the Servo Brake activates
388	189.76	-	Servo Brake halts motion to wait for gate (7 second wait)
388-535	189.76-264.96	21.07 J	Accelerate towards the cargo
535-807	264.96-392.9	-	Coast into the cargo for pickup
805-810	392.9-395.67	0.21 J	Quick burst backwards to not ram into cargo
810	395.67	-	End of track, pickup cargo
810-585	395.67-285.04	81.26 J	Reverse motor to accelerate back to gate with cargo
585-446	285.04-217.32	-	Coast into gate with cargo
446-438	217.32-213.39	3.27 J	Reverse Motor to slow down for the Servo Brake to activate
438	213.39	-	Wait for gate to lower (7 second wait)
438-150	213.39-69.17	80.76 J	Accelerate towards the start of the track with cargo
150-30	69.17-14.96	-	Coast into the start position
30-10	14.96-4.72	6.48 J	Reverse motors to slow for stop and activate servo motor brake
10	4.72	-	Wait 5 seconds to finish run. End of track and end of run
		Total: 220.37 J	

This final run proved to be the most efficient at 220 J compared to the other test runs the team ran even on the day of final testing. The team used the table above to help in getting to this final run data. The blue sections were the important points on the track that the team had to leave alone and code around. This was helpful in guiding the team's coding so that these important points weren't impeded upon. The discussion below will discuss the team's design process, cost minimization, and final run of the AEV from an onlookers perspective.

Discussion

From the four designs proposed in lab 5 (X-Wing, Y-Wing, Double Propellor, Reference), the team decided to move forward with the X-Wing model as it scored the highest from the screening and scoring charts, Tables 2 and 3. In the success criteria: balanced, minimal blockage, center of gravity location, maintenance, durability, cost, and aesthetics; the X-Wing scored higher than its competitors. The criteria where it did not perform well in comparison to others (maintenance, durability, and environmental) were improved through changes the team decided on. The majority of the proposed model was left unchanged, however, as the main issue with the model was the excess weight from the wings and body. This issue was solved by using light weight plastic material for construction. This also made the AEV significantly more aerodynamic. Maintenance and durability were also simultaneously improved by using the rigid materials, and securing bolts on the AEV better. The next proposed change to the model (servo-brake), was an extension of the original X-Wing, it would provide the model with a much more reliable and precise means of braking, to ensure its success on the track.

Table 2: Screening Chart from Lab 5

Success Criteria	Reference	Design X-Wing	Design Y-wing	Design Double Prop
Balanced	0	0	0	0
Minimal blockage	0	0	0	-
Center-of-gravity location	0	+	0	+
Maintenance	0	-	0	-
Durability	0	0	0	-
Cost	0	-	-	0
Environmental	0	+	+	-
Aesthetics	0	+	-	+
Sum +'s	0	3	1	2
Sum 0's	8	3	5	4
Sum -'s	0	2	2	2
Net Score	0	1	-1	0
Continue?	Combine	Yes	Combine	No

Table 3: Scoring Chart from Lab 5

		A Reference		Design X-wing		Design Y-wing		Design Double Prop	
Success Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Balanced	15%	3	0.45	3.5	0.525	3.5	0.525	3	0.45
Minimal blockage	5%	3	0.15	4	0.60	4	0.20	0.5	0.025
Center-of-gravity location	15%	2	0.30	3	0.45	3	0.45	4	0.60
Maintenance	5%	3	0.15	1	0.05	3	0.15	2	0.10
Durability	10%	2	0.20	2	0.20	3	0.30	1	0.10
Cost	15%	3	0.45	2	0.30	2.5	0.375	3	0.45
Environmental	15%	3	0.45	3	0.45	4	0.60	2	0.30
Aesthetics	20%	1	0.20	5	1	2.5	0.50	3	0.60
Total Score	100%		2.35		3.575		3.10		2.625
Continue?			No		Develop		Combine		No

In Performance test 1, the design from lab 3 was extended in order to create a better model. As stated before, from the lab 4 observations, the team elected to move forward with the X-Wing design. The two AEV concepts that were tested were the regular X-Wing model, X-Wing model with a servo- brake, and an X-wing model without the wings included. Because it was not consistent with design inspiration, the team quickly elected to opt out of the wingless model. Both the remaining models had distinctive dual wings on the rear of the model, as well as a lightweight plastic body that surrounds the components of the AEV. The wings and body were implemented to mimic the famous star wars space cruiser and also made the AEV aerodynamic. Dual propellor propulsion was implemented on the the rear of the model in a "push" system. In Both models the arduino was mounted on the top while the battery was on the undercarriage. The difference between the two models was the proposed servo- brake, mounted on the wheel arm of the final model. A brake lever arm would be connected to the servo in order to come in contact with the rail the AEV travels on. As observed in tables 4 & 5, the screening and scoring matrices for performance test 1, the X-wing with servo included, performed better than the original model. This was due to increased score performance in control and environmental efficiency, which were key components of the MCR. Subsequently, the servo's actions would be applied easily in the existing code where additional braking was necessary. The brake would be implemented at points along the track where precise stopping was necessary, such as at the midpoint gate. Accordingly, the performance test was an integral part of the team's decision making process for designs to be considered. It was especially helpful in making a choice between the two designs the team narrowed its scope to. What was found during performance test 1 and comparing two designs was that the servo motor design was the most effective at stopping the AEV where it was supposed to stop. Without the performance test, the team might not have been motivated to create the design with the servo motor brake, and thus would have a lower chance of completing the mission.

It was inferred from the data that the X-Wing model with the servo-brake included performed better than its competitor, the plain X-Wing model. From figures 4 and 5, the servo-brake implication results in the AEV model using less energy to stop in comparison to a propulsion stop alone. This was because less power was applied over a period of time to stop the model by propulsion. Also, as stated before, the use of the servo-brake allows the AEV to stop precisely, without any drift that may result in triggering the midpoint gate to shut. Besides the obvious errors in code consistency, the servo brake proved to be a success.

Table 4: Screening Chart from Lab 8, Performance test 1

Success Criteria	Reference	Normal X-Wing	X-wing - No Wing	X-wing + servo brake
Balanced	0	0	0	-
Center-of-gravity location	0	0	+	0
Control	0	+	+	+
Durability	0	+	-	0
Cost	0	-	+	-
Environmental	0	+	+	+
Aesthetics	0	+	-	0
Sum +'s	0	4	4	2
Sum 0's	7	2	1	3
Sum -'s	0	1	2	2
Net Score	0	3	2	0
Continue?	Combine	Yes	Yes	Yes

Table 5: Scoring Chart from lab 8, Performance test 1

		Reference		Normal X-Wing		X-Wing - No Wings		X-Wing + servo brake	
Success Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Balanced	10%	3	0.30	3.5	0.35	3	0.30	2	0.20
Center-of-gravity location	10%	2	0.20	3	0.30	2	0.20	3	0.30
Control	20%	2	0.40	3	0.60	2.5	0.50	5	1.00
Durability	10%	2	0.20	4	0.40	2	0.20	4	0.40
Cost	15%	3	0.45	3	0.45	3.5	0.525	2	0.30
Environmental	15%	3	0.45	3	0.45	4	0.60	4	0.60
Aesthetics	20%	1	0.20	5	1	2	0.40	3	0.60
Total Score	100%		2.20		3.55		2.725		3.40
Continue?			No		Develop		No		Develop

The results from lab 5 determined that the group wanted to move forward with the basic design of the X-Wing, as opposed to its counterparts. As observed in Tables 2 & 3, the X-Wing scored the highest on the scoring charts when compared to the others, as well as performing better in the screening chart. It was noted that the areas the X-Wing did not perform the best in (environmental, cost & maintenance), the team intended to improved by using durable, inexpensive, lightweight materials for construction, which were not implemented at the time. Accordingly, the results of lab 5 provided the basis of what was to be tested in performance test 1. As previously stated, the X-Wing was tested with the use of the servo brake, as well as without it. It must be noted that the X-Wing without the use of the wings was also considered, but quickly ruled out because it defeated the purpose of the aesthetic appeal. As observed in tables 4 & 5. It was decided based on the results and consistency of the AEV that the team wanted to move forward with this final model design and complete the code to make a full run on the track. The only additional material added to the AEV was a plastic encased body to make the AEV more aesthetically pleasing, making it look more like an X-wing fighter. The design process was successfully followed, resulting in the group creating an efficient and successful AEV. The final design is shown in figure 10 in the appendix.

In order to reduce the overall cost of the system, the team mainly focused on not using materials in the design process that would increase the cost of the AEV. This included lightweight scrap plastic material for the construction of the body and wings of the model. Although the implementation of the servo brake would cost the team additional money in construction, the benefits of its stopping ability outweighed its cost. In addition, inexpensive materials were used for the construction of the brake were used including cardboard, rubber bands and paper clips. Accordingly, another means of lowering the cost of the system was to maximize the efficiency of the energy. Through well-thought-out coding techniques, the team was able to create a system that used approximately 220 J of energy during its route. This value minimized as much as possible within the structure of the code.

Some areas of potential error in this project could come stem from a few places. The first being the wheel sensors. These were found to be very inaccurate compared to what was calculated based on the distance the AEV traveled. The only way to correct this, though, would be to either replace the sensors, or keep checking them and adjusting the code to match the inaccuracy. The next source of error would be the servo brake. What the team discovered was that the servo didn't initially operate successfully. This error was resolved by carefully implementing code that did not have conflicting functions at points along the track. An additional source of error encountered during the testing process, was rebound off the foam stopper at the end of the track while attaching to cargo. This could result in inaccurate position reading, possibly causing inconsistent test runs. The team resolved this issue by minimizing the incoming velocity of the AEV, minimizing rebound off the foam stopper. Lastly, an error that the team encountered was inconsistency with the AEV during the first test runs of a class period. The team resolved this issue by warming up the motors, allowing it to run for a period of time in order for the engines to perform at their highest level.

During the final run of the AEV the team was able to obtain a score of 50/50. This came about from the numerous test the team ran throughout lab. In the final run, the AEV did run a little longer than normal. For instance, at the first gate-stop, the AEV was about a centimeter away from tripping the brake sensor and stalling the run. Luckily enough, it stopped just in time and continued around the track to pickup the cargo. On the way back the AEV was able to stop at the gate fairly easily and continued towards the end of the delivery. At the final stopping point the AEV stopped a little closer to the green block than it did before, but ultimately stopped in time. Overall the final run was successful and used only 220 J of energy. It also got a total score of 82, tied for second in the class and has an Energy mass ratio of 971 J/Kg, 6th in the class. The overall score sheet is in the appendix.

Conclusions and Recommendations

Through the design process, the team successfully created an AEV model that was consistent with the goals of the MCR. The AEV completed the desired route with no errors, while minimizing energy usage and cost. From various testing processes, several observations were observed. From wind tunnel data the team determined that the most efficient propellor choice was the puller 3030 ran at a motor speed of approximately 30. Accordingly, as a result of testing different design choices, the X-wing performed better than its counterparts (Y-wing and double propellor), which was observed in screening and scoring matrices in tables 2 and 3. From this, the team would attempt to enhance this model by implementing a servo brake. The servo brake proved to be highly successful after initial difficulties, adding consistency and increased efficiency to testing. From this point the AEV was primarily finished, and only code structure needed to be corrected before the final run.

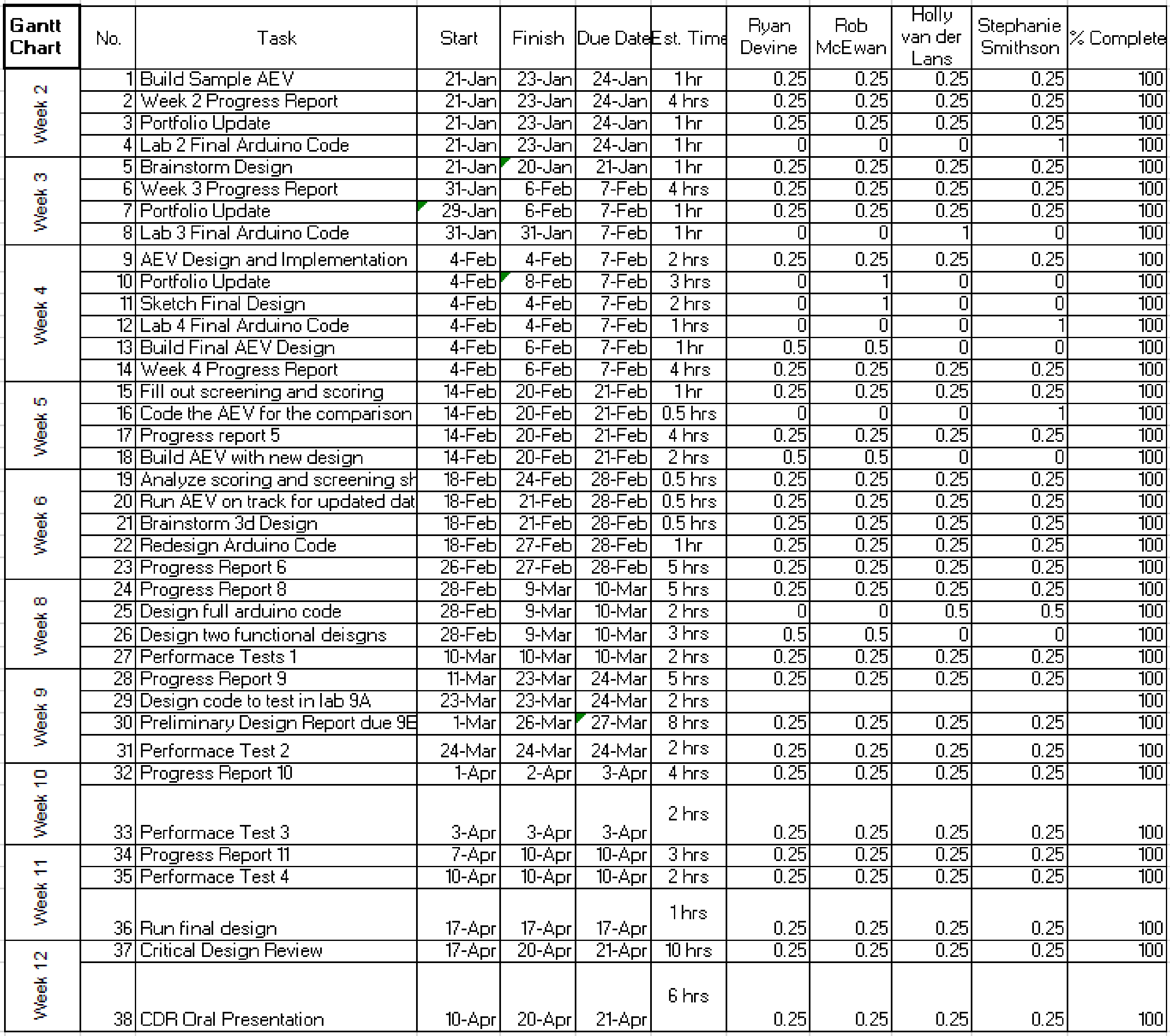
From the final run, the AEV performed exceptionally well. The team tied for second in total score while also meeting the requirements of the MCR. The team had a mass of 0.227 kg, a total energy usage of 220.364 J, time of run of 54.10 s, and an energy mass ratio of 970.77 J/kg. This must all be taken into consideration with the aesthetic appeal of the AEV, which had additional material on it to make it appear like an X-wing fighter.

The teams AEV was the best design because it excelled in multiple categories at once. Unlike other models in the class, the AEV had a designated aesthetic look in mind during creation. Other models that performed highly were simple designs, that utilized minimal material and had no aesthetic appeal to it. Most of those models were simple stripped down AEV’s, having the purpose of having the lightest AEV possible. The team could have taken this route, however, the team elected to try to perform as well as possible without losing the integrity of the design inspiration. Additionally, the team implemented a servo-brake into their design which was only seen from a couple other teams in the class. This created impeccable consistency when testing, allowing it to stop at exact points on the track. Lastly, the team's design performed well in categories in which the team did not have a direct goal to do so. The main goals of the team were in efficiency, cost, consistency and aesthetic appeal. The team unknowingly scored well in time, and weight. Regardless of the large amount of excess material, the team tied for the lowest weight. Additionally, the team scored the third lowest on time, which was never a goal. Subsequently, it must also be noted that the team never opted to perform a second run to try to increase its score. By dropping excess weight like others did, the team likely could have performed better.

The team encountered several errors in the early stages of testing that were a result of faulty equipment. Due to this, possible recommendations would be for newer materials to be used for construction. Additionally, the capabilities of the instructors could be improved by increasing knowledge of the materials being used, and more quickly identifying/ troubleshooting problems when they occur.

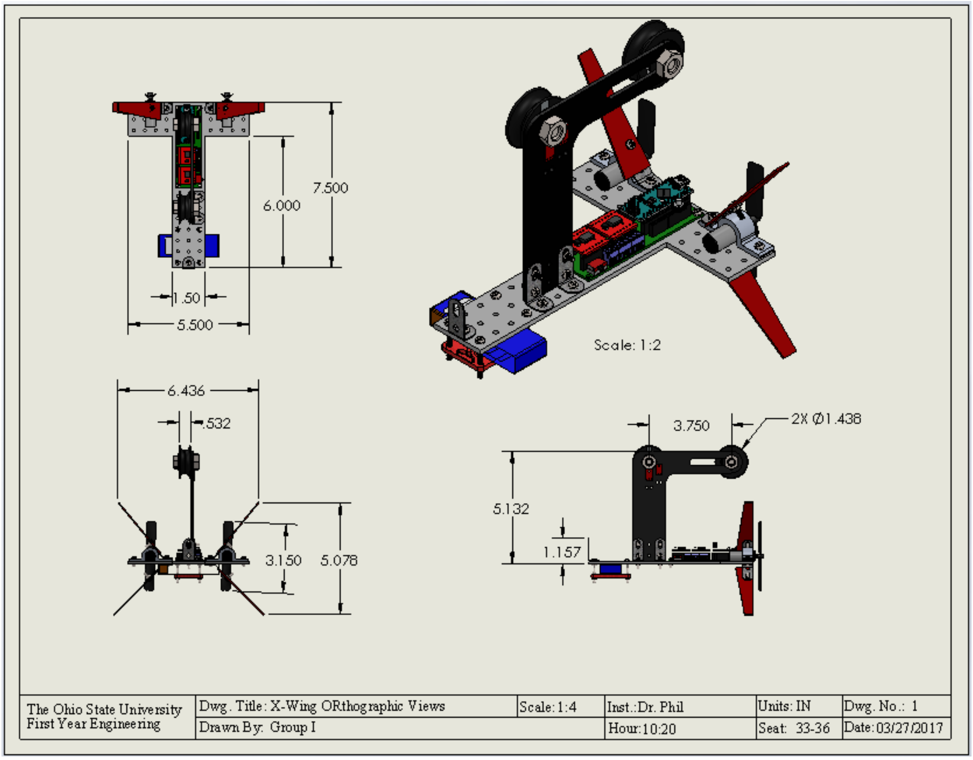
Appendix A

Table 6: Team Schedule



Gantt Chart	No.	Task	Start	Finish	Due Date	Est. Time	Ryan Devine	Rob McEwan	Holly van der Lans	Stephanie Smithson	% Complete
Week 2	1	Build Sample AEV	21-Jan	23-Jan	24-Jan	1 hr	0.25	0.25	0.25	0.25	100
	2	Week 2 Progress Report	21-Jan	23-Jan	24-Jan	4 hrs	0.25	0.25	0.25	0.25	100
	3	Portfolio Update	21-Jan	23-Jan	24-Jan	1 hr	0.25	0.25	0.25	0.25	100
	4	Lab 2 Final Arduino Code	21-Jan	23-Jan	24-Jan	1 hr	0	0	0	1	100
Week 3	5	Brainstorm Design	21-Jan	20-Jan	21-Jan	1 hr	0.25	0.25	0.25	0.25	100
	6	Week 3 Progress Report	31-Jan	6-Feb	7-Feb	4 hrs	0.25	0.25	0.25	0.25	100
	7	Portfolio Update	29-Jan	6-Feb	7-Feb	1 hr	0.25	0.25	0.25	0.25	100
	8	Lab 3 Final Arduino Code	31-Jan	31-Jan	7-Feb	1 hr	0	0	1	0	100
Week 4	9	AEV Design and Implementation	4-Feb	4-Feb	7-Feb	2 hrs	0.25	0.25	0.25	0.25	100
	10	Portfolio Update	4-Feb	8-Feb	7-Feb	3 hrs	0	1	0	0	100
	11	Sketch Final Design	4-Feb	4-Feb	7-Feb	2 hrs	0	1	0	0	100
	12	Lab 4 Final Arduino Code	4-Feb	4-Feb	7-Feb	1 hrs	0	0	0	1	100
	13	Build Final AEV Design	4-Feb	6-Feb	7-Feb	1 hr	0.5	0.5	0	0	100
	14	Week 4 Progress Report	4-Feb	6-Feb	7-Feb	4 hrs	0.25	0.25	0.25	0.25	100
Week 5	15	Fill out screening and scoring	14-Feb	20-Feb	21-Feb	1 hr	0.25	0.25	0.25	0.25	100
	16	Code the AEV for the comparison	14-Feb	20-Feb	21-Feb	0.5 hrs	0	0	0	1	100
	17	Progress report 5	14-Feb	20-Feb	21-Feb	4 hrs	0.25	0.25	0.25	0.25	100
	18	Build AEV with new design	14-Feb	20-Feb	21-Feb	2 hrs	0.5	0.5	0	0	100
Week 6	19	Analyze scoring and screening sh	18-Feb	24-Feb	28-Feb	0.5 hrs	0.25	0.25	0.25	0.25	100
	20	Run AEV on track for updated dat	18-Feb	21-Feb	28-Feb	0.5 hrs	0.25	0.25	0.25	0.25	100
	21	Brainstorm 3d Design	18-Feb	21-Feb	28-Feb	0.5 hrs	0.25	0.25	0.25	0.25	100
	22	Redesign Arduino Code	18-Feb	27-Feb	28-Feb	1 hr	0.25	0.25	0.25	0.25	100
	23	Progress Report 6	26-Feb	27-Feb	28-Feb	5 hrs	0.25	0.25	0.25	0.25	100
Week 8	24	Progress Report 8	28-Feb	9-Mar	10-Mar	5 hrs	0.25	0.25	0.25	0.25	100
	25	Design full arduino code	28-Feb	9-Mar	10-Mar	2 hrs	0	0	0.5	0.5	100
	26	Design two functional deisgns	28-Feb	9-Mar	10-Mar	3 hrs	0.5	0.5	0	0	100
	27	Performace Tests 1	10-Mar	10-Mar	10-Mar	2 hrs	0.25	0.25	0.25	0.25	100
Week 9	28	Progress Report 9	11-Mar	23-Mar	24-Mar	5 hrs	0.25	0.25	0.25	0.25	100
	29	Design code to test in lab 9A	23-Mar	23-Mar	24-Mar	2 hrs					100
	30	Preliminary Design Report due 9E	1-Mar	26-Mar	27-Mar	8 hrs	0.25	0.25	0.25	0.25	100
	31	Performace Test 2	24-Mar	24-Mar	24-Mar	2 hrs	0.25	0.25	0.25	0.25	100
Week 10	32	Progress Report 10	1-Apr	2-Apr	3-Apr	4 hrs	0.25	0.25	0.25	0.25	100
	33	Performace Test 3	3-Apr	3-Apr	3-Apr	2 hrs	0.25	0.25	0.25	0.25	100
Week 11	34	Progress Report 11	7-Apr	10-Apr	10-Apr	3 hrs	0.25	0.25	0.25	0.25	100
	35	Performace Test 4	10-Apr	10-Apr	10-Apr	2 hrs	0.25	0.25	0.25	0.25	100
	36	Run final design	17-Apr	17-Apr	17-Apr	1 hrs	0.25	0.25	0.25	0.25	100
Week 12	37	Critical Design Review	17-Apr	20-Apr	21-Apr	10 hrs	0.25	0.25	0.25	0.25	100
	38	CDR Oral Presentation	10-Apr	20-Apr	21-Apr	6 hrs	0.25	0.25	0.25	0.25	100

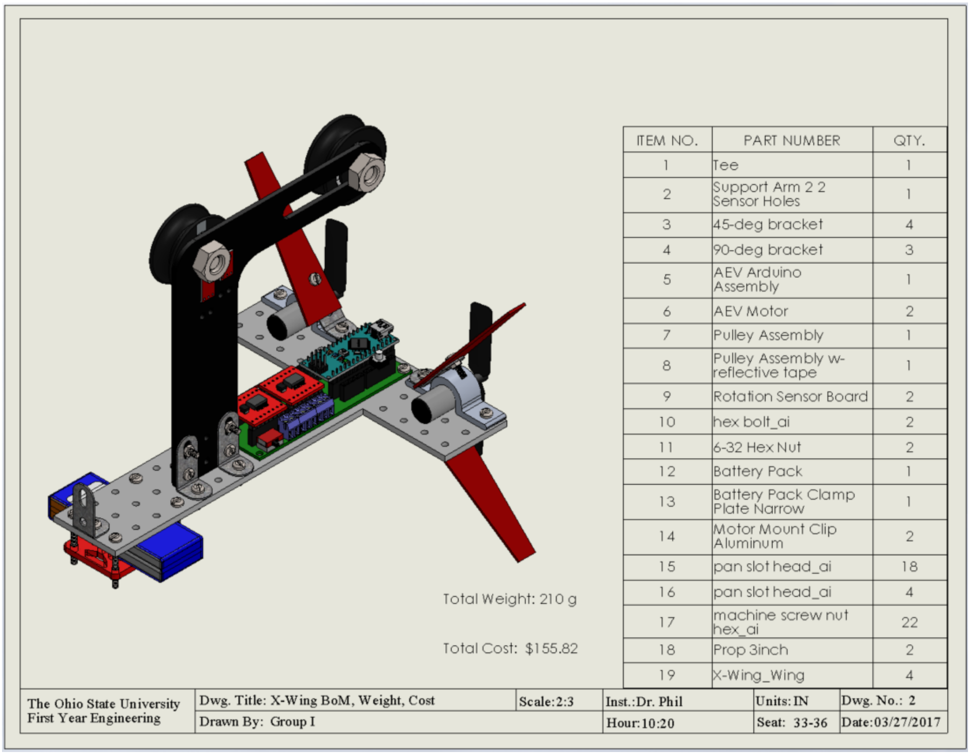
Appendix B



The Ohio State University
First Year Engineering

Dwg. Title: X-Wing ORthographic Views	Scale: 1:4	Inst.:Dr. Phil	Units: IN	Dwg. No.: 1
Drawn By: Group I		Hour:10:20	Seat: 33-36	Date:03/27/2017

Figure 6: X-Wing Orthographic Views w/ Dimensions



ITEM NO.	PART NUMBER	QTY.
1	Tee	1
2	Support Arm 2 2 Sensor Holes	1
3	45-deg bracket	4
4	90-deg bracket	3
5	AEV Arduino Assembly	1
6	AEV Motor	2
7	Pulley Assembly	1
8	Pulley Assembly w-reflective tape	1
9	Rotation Sensor Board	2
10	hex bolt_ai	2
11	6-32 Hex Nut	2
12	Battery Pack	1
13	Battery Pack Clamp Plate Narrow	1
14	Motor Mount Clip Aluminum	2
15	pan slot head_ai	18
16	pan slot head_ai	4
17	machine screw nut hex_ai	22
18	Prop 3inch	2
19	X-Wing_Wing	4

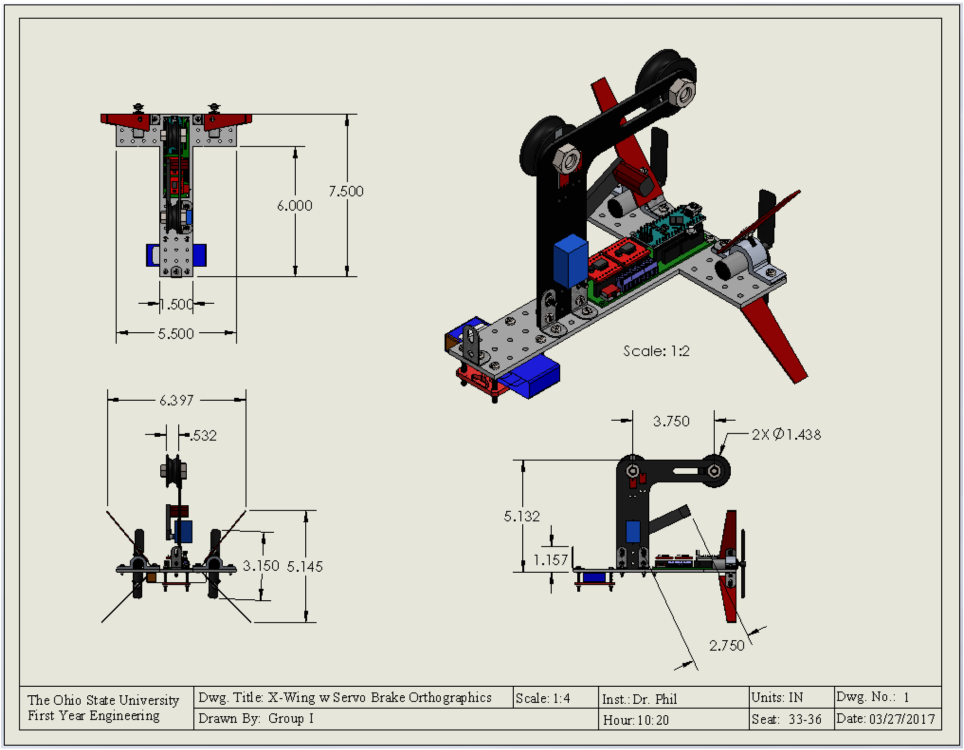
Total Weight: 210 g

Total Cost: $155.82

The Ohio State University
First Year Engineering

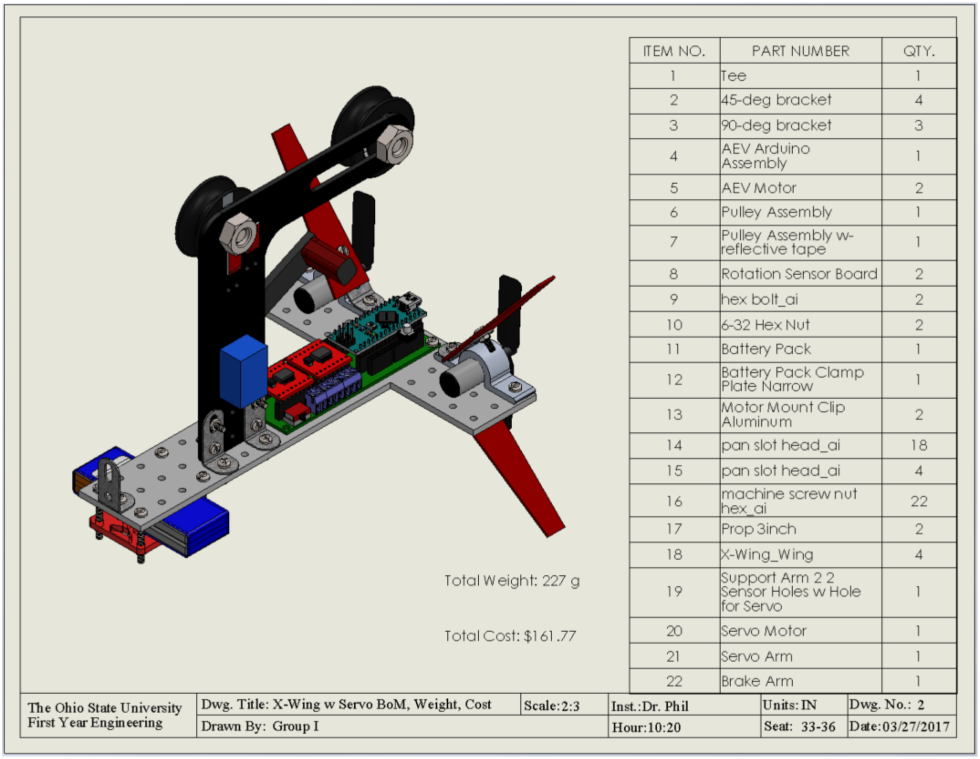
Dwg. Title: X-Wing BoM, Weight, Cost	Scale:2:3	Inst.:Dr. Phil	Units: IN	Dwg. No.: 2
Drawn By: Group I		Hour:10:20	Seat: 33-36	Date:03/27/2017

Figure 7: X-Wing w/ Bill of Materials, Weight, and Cost



The Ohio State University First Year Engineering	Dwg. Title: X-Wing w Servo Brake Orthographics	Scale: 1:4	Inst.: Dr. Phil	Units: IN	Dwg. No.: 1
	Drawn By: Group I		Hour: 10:20	Seat: 33-36	Date: 03/27/2017

Figure 8: X-Wing w/ Servo Brake Orthographic Views w/ Dimensions (Final Design)



ITEM NO.	PART NUMBER	QTY.
1	Tee	1
2	45-deg bracket	4
3	90-deg bracket	3
4	AEV Arduino Assembly	1
5	AEV Motor	2
6	Pulley Assembly	1
7	Pulley Assembly w-reflective tape	1
8	Rotation Sensor Board	2
9	hex bolt_ai	2
10	6-32 Hex Nut	2
11	Battery Pack	1
12	Battery Pack Clamp Plate Narrow	1
13	Motor Mount Clip Aluminum	2
14	pan slot head_ai	18
15	pan slot head_ai	4
16	machine screw nut hex_ai	22
17	Prop 3inch	2
18	X-Wing_Wing	4
19	Support Arm 2 2 Sensor Holes w Hole for Servo	1
20	Servo Motor	1
21	Servo Arm	1
22	Brake Arm	1

Total Weight: 227 g

Total Cost: $161.77

The Ohio State University First Year Engineering	Dwg. Title: X-Wing w Servo BoM, Weight, Cost	Scale: 2:3	Inst.: Dr. Phil	Units: IN	Dwg. No.: 2
	Drawn By: Group I		Hour: 10:20	Seat: 33-36	Date: 03/27/2017

Figure 9: X-Wing w/ Servo Brake w/ Bill of Materials, Weight, and Cost (Final Design)

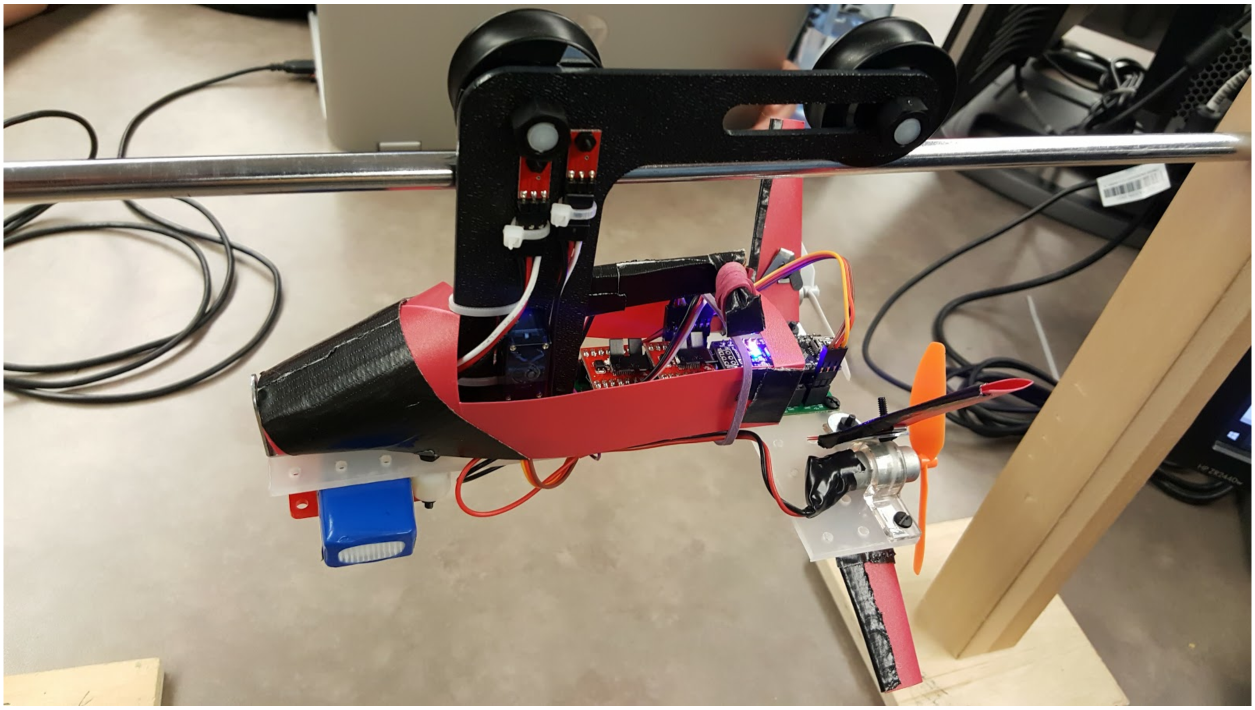


Figure 10: Final AEV Design w/ Lightweight Body on

Appendix C

Final code used for the final run

```
// First Half of track to gate
reverse(4);
rotateServo(45);
motorSpeed(4,32);
goToAbsolutePosition(160);

// Coast to gate
brake(4);
goToAbsolutePosition(365);

// Slow down to stop
reverse(4);
motorSpeed(4,30);
goToAbsolutePosition(388);

// Servo brake to stop for 7 seconds
brake(4);
rotateServo(10);
goFor(3);
rotateServo(45);
goFor(4);

//Second Half of Track to cargo pickup
reverse(4);
motorSpeed(4,32);
goToAbsolutePosition(535);

// Coast to cargo
brake(4);
goToAbsolutePosition(798);

// Slow to pickup cargo
reverse(4);
motorSpeed(4,20);
goToAbsolutePosition(802);

// Stop at cargo for 5 seconds
brake(4);
goFor(5);

//Way Back to gate with cargo
motorSpeed(4,50);
goToAbsolutePosition(575);
```

```
// Coast into gate
brake(4);
goToAbsolutePosition(450);

// Slow down at gate
reverse(4);
motorSpeed(4,30);
goToAbsolutePosition(438);

// Stop at gate with servo brake
brake(4);
rotateServo(10);
goFor(3);
rotateServo(45);
goFor(4);

//Second Half of track, gate to the start point
reverse(4);
motorSpeed(4,48);
goToAbsolutePosition(170);

// Coast into the start position
brake(4);
goToAbsolutePosition(40);

// Slow down at the end point
reverse(4);
motorSpeed(4,28);
goToAbsolutePosition(8);

// Use servo brake to stop for the end of the run
brake(4);
rotateServo(10);
goFor(5);
rotateServo(45);
```

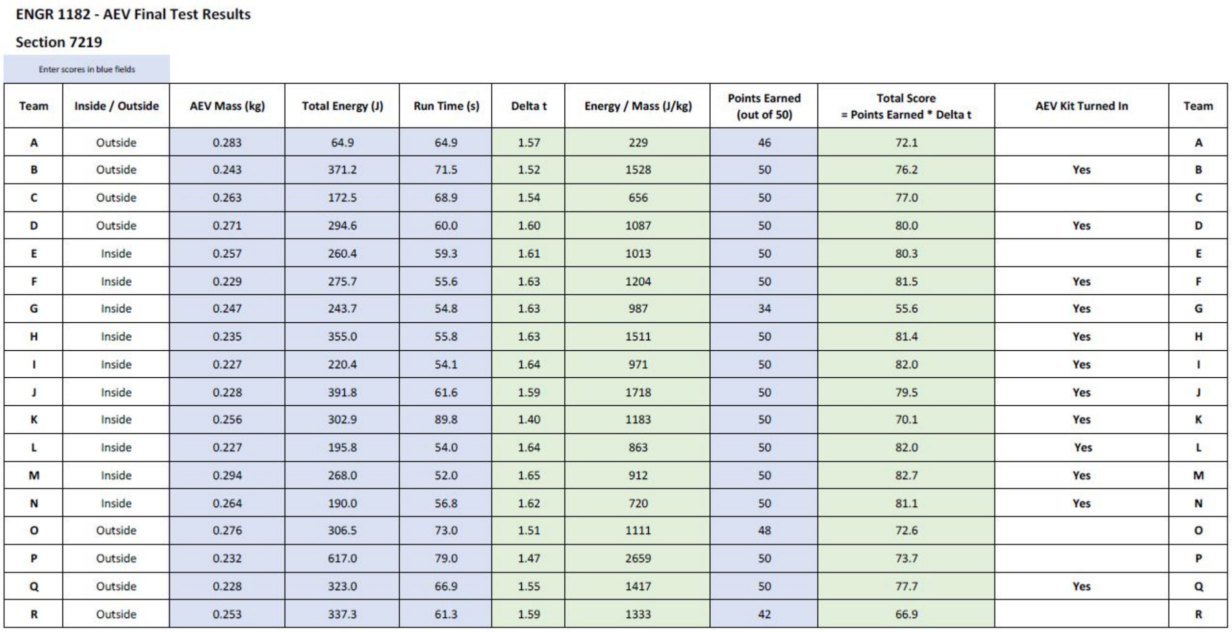
Code used as energy efficient attempt

```
//First Half
reverse(4);
rotateServo(45);
motorSpeed(4,30);
goToAbsolutePosition(143);

brake(4);
goToAbsolutePosition(388);
brake(4);
rotateServo(10);
```

```
goFor(3);
rotateServo(45);
goFor(5);

//Second Half of Track
motorSpeed(4,32);
goToAbsolutePosition(530);

brake(4);
goToAbsolutePosition(805);

reverse(4);
motorSpeed(4,30);
goToAbsolutePosition(810);

brake(4);
goFor(5);

//Way Back
motorSpeed(4,45);
goToAbsolutePosition(565);

brake(4);
goToAbsolutePosition(443);

brake(4);
rotateServo(10);
goFor(7);

//Second Half-- Way Back
rotateServo(45);
motorSpeed(4,45);
goToAbsolutePosition(170);

brake(4);
goToAbsolutePosition(40);

reverse(4);
motorSpeed(4,30);

goFor(2.5);
brake(4);
rotateServo(10);
goFor(5);
rotateServo(45);
```

Appendix D

Table 7: Class Results for Final Runs



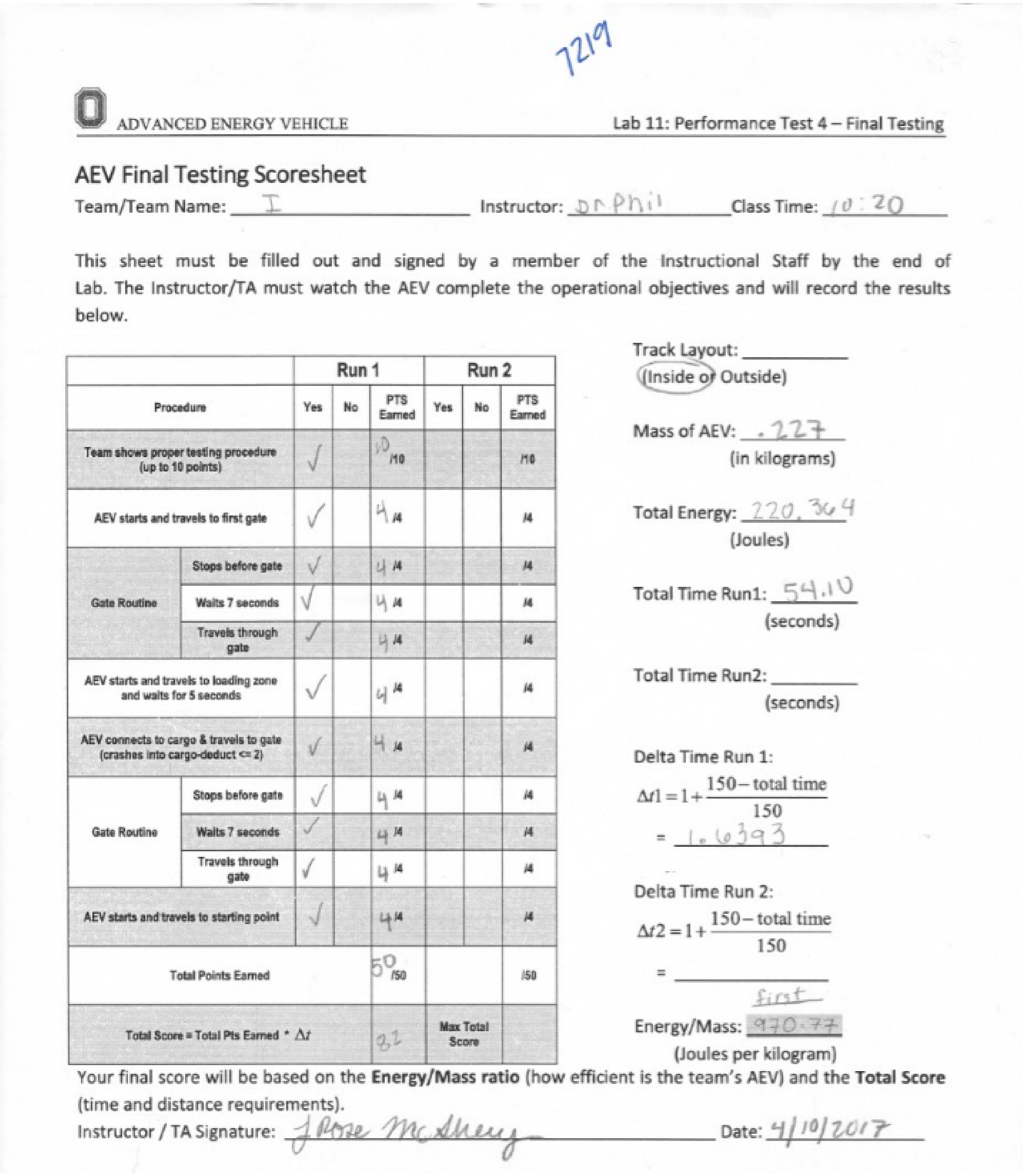
ENGR 1182 - AEV Final Test Results

Section 7219

Enter scores in blue fields

Team	Inside / Outside	AEV Mass (kg)	Total Energy (J)	Run Time (s)	Delta t	Energy / Mass (J/kg)	Points Earned (out of 50)	Total Score = Points Earned * Delta t	AEV Kit Turned In	Team
A	Outside	0.283	64.9	64.9	1.57	229	46	72.1		A
B	Outside	0.243	371.2	71.5	1.52	1528	50	76.2	Yes	B
C	Outside	0.263	172.5	68.9	1.54	656	50	77.0		C
D	Outside	0.271	294.6	60.0	1.60	1087	50	80.0	Yes	D
E	Inside	0.257	260.4	59.3	1.61	1013	50	80.3		E
F	Inside	0.229	275.7	55.6	1.63	1204	50	81.5	Yes	F
G	Inside	0.247	243.7	54.8	1.63	987	34	55.6	Yes	G
H	Inside	0.235	355.0	55.8	1.63	1511	50	81.4	Yes	H
I	Inside	0.227	220.4	54.1	1.64	971	50	82.0	Yes	I
J	Inside	0.228	391.8	61.6	1.59	1718	50	79.5	Yes	J
K	Inside	0.256	302.9	89.8	1.40	1183	50	70.1	Yes	K
L	Inside	0.227	195.8	54.0	1.64	863	50	82.0	Yes	L
M	Inside	0.294	268.0	52.0	1.65	912	50	82.7	Yes	M
N	Inside	0.264	190.0	56.8	1.62	720	50	81.1	Yes	N
O	Outside	0.276	306.5	73.0	1.51	1111	48	72.6		O
P	Outside	0.232	617.0	79.0	1.47	2659	50	73.7		P
Q	Outside	0.228	323.0	66.9	1.55	1417	50	77.7	Yes	Q
R	Outside	0.253	337.3	61.3	1.59	1333	42	66.9		R

Appendix E



7219

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

AEV Final Testing Scoresheet

Team/Team Name: I Instructor: Dr Phil Class Time: 10:20

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
AEV starts and travels to first gate		✓		4 /4			/4
Gate Routine	Stops before gate	✓		4 /4			/4
	Waits 7 seconds	✓		4 /4			/4
	Travels through gate	✓		4 /4			/4
AEV starts and travels to loading zone and waits for 5 seconds		✓		4 /4			/4
AEV connects to cargo & travels to gate (crashes into cargo-deduct <= 2)		✓		4 /4			/4
Gate Routine	Stops before gate	✓		4 /4			/4
	Waits 7 seconds	✓		4 /4			/4
	Travels through gate	✓		4 /4			/4
AEV starts and travels to starting point		✓		4 /4			/4
Total Points Earned				50 /50			/50
Total Score = Total Pts Earned * Δt				82	Max Total Score		

Track Layout: ____________
([✓ Inside] or Outside)

Mass of AEV: .227
(in kilograms)

Total Energy: 220.364
(Joules)

Total Time Run1: 54.10
(seconds)

Total Time Run2: ____________
(seconds)

Delta Time Run 1:

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

= 1.6393

Delta Time Run 2:

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

= ____________

first

Energy/Mass: 970.77
(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: J Rose McSherry Date: 4/10/2017