Preliminary Design Review

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Executive Summary

The purpose of the labs leading up to this point was to create an Advanced Energy Vehicle (AEV), that successfully and efficiently operates along a rail. The AEV will be responsible for going around a predetermined path that includes inclines and declines, many stops, and changes in direction. The AEV will need to pick up a passenger car and safely transport it along the predetermined path. While doing this the AEV must be the most energy efficient possible to protect the environment.

There was a lot of brainstorming when coming up with AEV ideas, but one main design stood out to the whole group. Design consists of a very simple, lightweight design with right trapezoidal wings and three bladed propellers. The second design was a combination of two group member's designs, which includes wings tilted at 45 degree angles extended with small rectangles to increase aerodynamics. This design also includes the three bladed propellers for better efficiency. Eventually a code was created to test the AEV designs on the monorail track and compare the data. After the AEVs were tested, the data was downloaded from the Arduino board and analyzed using the Analysis tool to then be plotted. After analyzing the data, it was obvious that design one was the more efficient AEV, but the second design had better balance, so the team moved the Arduino board and wheels to give design one the balance it needed.

After careful analysis and discussion amongst the team, the chosen design was the first design because it was roughly 1% more efficient than the second design mostly due to the lack of extra unneeded weight. The final design will be a combination of weight advantages from the first design and balance advantages from the second design. The team believed that this would maximize the success of the AEV while keeping the safety of the passengers and environment in mind.

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Introduction

Before the utilization of the two AEV designs, a series of labs served to experiment on and learn about various components of the project. Continuous trials using an Arduino-based code allowed a production of final draft that completes the AEV run. Two AEV designs were built for comparison, where two flavors of mechanics (that is Supplied Power vs. Time and Supplied Power vs. Distance) were observed for the objective of efficiency. Additionally, another flavor (that is System Efficiency vs. Advance Ratio) described which propeller's direction were suitable. These graphic relationships were formulated, using a student's MATLAB code that analyzed the AEV's EEPROM data. As a model to display propriety, two SolidWork models were created, which analogized the value (shown by the bill of materials) for each designs.

The purpose of the preliminary design was to successfully formulate a code that will meet the mission's objective, that is to have a code that fulfills an operation consistency against the instabilities along the monorail. Furthermore, the amount of battery power within the AEV attributed to variations in the run. A code that utilizes an "auto-fix" function could eliminate these instabilities and variations altogether.

Another purpose was to minimize the energy/mass ratio, as an intent to fulfill an operational efficiency. Efficiency would be crucial, augmented by a factor of 20% in an early concept screening/scoring, for the lowest price of the tour (as described by the MCR). To complete this, the physical design must be optimized, using the least amount of components and the smallest panels for construction. The energy/mass ratio can be estimated by those flavors (described in Supplied Power vs. Time and Supplied Power vs. Distance). Additionally, peak magnitudes in the graphs can quantify the energy used for each designs.

Experimental Setup

First, the AEV was scrutinized for missing parts/connections. To avoid the multiple occasions when the wire connecting from the battery to the Arduino board, became broken, and preliminary check up was required to minimize any more delays in the lab. Afterwards, the battery charger was set up, with its power supply connected to the power outlet, as a preparation to charge the AEV during the break duration when the students returned to their table. At their table, the Arduino sketchbook should be opened for code manipulation. The

Manual and Guidelines document should be a part of the opened files. SolidWorks software should be used to generate virtual models.

Results/Discussion

Below introduces the two main designs, Design 1 and Design 2, that underwent the performance testing, as to determine which design accomplished the mission's objectives.

Figure 1. SolidWorks Model for Design 1

Figure 1. displays the SolidWorks Model for Design 1, the final design that was decided after processes of concept screening and scoring from Lab 3. Design 1 was constructed with flat/angled wings (that was marked with approximately 15 holes), as one of the least sized yet reasonably aerodynamic shape for the AEV. Two three-bladed propellers were utilized and constrained at the two ends of the wings, that models a similar design for modern airplanes. The main panel that is attached to a L-shaped hanger, were decided as the best combination of engineering virtues, like compactness and low weight.

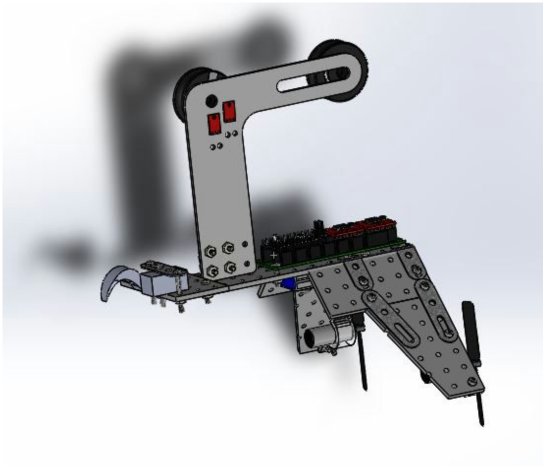


Figure 2. SolidWorks Model for Design 2

Design 2 is displayed by Figure 2. Design 2 was constructed with downward angled wings with a rectangle extending the wing length. This design was created because the team thought that if the wings were extended it would improve the aerodynamic properties of design 1 in figure 1. In reality the AEVs are not moving fast enough for aerodynamics to be a factor so the added weight from the longer wings will lower the AEVs efficiency.

Both models began with a concept drawing, that was then scrutinized along various qualities inside a scoring and screening method. The names for the early designs were labeled with letters, rather than numbers, and they lacked the servo motor and the servo hook.

Success Criteria	Design X	Design Y	Design Z
Balanced Around Turns	-	0	+
Minimal Blockage	0	0	0
Center-of-gravity Location	-	-	+
Maintenance	0	0	0
Durability	0	0	0
Cost	0	0	0
Environmental	-	0	0
Sum +'s	0	0	2
Sum 0's	4	6	5
Sum -'s	3	1	0
Net Score	-3	-1	2
Continue	No	No	Develop

Table 1. displays categorical scores for designs X, Y and Z

Table 1. represents the scoring of the three different AEV designs the team came up with. The criteria choices are what best represent the efficiency and performance of the AEV. The zeros represent that that specific element of design has neither a positive or negative impact, a negative means that element of design has a negative impact on the final AEV, and a positive means that specific design element has a positive impact on the AEV.

		Design X	Design Y	Design Z	Sample AEV

Success Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Balanced	5%	3	0.15	4	0.2	5	0.25	3	0.15
Minimal Blockage	15%	4	0.6	4	0.6	4	0.6	3	0.45
Center-of-Gravity location	10%	2	0.2	2	0.2	5	0.5	2	0.2
Maintenance	25%	3	0.75	3	0.75	3	0.75	3	0.75
Durability	15%	3	0.45	3	0.45	3	0.45	4	
Cost	20%	3	0.6	3	0.6	3	0.6	3	0.6
Environmental	10%	2	0.2	3	0.3	3	0.3	3	0.3
Total Score	100%	20	2.95	22	3.1	26	3.45	21	3.2
Continue?		No		Develop		Develop		No	

Table 2. displays weighted, categorical scores for Designs X, Y, and Z, and Sample AEV

Table 2. represents of the scoring of three AEV designs. In this matrix, scoring consisted of a weighted numerical system, ranging from 1 to 5 that is weighted from the percentage of various categories. This allows scores from some categories to stress the overall score of the design more than others. Depending on what team values the most, the students valued cost and maintenance as the highest importance for design. The categories were weighted 20% and 25%, respectively.

Each design was separately scored based on the design criteria in table 1. As shown, most parts of the design were neither positive or negative to the outcome of the AEV. The Sample AEV was not balanced around turns and it had a bad center of gravity. This was due to the fact that the hanger and wheels were not perfectly centered, which caused the AEV to hang at an angle. Similarly, Design X was not balanced around turns. It also had a poor center of gravity, shifting its weight towards the propellor side of the model. It was not the most environmentally friendly AEV out of the choices. The three negatives put Design X in last place. Design Y was a plain design, causing it to have a lot of zeros, but it had one negative because it had a poor center of gravity due to the distribution of weight. With only one negative, this put the design in second place. Design Z was the final design choice because it scored the highest with positives in balance around turns and center of gravity. This is because the weight was distributed evenly and the wheels and hanger are placed in the most efficient spot.

Looking at the ranking of the total scores, Design Y and Design Z were the highest, which meant that they were chosen for further testing at the full AEV track. As a preface for classification, Design Z became Design 1 and Design Y became Design 2 (stated elsewhere in this PDR). Both held some cons, much of which circumvents around the case for poor center of gravity and the tilt along the hanger’s pointed axis, but they retained some pros that aids the project's mission for proper, efficient designs. Further testing will determine the total energy used, and this factor will equate the use of Design 1 as the final design.

During the run with Design 1, it performed very well. It was able to stop at each of the predetermined stops as it performed the circuit around the track. Design 2 performed adequately as well and was able to stop at the predetermined locations. The designs performed similarly under the same control program because the control program was based on the AEV's location on the track rather than time. The team expected Design 1, with its lighter weight, to be better than Design 2, than its longer wings, but when the runs were completed there was very little difference between the two designs in terms of Power vs. Distance (as shown in figures 3-7). In addition, both designs were very similar in terms of supplied energy because the control program was the same as shown in tables 3 and 4.

The team benefitted from performance test one because they learned that weight is a bigger factor to the movement of the AEV because design one was lighter than design two. As shown in figures 9 and figures 10, the energy usage for design two is higher than design 1 as it navigates through the course. Even though the difference between design 1's energy usage and design 2's energy usage is minimal, the energy saved by design 1 makes a big difference because as more runs are performed the battery for design 2 would die faster than the battery used for design 1. The team learned a few things from system analysis 1 and 2. The team learned that the three bladed propeller was more efficient(as shown in figures 7 and figures 8). The team also learned that design 1 is more efficient than system analysis two because of the weight difference between design 1 and design 2.

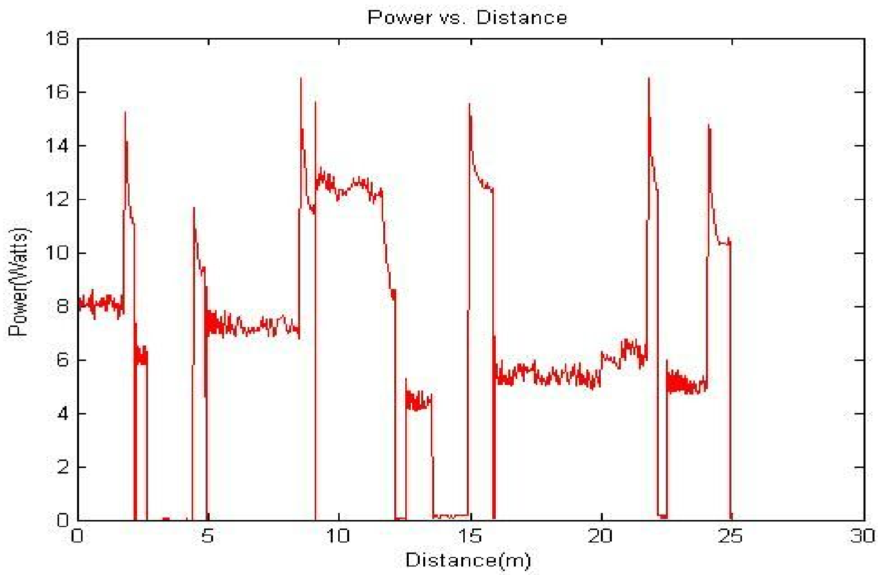


Figure 3. Design 1's Supplied Power vs. Distance during Performance Test Run

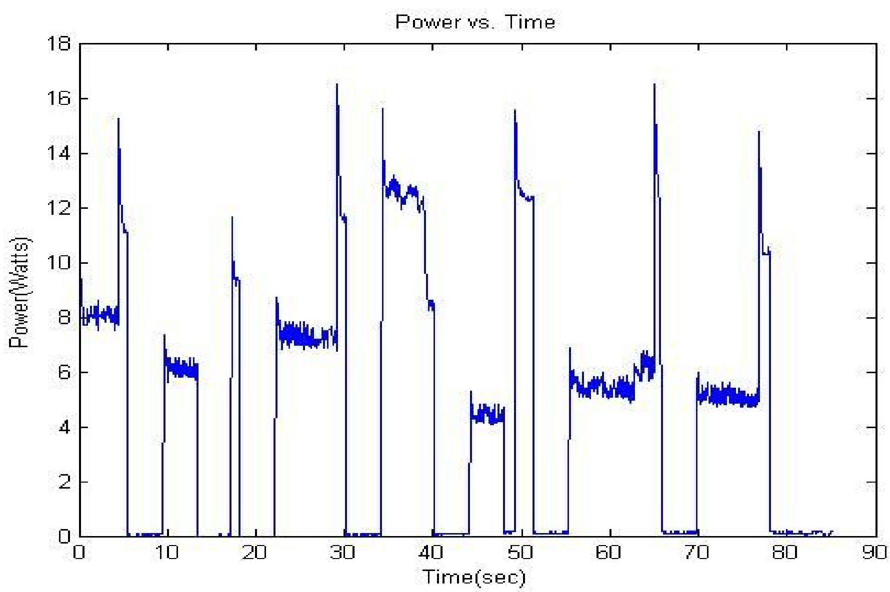


Figure 4. Design 1's Supplied Power vs. Time during Performance Test Run

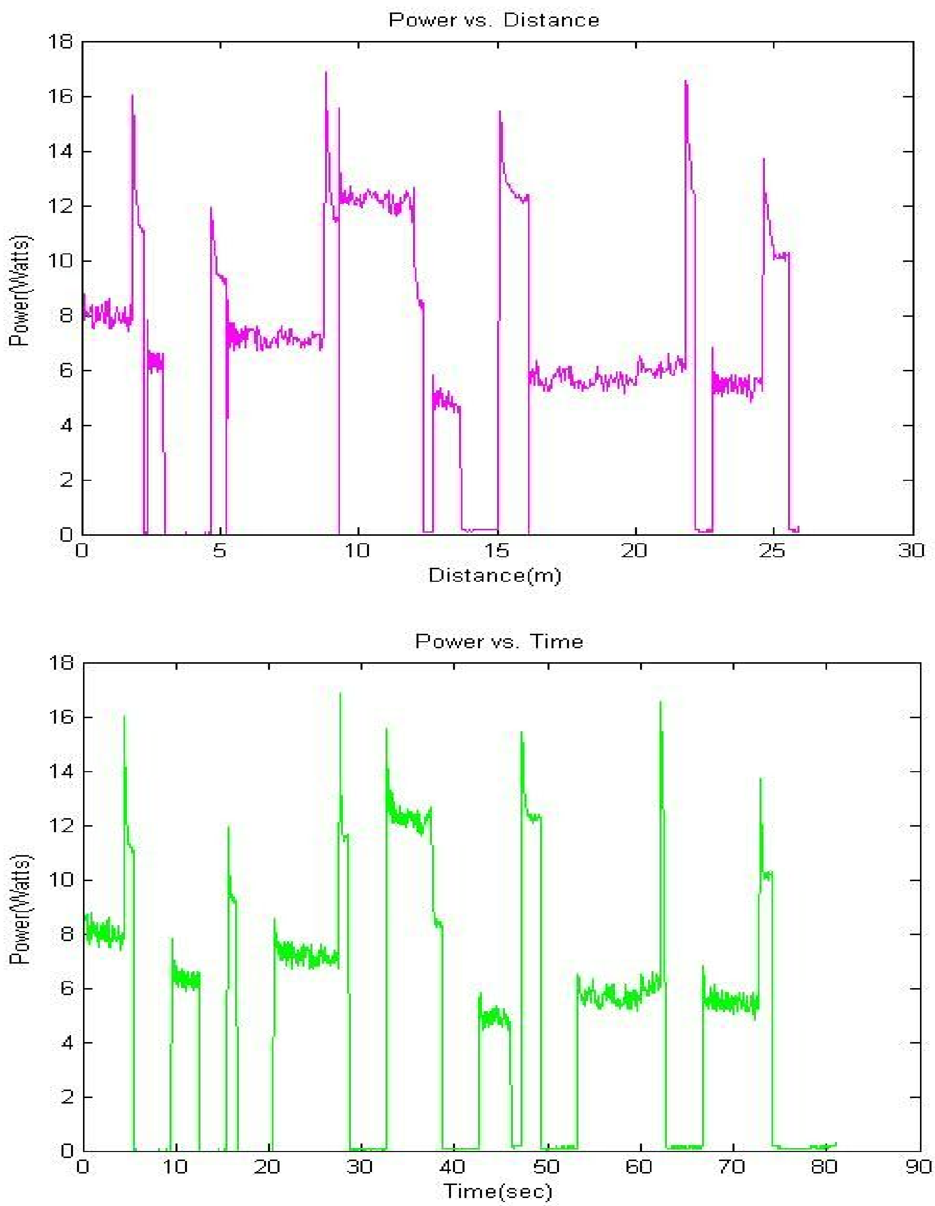


Figure 6. Design 2's Supplied Power vs. Time during Performance Test Run

Comparing Figure 6. from Figure 4., one can notice the small difference in the peaks/ranges of the graph. While Figure 6. displays a range of slimmer and taller peaks, Figure 4.'s ranges were thicker and (slightly) shorter. This graphic appearance can infer longer, yet weaker propulsions during the tour, with a smoother ride that is executed by the code. Elements of smoothness or ease can benefit the wayfaring aspect of the project, since the traveler's' preferences affect the quality of design. Since Design 1's performance was reproduced by Figure 4., the figure serves to support the designation of the design, in running the full track with real cargo attached to the servo. Some cautions to consider are the inherent variations within each trials. While one trial can produce desirable results under the mission's objectives, other trials can reveal the true parameters. The students' decision to designate Design 1 is still constricted to the inherence of chance.

Other potential errors may include inherent/mechanical errors within the Arduino board. As the students are heavily dependant on raw data, provided by the automatic EEPROM data, any mishaps during the digital reading can produce false data (and eventually into false observations). Another error may come from the wearing and slight changes in the monorail. The monorail is shared by numerous group's AEVs, and the continuous usages/runs can engender changes of friction, incline angles, (perhaps) the length, etc. All of these deviates the control of perfect data.

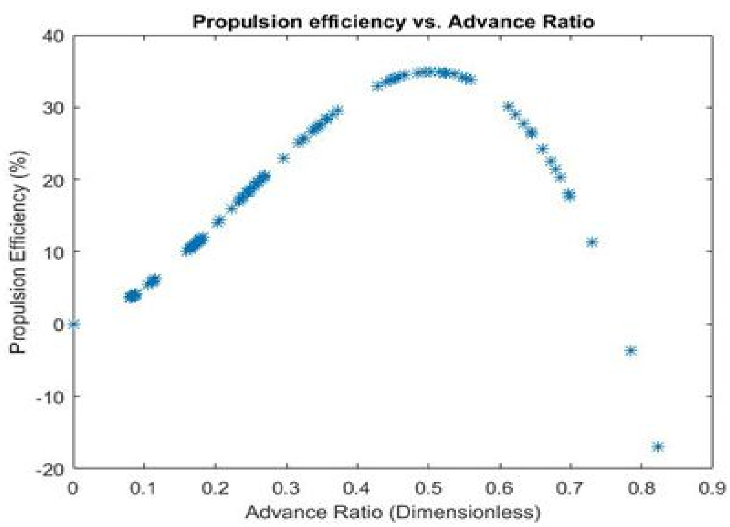


Figure 7. Propulsion Efficiency vs. Advance Ratio at Puller

Figure 7. Shows that the maximum Propulsion Efficiency falls between the 40% to 30%, approximately at exactly 35%. The AEV requires the highest efficiency per propeller strength during the tour.

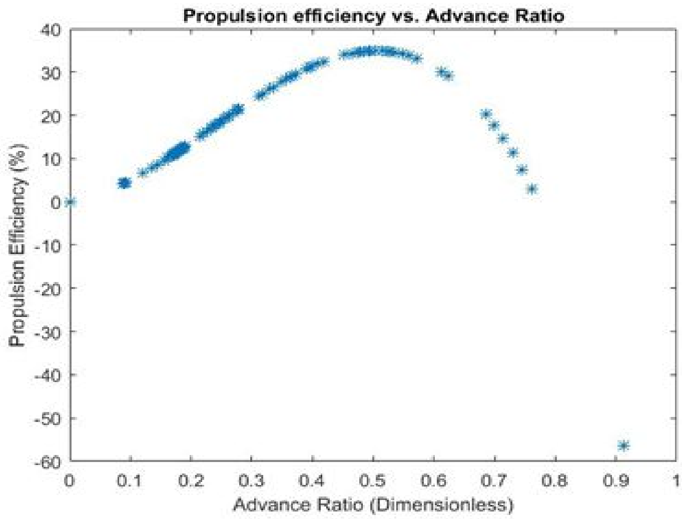


Figure 8. Propulsion Efficiency vs. Advance Ratio at Pusher

Figure 8. Defines the pusher position of the AEV propellers to be the most efficient, with the efficiency peaking at approximately 37%. Though this value is not much higher than the puller's, the difference in Propulsion Efficiency can prove to be beneficial during the duration of the tour.

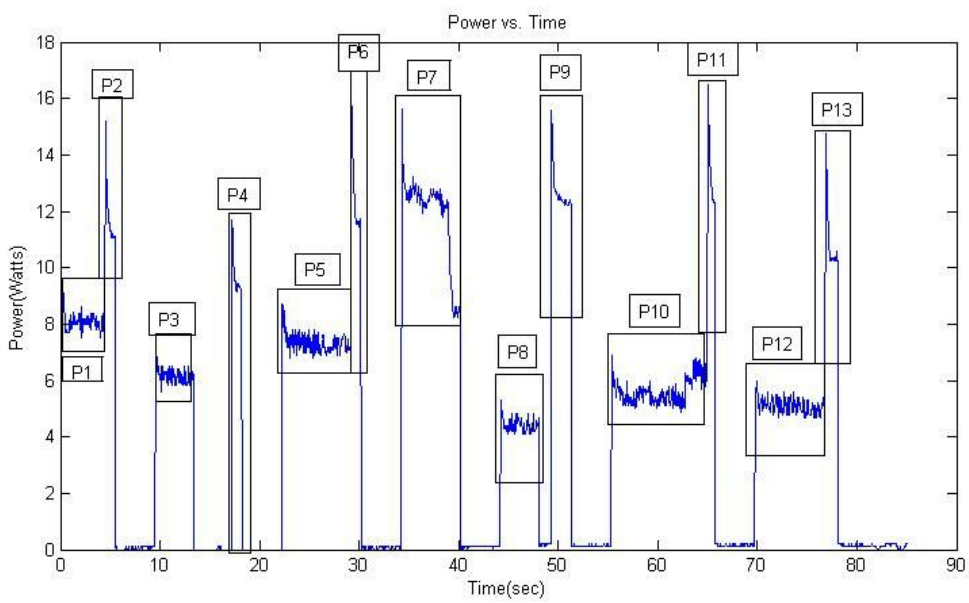


Figure 9. Design 1's Supplied Power vs. Time (with Phases) during Performance Test Run

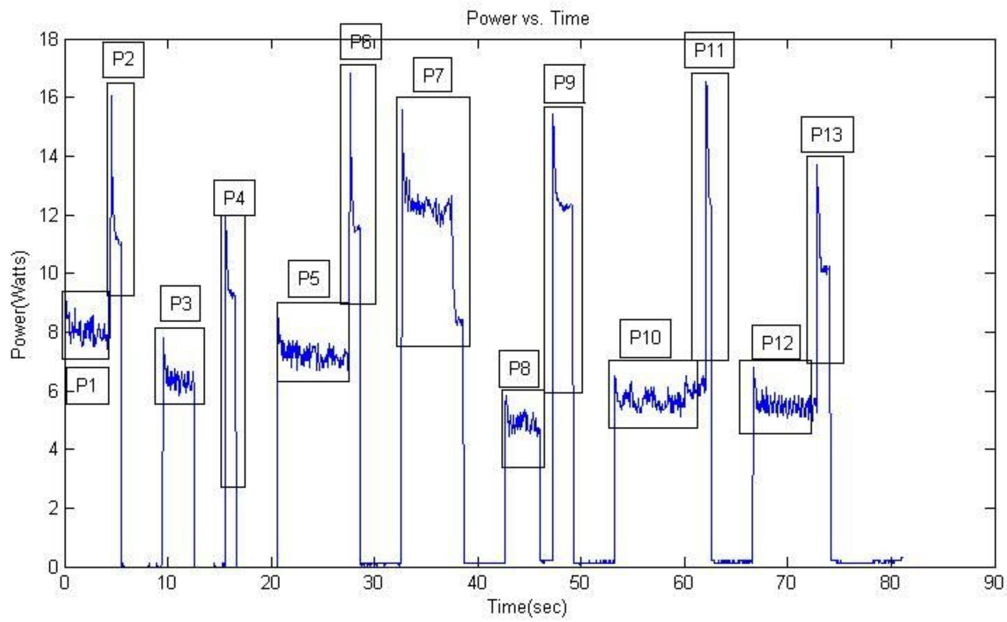


Figure 10. Design 2's Supplied Power vs. Time (with Phases) during Performance Test Run

Phase	Arduino Code		Supplied energy (joules)	
1	motorSpeed(4,26);		40.7035	
	goToAbsolutePosition(-145) ;			
	motorSpeed(4,32);			
	goFor(1);			
2	motorSpeed(4,20);		14.2150	
	goToAbsolutePosition(-145) ;			
	motorSpeed(4,0);			
	goToAbsolutePosition(-8);			
	motorSpeed(4,30);			
	goFor(1);			
3	motorSpeed(4,23);		44.8563	
	goToAbsolutePosition(320);			
4	motorSpeed(4,35);		22.3601	
	goFor(1);			

5	motorSpeed(4,35);		72.6231	
	goToAbsolutePosition(570);			
6	motorSpeed(4,28);		12.4829	
	goFor(1.25);			
7	motorSpeed(4,18);		65.9135	
	goToAbsolutePosition(505);			
	motorSpeed(4,0);			
	goToAbsolutePosition(400);			
8	motorSpeed(4,35);		18.3746	
	goFor(2);			
9	motorSpeed(4,20);		25.8350	
	goToAbsolutePosition(0);			
10	motorSpeed(4,22);		58.6724	
	goToAbsolutePosition(-145) ;			
11	motorSpeed(4,34);		7.9240	
	goFor(.5);			
12	motorSpeed(4,18);		37.4389	
	goToAbsolutePosition(-80);			
13	motorSpeed(4,32);		14.8349	
	goFor(1.25);		**Total Energy**	430.8567

Table 3. Phases, Code and Supplied Energy for Design 1

Phase	Arduino Code		Supplied energy (watts)	
1	motorSpeed(4,26);		42.6841	
	goToAbsolutePosition(-145) ;			
	motorSpeed(4,32);			

	goFor(1);			
2	motorSpeed(4,20);		23.4163	
	goToAbsolutePosition(-145); ;			
	motorSpeed(4,0);			
	goToAbsolutePosition(-8);			
	motorSpeed(4,30);			
	goFor(1);			
3	motorSpeed(4,23);		45.2641	
	goToAbsolutePosition(320);			
4	motorSpeed(4,35);		24.5685	
	goFor(1);			
5	motorSpeed(4,35);		75.9846	
	goToAbsolutePosition(570);			
6	motorSpeed(4,28);		11.8695	
	goFor(1.25);			
7	motorSpeed(4,18);		69.3568	
	goToAbsolutePosition(505);			
	motorSpeed(4,0);			
	goToAbsolutePosition(400);			
8	motorSpeed(4,35);		20.7968	
	goFor(2);			
9	motorSpeed(4,20);		28.9674	
	goToAbsolutePosition(0);			
10	motorSpeed(4,22);		62.7684	
	goToAbsolutePosition(-145) ;			
11	motorSpeed(4,34);		9.8796	

	goFor(.5);			
12	motorSpeed(4,18);		41.6854	
	goToAbsolutePosition(-80);			
13	motorSpeed(4,32);		19.3958	
	goFor(1.25);		**Total Energy**	453.5697

Table 4. Phases, Code, and Supplied Energy for each phase of Design 2

Conclusion

Two different AEV designs were tested along a monorail track in the classroom using the same code to easily compare the advantages and disadvantages of each design. Both designs used the same code to make the comparison easier and more straightforward. Once the designs were tested, the data was pulled from the Arduino board and analyzed to determine which AEV would be the most energy efficient.

After analyzing the data and making physical observations, it was concluded that Design One was the more efficient design but it still needed to be tweaked. The balance of design one was not favorable so the Arduino board and wheelbase were adjusted to mimic the layout of Design Two. Design One also had benefits because it was lighter, faster, and more cost effective which helped the team make the final decision to use Design One. In the future of this project, Design One will be further tested and changed as needed to make the AEV as close to perfect as possible.

One error that occurred throughout the duration of the labs was the lack of battery power. In the beginning the team had trouble getting the AEV to work but it was solved by getting a new battery. Often times when the battery was run too many times without charge, it would weaken the AEV and change the results. To fix this problem the team decided to come in early to charge the battery prior to labs. Often times the team would run into problems when trying to test both AEV's in one lab period because taking apart the AEV was a tedious process due to all the small parts. This was improved by performing multiple tests for one AEV per lab and doing the same tests for the other AEV a different lab. Overall, time management was a big problem because the team found there was not enough time in the lab to perform the proper tests and had to stay late multiple times. This lab could be more efficient by adding another monorail track to the room or not allowing overflow from other classes. As a whole, this lab has been a great success and the team has learned many valuable lessons about problem solving, coding, and engineering as a whole.

Recommendations may include some personal virtues as an Engineering. The field of Engineering, other than, requiring extensive knowledge and experience with tangible concepts, requires a spirit with patience and an overall interest to the study. Throughout the series of AEV labs, there were numerous occasions when systematic failures took its toll, and the students either gave up during the lab or banished the idea of success as a whole. However, with each recurrence of failures and, eventually, returning to the purpose of the course, a bittersweetness is revealed when the students mature against the difficulty. A personal virtue is gained, and accomplishing a successful project seems more possible. The recommendation is to push through many difficulties.

Arduino Code:

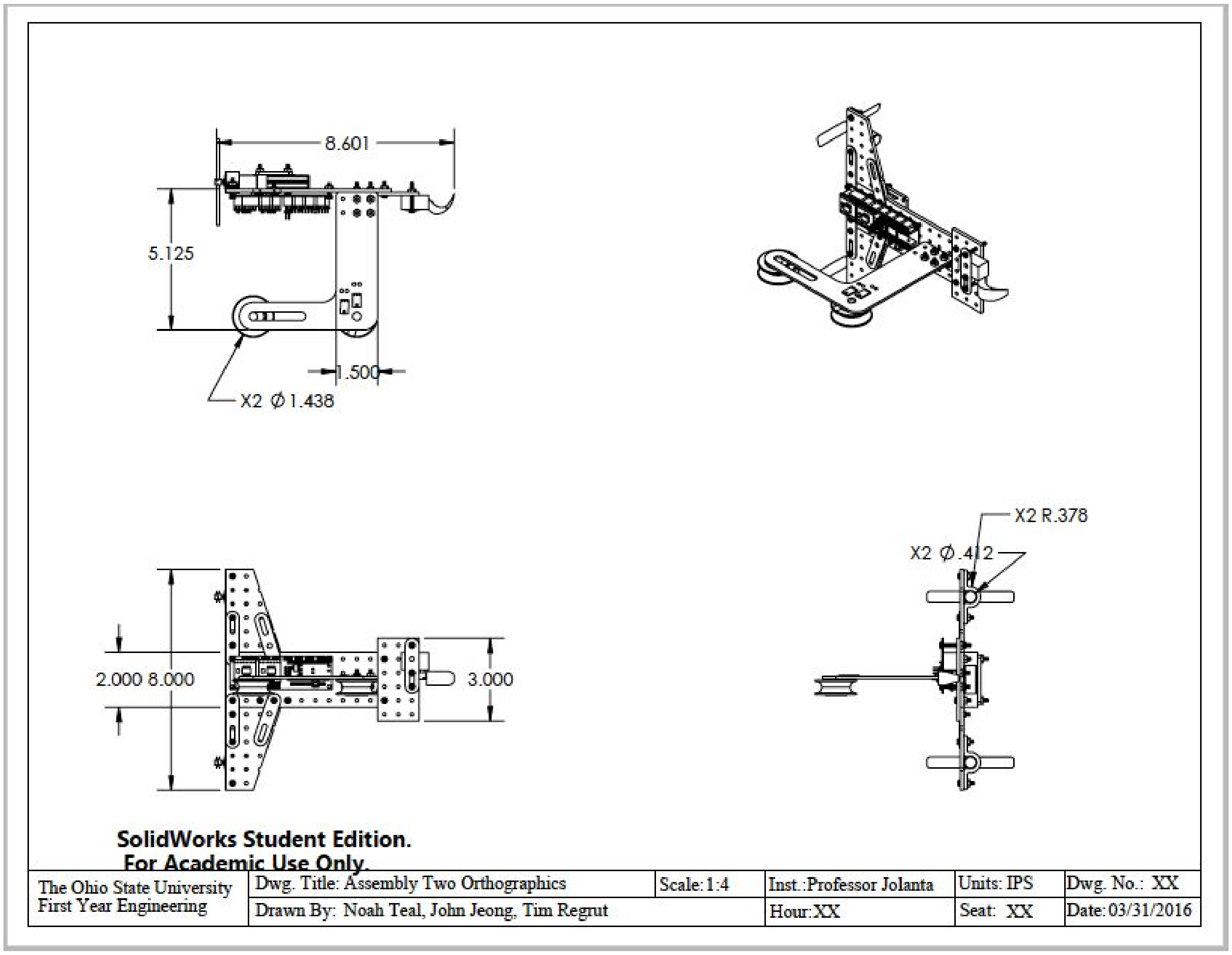
```
reverse(4);
motorSpeed(4,26);
goToAbsolutePosition(-145);
brake(4);
reverse(4);
motorSpeed(4,32);
goFor(1);
brake(4);
goFor(4);
// top of hill to stop at bottom of hill
motorSpeed(4,20);
goToAbsolutePosition(-145);
motorSpeed(4,0);
goToAbsolutePosition(-8);
brake(4);
reverse(4);
motorSpeed(4,30);
goFor(1);
brake(4);
goFor(4);
// bottom of hill to other side of loop
reverse(4);
motorSpeed(4,23);
goToAbsolutePosition(320);
brake(4);
reverse(4);
motorSpeed(4,35);
goFor(1);
brake(4);
goFor(4);
// other side of loop to top of hill
reverse(4);
motorSpeed(4,35);
goToAbsolutePosition(570);
brake(4);
```

```
reverse(4);
motorSpeed(4,28);
goFor(1.25);
brake(4);
goFor(4);
// top of hill to bottom of hill
motorSpeed(4,18);
goToAbsolutePosition(505);
motorSpeed(4,0);
goToAbsolutePosition(400);
brake(4);
reverse(4);
motorSpeed(4,35);
goFor(2);
brake(4);
goFor(4);
// bottom of hill to other top of hill
reverse(4);
motorSpeed(4,20);
goToAbsolutePosition(0);
motorSpeed(4,22);
goToAbsolutePosition(-145);
brake(4);
reverse(4);
motorSpeed(4,34);
goFor(.5);
brake(4);
goFor(4);
// top of hill to maintenance station
motorSpeed(4,18);
goToAbsolutePosition(-80);
brake(4);
reverse(4);
motorSpeed(4,32);
goFor(1.25);
brake(4);
goFor(4);
```

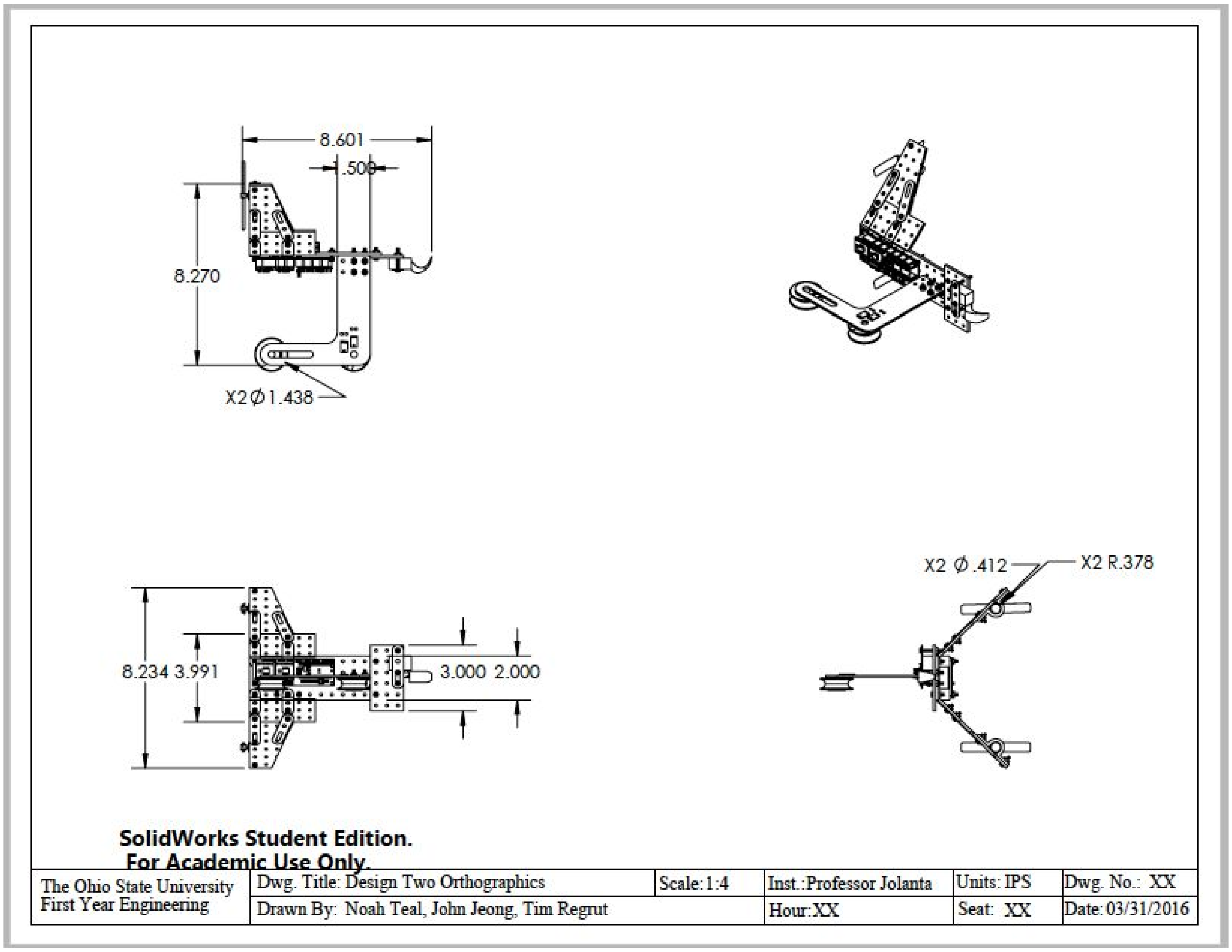
Project Schedule (Performance Test 1)

No.	Task	Start	Finish	Due Date	Teammate 1	Teammate 2	Teammate 3	Completion
1	Wind Tunnel	3/2/16	3/2/16	3/16/16	x	x	x	100%
2	AEV 2 Construction	3/14/16	3/16/16	3/16/16	x			100%
3	AEV 2 Testing	3/14/16	3/14/16	3/16/16			x	100%
4	AEV 1 Construction	3/14/16	3/15/16	3/16/16	x			100%
5	AEV 1 Testing	3/15/16	3/24/16	3/31/16			x	100%
6	TRR	3/14/16	3/15/16	3/15/16		x		100%
7	SolidWorks Models	3/2/16	3/30/16	3/31/16		x		100%

***Teammate 1: Noah Teal, Teammate 2: John Jeong, Teammate 3: Tim Regrut**



AEV Design Two


8.601
.500
8.270
X2 Ø 1.438
X2 Ø .412
X2 R.378
8.234 3.991
3.000 2.000
SolidWorks Student Edition.
For Academic Use Only.
The Ohio State University
First Year Engineering
Dwg. Title: Design Two Orthographics
Scale: 1:4
Inst.: Professor Jolanta
Units: IPS
Dwg. No.: XX
Drawn By: Noah Teal, John Jeong, Tim Regrut
Hour: XX
Seat: XX
Date: 03/31/2016

Bill of Materials

Propulsion System								
	# Given	# Returned	Unit Price	AEV 1 Units Used	Amount Owed AEV 1	AEV 2 Units Used	Amount Owed AEV 2	Replacement Tally
Arduino	1	0	$100.00	1	$100.00	1	$100.00	0
Electric Motors	2	0	$9.99	2	$19.98	2	$19.98	0
Count Sensor	1	0	$2.00	1	$2.00	1	$2.00	0
Sensor Wire	1	0	$2.00	1	$2.00	1	$2.00	0
Servo Motor	1	0	$2.00	1	$2.00	1	$2.00	0
Propellers	6	0	$0.45	2	$0.90	2	$0.90	0
Body Structure								
	# Given	# Returned	Unit Price		Amount Owed			Replacement Tally
T-Shape	1	0	$2.00	0	$0.00	0	$0.00	0
X-Shape	1	0	$2.00	0	$0.00	0	$0.00	0
2"x6" Rectangle	2	0	$2.00	1	$2.00	1	$2.00	0
2.5"x7.5" Rectangle	1	0	$2.00	0	$0.00	0	$0.00	0
1"x3" Rectangle	4	0	$1.00	1	$1.00	3	$3.00	0
1.5"x3" Rectangle	3	0	$1.00	0	$0.00	0	$0.00	0
Trapezoids	4	0	$1.00	2	$2.00	2	$2.00	0
L-Shape Arm	1	0	$3.00	1	$3.00	1	$3.00	0
T-Shape Arm	1	0	$3.00	0	$0.00	0	$0.00	0
Wheels	2	0	$7.50	2	$15.00	2	$15.00	0

Battery Supports	2	0	$1.00	1	$1.00	1	$1.00	0
Brackets & Tools								
	# Given	# Returned	Unit Price		Amount Owed			Replacement Tally
Angle Brackets	12	0	$0.84	2	$1.68	6	$5.04	0
Screw Driver	1	0	$2.00	1	$2.00	1	$2.00	0
1/4" Wrench	1	0	$2.00	1	$2.00	1	$2.00	0
Motor Clamps	2	0	$0.59	2	$1.18	2	$1.18	0
#55 Slotted Strip, 2"	8	0	$1.26	0	$0.00	0	$0.00	0
Hardware								
	# Given	# Returned	Unit Price		Amount Owed			Replacement Tally
Bulk Screws & Nuts	1	0	$2.88	1	$2.88	1	$2.88	0
				AEV 1 Total:	160.62	AEV 2 Total	165.98	