# Preliminary Design Review

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March 27, 201

# Executive Summary

The purpose of Labs 8 and 9 were to develop two AEV designs, and two Arduino codes. This is important because it allows different concepts to be compared so that the vehicle designed is as efficient as possible. However, only one AEV design was tested due to 3-D printed parts being submitted late. The team plans to test additional designs in upcoming weeks once all necessary parts are acquired.

Development of multiple Arduino codes was delayed due to the team having trouble with our vehicle's wheel count sensors. We discovered that our issues were due to two factors; one being that the reflective tape on the wheel being damaged. It was also discovered that if the Arduino is not properly reset in between runs, the sensors do not work and power is not cut when it is supposed to be. Once this problem was solved, the team was able to develop multiple codes that successfully stopped our vehicle at the first gate. These codes were compared, and the most energy efficient ones will be further refined in upcoming labs.

The development of an Advanced Energy Vehicle is needed because the power needed to operate it is in limited supply. Due to this, the team is designing a vehicle that will use the least amount of energy possible. One major design concept is to construct a very low weight vehicle to cut down power usage, and minimize the energy/mass ratio. Our vehicle has also been designed so that one of the propellers can be used as a puller, independent of the direction that the vehicle is traveling. The propellers have also been dropped below the main body of the vehicle. This has been done to increase the torque that they apply on the vehicle. The software being written is designed so that the vehicle only runs the motors for a short amount of time, and letting the vehicle coast for most of the track. Experimentation has shown that this greatly cuts down the amount of energy used.

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## Introduction

The purpose of this lab series was to use knowledge gained from the previous eight labs. The team was to use this knowledge to build and design two different AEV designs to be tested and compared. The team was also to use several techniques to compare the AEV. The first lab had each team member design a concept for the  AEV. The first design was based on one of these first concepts. The group used the technique of concept screening and scoring to compare and quickly select the best design based on the team's criteria. This method to compare the AEV designs was given to the team in the Concept Screening and Scoring Lab.  The team created a code to test the AEV's. The team used the knowledge gained in the Arduino Programming Basics Lab. This lab gave the commands to control the motors and other aspects of the vehicle around the track. The External Sensors lab gave the team knowledge to control the distance that the AEV would travel around the track.  The System Analysis 1 lab gave the team insight on which size of propellor was more efficient. This lab also gave the team the knowledge about which propellor configuration was the most efficient. System Analysis 2 and System Analysis Tool, gave the team insight on how to find the power usage of the AEV when ran around the track. The System Analysis Tool created a graph of power versus time , and the tool would give the amount of energy used during the run. All of these previous labs  were to help the team to create and compare the two designs the team created for this lab series. Due to complication with malfunctioning parts , as will be explained further, the team was not able to compare two different designs, though the team was able to compare different codes for a single design.

The team was given the mission to transport R2D2 units by the rebel alliance. After the destruction of the the Death Star, the galactic empire is starting  to rebuild the empire's army. The rebel alliance has to build the alliance's army on remote planets to be sure that the galactic empire is not aware. The power is scarce on these remote planets. The system that the rebel alliance plans on using is a monorail system to transport the R2D2 units. The R2D2 units are built on one side of the planet, and the units have to be transported to the other side where the interceptor aircrafts are being built [1]. With limited power the Rebel alliance is in need of an energy efficient vehicle system to conserve all  power possible to transport the units.

## Experimental Methodology

In the lab series the team tested multiple codes to get to the gate. The design of the vehicle was also modified slightly as to allow for less obstruction of airflow. The code was modified slightly each run to give more efficient runs each time. After slight modification to certain sections of code, that section of code was kept the same for the rest of the lab series. This made for more replicable results for each run. The team used different equipment and computer programs to help create , compare, and replicate results found by the team.

The team used two different computer based programs to both program and compare the two separate designs. The first program was the arduino coding program. The team used this coding program to write codes that was used by the AEV. The programming language was similar to C or C++ syntax. The second computer based program was MatLab based. This program took the EEProm data from the arduino board, and calculated power usage and graphed incremental power versus time. This tool significantly sped up the comparison process of the each code created. This program also made experiments more replicable because this program reduced the human error in the calculation of the EEProm. Those were the two different computer programs used to code and compare the two designs.

The team also used several pieces of physical equipment throughout this lab. The team used the inside test track, arduino board, battery, motors, and 3030 propellers, as well as multiple other components to construct the vehicle. The team also used external sensors and the wheel with reflective tape to track position.

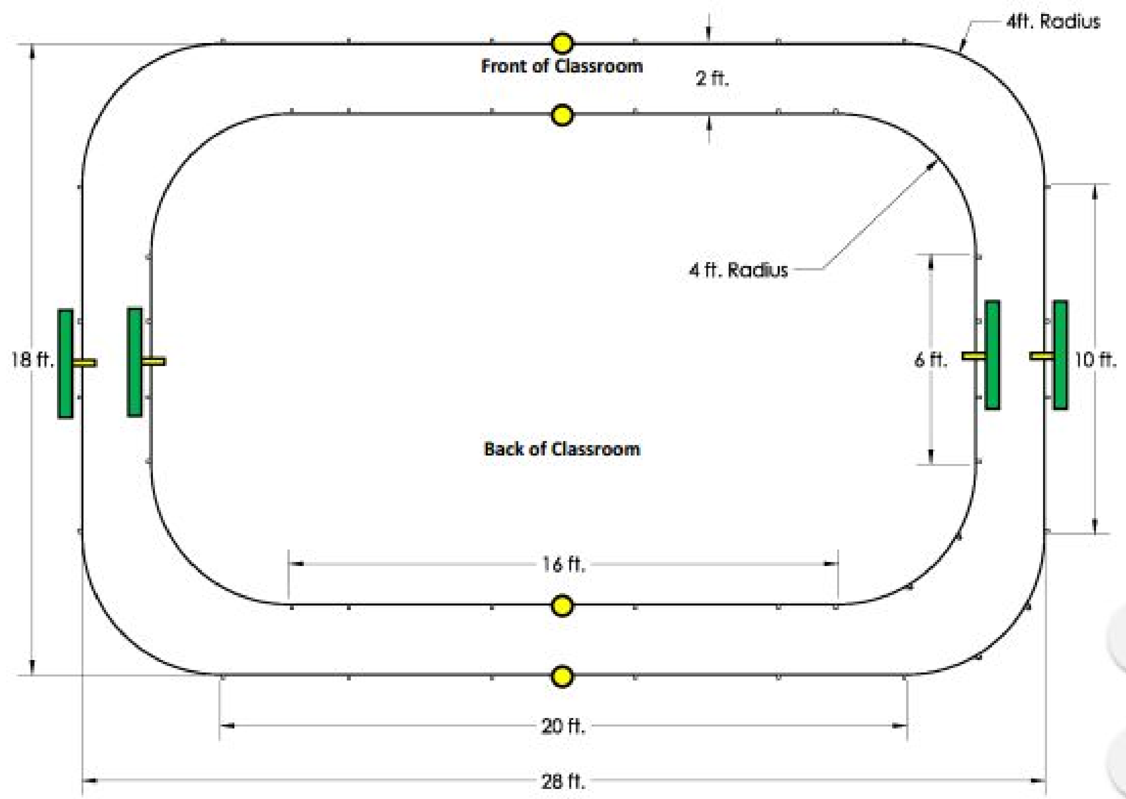



Figure 1: AEV Test Track Layout [1]

The right half of the inside track is where the team tested the AEV throughout this lab series. The track is around 34 feet long. The team had the AEV go from the start( one bottom yellow dot) to the gate (the green bar).

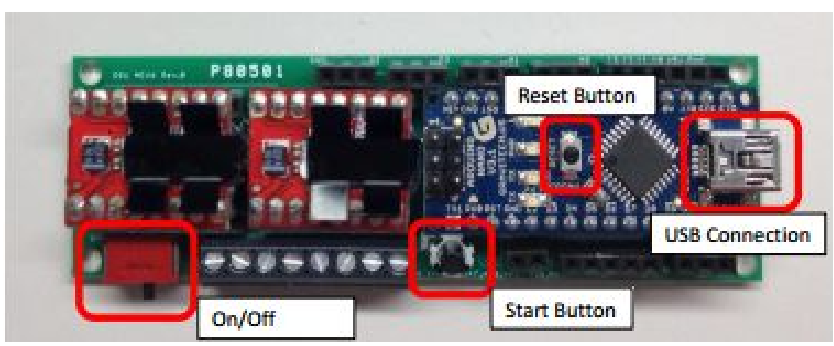



Figure 2: Arduino Board[1]

This is the AEV controller with an arduino nano, which is also called the Arduino Board. This device held and executed the code wrote by the team. The arduino board also holds and records data from the previous executed run. This is considered the heart of the AEV. This controller has ports that lead to the external sensors  and motors.

Figure 3: Reflectance Sensor (Left) and reflected taped wheel(Right)[1]

This figure shows one of the two Reflectance Sensors that is utilized by the team to track the position of the AEV as well as the wheel with reflectance tape as to allow the sensor to detect the rotation of the wheel . The Arduino board counts the non-reflectance surfaces as the wheel turns. These units are called marks. There is .4875 inches per mark. The team utilized this proportion to convert the distance the team needed the AEV to go into marks. The team then programmed the AEV based on marks.

Results

When going through the screening and scoring of the group designs it came down to two final builds that would be used and modified for the final tests a combination of two of the developed AEVs or the original AEV the team was given. After scoring between the two designs(table 2) the team decided to continue tests and modifications with our own personal design.

| | With Modded Arm | Without Modded Arm |
|---|---|---|
| Weight | 5/5 | 3/5 |
| Balance | 5/5 | 2/5 |
| Coast Distance | 5/5 | 4/5 |
| Simplicity | 4/5 | 4/5 |
| Propeler Placement | 5/5 | 5/5 |
| Total Score | 23/25 | 18/25 |

Table 1: Scoring Matrix

Due to the vast amount of time consumed by solving the situation with the group's sensors the testing window for this lab was very small. The tests that were done focused on approaching the gate with minimal energy consumption and no reversal of the motors, this resulted in the AEV using a strong initial output and cutting all engines at just under the halfway mark to glide to a stop at the gate. Though the AEV will stop in the correct spot the majority of the time the group will need a few further tests to fine tune the code to work every time. Another outcome of these tests has led the group to use relative positioning rather than the constant use of absolute position within the code. This change in mentality is due to the group's reliance on coasting instead of throttling the motors in the opposite direction to stop movement. Figure 4 shows the most efficient run the team had while testing. Though this was the most efficient the differences in the majority of our tests was only about 3-5 joules.

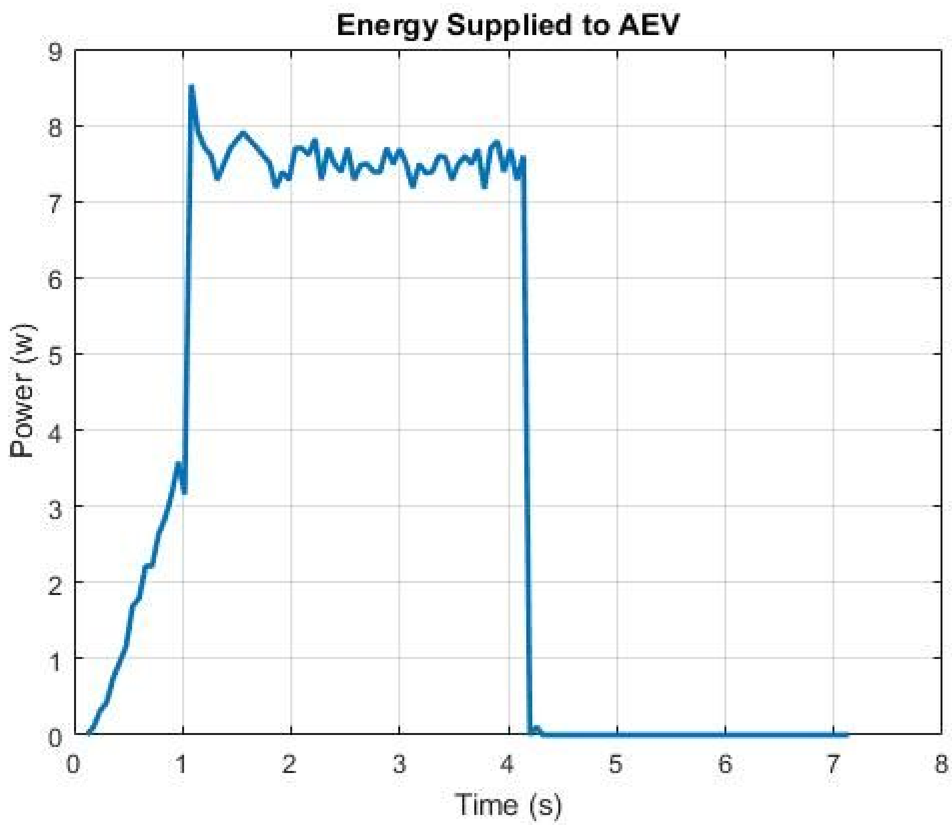



Figure 4: 25.21 Joules of energy was used in the energy curve above.

## Discussion

Two different AEV designs were to be tested using the same code during the first performance test. The team's first design consisted of an upside-down T-shaped piece, which hangs vertically from the wheels. The arduino board and battery were attached to the body of the T-shaped piece with the two propellers facing opposite directions, one on each arm of the bottom of the T-shaped piece. The idea behind the opposite facing propellers was that the vehicle will be equally efficient traveling in either direction on the track, with one propeller pushing while the other is pulling. This design is shown in the appendix. The second vehicle design was a similar concept, but with the arduino board, battery, and motors all connected by the same piece. This design is shown in the appendix.

Because of difficulties the group had with the wheel count sensors, time only allowed for the first design to be tested. The results of the testing are shown above. The lightweight design and free air flow between the propellers contributed to the efficiency of the vehicle during the test runs. Another contributor to the efficiency of this design was the propeller placement; the propellers being placed at the bottom of the T-shape allowed for the most possible torque. The increased torque decreases the power necessary to move the vehicle. It is predicted the second design, once tested, will be slightly less efficient than the first, due to the arduino and battery potentially obstructing the airflow between the propellers. To finish the first performance test and to be able to compare the two vehicle designs, testing of the second design will be done in the upcoming week.

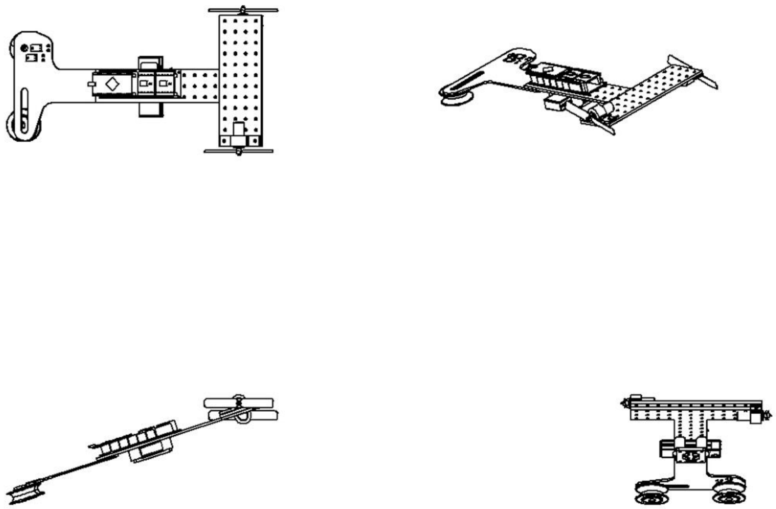
One potential source of error could stem from the problems the group had with the wheel count sensors during testing. During testing, the sensors were inconsistent, and sometimes did not allow for the code to run properly. Because of this, there were many failed test runs, and time was lost which could have been used to test the second design and repeat the testing for better results. The sensor issues seemed to be resolved by the end of testing however. This potential source of error will be resolved in the upcoming week after the team is able to properly complete the testing.

## Conclusions & Recommendations

The main purpose for Performance Test 1 was to have the team design and create two AEV prototypes. This lab series then had the team test which vehicle was more efficient down the track using a control code. The team used knowledged accrued from previous labs to design vehicles that would be the most efficient in the team's eyes. The concept screening and scoring lab aided in being able to compare the two vehicles. System Analysis 1 showed the team that the most efficient propellor was the 3030 in the puller configuration. System Analysis 2 taught the team how to calculate power usage, as well as show how to use the system analysis tool to create graphs in order to compare the power usage in each vehicle.

The team was only able to complete testing on one of the two vehicle designs during the first performance test. This was due to errors in the sensors that continued to occur, which kept the team from being able to test as often as planned. Throughout the previous labs up to and including the first performance test, the wheel count sensors for the group would often not read the wheel counts. This continued to be an issue for the team even after replacing the sensors and referring to the instructors and TAs for help multiple times. Toward the end of lab 8, the group was able to resolve the issue. In order to make up for lost time and complete the first performance test, the team plans to use lab 9a to complete testing on the second vehicle design. Because of the incompleteness of the performance test, however, the team cannot yet make a decision on the vehicle design to move forward with. For future labs, the team will factor potential malfunctions of this sort into planning the schedule, in order to have additional time set aside in case more issues arise.

Appendix

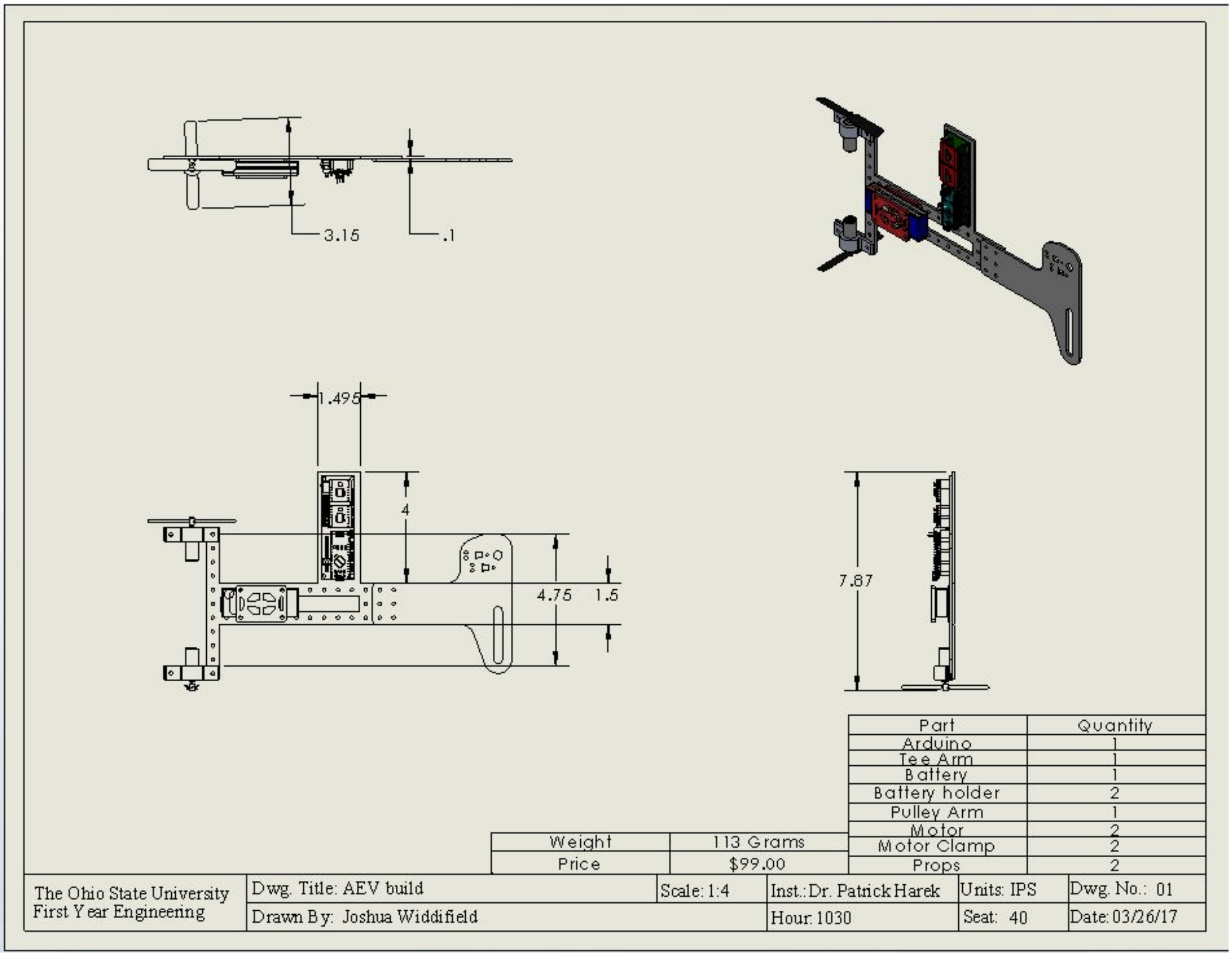


| | | | | | |
|---|---|---|---|---|---|
| The Ohio State University<br>First Year Engineering | Dwg. Title: AEV Design Concept 1 | Scale: 1:4 | Inst.: Dr. P | Units: US | Dwg. No.:01 |
| | Drawn By: Team J | | Hour: 10:20 | Seat: J | Date: 3/27/17 |

| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | AEV Motor | | 2 |
| 2 | Arduino | | 1 |
| 3 | Battery Pack | | 1 |
| 4 | Pulley Assembly | | 1 |
| 5 | Pulley Assembly w-reflective tape | | 1 |
| 6 | Rotation Sensor Board | | 2 |
| 7 | Support Arm 1 2 Sensor Holes V2 | | 1 |
| 8 | Tee | | 1 |
| 9 | Motor Mount Clip Aluminum | | 2 |
| 10 | Medium Rectangle | | 1 |
| 11 | Prop 3inch | | 2 |
| 12 | Battery Spacer | | 4 |
| 13 | Battery Pack Clamp Plate Narrow | | 1 |

| Estimated Weight | Estimated Price |
|---|---|
| 113 Grams | |

| | | | | | |
|---|---|---|---|---|---|
| The Ohio State University<br>First Year Engineering | Dwg. Title: AEV Concept 01 Bill of Materials | Scale: n/a | Inst.: Dr. P | Units: US | Dwg. No.:02 |
| | Drawn By: Team J | | Hour: 10:20 | Seat: J | Date: 3/27/17 |




| Part | Quantity |
|---|---|
| Arduino | 1 |
| Tee Arm | 1 |
| Battery | 1 |
| Battery holder | 2 |
| Pulley Arm | 1 |
| Motor | 2 |
| Motor Clamp | 2 |
| Props | 2 |

| | |
|---|---|
| Weight | 113 Grams |
| Price | $99.00 |

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|---|---|---|---|---|---|
| The Ohio State University<br>First Year Engineering | Dwg. Title: AEV build | Scale: 1:4 | Inst.: Dr. Patrick Harek | Units: IPS | Dwg. No.: 01 |
| | Drawn By: Joshua Widdifield | | Hour: 1030 | Seat: 40 | Date: 03/26/17 |

References

1. Whitfield, C., West, D., & Allenstein, J. (2015, August 07). THE OHIO STATE UNIVERSITY ADVANCE ENERGY VEHICLE DESIGN PROJECT LAB MANUAL. Retrieved February 2, 2016, 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