Introduction:

The test conducted during Performance Test 1 was performed in order to help minimize the energy usage for completing the MCR. The goals of this lab were to construct two different AEV's and measure how much energy each used while running the same code. The AEV analysis tool was used to measure the energy used to complete each run in joules. This report provides data supporting the determined conclusion and discussion regarding the design that will minimize the energy usage for retrieving the R2 unit to the rebellion, giving us an even playing field against the empire.

Experimental Methodology:

Teams were commissioned by the rebel alliance to make a fuel efficient and dependable vehicle to retrieve a captured R2 unit from the evil empire. Each team was given an AEV Arduino sketchbook, as well as material to design and build an AEV through team brainstorming. After a preliminary design and code were made and tested on the track, the data could then be analyzed using the matlab AEV analysis tool to see the energy used for that run. The design and code are then adapted to the team's wants or what is lacking until final testing, where the final product is tested and timed on the track.

Results/Discussion:

The original design concepts the team came up with were all applied in the usage of both designs tested recently. Some of the designs called for parts to be made or separate materials not provided to be bought. The team decided to avoid any extra strain in searching for parts or building new ones to minimize cost and focus more on the proper coding of the AEV to complete the specified directives of the mission. Concepts that were taken from the original designs include the usage of lateral wings to give the AEV an aerodynamic edge, and an easily adaptable rectangular base which has a clear center of balance. Another factor that came from the early stages of development was the propeller type to use. The team decided on the 2510 propeller in the pusher configuration. The decision was based solely on the propeller's performance in the wind tunnel. As seen in figure 1, the propulsion efficiency of the 2510 pusher compared to the other propeller configurations peeked earlier in advance ratio and higher in propulsion efficiency. By selecting this propeller, the efficiency of the AEV at lower motor speeds will be optimized as the motor cannot exceed 50%.

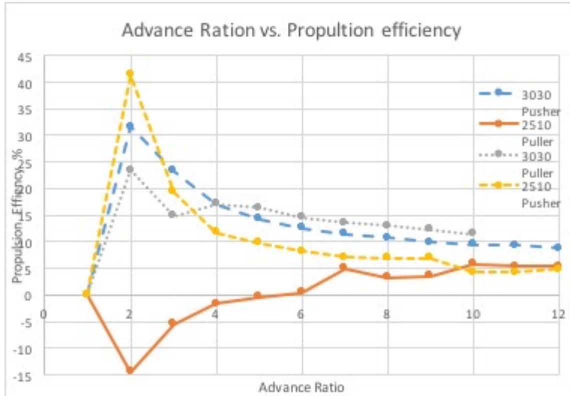

Figure 1: Propeller Efficiency vs Advance Ratio in Wind Tunnels

For design 1 the group began with a very simple design that was similar to the sample design. The base of the first design was a rectangular board provided, which was 7 in in length. Attached to the board were wings at each side cut to an angle as seen in figure 2, and added around 0.5 inches to the length. The purpose of the wings was to make the AEV more aerodynamic in order to cut down on the fuel consumption of the vehicle. To utilize space efficiently, the Arduino board was placed underneath the base to allow room for the wings to be applied using wings screwed into the top of the base of the board. The arm attachment that connects the vehicle to the rail was placed off centered and behind the Arduino board to keep the AEV balanced horizontally as well as vertically giving the height to be about 5.8 inches. Directly underneath the attachment arm on the other side of the base of the AEV was the battery holder so the Arduino would not have a problem reaching the power source. The motors were kept close to the Arduino by placing them on the wings attached to the base.

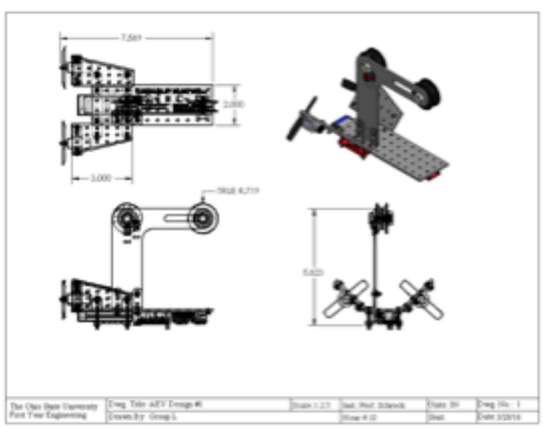

Figure 2: Design 1 Isometric and 3 Orthographic views

Design 2 saw a similar structure to design 1. Instead of a rectangular base, a T-shape was used with a length of 8.3 inches. By using the T-shaped base, the motors and propellers were able to be evenly spaced without having to add anything extra to the board to attach them, as seen in figure 3. With the motors in the rear of the AEV, the Arduino board was placed on the lateral part of the T-shape. The attachment arm was once again placed off center near the rear of the base, like design 2, to balance the AEV, with a height of 6 inches. The battery holder was placed underneath the attachment arm and between the motors. The battery holder was also placed off-center to combat a balance problem that the design was having. 2 rectangular boards were added to the front to aid in balance, giving a total width of 6.5 inches

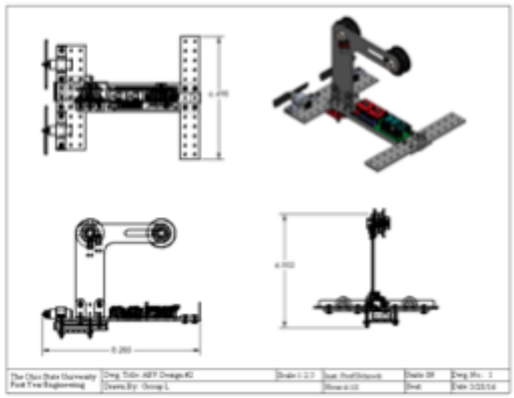

Figure 3: Design 2 Isometric and 3 Orthographic views

Both designs were run using the same Arduino code in order to compare the energy usage of the AEV. All directives that the AEV was programed to do, such as stopping at the gate and picking up the R2 unit gently, were completed by both designs. There however slight differences in the way the tasks were completed, however. Design 1 appeared to be moving at a higher speed than design 2. Because of this, the vehicle moved more wildly than with design 2, but it was able to pull the R2 unit at a greater speed as well.

The final design that the team used was based largely off the second design. The only parts that differed between the two were the final design scrapping the idea of the wings at the front of the AEV. It was agreed by the group that these did little in helping the AEV and thought that the loss of weight from removing the wings will provide a better benefit than the little aerodynamic edge the AEV was given with them. Finally, the team realized the magnet sometimes missed picking up the R2 unit using the magnet. To solve the problem, a metal apparatus was constructed, as seen in figure 4, on the front of the AEV to allow there to be a wider range of area in which the R2 unit could connect

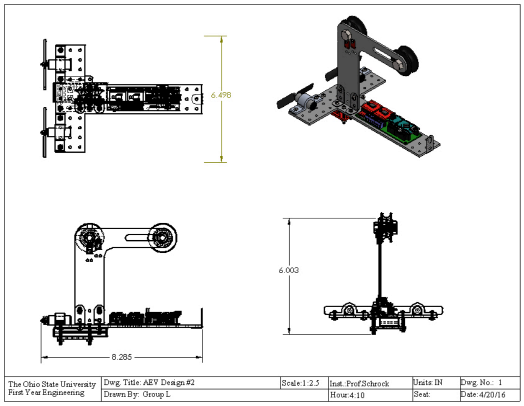

Figure 4: Final design Isometric and 3 orthographic views

When comparing the energy usage of the 2 designs trends became more evident that were not seen by the eye. Design 2 was discovered to have the lower energy usage of the 2. When comparing the plots from figure 5 and 6, the total supplied energy for design 2 was less than for design 1. Design 2 also completed the run faster, below 30 seconds, than design 1 which took just over 30 seconds for the program to stop suggesting that design 2 is actually the faster of the 2.

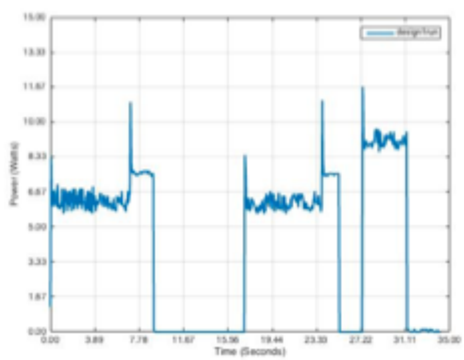

Figure 5: Plot of Supplied Power vs. Time for Design 1

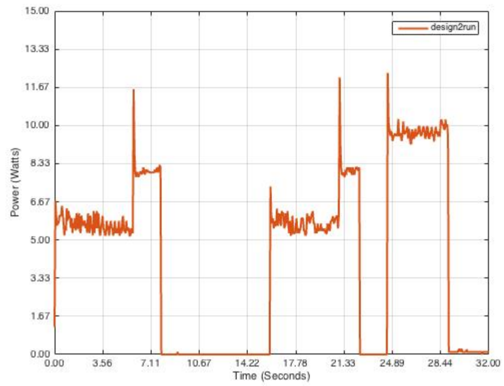

Figure 6: Plot of Supplied Power vs. Time for Design 2

When pairing the plots of figures 5 and 6 to the phase table in table 1 it can detail in how the 2 designs work when certain codes are executed and identified. Although overall design 2 had a lower total energy usage in 134.23 J, it used more energy than design 1 when the motors were on for the longer periods of time in the code, but was more efficient when short directions were assigned. The overall better efficiency of design 2 may be because of it being lighter than design 1 so less energy is used to pull the AEV along the track.

Table 1: Phase Table of Arduino Code with Total Energy Usage

Adruino code	Time Design 1 (s)	Total Energy (J)	Time Design 2 (s)	Total Energy (J)
motorSpeed(4,25);				
goToAbsolutePosition(300);	6.96-0	43.25	0-5.76	32.48
reverse(4);				
motorSpeed(4,30);				
goFor(2);	6.96-9.06	15.85	5.76-7.80	16.46
motorSpeed(4,0);				
goFor(8);	9.06-16.98	0	7.80-15.84	0
reverse(4);				
motorSpeed(4,25);				
goToAbsolutePosition(712);	16.98-23.76	41.52	15.84-20.94	29.23
reverse(4);				
motorSpeed(4,30);				
goFor(1.5);	23.76-25.26	11.46	20.94-22.43	12.26
brake(4);				
goFor(2);	25.26-27.3	0	22.43-24.48	0
motorSpeed(4,35);				
goToRelativePosition(-300);	27.3-31.2	35.53	24.48-29.98	43.8
		147.61		134.23

The better fuel efficiency of the second design matches what would be expected based on trends seen in real life. Because design 2 has a lower mass than design 1, it is able to apply the same amount of force, being the motor power percentage, and go farther than something with more mass. This explains the increase in speed, which also decreases the time of the run. Contrary to this theory, design 2 used more energy than the first during the longer code commands as seen in table 1. this error in theory may be the reverse propulsion of the motors when the vehicle is trying to come to a complete stop. This would use more energy over the short interval which may account for the extra power supplied. To solve this error a possible coding solution can be suggested for an alternative way to stop the vehicle that is more energy efficient, such as coasting to a stop

Analyzation of the supplied power during the length of the program led the team being able to score the designs effectively compared to the previous design using both screen and scoring matrices. According to the screening from table 2, although design 1 outperformed the design from lab 3 by 3 points, design 2 was able to obtain a score 3 points higher with 5. Design 2's superiority was also seen in the scoring matrices in table 3 where it had the highest score of 7.85.

Table 2: Concept Screening of Designs 1 & 2 and Lab 3 design

Success Criteria	Reference	Design 1	Design 2	Lab 3 design
Balance	0	+	+	0
Weight	0	-	+	-
Speed	0	-	0	-
Durability	0	+	+	-
Looks	0	0	+	+
Cost	0	0	0	0
Creativity	0	0	+	+
Sum of +	0	3	6	2
Sum of 0	7	3	2	2
Sum of -	0	2	0	3
Net Score	0	2	5	-1
Continue	-	no	yes	no

Table 3: Concept Scoring of Designs 1 & 2 and Lab 3 design

		Design 1		Design 2		original design	
Success criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Balance	15%	8	1.2	9	1.35	5	0.75
Weight	20%	4	0.8	7	1.4	4	0.8
Speed	15%	5	0.75	7	1.05	5	0.75
Durability	20%	9	1.8	8	1.6	5	1
energy usage	5%	5	0.25	7	0.35	5	0.25
Cost	15%	10	1.5	10	1.5	10	1.5
Creativity	10%	3	0.3	6	0.6	6	0.6
Possible Score	10%						
Total Score			6.6		7.85		5.65
Continue			no		yes		no

The final design and design 2 were similar enough to use the same scoring and screening matrices for the 2 because even though the wings were taken out to reduce weight, the added metal coverage to ensure the R2 unit stayed attached added onto the weight. What made the difference between design 2 and the final design was the code that was executed. The final code incorporated both coasting at points where the bridge was not involved and the reverse propulsion method to come to a stop only at the points where the bridge was involved. As shown in figure 7, phases 1 and 3 were the only phases that ran the reverse propulsion method while the other code in figure 8 not only had reverse propulsion for every phase, which caused large energy spikes, but also had the motors on longer than the final code since after the final was run to a shorter distance the motor cut off and wasn't operating the whole time on the track.

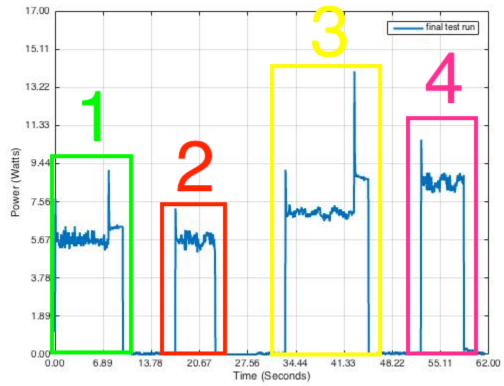

Figure 7: Final run plot of power(watts) vs. Time(s) with phases

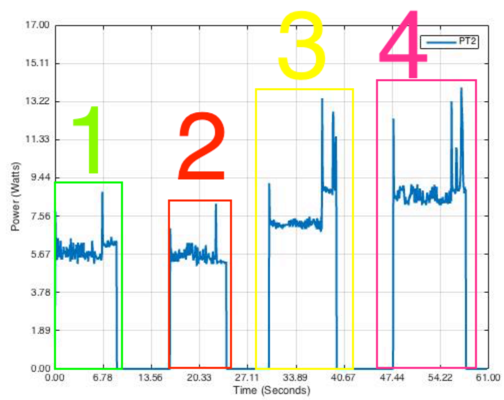

Figure 8: Original code plot of power(watts) vs. Time(s) with phases

During the final test, the AEV was able to successfully make its way to the gate and progress towards the cargo area to pick up the R2 unit. Once R2 was retrieved, the AEV came up a little bit short on its way back to the gate and it needed some assistance from the rebel alliance. Further assistance was needed for R2 to traverse to the drop-off area. The rebels used only 229 J to complete the mission. What was more impressive from the run was that it was completed in 70 seconds. With the rebel alliance being able to move cargo that fast, the empire never stood a chance.

The final run was hampered by inconsistencies or errors that the team could not properly prepare for. At times, the AEV would run through the course perfectly with no faults, while on other runs, such as the final run, it would run differently and not perform some of the tasks designed for it. These follies can be attributed things beyond the team's control, such as testing in different rooms where the conditions were not exactly the same in both rooms. There also appeared to be faults in the R2 unit being crooked or tampered with. Lastly, the track was sometimes changed in mid-testing periods by other teams.

Conclusion:

The group successfully produced two AEV designs and recorded how much power each used using the AEV analysis tool. After running the same Arduino code for each design, it was found that the total energy used for Design 1 was 147.61 J while the total energy used for Design 2 was 134.23 J, which can be seen in Table 1. The results from the concept screening, as seen in Table 2, show us that the net score for Design 1 was 2 points while Design 2 scored 5 points. Design 2 also scored higher for the concept scoring shown in Table 3 with a 7.85 compared to Design 1's 6.6. Design 2 was chosen as the final design with some modifications done.

By incorporating the final design with the new code, the AEV was able to perform at a higher efficiency of 229 J as opposed to the 257 J that the old code accumulated. The AEV design is similar to other teams, but it is the coding that makes it unique. Incorporating both coasting as well as reverse propulsion, the AEV optimizes efficiency and speed at the same time, providing a lower energy reading than most groups. Although the final run fell short of the stop gate once and returning the starting area, these can be attributed to errors and, if more time was permitted, the team could have programed accordingly. It would also be ideal to form 2 codes, 1 for each room in order limit the error between rooms. The team could also have its own R2 unit to test with so different weight or orientations of the unit will not affect the final run.