Critical Design Review

Submitted to:
Inst. Phil Schlosser
GTA Melissa Hrivnak

Created by:
Team D

Yuyi Chang
Kaitlyn Parker
Rachel Schwanekamp
Joshua Subler

Engineering 1182
The Ohio State University
Columbus, Ohio
21 April 2017

Executive Summary

The team had one main goal for the mission, to acquire the other vehicle on the other side of the track and bring it back to the starting position for the AEV. A secondary focus of the team was to accomplish this as efficiently as possible, in terms of energy and cost. Another one of the foci the group had was develop a code that would complete the mission as fast as possible.

To do this the team had to have the AEV stop at a gate twice, once on the way and once on the way back to the starting position, and hold at that position for seven seconds for the gate to come down. Furthermore the team had to reduce parts on the AEV, specifically some of the more expensive and heavy parts, which would both help efficiency and the speed on the AEV along the track.

To determine how the team was doing when it came to accomplishing this goal, they relied heavily on the EEPROM data that would be extracted from the AEV after a run. This data would be downloaded, and would tell the team how energy intensive the run was. This would lead to minor adjustments on the code to increase the efficiency, gradually bringing the team under the 300 joule line.

The team's final AEV was very similar to the stock AEV, with some modifications. The first of these modifications was that the arduino board was placed on the bottom of the board, hanging. This was done to increase the balance of the AEV, something the team found was very important as it would affect the energy consumption of the AEV, as a bad balance cause lateral movement when the AEV accelerates. This was the major finding for Performance Test 1.

The major finding from the second performance test was how to develop the code going forward. The team realized through the data that was extracted from the AEV was that they needed to use a code that would be based off the position of the AEV, as opposed to time as the was originally trying to do. The issue with time, the team found, was that it was not consistent. The team also determined the way it would stop the AEV, through determining if the AEV was moving backward or not when coming to the gate. This allowed for greater control of the AEV. In the third and final test the team allowed the AEV to coast half the time to reduce the energy the AEV was using. This did open the door to some inconsistency, but not enough to deter from the increased efficiency. This would offset some of the energy costs from the air brake the team was using throughout the run.

Ultimately all of this lead to the team successfully making it around the course in just under a minute, by .02 seconds, and to be under 300 joule mark, at 294 joules used throughout. This gave the team a score of 80.0 when the perfect 50 was multiplied by the delta T, and gave the team a 1087 J/kg ratio, which was an average value.

Table of Contents

List of Tables and Figures

Introduction

The goal of the mission was to construct an Advanced Energy Vehicle (AEV), and develop a code to send it around a track, stop at a gate twice, pick up another vehicle, and return back to the starting position. The team did this through a series of tests that took them through the design phase. This was done through labs were the team came up with individual designs and scored these design based on their own parameters. There was also hardware tests to ensure everything was working on the AEV. These tests and design phases will not be explained in great detail, but are worth noting.

The first of these tests, named Performance Test 1, lead the team down the path to which AEV they would uses. This is important as some codes do not work with some AEV designs, due to weight to thrust ratio issues. The second test, the team was instructed to determine what they would use for the major parameters for coding going forward, be it time or marks. This test determined how the team would code for the rest of the time, making it perhaps the most important test. The final test before evaluation was to determine how the team would make the AEV more energy efficient. This was important as this a major key to the team's evaluation, as the point of the AEV was to be as energy efficient as possible.

Experimental Methodology

In Performance test 1 , the team had to determine which vehicle design they would continue to work with. The team tested each design with the same code to compare them equally. First, they ran each design on the straight track. They then used the data from the runs to see how the AEV designs used energy. Next, the team ran the designs on the actual track, making them stop at the first gate. Data was collected from each of these runs and compared as well. Using the data that the team collected, they were able to make a concise decision on which AEV they would continue to test with.

By Performance test 2 lab, the team had already selected their vehicle, and had been getting familiar with coding. Initially, the team had been using a code that utilized time as their main means for moving the AEV. Instead, the team decided to use a code that used marks. To accomplish this, the team essentially guessed and checked how many marks they needed to code their AEV to go. Their goal was to get the AEV to the gate. They started with 500 marks, and using the goToRelativePosition function, they coded their AEV to travel 500 marks. This ended up being too much, so they coded their AEV to go 450 marks, and repeated this until their AEV's motor stopped soon enough that their AEV coasted to a stop before the gate.

During Performance test 3 lab, the team was instructed to use their chosen AEV, and their chosen coding strategy to finish their code. They were also instructed to modify their code in any way to help the AEV run in a more energy efficient way. The team completed this by writing their code incrementally. First, the team programmed their code to get to the first gate and stop. Next, they coded how long the AEV would wait at the gate. Then, they coded the AEV to move through the gate, attach to the caboose, and wait five seconds. After that, the code was essentially the same - just moving backwards. There was only a small change that they had to make in the code. The team had to figure out how much extra power the AEV needed to pull the additional weight of the caboose. They did this by starting with 5% more power, and then increasing by 5% every run until the power setting made the AEV pull the caboose as fast as when the AEV ran by itself. Once the code was complete, the team repeatedly tested the AEV on the track to make sure that it worked every time.

Results

The final score of the AEV and the code was a 50 out of 50. This means the team completed everything in the MCR without any extra contact to the AEV. The total time it took for the AEV to travel along the track was just under 60 seconds, 59.98 to be exact. This meant that the adjusted score for the design was 80.0, about the average in the class. The energy consumed by the AEV along the run was 294 J, and the total weight of the AEV was .271 kg. This lead to a energy to weight ration of 1087 J/kg ratio, about average throughout the class.

Table 1: Design Scoring Matrix

	Given	Yuyi	Josh	Rachel	Kaitlyn	Team	Yuyi.2
Cost	0	-	-	+	-	-	+
Energy Efficiency	0	0	+	-	0	+	-
Balance	0	+	+	+	+	+	+
Durability	0	+	0	+	0	+	0
Weight	0	-	-	-	-	-	0
Maintenance	0	-	0	0	-	0	+
Aerodynamics	0	+	+	-	+	+	-
sum +	0	3	3	3	2	4	3
sum 0	7	1	2	1	2	1	3
sum -	0	3	2	3	3	2	2
Net Score	0	0	1	0	-1	2	1
Continue?	No	Develop	Develop	No	No	Develop	Develop

This is an updated scoring sheet based off of the tests results. In the original scoring sheets the team valued Yuyi's second design much higher than they should have, as the test would eventually would show.

Table 2.1: Design Screening Matrix

	Given			Yuyi		Josh	
	Weight	R	WS	R	WS	R	WS
Cost	15.00%	3	0.45	2	0.3	2	0.3
Energy Efficiency	25.00%	3	0.75	3	0.75	4	1
Balance	15.00%	2	0.3	4	0.6	4	0.6
Durability	5.00%	3	0.15	4	0.2	3	0.15

Weight	20.00%	3	0.6	2	0.4	2	0.4
Maintenance	5.00%	4	0.2	3	0.15	4	0.2
Aerodynamic	15.00%	2	0.3	5	0.75	4	0.6
Total Score			2.75		3.15		3.25
Continue?			No		Develop		Develop

Table 2.2: Design Screening Matrix - Continued

Rachel		Kaitlyn		Team		Yuyi 2.0	
R	WS	R	WS	R	WS	R	WS
4	0.6	2	0.3	2	0.3	5	0.75
2	0.5	3	0.75	4	1	3	0.75
3	0.45	3	0.45	3	0.45	3	0.45
4	0.2	3	0.15	4	0.2	3	0.15
2	0.4	2	0.4	2	0.4	4	0.8
4	0.2	3	0.15	4	0.2	5	0.25
1	0.15	3	0.45	5	0.75	2	0.3
	2.5		2.65		3.3		3.15
	No		No		Develop		Develop

Note: R - Rating, WS - Weighted Score, E. Efficiency - Energy Efficiency

The two pictures above are the updated scoring sheets after the tests happened. The major change is to Yuyi's second design which is no longer the highest score out of all of the designs. This again reflects what happened during the tests, when that design was not powerful enough to propeller the AEV with any sort of efficiency.

Discussion

The total cost of the AEV was $160. The cost includes boards, motors, wheels, and any other support devices used on the AEV. The team reduced the cost by not using excess amount of connection parts as well as switching larger board to smaller one. Although the second design as proposed in preliminary design review reduced the cost significantly by uninstall one motor, the design was still not used because the performances were inconsistent where this negative effect was larger than the positive effect brought from reduced system cost.

The energy cost of the AEV in typical test run was about 300 J. The energy was calculated based on the EEPROM data downloaded after each test run. The most part of the energy was used after the AEV picked up the R2D2 where weight of the assembly greatly increased, resulting a higher friction when moving on the track.

The performance tests affected the team's design process on both hardware and software parts. On the mechanical part, the team revised the selected AEV design by changing the mounting position of the Arduino and T shape board, which helped the AEV to have a better center of gravity. Originally the Arduino was faced up and mounted at the front of the AEV, and the T shape board was connected with the base board near the Arduino board. The team found in the test run that after picking up the R2D2, the AEV became easily to face upward where the front wheel lost contact with the track. This caused a safety hazard for AEV operation, and it was believed to lead some mark sensor error due to the imbalance position. After the modification, Both Arduino and the T shape board were placed at relative the center of the base board. The Arduino board was mounted facing downward on the base board in order to make more space for the connection of T shape. The position of two wings with motors mounted were also changed to make sure the center of gravity of the AEV was remain roughly at the center vertical line on the base board. The revisement was kept in as simple as possible so that not delay was caused due to the modification.

Two types of propellers were provided the beginning of the building season, the propeller 3030 and propeller 2510. The choice of propeller was developed based on wind tunnel test data. The figures shown below demonstrated the relationship between propulsion efficiency and advance ratio of the two propeller. These data was calculated from calibrated thrust as well as motor RPM. Knowing that the propulsion efficiency suggested the energy efficiency of the propellers. The more efficiency the propeller was, the more the energy was used to move AEV forward. According to the graphs, the propeller 3030 had a efficiency of about 50%, wherase the propeller 2510 only had a maximum of 17% efficiency. Since the project was seeking for an optimal energy consumption, the team decided to used propeller 3030 so that the energy efficiency could be maximized whatever the amount of power was used in the operations.

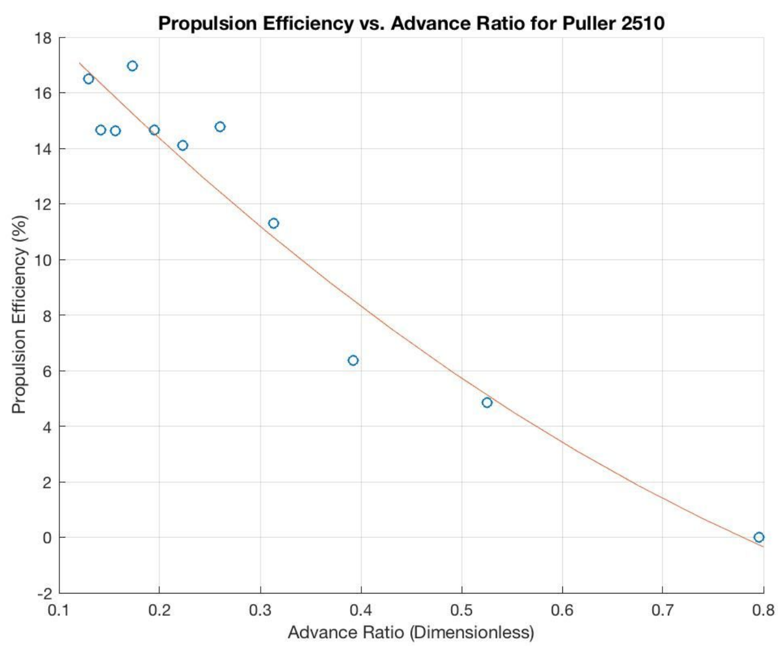

Figure 1: Propulsion Efficiency vs. Advance Ratio for Puller 2510

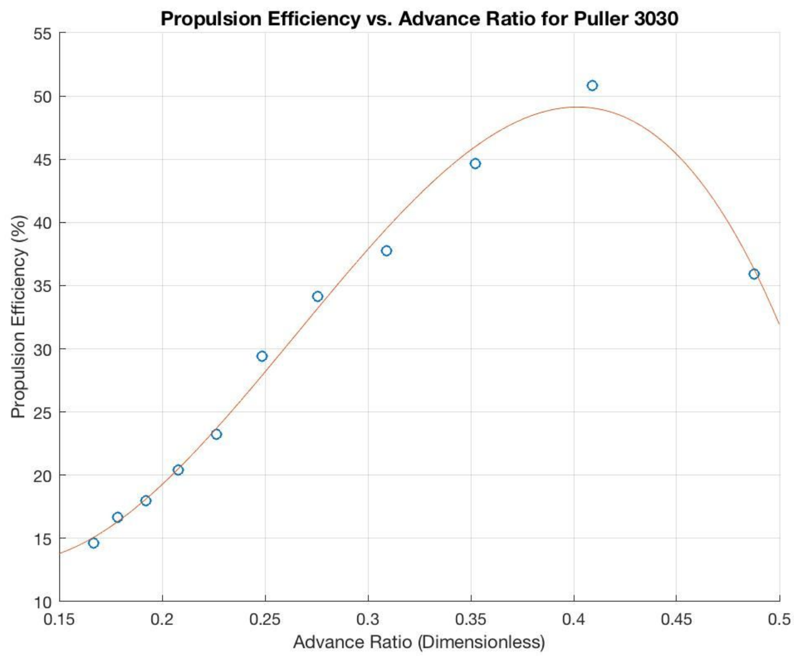

Figure 2: Propulsion Efficiency vs. Advance Ratio for Puller 3030

The EEPROM data was downloaded from test run to analysis the AEV total energy consumption and energy used in each phases. The data was converted into physical parameters, and the supplied power was calculated based on the physical parameters. The relationship between supplied power and time on the track was shown below.

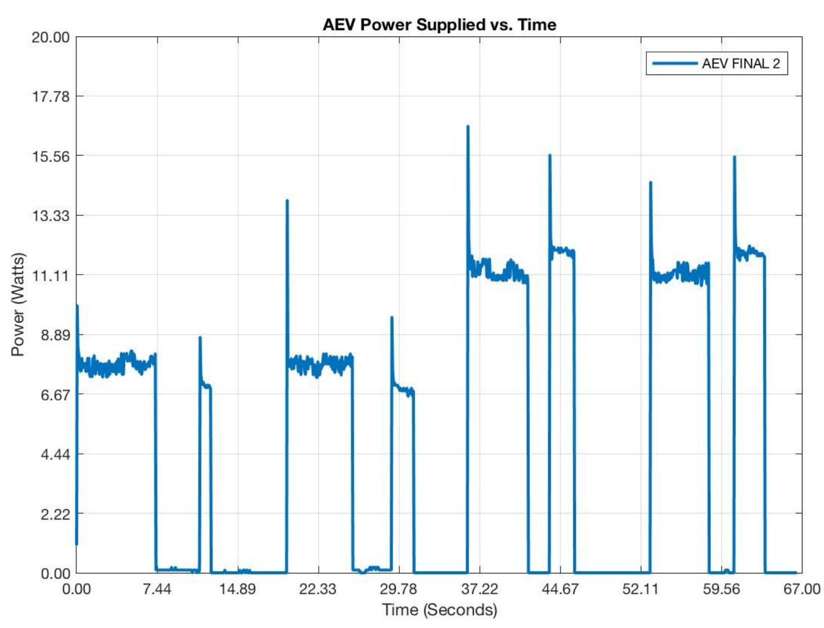

Figure 3: The supplied power vs. time in typical test run

As can be seen from the figure, the AEV started accelerating in the first phase with an average supplied power of 8.33 W which lasted for 5 seconds or about 3.0 meters. After casting about 500 marks, the AEV initiated the reverse power and stopped at the gate. The AEV didn't start moving until waiting 6 seconds at the gate. The AEV followed the accelerating - casting - reversing thrust procedures to pick up the R2D2, and finally returned to the start position. The team calculated the energy used in each phases, and the energy used in each section can be found in table 1 as shown below.

Table 1: Energy used in each phases during typical test run

Phase	Energy Used (J)	AEV Code

1	57.42	reverse(4);
		motorSpeed(4, 30);
		goToRelativePosition(263);

2	0.00	reverse(4); // Reverse polarity
		motorSpeed (4,0);
		goToRelativePosition(205);

3	7.98	motorSpeed(4,30); // Set all motors speed to 30%
		while(getVehicleDirection() == 1){
		goFor(0.001);
		}

4	0.00	motorSpeed(4,0); // Set speed to 0
		goFor(7); // Wait 7.5 sec

5	49.20	reverse(4);
		motorSpeed(4,40);
		goFor(0.05);
		motorSpeed(4, 30);
		goToRelativePosition(275);
		brake(4);

6	0.00	motorSpeed(4,0); goToRelativePosition(218);

7	14.05	reverse(4);
		while(getVehicleDirection() == 1){
		motorSpeed(4,30);
		goFor(0.01);
		}

8	0.00	motorSpeed(4,0);

		goFor(5);

9	62.19	motorSpeed(4, 45);
		goToRelativePosition(-247);
		brake(4);

10	0.00	motorSpeed(4, 0); goToRelativePosition(-175);

11	27.01	reverse(4);
		while(getVehicleDirection() == 0){
		  motorSpeed(4,55);
		  goFor(0.001);
		}
		brake(4);

12	0.00	goFor(7);

13	60.05	reverse(4);
		motorSpeed(4,45);
		goToRelativePosition(-270);
		brake(4);

14	0.00	motorSpeed(4,0); goToRelativePosition(-180);

15	33.11	while(getVehicleDirection() == 0){
		    motorSpeed(4,45);
		    goFor(0.001);
		}

Total Energy Used		311 J

Two final test runs were conducted in the test session. The first test run resulted in 42 out of 50, while the second test run resulted the full credit. During the first run, the AEV encountered several issues that rarely happened in the previous test runs. The first penalty happened when the AEV first attempted to cross the gate after stopped for 6 seconds. The AEV was stuck on the truck after the forward motor power was initiated. This happened because the AEV stopped at the connection nord between two sections of tracks. The connection part formed a little cave that prevent AEV from accelerating under given motor power. The second penalty happened after the AEV tried to stopped at the mid of the gate. This happened after the AEV successfully picking up the R2D2; however, the AEV assembly went too fast when approaching the gate. The second approach sensor installed on the gate was triggered. As a result, one of the team member had to push back the AEV and held the AEV after the gate was opened. The result from first run was not satisfactory since extra energy was consumed as well as waste of time. In this case, the second test run was performed shortly after the first one. The AEV operated perfectly in the last run which result in 50 out 50 points. The total energy used in this run was 296 J, and the total time spent on the track was 60.0 seconds. The AEV and the R2D2 were stopped at the expected locations, as well as the full completion of MCR while following the safety testing procedures.

Conclusion and Recommendations

The AEV project consisted of mechanical design, control program develop, documenting, system analysis, and team work. In order to produce a satisfactory AEV design, the team understood the features of each component and the mission concept. The preliminary AEV designs were proposed individually based on different design factors. The team design, came from the integration of individual designs, was revised and improved based on the performance test results. The final AEV was capable to complete all mission requirements as well as operating safely and consistently. The AEV was able to fully complete the mission concepts.

The total run time was 60 seconds with about 300 J energy consumption. The consistency of the AEV was guaranteed by using a closed-loop speed control to make sure the AEV could completely stop at the gate every time.

The final design of the AEV was a picked because of its ability to perform well on the track. It was faster, had a better center of gravity, and it was better at handling track inconsistencies than other designs. In comparison with the other AEV's in the classroom, what made this AEV stand out was its code. The code used a while loop as an extra security to ensure that the AEV was traveling in the right direction during stops. This helped the team deal with inconsistencies and variations among different tracks.

A recommendation for the AEV project is to have students test their AEV for marks error earlier in the semester. The team's AEV's sensors were faulty, and it wasn't until about halfway through the semester that they were instructed to test their sensors. Up until that point, the team struggled to make their code work, and they didn't know why. This put the team behind, and they could've focused their efforts on improving their AEV instead of trying to write a code that was never going to work with the original sensors.

Appendix

Task	**Start Date**	**Due Date**	**Primary Person**	**Secondary Person**	**Est. Time**	**% Complete**
Lab 2 Report	1/17/17	1/24/17	Yuyi - submit report	All	3 hr	100
Lab 3 Report	1/24/17	1/31/17	Josh - submit report	All	3 hr	100
Lab 4 Report	1/31/17	2/7/17	Rachel - submit report	All	3 hr	100
Lab 5 Report	2/7/17	2/14/17	Kaitlyn - submit report	All	3 hr	100
Lab 6 Report	2/14/17	2/21/17	Yuyi - submit report	All	3 hr	100
Lab 8 Report	3/3/17	3/10/17	Rachel - submit report	All	3 hr	100
PDR	2/14/17	3/27/17	Yuyi - submit report	All	5 hr	100
Lab 10 Report	3/24/17	4/3/17	Josh - submit report	All	3 hr	100
Lab 11 Report	3/31/17	4/10/17	Rachel - submit report	All	3 hr	100
Final Project Report	4/3/17	4/21/17	Yuyi - submit report	All	7 hr	100
Oral	3/22/17	4/21/17	Josh -	All - practice	3 hr	100

Presentation - Final			submit draft	and present		
Project Portfolio	1/24/17	4/21/17	Kaitlyn - adjust layout, add info	Rachel - ensure info is correct and accurate	7 hr	100
AEV Initial Construction	1/24/17	3/27/17	Yuyi - bring AEV to class, ready for assembly	All - assist in assembly	2 hr	100
AEV Final Construction	3/28/17	4/21/17	Josh - bring AEV to class, ready for assembly	All - assist in assembly	3 hr	100
AEV Solidworks Modeling	3/23/17	4/21/17	Yuyi - begin basis for modeling	All - ensure models look correct	3 hr	100

SolidWorks Drawing

Design 1
Estimated Weight: 201 g

Table 2: Estimated Cost for Final Team Design

	Qnty	Price
Electric Motor	2	$19.98
Arduino	1	$100.00
Count Sensor	2	$4.00
Count Sensor Connector	2	$4.00
Propellers	2	$0.90
2.5" X 7.5"	1	$2.00
1" X 3"	4	$4.00
Trapezoid	2	$1.00
Wheel	2	$15.00
Battery Support	1	$1.00
Angle Brackets	8	$6.72
Motor Clamps	2	$1.18
		$159.78

The orthographic and assembly drawing with bill of materials can be found in the next pages.