# Preliminary 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

27 March 2016

## Executive Summary

In Lab 8, teams of engineering students worked on perfecting the design of the AEV. The team brought in two designs and evaluated their performance to see which was the best to complete the mission outlined in the Mission Concept Review. The purpose of this assignment was to figure out which design was the best and to tweak any aspects of it that could improve its purpose. The objective of the AEV is to travel across the track with maximum efficiency in order to fit the Star Wars theme of creating a monorail system on a planet where power is a luxury.

The two designs that were being tested were the “Airplane” and “A-Wing 2.” Differences between these two are found in the wings. In the “A-Wing 2”, the wings are mounted with the 45 degree angle brackets while the wings for the “Airplane” are mounted with flat brackets. Because the wings in the “Airplane” design are mounted flat, the pieces do not require extra brackets to ensure stability, so weight is saved with this design, while maintaining structural integrity.

The results of performance test one showed the Airplane design outperformed the A-Wing 2 design in completing the task described in the Mission Concept Review. The results of the test showed greater efficiency, effectiveness, and repeatability in the Airplane design.

It is recommended that the group use the AIrplane design for future testing of the AEV. Since this design performed best compared to other designs under the same circumstances, the group can continue to test other variables such as the code while using the same AEV design. In this way, it will be simpler to test one variable at a time since the final design has been chosen.

## 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. The team 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. Since there are so 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. In Lab 8, the group worked on the first performance test and the results showed that the team has an AEV that works extremely well and has little to improve.

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.

The test performance in Lab 8 is being completed in order to finalize the AEV. Once the team has worked out the design, code, and energy efficiency the AEV will be complete. At this point, the team was deciding whether a design with slanted wings (A-wing) or flat wings (Airplane) is a better design. The team decided that the flat winged design would be kept due to the addition of additional brackets for extra stability.

## Experimental Methodology

In this lab, performance test one was completed. For performance test one, two designs were compared for their ability at completing the task. This was important to complete first because the code could then be modified to optimize the best design, thus getting the best possible result. For this performance test, the two designs being compared were not very different, but the differences in balance and consistency were enough to show that the second AEV design was superior, and would be the design to use in future performance tests.

The setup for performance test one used the AEV overhead track of room 224 in Hitchcock Hall. The AEV assembled used an Arduino control board and 3030 pusher/puller propellers. The two preliminary designs were tested on completion of the task described in the Mission Concept Review. The task includes the AEV starting from stop in the beginning of the track, and coming to a full stop at the gate. The AEV then waits ten seconds and leaves as the gate lowers. The AEV then goes to the R2-D2 unit, connects via a magnet on the front of the R2-D2 unit. After the R2-D2 unit is connected, the combined AEV - R2-D2 unit travels backwards toward the gate where it pauses for another ten seconds. Then the unit travels back to the starting position where it stops for the final time.

## Results

The team constructed two prototypes for the AEV and tested them to see which was more efficient in energy consumption and completing the mission. The first prototype tested was the A-Wing 2 design, which was discussed in lab Lab 01. It was a combination of some of the main concepts generated by the team. It was rated highest out of all the other designs in the concept screen and scoring matrices. The original sketch is shown in Figure 1.

The second prototype that was tested was the Airplane design. It was a simple design that had efficiency as a higher priority than flash. It has long wings, which maximized the balance around turns. It scored the second best on the concept screening and scoring matrices. The original concept design from Lab 01 is shown in Figure 2.

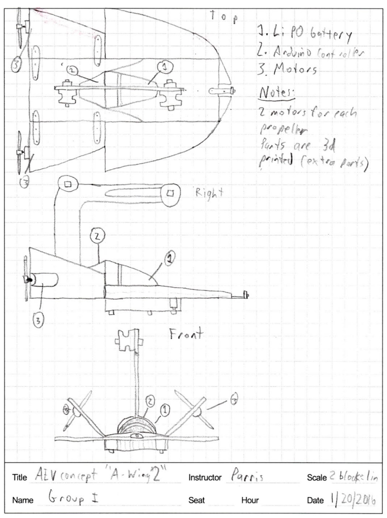



*Figure 1: Original sketch idea for A-Wing 2*

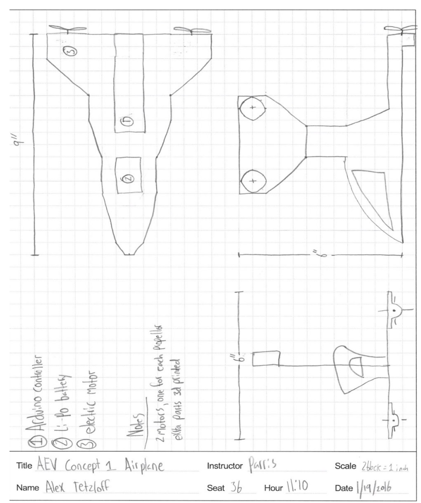



*Figure 2: Original Sketch idea for Airplane*

The original scoring and screening matrices were critical to the choosing of which design to continue to improve and build. The screening matrix from lab 03 is displayed in Table 1. The scoring matrix from lab 03 is shown in Table 2.

*Table 1: Concept Screening Matrix for original sketches*

| 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 for original sketches*

| | | 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 | |

It is clear to see why we chose to continue to develop the Airplane and A-wing 2 into production. It was originally thought that the A-Wing 2 would be slightly better than the Airplane, but that was disproved in testing, which will be discussed later.

After trials were performed and the arduino data were uploaded to the computer, the data from the two prototypes were analyzed to see which was more efficient. The time vs. power plot for the A-wing 2 prototype is shown in Figure 3. The time vs. power graph for the Airplane is shown in Figure 4.

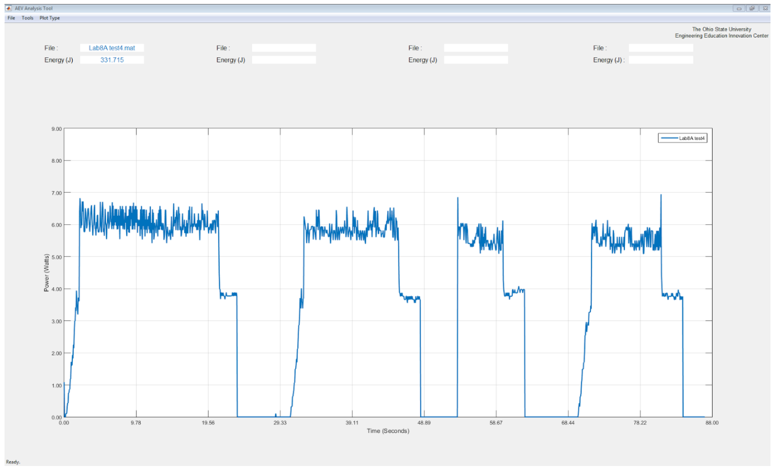



*Figure 3: A-Wing 2 time vs. power plot*

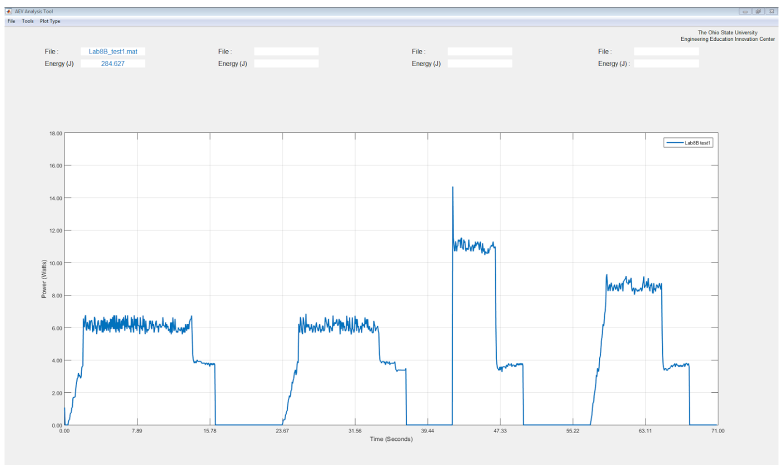



*Figure 4: Airplane time vs. power plot*

The team noticed that the Airplane prototype was much more efficient because it finished the objective in 30 less seconds compared to the A-Wing 2. Thus, the Airplane use far less power. There was a very significant contrast in total energy. The A-Wing 2 required about 332 J to complete the task, while the Airplane required about 285 J. We believe this occurred because the long wings of the airplane helped balance on turns. Another reason we believe this happened is because the Airplane is lighter than the A-Wing 2 since it has less brackets on the wings. This outcome was not expected because the A-Wing 2 was more compact. This actually hindered its performance even further because it would cause more twisting on the railings. This in return would cause the wheels to lock and/or lose contact with the track. This results in more power required to complete the mission.

The performance test affected the team's design process. What the group thought would be perfect design in the sketching process actually was not when testing. The group had to make slight adjustments to the location of components to maximize balance and energy efficiency. We would have never have known to make these adjustments without the trials. The System analysis labs helped the team obtain the ability to analyze the AEV's performance at a deeper level. We can use it to analyze incremental energies, which code performs better in for power efficiency, and distance vs. power. The distance vs. power plot helps us to see where the AEV is using energy in code when it is not moving. We can then use this information to eliminate unnecessary code. The incremental energies can be used to see how the AEV performs at specific points on the track. This was used as a whole to pick the Airplane as the team's AEV.

The breakdown of the code for The Airplane's run is shown below in Table 3. The difference was that the time was significantly less for the Airplane than the A-Wing 2, which made its total Energy significantly less.

*Table 3: Energy and Phase breakdown for Airplane run*

| 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 |

The 3030 propeller was chosen for both designs because of the data found in lab 05. The propulsion efficiency vs. advance ratio was higher for the 3030 propeller than the 2510. Thus, the team picked the 3030 because it would save energy. The 3030 plot is shown in Figure 5, and the the 2510 plot is found in Figure 6.

*Figure 5: 3030 wind tunnel propulsion efficiency vs advance ratio is shown below*

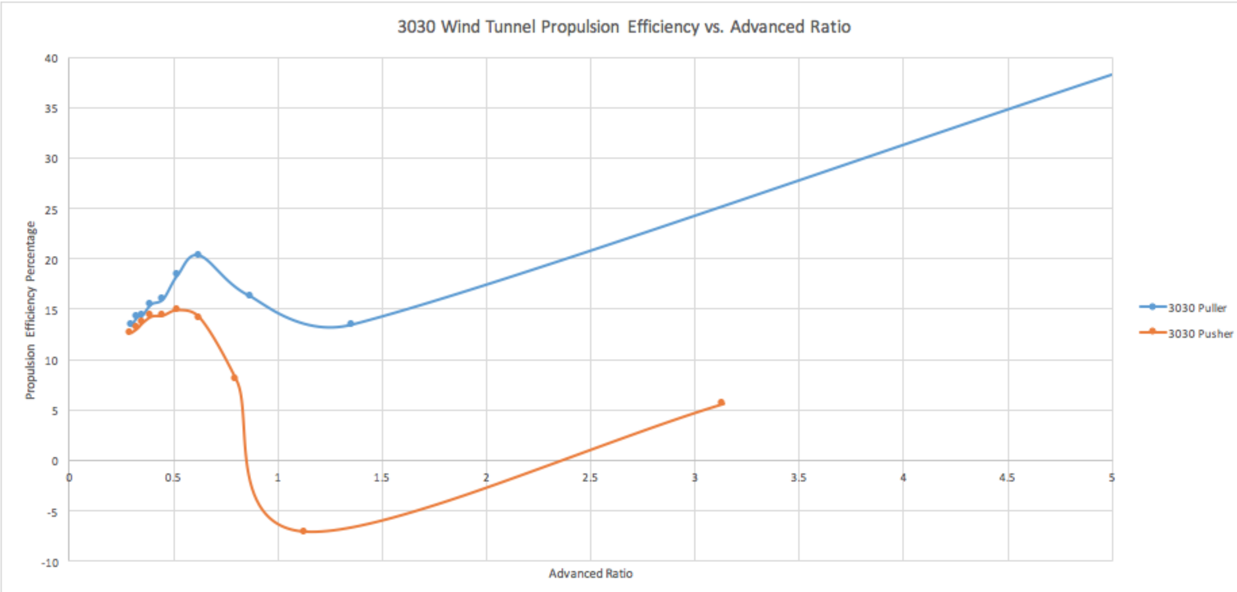
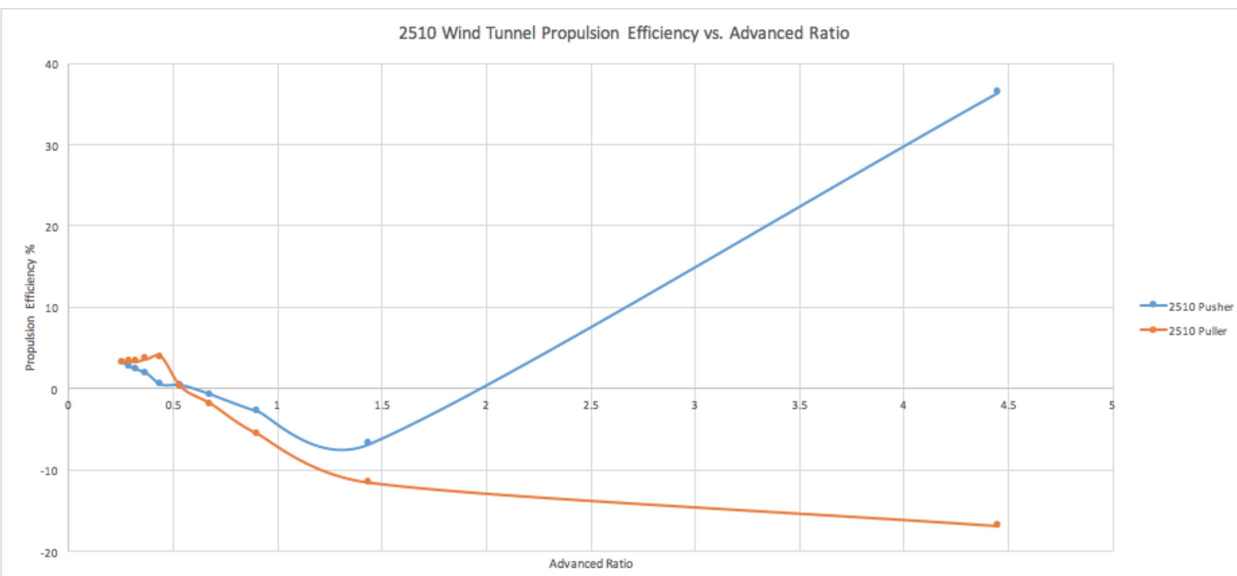



*Figure 6: 2510 wind tunnel propulsion efficiency vs advance ratio is shown below*




# Discussion

The results from the concept screening and scoring were conclusive in showing the two most effective designs, A-Wing 2 and Airplane. The designs were compared for multiple criteria to complete the screening, as seen in Table 1. The Airplane received pluses for balance, center-of-gravity, cost, and environmental, with a total of four pluses. The A-Wing 2 received pluses in balance, minimal blockage, center-of-gravity, and environmental, for a total of four pluses. The Airplane AEV also received a minus for minimal blockage and the A-Wing 2 received one for cost, resulting in a score of 3 for both designs.

The concept scoring matrix (Table 2) shows that the Airplane and A-Wing 2 received the highest scores, with a 3 and 3.05 respectively. These results are conclusive with the results of the screening matrix, and proves again that these are the two designs which should be used for the next performance tests.

The graphed results from the performance test shows the efficiency differential between the Airplane and A-Wing 2. The Power versus time graph of the A-Wing 2 design can be seen in Figure 3. This graph shows that the highest power levels necessary for the completion of the task in the MCR was approximately 6.5 Watts. This is much lower than the power required by the Airplane, with a top power usage of approximately 11.5 Watts. However, the Airplane took less time to complete the task, and thus the total energy usage was lower. For this reason, the Airplane was deemed more efficient.

The potential for error in concept screening and scoring is virtually non-existent, as the designs were reviewed for effectiveness based on objective criteria. Performance test one had a larger potential for error. The AEVs tested were not entirely consistent, and the variability of the track and the balance of the AEV meant that results varied from test to test. To limit the effect of variability, the single best run of each design was taken to be compared to each other.

The tested theory that A-Wing 2 would out-perform Airplane based on original testing was proven wrong. The efficiency of Airplane was superior to that of A-Wing 2 in performance test one, and therefore is the design which will be used for the following performance tests.

The two prototypes used were the Airplane and the A-Wing. The features of the Airplane which are believed to have made it more efficient are the straight wings, making it more balanced around corners than the A-Wing 2, a slightly lighter body to increase the efficiency and better the center of gravity.

During the test runs for performance test one, it was observed that the Airplane completed the task in a shorter amount of time, and with more balance than the A-Wing 2 design. This coincides with the scoring showed in Tables 1 and 2, and the performance graphs shown in Figures 3 and 4.

## Conclusion & Recommendations – Alex

The AEV Performance Test 1 showed very important trends in its data that let the team make decisions regarding the AEV's design. It was shown in the graphs that the Airplane AEV performed the test with better efficiency and also was shown to have better balance. The test consisted of the AEV running the track, stopping at the halfway point and then picking up the R2-D2 with a magnet. The AEV then reverses and does the exact same thing on the track again.

Using the data gained from Performance Test 1, The team has decided to make its final AEV based off of the Airplane model. This design was the most efficient and it includes flat, stable wings, as opposed to the angled wings of the A-Wing design. The 3030 propellor was chosen for this model because it was more energy efficient than the 2150 propellor. There was little to no error in the concept screening and the analysis of the propellor efficiency but there could have been error in other places. The error could have been from the test runs as the balance in each run of the AEV is easily changed due to the placement of the battery. The team was able to successfully run the AEV enough times to collect good data and perfect our code so there were no issues with lack of time. We were able to complete the lab and do not have anything left over to finish in lab 9.

It is recommended that the team works on perfecting their code for the AEV and also puts in more time tweaking the design. They could possibly move parts around to make the AEV have better balance or they could even take off any unnecessary supports. The AEV should also be carefully transported as it sometimes gets off balance due to rough transportation.

## Conclusion & Recommendations – J.P.

This lab was performed to perfect the design of the AEV to maximize efficiency and performance. This was done by using the system analysis tool to analyze which AEV prototype did better after their trial. The team used their combined knowledge of previous labs to get a deep understanding of what happened during the trial. The concept scoring and system analysis tools were especially helpful. After analyzing the data, it was found that the Airplane prototype was more efficient with time and energy when completing the mission objective. The mission object consisted of going to the gate, waiting for seven seconds, getting R2-D2, waiting 5 seconds, returning back to the gate, waiting 7 seconds, and then returning to the start. Also, we reused the information from lab 05 to keep the 3030 propeller because our data showed it was a better propeller for efficiency. We noticed that the Airplane performed better because it was lighter, had better balance around turns, and did not restrict the wires as much.

In the line of this new data, we chose to continue the Airplane design and drop the A-Wing 2. This is because the Airplane required about 80J  and 30 seconds less of energy than the A-wing 2We also learned some ultimate knowledge that we can use in the future. We learned how to better use the system analysis tool to compare similar AEV's. We learned how to manipulate the code to complete the task in a quicker and more energy efficient way. Lastly, we learned we became familiar with design analysis. We successfully eliminated a bad design through analysis. All of this knowledge is in correspondence to the lab objectives.

The team successfully addressed error can address it in the future by doing several things. First, the balance of the AEV must be the exact same every time so that the code does not need to be changed to account for the lack of balance. Our group had major problems with this topic in the beginning of the lab, but overcame adversity and fixed the problem. Also, there was inconsistency in the AEV's performance given the same code. The code was manipulated slightly to leave less up to chance and more up to facts. The AEV was started at the same point every time and the team incorporated more coasting so that the AEV has a wide distance to succeed, rather than a very minute distance.

I recommend that the AEV be ran in trial several times and averaged to get the most accurate result. Also, every trial should be recorded and not just the trials were the objective is achieved. Also, while the team all has specific jobs, each individual should get exposed to different aspects of the project to be more well-rounded for their career and the presentation. We completed the entire lab so there are no reasons for incompleteness

## Conclusion & Recommendations – Jeffrey

This lab was completed in order to determine which design would be most effective and efficient. Each design, “A-Wing” and “Airplane,” was run to pick up the R2-D2 model with a magnet. The vehicles had to stop at the halfway points each direction at a gate, then continue to pick up the R2-D2, or back to its start.

Using the data gathered from this lab, the team chose to go with the “Airplane” design. It has less parts, so it is cheaper, and because of it having less parts, it also weighs less. This design is also more balanced than the “A-Wing” design and has more stability among the parts such as the trapezoid pieces and the AEV motors. The 3030 propeller was chosen instead of the 2510 propeller based on data from the wind tunnel testing in the Propulsion Efficiency lab.

Sources of error were found mostly in the inconsistent performance of the AEV. The battery can always be mounted in a slightly different position each time the AEV is put together, which can alter the balance of the AEV and thus change the AEVs performance on the track. Though it easy to tell when the AEV is off balance to high degree, it is difficult to perfect the placement of the battery. When the balance is off to a high degree, the AEV struggles to move when placed on the track with the standard program running. However, when the balance is slightly off, the AEV may not stop at the correct position at the halfway points and to pick up the R2-D2 unit.

In order to iron out these inconsistencies, the balance and placement of the battery is often checked by team members. The battery mount is tightened when the team decides that the battery is in the proper place, so the battery will be unlikely to move when perfect balance is found. The AEV is always placed at the exact same point to start the program on the track. Also, much attention is given to perfecting the programming so the program being successful is not based on luck.

It is recommended that the team alter the battery mount to allow for the most possible balance on the AEV. The team also can look to modifying the “Airplane” design to cut even more weight, to make the AEV more efficient, though while still maintaining its structural integrity. Tweaks can always be made to the programming the perfect the positioning of the AEV.

## Conclusion & Recommendations – Dan

This lab was completed to gain insight into which design was to be used for future tests. This performance test compared two designs, the Airplane and A-Wing 2 designs, based on efficiency and effectiveness at completing the task laid out in the Mission Concept Review. The concept screening and scoring review provided a numerical representation of the positive and negative qualities of the two designs, giving clearer insight into the effectiveness of the two designs. The task that the AEVs were to complete was to move forward to the gate, wait ten seconds, and then move forward to the R2-D2 unit and come to a stop. The AEVs then moved backwards, with the R2-D2 unit attached, and returned to the beginning, once again stopping at the gate for ten seconds.

Upon completion of the performance test, it was concluded that the most effective design was the Airplane design. This design was chosen as it was lighter and therefore more efficient than the A-Wing 2 design. Additionally, the Airplane design was more evenly balanced than the A-Wing 2 design because its wings laid flat and distributed the weight more evenly. After collecting data on propeller efficiency in a previous lab, it was determined that 3030 propellers offered greater efficiency than that of 2150, and therefore were chosen for the AEV design.

In regard to resolving error, multiple obstacles were overcome throughout the completion of this lab. First, the trials conducted for performance test one involved a moderate level of inconsistency. Possible reasons for this inconsistency are thought to include balance differences from the positioning of the battery on the AEV, conditions of the track, and the charge of the battery. To overcome these inconsistencies, the group used the data collected from the most effective attempts from each design. By using the best attempt from each design the effectiveness of each design was compared as evenly as possible.

It is recommended that the group seek to further improve the efficiency and effectiveness of the Airplane design. Possible improvements include decreasing the total weight of the vehicle through the creation of replacement parts in SolidWorks as well as improving the balance by modifying the battery mount.

## 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 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | AEV 1 Construction | Jan 25 | Feb 9 | Feb 11 | | | | x | 100 |
| 2 | AEV 2 Construction | Feb 9 | March 20 | March 21 | x | | | x | 100 |
| 3 | AEV 1 Testing | March 21 | March 22 | March 25 | x | x | x | x | 100 |
| 4 | AEV 2 Testing | March 22 | March 25 | March 25 | x | x | x | x | 100 |
| 5 | Weekly Report | March 27 | March 27 | March 28 | x | x | x | | 100 |
| 6 | Solidworks Models | March 27 | March 27 | March 28 | | | | x | 100 |

*Figure 1: Airplane Orthographic Views*

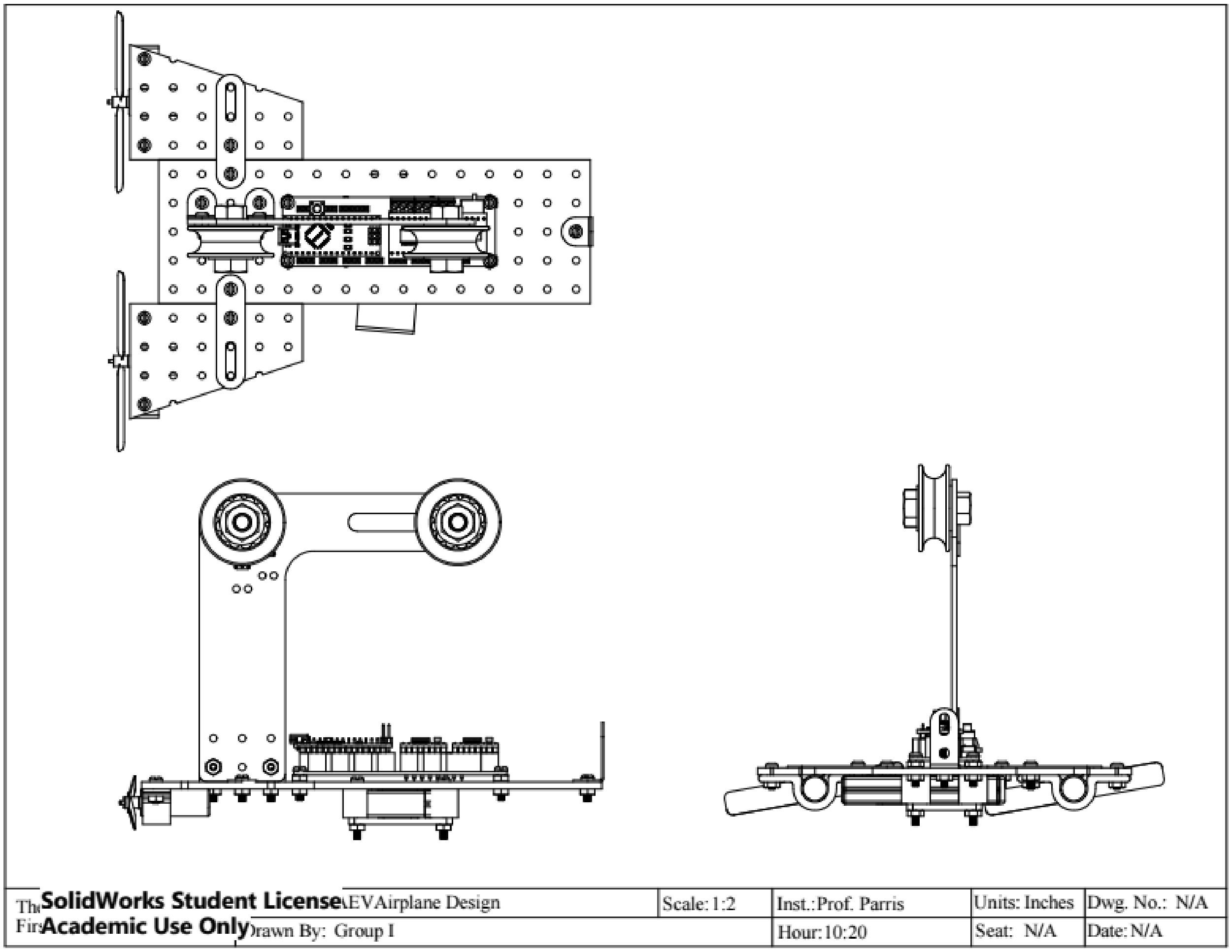
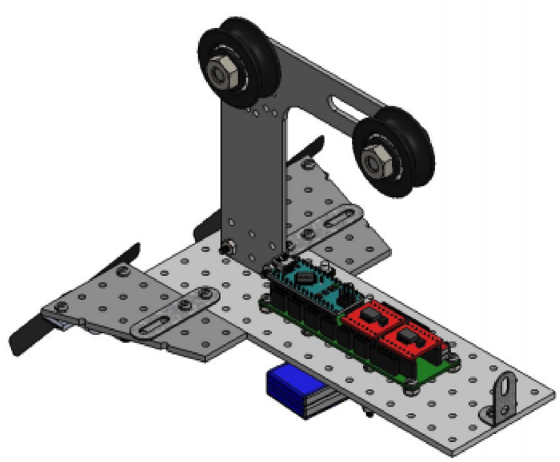



*Table 2: "Airplane Costs"*

| 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:** | 200 grams |

*Figure 2: Airplane 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 | 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 AEV Airplane Sheet 2 | Scale: 1:2 | Inst.:Prof. Parris | Units: Inches | Dwg. No.: N/A |
| Fir Drawn By: Group I | | Hour: 10:20 | Seat: N/A | Date: N/A |

*Figure 3: A-Wing Orthographic Views*

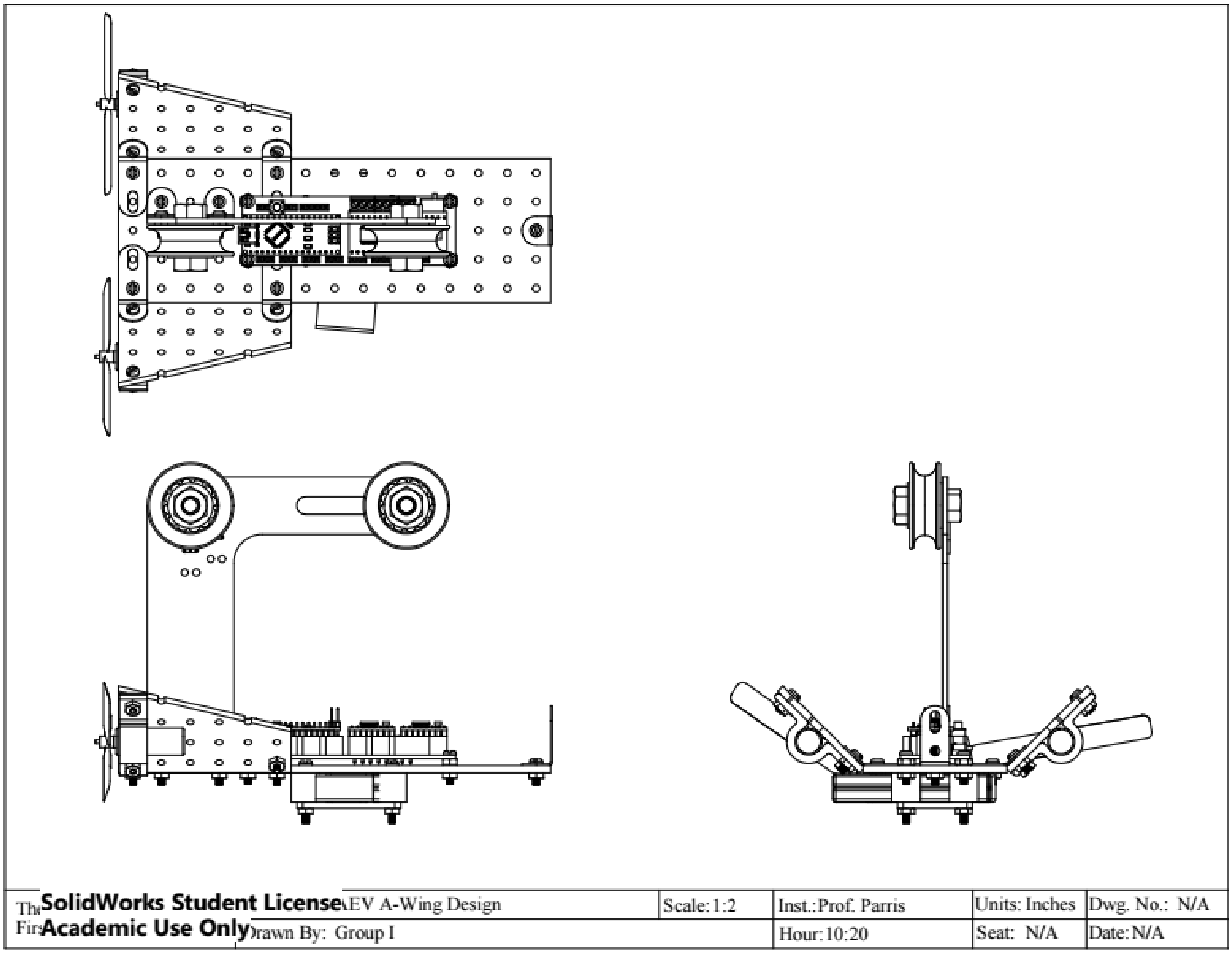
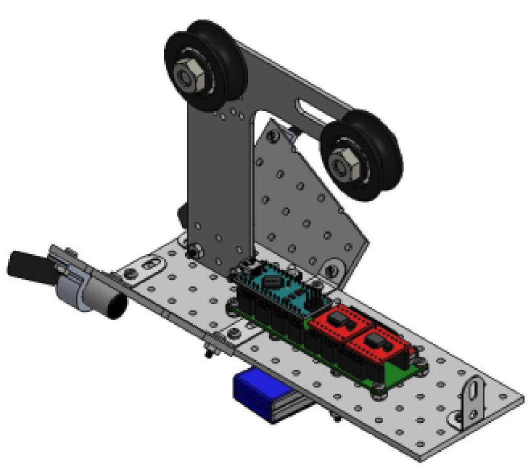



*Table 3: "A-Wing Costs "*

| 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:** | 230 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 |

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