Preliminary Design Report

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Executive Summary

The AEV design project is intended to provide a team-base environment such as in the real world while developing and designing an Advance Energy Vehicle (AEV). The project will help teach good teamworking skills and introduce students to the design process. During the course of the project, a different lab is performed each week. Each lab serves as a purpose to teach the group how to improve upon what they have already. While learning about the design process, different experiments are conducted that show the group what aspects would help improve the AEV's performance if changed. The AEV and having to have it make a successful run picking up the cargo is used as a source for the group's attention. While completing the task at hand, the group will unknowingly be improving upon their teamworking skills, responsibility, and brainstorming skills.

In this day of age of technology with resources depleting, it is important that we must sustain all energy and use as least amount of energy as possible. By finding the best AEV design that uses, the least amount of energy, it will help us sustain that energy. Throughout the course of the project, different aspects will be learned on how the design of the AEV can be managed to make it the most energy efficient.

During the lab, many tasks were performed to find such ways to use less energy. Lab 2 helped test different propellor configurations and which would be best for using the least amount of energy. Along with propellor configuration, different aspects such as balance, minimal blockage, low weight, and center of gravity all affect the AEV's performance and power consumption. A clear trend is that the lower the AEV's weight is, the less power it uses. For the most affected propellor, a propellor in the pull configuration with a large diameter is the best when considering propulsion efficiency. For the AEV to complete a successful run by picking up the cargo and returning back to the starting point, many aspects can be tweaked to improve upon the design.

The project has shown potential error. For example, while testing our code, it was noticed that the reflectance sensors installed to the AEV were not reading 8 marks per wheel count. This resulted in inaccurate readings of the AEV's absolute position. In order to solve this problem, a different sceanario code was developed that instead of using absolute position from the sensors as a reference point, use time instead.

By testing various aspects of how the AEV design could be altered to make it as energy efficient as possible, some key contributions to this would be propellor configuration, weight, and minimal blockage. With the pull propellor configuration, the AEV's propulsion efficiency is more effective than of the push. With low weight and minimal blockage, lower weight means less energy used, and minimal blockage makes the design more aerodynamic. Taking all these ideas into consideration, the results of these experiments are shown below, and explained how they are used within our preliminary design.

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Introduction

The purpose the AEV design project was to introduce students to teamworking skills, design processes, and working within a working environment which includes teamwork, responsibility, lab documentation, etc. The project itself consisted of brainstorming an AEV design, while using data gathering in lab to continuingly improve upon AEV design and energy efficiency. The goal of the AEV is to complete a full run of the track which includes having to pick up cargo and returning to the starting point. Along the way, obstacles such as corners to turn and gates to stop at are added into perspective.

This reports serves as the purpose to inform the reader of how the experiments were performed, and what data was gathered throughout the labs. Based on the data, the report will provide details of how they were interpreted, how they were used to make further developments to the AEV, and if the AEV is on track to complete the full track.

Experimental Methodology

Lab 01 of the AEV project consisted of an introduction into the AEV controller, Arduino, and basic command functions involved. The students were introduced different commands such as celerate(), were. Before any programming could be done, the basic structure of the AEV had to be built. To do this, two propellers were mounted and connected to the two motors and battery. Once constructed, all components were then hooked up to the central AEV controller chip. The propellers could then be programed through Arduino using the function commands celerate, motorSpeed, goFor, brake, and reverse which were introduced. A scenario code was developed by the students to test as shown in the appendix (A1).

Lab 02 of the AEV project was broken up into two parts. Part one consisted of installing the external sensors onto the AEV. The purpose of the sensors are so that the AEV can keep track of where it is on the track, and the direction it is going. Using a small #2 bolt, nut, and zip tie, the two sensors are attached on the side of the vertical support opposite the wheel. To test the sensors, a reflectance sensor test must be run by typing in “reflectanceSensorTest();” into the code, and connecting the AEV to the computer via USB. On the computer, within the Arduino window, the serial monitor is open and set to 115200 baud. Finally, by clicking the start button on the Arduino board a series of “1” should appear in the serial monitor and by moving the wheels, the window will inform the user of the AEV’s absolute position as well as the direction.

Figure 1: Reflectance Sensor On Vertical Support

The second part of lab consisted of one of the team members observing the wind tunnel, recording data of the thrust scale reading, current, RPM, and arduino power setting in an excel spreadsheet.

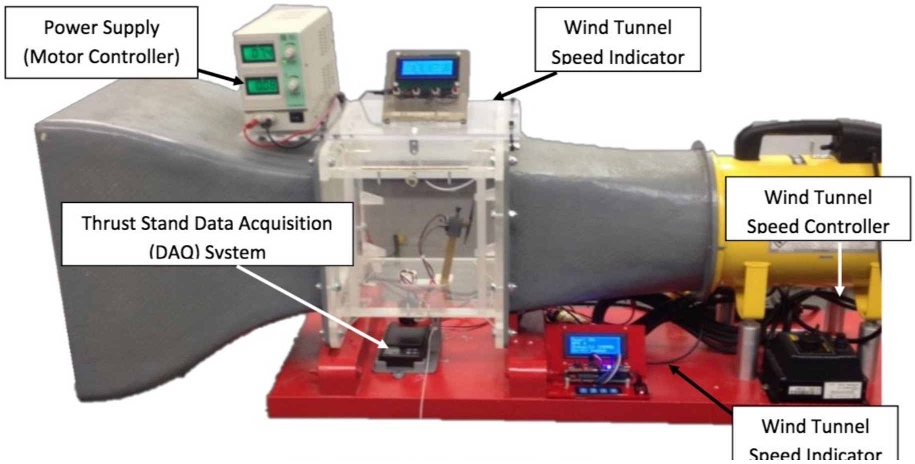


Figure 2: Wind Tunnel

Lab 03 consisted of creative design thinking. During this lab, the group was tasked with brainstorming potential ideas for the AEV. Using creative design thinking techniques each member independently created a AEV design. The AEV concepts were then sketched on orthographic drawing paper. After the individual sketches were done the group then brainstormed together combining ideas to sketch a group AEV design on orthographic paper that fit the design considerations.

Lab 04 consisted of a system analysis test. First the group designed a program to run the basic AEV found in figure 3 to record data from. Once the program was created the group ran the AEV on the track to record data from the trial. The data collected was time in milliseconds current in ADC counts, voltage in ADC counts, marks, and position on the track. The data collected was then uploaded to an excel sheet. Using the initial data found, the group solved for power, incremental energy, and total energy. The group then graphed a power vs time graph. Looking at the data, the specific sections of the graph were then divided up into different phases. These phases represented different commands in the test code. The group then labeled each phase with the corresponding Arduino code.

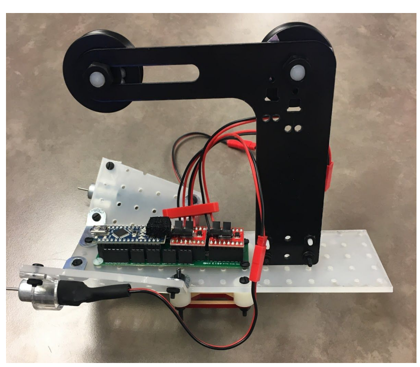


Figure: 3 Constructed AEV

Lab 05 consisted of screening and scoring of different design concepts. FIrst, group came up with different metrics to judge the drafted AEV designs. The traits the grouped focused on were: ballance, minimal blockage, center of mass location, maintenance, durability, cost and environmental impact. With these things in mind the group judged the designs using a concept screening chart. This consisted of rough rating of each of the traits using + and - marks. In a screening chart each of the traits are weighted equal. The team then determined which metric was more important and judged the different AEV designs through a concept screening chart which gave a much more accurate rating of each of the designs.

Lab 06 consisted of a quiz that measured each of the group members knowledge of all the AEV project. This consisted of engineering calculations, reading graphs, and identifying different hardware parts.

Lab 07 consisted of a group presentation that included a brief summary of the first 6 labs. This summary includes the major take aways, data, ideas, and designs that played a role in the making of the group's current AEV status.

Lab 08 consisted of the first performance test. In this lab the group compared the top 2 designs . The group ran a sample code in both AEVs and recorded the data. Using the found data the group graphed a power vs. time graph to determine which design used less power. During the days of lab 08 the group changed and tweaked the designs to improve on the AEV.

Results

For the first lab, there were no results gathered, instead, the group was tasked of writing our own code off a set of conditions. This purpose of this exercise was to help familiar the group with basic arduino codes that would be used for the AEV. The code made in the lab can be found in the appendix (A1).

For the second lab, the goal was to see which propellor would work best. Four different propellers, (Push/Pull 3in diameter), and (Push/Pull 2.5in diameter) were tested. The data gathered for each propellor were thrust scale reading, current, RPM, and arduino power setting. The results for the first propeller are shown in table 1 below.

Table 1: Wind Tunnel Results (Push, D:3in)

Current (amps)	Thrust Scale Reading (g)	RPM	Arduino Power Setting (%)
0	162.1	0	0
.12	160	1616	10
.21	156.6	2694	15
.3	152.3	3832	20
.38	150.1	5029	25
.47	147.9	6227	30
.55	146.2	7604	35
.62	144.4	8982	40
.68	142.5	10159	45
.72	141.6	11377	50
.74	138.6	12514	55
.76	137	13532	60

A graph of the trust scale reading vs power setting was made. As shown below, it can be seen that as the Arduino Power setting is increased, the thrust scale reading decreases.

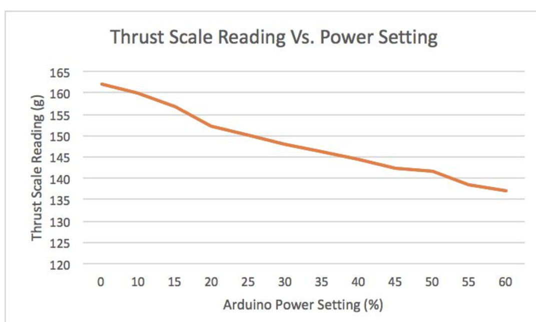


Figure 3: Thrust Scale Reading Vs. Power Setting (Push, D:3in)

The data from table 1 was then used to calculate then used to calculate the propellor advanced ratio and propulsion efficiency. Figure 4 below shows the advanced ratio vs propulsion efficiency of the 3in diameter push propellor.

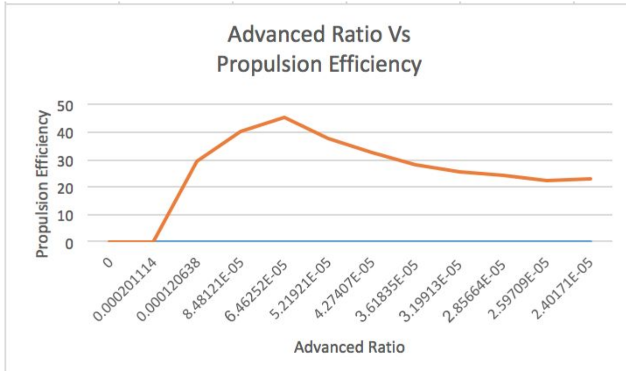


Figure 4: Advanced Ratio Vs Propulsion Efficiency (Push, D:3in)

Table 2 below shows the data gathered from the second wind tunnel which had a 3in diameter propeller in the pull orientation.

Table 2: Wind Tunnel Results (Pull, D:3in)

Configuration =	Pull	D=3.0in	30deg
Current (amps)	**Thrust Scale Reading (g)**	**RPM**	**Arduino Power Setting (%)**
0	154.8	0	0
0.19	159	2035	10
0.28	160.6	3053	15
0.38	163.8	3952	20
0.47	167.2	4730	25
0.57	171.8	5508	30
0.67	177.8	6287	35
0.77	184.4	7005	40
0.85	190.2	7604	45
0.94	197	8203	50
1.04	203.2	8862	55
1.13	211.5	9520	60

The graph below shows the thrust vs Arduino power setting of a 3in diameter propeller in the pull configuration.

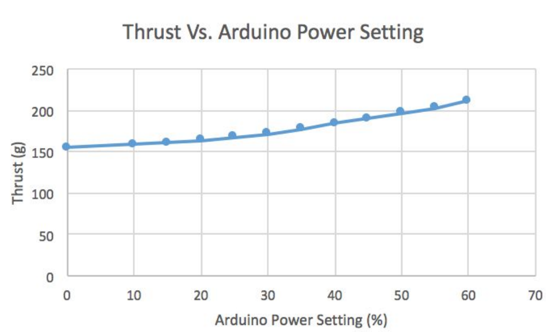


Figure 5: Thrust Scale Reading Vs. Power Setting (Pull, D:3in)

Figure 6 below shows the advanced ratio vs propulsion efficiency of a 3in diameter propellor in the pull configuration.

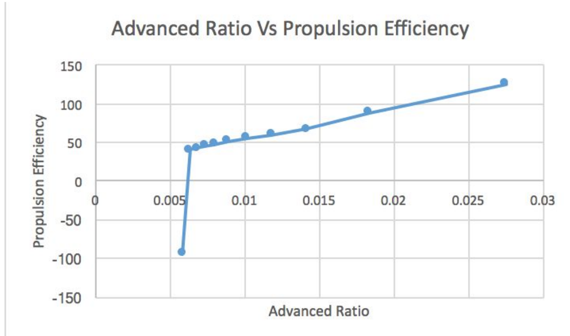


Figure 6: Advanced Ratio Vs Propulsion Efficiency (Pull, D:3in)

Table 3 below shows the data gathered from the third wind tunnel which had a 2.5in diameter propeller in the pull orientation.

Table 3: Wind Tunnel Results (Pull, D:2.5in)

Configuration =	Pull	D=2.5in	10deg
Current (amps)	**Thrust Scale Reading (g)**	**RPM**	**Arduino Power Setting (%)**
0.16	143.8	0	0
0.26	143.8	2275	10
0.35	144	3233	15
0.44	146.4	4071	20
0.53	149.6	4850	25
0.63	153.4	5628	30
0.73	158.6	6407	35
0.82	163.4	7065	40
0.9	167.9	7544	45
0.99	173.5	8203	50
1.07	178.9	8802	55
1.15	185.4	9401	60

Figure 7 below shows the thrust vs Arduino power setting of a 2.5in diameter propeller in the pull configuration.

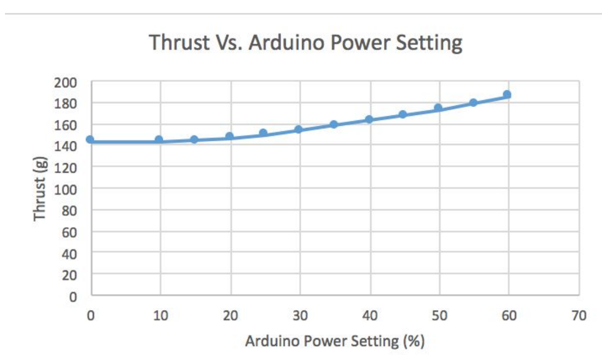


Figure 7: Thrust Scale Reading Vs. Power Setting (Pull, D:2.5in)

Figure 6 below shows the advanced ratio vs propulsion efficiency of a 3in diameter propellor in the pull configuration.

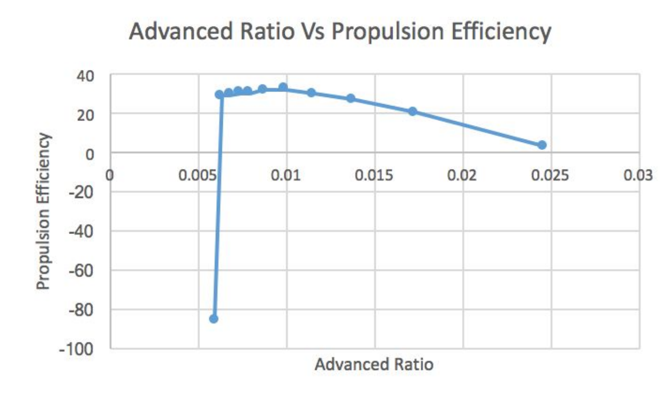


Figure 8: Advanced Ratio Vs Propulsion Efficiency (Pull, D:2.5in)

Table 4 below shows the data gathered from the third wind tunnel which had a 2.5in diameter propeller in the pull orientation.

Table 4: Wind Tunnel Results (Push, D:2.5in)

Configuration =	Push	D=2.5in	10deg
Current (amps)	**Thrust Scale Reading (g)**	**RPM**	**Arduino Power Setting (%)**
-0.11	143.6	0	0
0	139.1	1616	10
0.08	135.4	2514	15
0.18	131.8	3413	20
0.28	127.8	4191	25
0.38	123.6	5029	30
0.48	118.8	5868	35
0.57	114.4	6706	40
0.66	109	7485	45
0.74	104.5	8263	50
0.84	98.5	9000	55
0.95	90	9760	60

Figure 9 below shows the thrust vs Arduino power setting of a 2.5in diameter propeller in the push configuration.

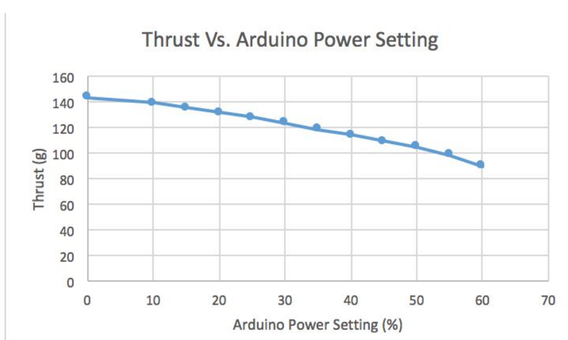


Figure 9: Thrust Scale Reading Vs. Power Setting (Push, D:2.5in)

Figure 10 below shows the advanced ratio vs propulsion efficiency of a 3in diameter propellor in the push configuration.

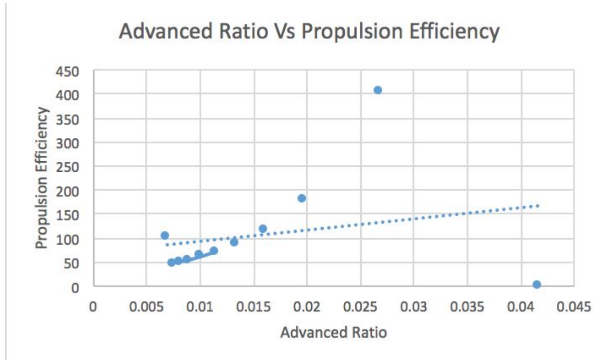


Figure 10: Advanced Ratio Vs Propulsion Efficiency (Push, D:2.5in)

For the third lab, each group member brainstormed about how the AEV could be redesigned. Each of us was tasked of creating our own prototypes. Figures 11- Figure 14 are the designs each team member developed.

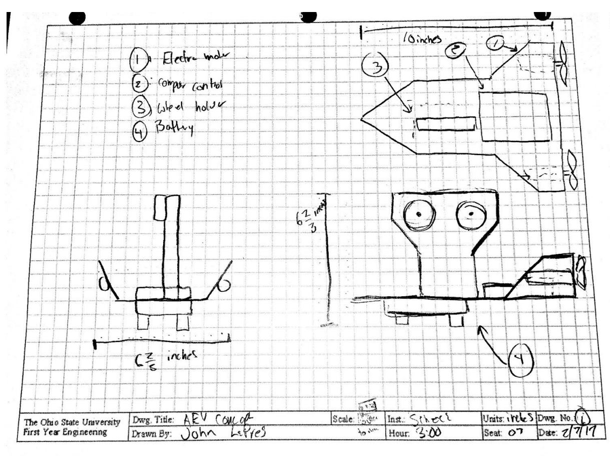


Figure 11: John's Design

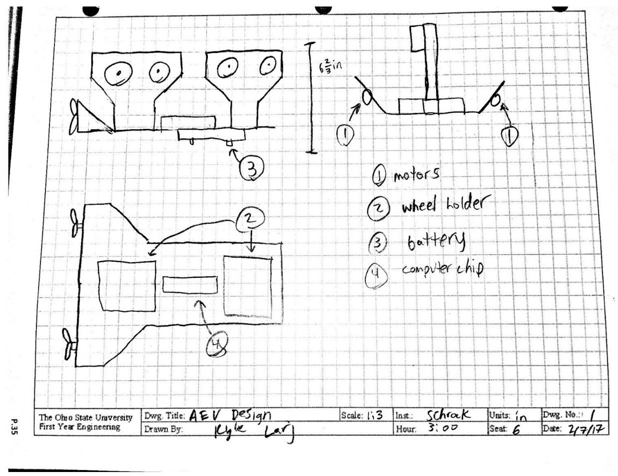


Figure 12: Kyle’s Design

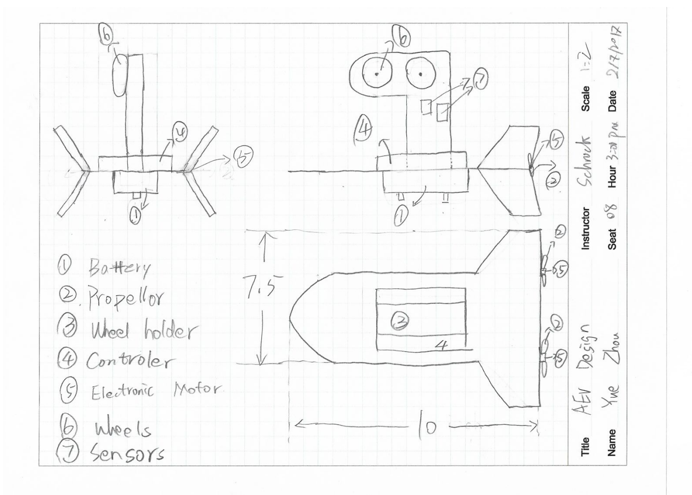


Figure 13: Yue’s Design

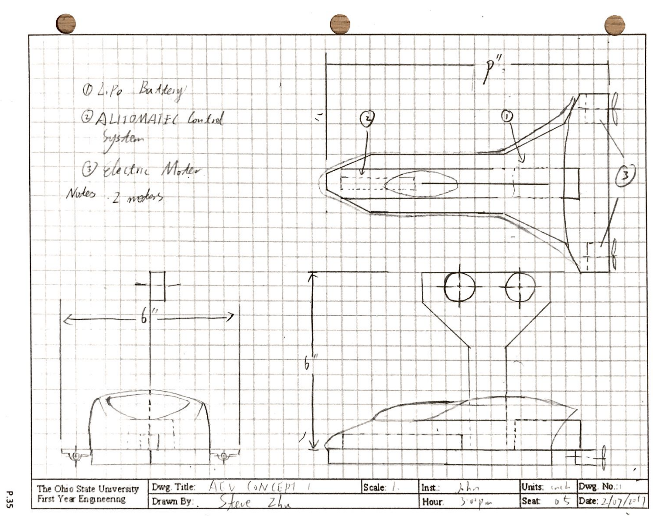


Figure 14: Steve’s Design

For the fourth lab, the group gathered data from EEPROM (Electrically Erasable Programmable Read-Only Memory) on the Arduino Nano. The data collected from the experiment contains EEPROM time(time in milliseconds), current (I_E), voltage (V_E), and wheel counts from the reflectance sensors. Using this information, time (sec.), current (amps), voltage (volts), distance (m), position (m), supplied power, and incremental energy can be calculated using the formulas shown below. Sample calculations provided in the appendix.

Time: $t = \frac{t_E}{1000}$ ....(A1)

Position/Distance: *s = 0.0124*pos* ....(A2)

Current: $I = \left(\frac{I_E}{1024}\right) * V_R * \left(\frac{1\,\text{Amp}}{0.185\,\text{Volts}}\right)$ ....(A3)

Voltage: $V = \frac{15 * V_E}{1024}$ ....(A4)

Incremental Energy: $E_j = \frac{P_j + P_{j+1}}{2} * (t_{j+1} - t_j)$, for $j = 1,\ldots,N-1$ ....(A5)

Supplied Power: $P = V * I$ ....(A6)

To check to see how much energy the AEV is using throughout the run, a supplied power vs time graph was created. It shows the different phases within the AEV test run. The different levels of supplied power can be attributed to how much power was being supplied to the motors. During the course of the run, the AEV accelerated, decelerated, and motor speeds were changed.

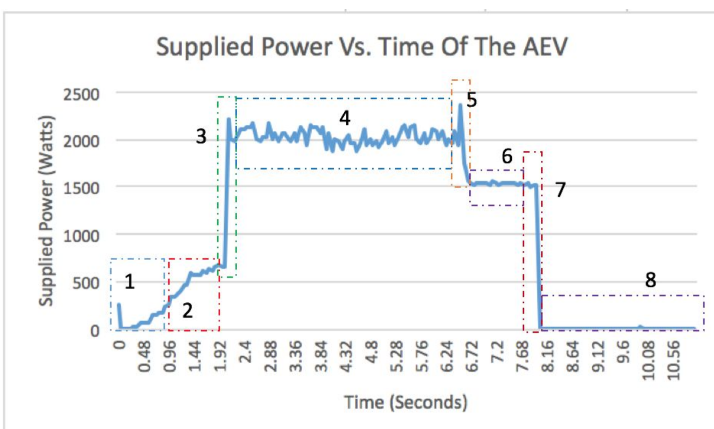


Figure 15: Supplied Power Vs. Time

From the phase graph above, a Table 2 shown below breaks down each phase individually by providing the time period and Arduino code responsible for each phase.

Table 5: Phases of AEV

Phase	Arduino Code	Time (seconds)	Total Energy (Joules)
1	reverse(4)	0-.96	104.5
2	reverse(4)	.96-1.92	620.5
3	celerate(4,0,20,2)	1.92-2.16	992.6
4	motorSpeed(4,33)	2.16-6.24	9293.3
5	reverse(4)	6.24-6.72	10100.4
6	reverse(4) motorSpeed(4,20) goFor(1.5)	6.72-7.68	11663.5
7	brake(4)	7.68-8.16	12072.1
8	celerate(4,0,0,2)	8.16-end	12073.5

For the fifth lab, we used Concept Screening method to compare the four designs and chose the comparatively best design for the later labs. We considered seven factors which are Balance, Minimal blockage, Center of gravity, Maintenance, Durability, Cost and Environmental friendibility. As a result, Steve's design has the most positives which are the Balance, Minimal blockage and Maintenance. Thus, the group decided to use Steve's design as the final option. Table 3 shows a concept screening between each design. The concept screening provided a quick comparison between all four designs.

Table 6: Concept Screening Scoresheet

Success Criteria	Reference	Design A	Design B	Design C	Design D
Balanced	0	+	+	+	+
Minimal blockage	0	0	-	0	+
Center-of-gravity	0	0	0	+	0
Maintenance	0	0	-	0	+
Durability	0	0	+	0	0
Cost	0	0	0	0	0
Environmental	0	0	0	0	0
Sum +'s	0	1	2	2	3
Sum 0's	0	6	3	5	4
Sum -'s	0	0	2	0	0
Net Score	0	1	0	2	3
Continue?	-	Modifications	No	Yes	Yes

Table 4 shown below shows a concept scoring of all four designs. This differs from the concept screening by ways that it weights each category we want to take into consideration for the final design and give each a score.

Table 7: Concept Scoring Matrix

		A Reference		Design A		Design B		Design C		Design D	
Success Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating2**	**Weighted Score3**	**Rating**	**Weighted Score4**	**Rating 5**	**Weighted Score**	**Rating 6**	**Weighted Score7**
Balanced	25%	3	0.75	4	1	4	1	4	1	4	1
Minimal blockage	15%	3	0.45	3	0.45	2	0.3	3	0.45	3	0.45
Center-of-gravity location	15%	2	0.3	2	0.3	2	0.3	3	0.45	2	0.3
Maintenance	25%	2	0.5	2	0.5	1	0.25	2	0.5	3	0.75
Durability	10%	2	0.2	2	0.2	3	0.3	2	0.2	2	0.2
Cost	5%	3	0.15	3	0.15	3	0.15	3	0.15	3	0.15
Environmental	5%	3	0.15	3	0.15	3	0.15	3	0.15	3	0.15
Total Score			2.5		2.75		2.45		2.9		3
Continue?					Modifications		No		Yes		Yes

Labs 6 and 7 consisted of a Lab Proficiency Quiz and oral presentation. The lab proficiency quiz (LPQ) consisted of testing the group members on various aspects of the AEV project so far. This includes, sample calculations, Arduino programming basics, and different parts relating to the AEV. Next was the oral presentation. The purpose of this presentation was to provide our classmates and instructors updates on the status of our design and the steps taken to reach its current state.

For Lab 8, the group had to test two different designs and see which one was more energy efficient. Using the design developed based off the concept scoring, and a design similar to the original stock design, both were tested using similar codes and a performance analysis test was run. The figure below shows the supplied power vs time of the first design tested in lab 8.

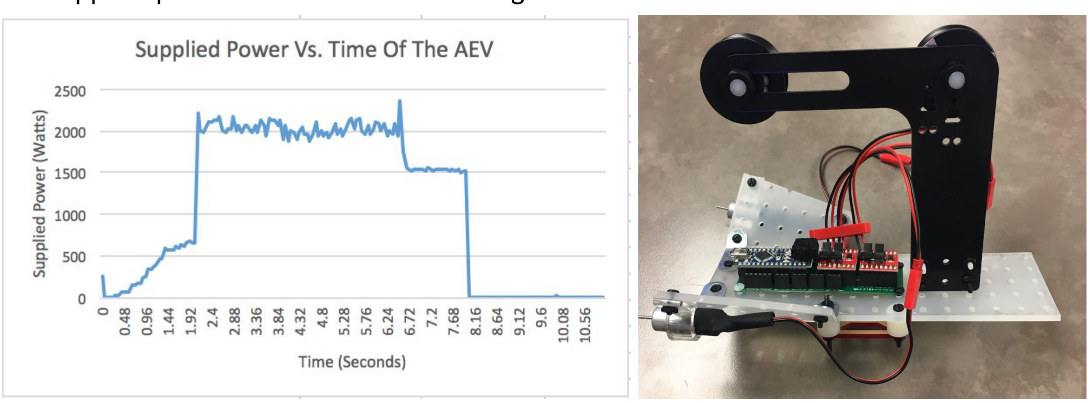
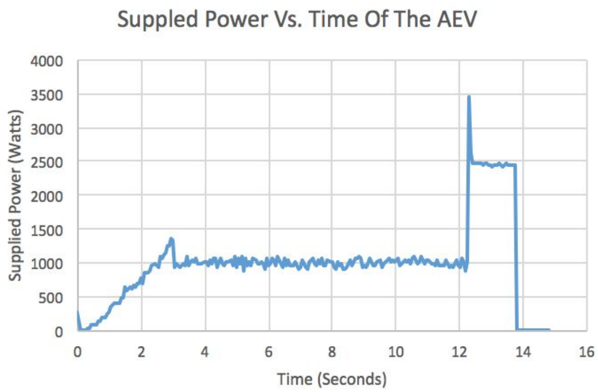


Figure 16: Design 1 Performance Test

The figure below shows the supplied power vs time of the second design tested in lab 8. When compared to design 1, design 2 uses significantly less power as seen in the time interval [2,10] seconds.



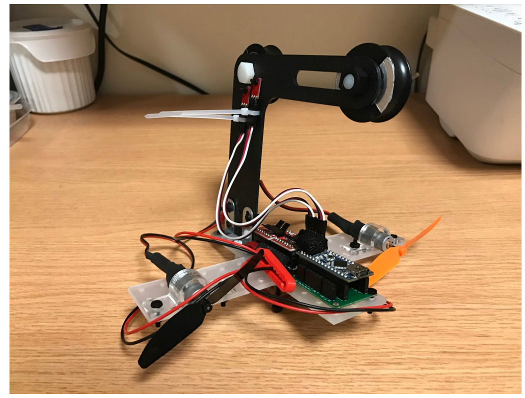


Figure 17: Design 2 Performance Test

Discussion

Based on the result of above, there are many factors that can affect the performance of the AEV. Different factors are tested throughout the project. For example, during lab 2, different propellor configurations were tested in order to see which would work best. The results showed that, the pull propellor configuration had the best advanced ratio vs propulsion efficiency. When comparing the size of each propellor, the propellor with the greater diameter resulted in a larger thrust. In order to sustain the most thrust and best advanced ratio vs propulsion efficiency, a propellor with the pull configuration and a large diameter is recommended. Another factor that affected the AEV performance is aspects within the AEV design. In lab 5, concept screening/scoring were set up to narrow down the design with the best result. In the concept scoring, different categories were weighted based on how they would affect the AEV. Balance, center of gravity, and minimal blockage were a few of the highest weighted categories. By having a better balance, the AEV does not wobble coming around the corner of the track. Center of gravity also affects the movement of the AEV similarly to the balance. Third, minimal blockage provides the AEV with better aerodynamics, and less parts in the way. For example, if the chosen design has the wires all over the place, the wires may get in the way of the propellers. Finally, another factor that affects the performance of the AEV is weight. The less weight, the less energy needed to power the AEV.

The results in lab 8 compare the stock AEV design (design 1) along with the selected AEV design from the concept screening/scoring (design 2). As shown below, design one is the reference A design in Table 8 along with a picture (Figures 3&16) while design two corresponds to design D. A description of both prototypes are, design one has a larger base than design two. Two wings are attached on the rear end where the propellers are mounted at an angle. In addition, the AEV controller chip is mounted on the topside of the base whereas the battery is mounted on the bottom. A description of design 2 is that the base is a T-shaped which is less weight than design 1's base. Unlike design 1, the propellers are mounted on the wings of the T-shaped base instead of the rear end. Finally, the AEV controller chip, and battery are attached similarly to design 1.

Table 8: Reference A Vs. Design D

		A Reference		Design A		Design B		Design C		Design D	
Success Criteria	Weight	Rating	Weighted Score	Rating2	Weighted Score3	Rating	Weighted Score4	Rating 5	Weighted Score	Rating 6	Weighted Score7
Balanced	25%	3	0.75	4	1	4	1	4	1	4	1
Minimal blockage	15%	3	0.45	3	0.45	2	0.3	3	0.45	3	0.45
Center-of-gravity location	15%	2	0.3	2	0.3	2	0.3	3	0.45	2	0.3
Maintenance	25%	2	0.5	2	0.5	1	0.25	2	0.5	3	0.75
Durability	10%	2	0.2	2	0.2	3	0.3	2	0.2	2	0.2
Cost	5%	3	0.15	3	0.15	3	0.15	3	0.15	3	0.15
Environmental	5%	3	0.15	3	0.15	3	0.15	3	0.15	3	0.15
Total Score			2.5		2.75		2.45		2.9		3
Continue?					Modifications		No		Yes		Yes

To see if these changes have any impact on the performances, both designs were put under a system analysis test to see how much power each design used. Design 2 featured better balance, aerodynamics, center of gravity, less weight, and minimal blockage when compared to design 1. The results of lab 8 as shown earlier in the report confirm the hypothesis that these aspect would help make the AEV more energy efficient. Comparing the supplied power vs time graphs for both designs, design 2 had a significantly supplied power than design 1. Observations within each test were that while testing design 1, the original code used to test it would not move the AEV originally because of its weight. To solve this, the power and motor speed had to be upgraded. As for design 2's run, the test went smoothly with no errors observed. Having to provide more power to design 1 ultimately made it have no shot of beating design 2's in energy efficiency.

Throughout each lab, there is always the chance of potential error in all the experiments. After analysing the design and the whole process of the testing, some potential errors were observed. The sensors are a key factor of the AEV moving to the right position, but they are easy to be imprecise. During the lab, both sensors on our AEV had some problem. Every time we tested the AEV using the same value of absolute value position, the AEV stopped at different locations. Then we decided to test the sensor. We used the simple rail on our desk and make the AEV go back and forth, and we ran the sensor test on the computer. The result is that every time the AEV went to the same point, the value showed on the sensor test was different. However, after we seeked help from GTA, the sensors went back to normal. Another potential error is that when the AEV turning in the corner, the center of gravity of our AEV became unstable. We tried to decrease the speed to make it stable but the result was not as ideal as we thought. The center of gravity still unstable but the amplitude decreased. Thus, a potential solution would be to change the orientation of the base in order to create a more balanced AEV.

Based on the labs conducted, it can be assumed the experiments performed throughout the project are intended to help improve upon all designs. This means that less weight, better balance, minimal blockage, and better center of would improve upon the AEV's performance as tested numerous times. When comparing our results to this theory, not only does it confirm it, but it also lays a pathway for how we can improve upon the design in the process. By continuing testing designs for better balance, blockage, etc. and using the previous design as a reference, it can only benefit the future developments by upgrading each aspect each time to better the design and performance.

Conclusions and Recommendations

The goal of this lab is to get the AEV to go pick up the cargo and return the starting point along the track while also introducing students to teamworking skills, design processes, and working within a working environment. By having everyone in our group do an even amount of work, complete specific tasks, and contribute to the design process, every member can be ensured that they have met these goals. This project teaches responsibility and time management. The AEV is used to narrow down our focus. As we continue to improve upon its design, we unknowingly are improving upon each of our brainstorming skills, responsibility, and teamworking skills.

For the AEV to make a successful run, several factors have to be accounted for. The first of which is propellor orientation. Using the data from Table 1 to Figure 10, a clear trend is shown that the pull propellor configuration is more superior to the push. This is because it has a larger advanced ratio to propulsion efficiency meaning it will experience better efficiency while using less energy. During lab 2, not only was the orientation of the propellor tested, but also various sizes of the propellor such as a 3 in and 2.5 in diameter. Looking at both propellers thrust vs Arduino power setting graphs, a clear trend can be identified that the larger the blade, the less energy is needed, and the more thrust it produces. Along with propellor configuration, there are also aspects to the AEV design that can contribute to the AEV's performance. Things such as balance, center of gravity, minimal blockage, and low weight were all examined during lab 5 in which they were all weighted accordingly and then implemented into the final design. All of these features were then tested in lab 8 using an AEV design that had scored better in each of these categories from the concept scoring and then tested against the stock AEV design. The results as shown in Figures 16 and 17 show that significantly less energy was used for the AEV which excelled in each of the categories.

Throughout the course of the project, the group ran into several problems. Earlier, it was discussed that the group was having trouble with our reflectance sensors working. After doing a reflectance sensor test, it was observed that one full wheel count would not always account for 8 marks. To solve this problem, the group decided to develop a code that did not rely so much on the reflectance sensors. The solution was to create a code based off time instead of the sensors. The code ended up being inconsistent along with the reflectance sensor code. To solve this problem, it was concluded that we may have to rely on the AEV coasting partially towards the gate instead of using sensors or time. An in progress code is now being developed for this problem and will continue to be tested throughout performance test 2 in the upcoming labs.

Another error observed throughout the project was that In our original design (stock AEV design) we noticed that coming around the corner, the AEV wobbled way too much and used too much power. To resolve this error, the group concluded that we must make a design with a better balance, center of gravity, and less weight. Using the concept screening as mentioned numerous times in the report and also the AEV prototypes each group member made, we built an AEV design that included all these aspects. Results from upgrading these aspects to the design as shown during the AEV's run as it no longer wobbles around the corner, it is always balanced, and during lab 8 it showed significantly less power consumption than the original design.

Based off all the information collected in this project, for the best AEV design possible, it is recommended that a design with a pull propellor configuration be made with the largest blades. Since the AEV must return to the original starting point during its run, it has to go in reverse at some point. For the best possible results, it is recommended that there be a propellor on each side of the AEV. If the AEV is moving forward, have the propellor in the rear end in the push configuration while the one in the front in the pull configuration. If the AEV is going in the reverse direction, this scenario would then just be flipped. Using a design like this would help manage energy consumption and the effectiveness of the propellers. Next, in order to save as much energy as possible, it is also recommended that the AEV have the most balanced, aerodynamic, and lowest weight as possible. As shown in figures 16 and 17, after all of these categories were improved upon and then implemented into the design, significantly less power consumption was achieved.

During the project, the group has managed our time well and have had no troubles in completing assignments. In the appendix, a schedule of the group's performance test 1 and performance test 2 are provided. Up to this point, we have used all the results gathered to help us implement the very best design possible. Below is a picture of our current preliminary design.

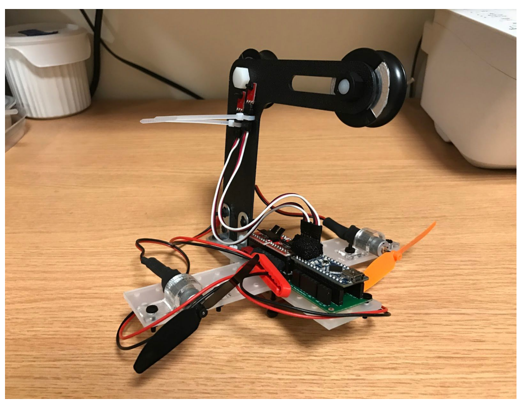


Figure 18: AEV Design

Appendix:

Sample Calculations:

Time=(Te/1000)= 2400/1000=2.4 seconds…………………………………………………………(A1)

Distance= .0124 * Marks = .0124*4= .0496 Meters………………………………………………(A2)

Position=.0124* Marks= .0124*4=.0496 Meters…………………………………………………...(A2)

Current= (Ie/1024)*Vr*(1amp/.185 volts)= (94/1024)*2.46*(1/.185)=267.45 Amps……………(A3)

Voltage=15*Ve/1024=(15*539)/1024=7.89 Volts…………………………………………………..(A4)

Incremental Energy= (Pj+Pj+1)/2*(tj+1-tj)= (2111.1.66+2142.05)/2*(2.46-2.4)=127.6 J………(A5)

Supplied Power= V*I=(267.45*7.89)=2111.66W…………………………………………………..(A6)

Table 1: Team Task Schedule for Performance Test 1

Performance Test 1	**No.**	**Task**	**Start**	**Finish**	**Due Date**	**Est Time**	**John LaPres**	**Yue Zhou**	**Kyle Larj**	**Steve Zhu**	**% Complete**
	1	AEV 1 Construction	7-March	7-March	21-March	4.0h	1.0h	1.0h	1.0h	1.0h	**100**
	2	AEV 1 Testing	7-March	7-March	21-March	2.0h	0.5h	0.5h	0.5h	0.5h	**100**
	3	AEV 2 Construction	8-March	21-March	21-March	4.0h	1.0h	1.0h	1.0h	1.0h	**100**
	4	AEV 2 Testing	8-March	21-March	21-March	2.0h	0.5h	0.5h	0.5h	0.5h	**100**
	5	Weekly Report	7-March	20-March	21-March	1.0h	0.25h	0.25h	0.25h	0.25h	**100**

Table 2: Team Task Schedule for Performance Test 2

Performance Test 2	**No.**	**Task**	**Start**	**Finish**	**Due Date**	**Est Time**	**John LaPres**	**Yue Zhou**	**Kyle Larj**	**Steve Zhu**	**% Complete**
	1	Code 1 Construction	22-March	22-March	28-March	4.0h	1.25h	0.75h	1.25h	1.25h	**100**
	2	Code 1 Testing	22-March	22-March	28-March	2.0h	0.5h	0.5h	0.5h	0.5h	**100**
	3	Code 2 Construction	24-March	24-March	28-March	1h	0.25h	0.25h	0.25h	0.25h	**100**
	4	Code 2 Testing	24-March	24-March	28-March	2.0h	0.5h	0.5h	0.5h	0.5h	**100**
	5	Weekly Report	22-March	24-March	28-March	1.0h	0.25h	0.25h	0.25h	0.25h	**100**