Preliminary Design Review

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Columbus, OH
March 23, 2017

Executive Summary

The purpose of this project is to work with concepts of project management and teamwork, the design process, and project documentation. Project management is demonstrated through the upkeep of a project portfolio that tracks what the lab group is doing in each lab and shows how the team got to its final product. The team must work together on the project and present its findings to demonstrate teamwork. The design process includes various steps that include identifying requirements and constraints, gathering background information, brainstorming concepts, identification of materials, initial design and analysis, and completing a cycle of building, testing, modifying, and documenting. Project documentation is done by creating progress reports each week along with midterm and final written reports, a project portfolio, and an oral presentation.

The group is creating an Advanced Energy Vehicle (AEV) to help the Rebel Alliance prepare for war with the Galactic Empire who is rebuilding their army. The Rebels must prepare on remote planets to avoid detection by the Empire and ensure that their operations are not known. The remote planets have limited resources and need the AEV to be able to function with as little power as possible. The vehicle will be used on a monorail system to transport R2D2 units to the area where interceptor aircrafts are being assembled. Due to the lack of resources on the planet, the vehicle must use as little energy as possible to pick up and deliver the cargo.

Labs 01 through 09 have resulted in several conclusions. The most important among these include the propeller choice, overall considerations, and main focus. The different propellers were tested during Lab 02, and it was found that the puller orientation was more effective than pusher. It was also determined from the data that the 2510 propellers would be more efficient than the 3030 propellers. However, when this was tested in the next lab, it was found that the 2510 propellers could not produce enough thrust to move the AEV, and the 3030 propellers had to be used. In Lab 03, the group members each brainstormed a design for the vehicle, and then all the ideas were put together into one design for the group. The design had a nose in the front to increase aerodynamics, and it was at this point the group realized that it had left out some considerations. The most important consideration that was forgotten was that the AEV had to travel backwards. The nose put in the front would create more drag on the way back and decrease efficiency, so the group learned to consider all aspects of the mission before designing. When performing concept screening and scoring in Lab 05, it was found that none of the initial designs had the qualities desired such as balance, aerodynamic, and lightweight. Therefore, an entirely new design was created focusing on lightweight. This is because if the vehicle is lightweight, it will have fewer materials and more energy efficiency which would help meet several criteria by focusing on just one. This was exemplified in the next design which was intended to have the least amount of weight as possible.

It is recommended that the above results are taken into consideration for the Rebel Alliance as they build an Advanced Energy Vehicle. 3030 propellers should be used because they provide considerably more thrust than the 2510 propellers. They should be used in a puller orientation in order to maximize efficiency. The vehicle design should have a focus on being lightweight in order to keep material costs low and conserve energy which is limited on the remote planets. The Rebel Alliance should also be sure that the final design chosen considers all parts of the mission including moving forwards, backwards, and stopping.

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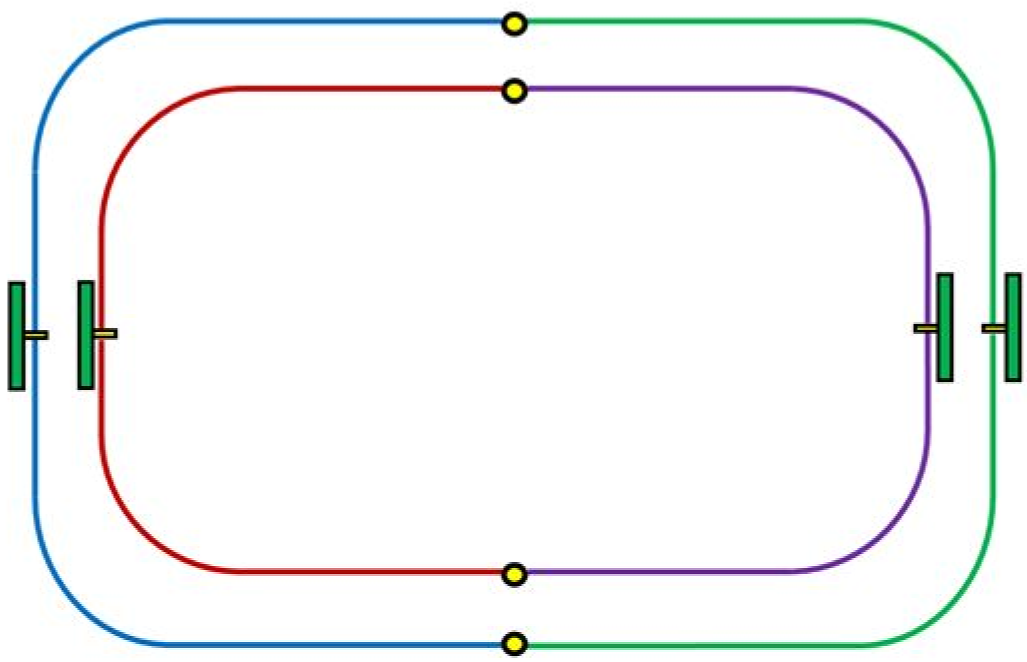
Introduction

The purpose of the project is for the group to work with and practice skills related to project management and teamwork, the design process, and project documentation. Project management is practiced by updating a project portfolio to help maintain appropriate progress each week until the project is completed. Teamwork is practiced by working together on the development of the AEV, including its construction, testing, and documentation. The group will experience going through the design process by identifying the requirements and restraints of the project, gathering all background information, brainstorming ideas, deciding what materials are needed, completing an initial design and analysis, and finally building, testing, modifying, and documenting the vehicle. The documentation will be completed by writing progress reports each week to record the advancements made, writing a midterm and final report, consistently adding to the project portfolio, and lastly an oral presentation.

This report goes into detail of what the group has done through Lab 09. The experimental methodology describes what procedures have been completed and how they have been completed. It also includes all the tools that were used or required to perform each task. The results involve what was found by completing the procedures and highlights the important takeaways from the tests performed. It includes any observations made, data collected, and data analyzed during the process of creating and testing the AEV. In the discussion, the results are analyzed to find what they mean in relation to the project. It describes how the findings affect the construction and design of the AEV. The current designs are reflected in the summary/conclusions. It shows what the items in the results and discussion eventually led to, and examines how they impacted the designs that is currently used. Finally, an appendix is included to provide images of the prototype designs created in SolidWorks and a schedule detailing the plans for completing the project.

Experimental Methodology

This lab has a very generalized procedure that revolves around the goals of the mission. The first step in the procedure is to define the equipment needed to design the alternate energy vehicle. The most important pieces of equipment needed for the AEV to complete its mission is the Arduino controller, motors, propellers, battery, wheels to sit on track,a magnet, and a base to hold all of these parts in one place. The group will choose a design that combines all of these parts onto the base in the cheapest, easiest, least time-consuming, and efficient what possible. Once the design is determined, the group will use the arduino controller and a computer program to program the AEV to perform an exact mission given at the beginning of the year. The mission is to use the motors to move the AEV down a track, stop just short of a gate, wait ten seconds for the gate to open, go to end of track and pick up an R2D2 unit using a magnet, and then return back the same way. The AEV will stop at the gate for another ten seconds until it open and the AEV can return to its starting point with the R2D2 unit. The AEV is programmed to do this because the commands being typed on a computer are uploaded to the arduino, which then runs those specific commands on the motors attached to the AEV.



***Layout of tracks being used for the AEV to run on**

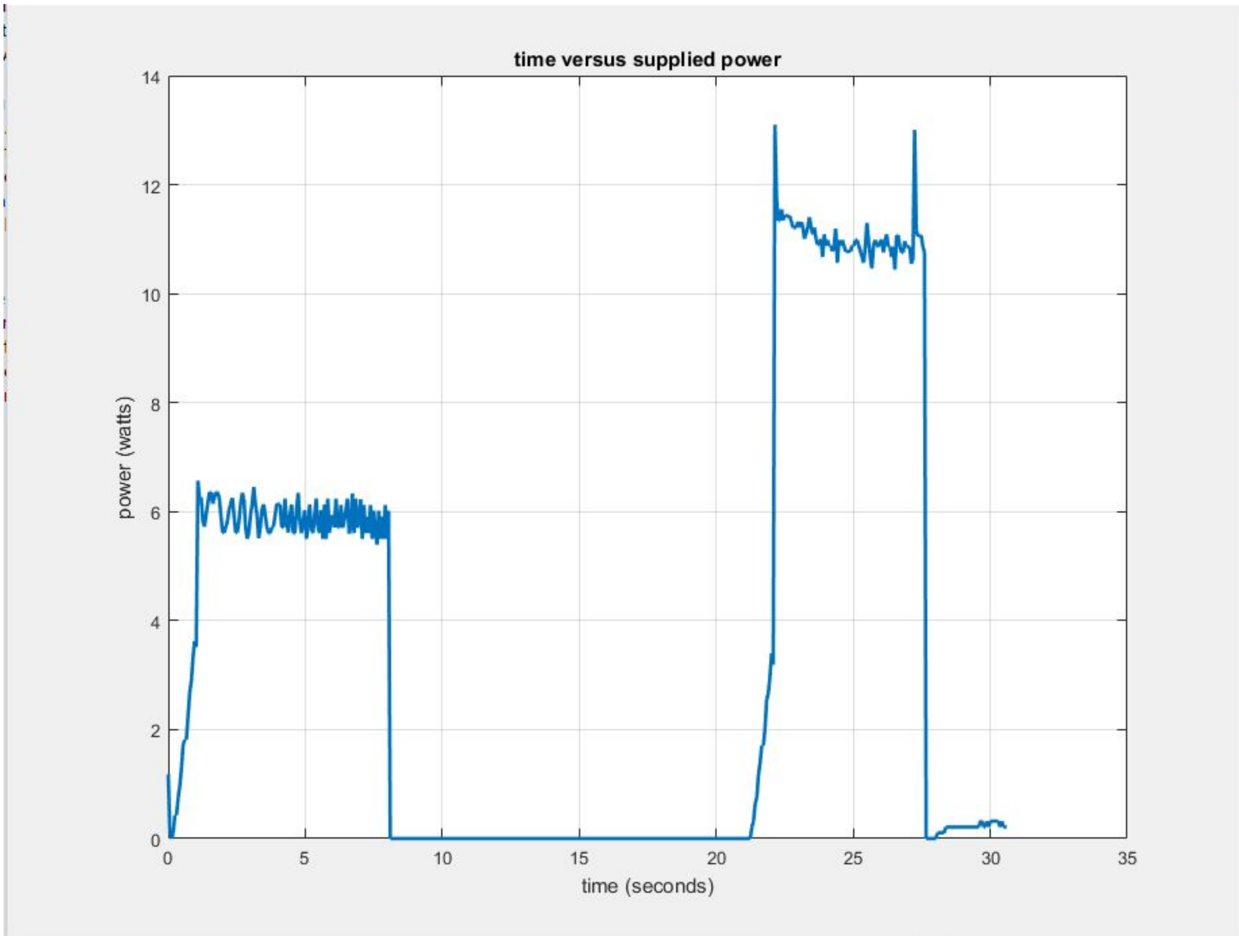
Results

The two designs used in the first performance test were designs almost identical to the AEV design used in most of the labs to test codes as well as serving as the reference AEV design when constructing the concept screening and scoring sheets in lab 5. None of the four designs from the team members scored a higher score than the reference design, so they didn't have any influence on the other design tested in the first performance test, except for showing the missing attributes needed to be included in the second design. The group, after finding out the flaws in each of the four designs, worked together to come up with a second design. This design, shown in the Appendix, was a vertical design with the motors on each end (front and back) such that one pushes while the other pulls and the battery and Arduino being attached in the middle (one on the left and the other on the right). The new design was then included in the concept screening and scoring sheets from lab 5 to see if the desired attributes were reached. The revised concept screening and scoring sheets can be found in the Appendix labeled "Concept Scoring," "Concept Scoring," and "Weighted Concept Scoring."

The runs with the code provided insight on how well one design worked compared to the other (for each prototype). The 3030 propeller was used over the 2510 propeller based on the results from an earlier lab, which showed the 3030 propeller was much more efficient the 2510 propeller. The results can be found in the Appendix as Charts 1 and 2 respectively. Figure 2 shows the propulsion efficiency compared to advance ratio of the 3030 propeller. In addition, in the first test done on the track from several weeks ago, the group tried 2510 propellers, which hardly moved the AEV, but then the group switched to 3030 propellers and were able to move the AEV significantly better. The first design tested was one which was similar to the design the group constructed on SolidWorks. However, since the design was not made on the first day of testing, the group constructed a similar design with the provided AEV pieces. The design constructed did not include the vertical piece of the upside-down T-shaped base, just the horizontal piece, which would provide enough insight on how to design and adjust the code when the base piece is printed for a second time. It must be printed again because the first piece printed was not dimensioned correctly, as the part behind each motor (where the wires come out) was not accounted for in horizontal length so the motors did not fit. The motors on this vertical piece would work together in different configurations, as one would be in the puller configuration while the other would be in the pusher configuration so the motors would not offset. This required a slight adjustment in the code for the second piece tested. The other piece tested was a horizontal piece with a shape resembling a lowercase "t." Each motor would be in the same configuration, so the code was adjusted to remove the reverse function to one motor. Other than that, the successful code in the performance test for the first prototype was used in the performance test for the second prototype. The successful code was able to move the AEV forward on the track and then come to a stop right before the gate. The gate was allowed to open and then the AEV vehicle moved through the gate before crashing into the block at the end of the track. When the same code was used in the second design, the second prototype hit the gate somewhat forcefully, indicating the second design was much more efficient than the first because it used the same percent power for the same amount of time but would have traveled a lot further (if it wasn't stopped by the gate). This was an unexpected result as the group anticipated the first design to be much more efficient than the second.

The results from the test runs have not changed much in terms of the team's design process, but the team is looking at the results and considering why the second design was more efficient than the first. Another piece needs to be printed that better fits the horizontal parameters of the upside down T and then tested and compared to the second prototype. The information from the first test, in which a vertical representation is depicted below on page 6 as Figure 1. The first had five phases in which it ran, although the last phase occurred after AEV crashed into the end of the track. The energy used at each phase (in increasing order) was 0.041894, 43.086386, 0.006414, 62.381854, and 0.576057, with a total energy used amounting to 106.092606. Phase 1 was represented by the first accelerate function, celerate(4,0,25,.5). Phase 2 was represented by goFor(7) in which the AEV moves at 25% power for 7 seconds. Phase 3 was represented by brake(13), which cut the power to the motors. Phase 4 was represented by both the a celerate and goFor function. The two respective functions were celerate(4,0,40,.5) and goFor(5.5). Phase 5 was not represented by a function of code because phase 5 was when the AEV hit the end point of the track and fell off. Two different speeds were tested on the track, with each accelerating in the same amount of time and the second speed running for a shorter time. Even though it ran for a shorter amount of time, the second speed, 40% (phase 4), used much more energy than the first speed, 25% (phase 2).

Figure 1



Discussion

Through the groups test runs two prototype designs were used. These different designs are based off what the group has in mind for the final design. The design will use a vertical design with a focus on using propellers in two different ways. The propellers will be used one in front of the vehicle with the blade pulling the vehicle, and the other will be in the back pushing the vehicle. The sides of the base will be used to hold the battery and the arduino. The thought behind using both propeller methods is that the same energy will be used for all the directions that the vehicle will have to travel. Of course on the way back through the track there will be more power used in order to transport the cart carrying R2D2.

In the prototype test run 1, a design was used that is extremely similar to the that of the final design. The major difference being that the final design will use custom designed parts and not just simply the ones provided in the AEV kit. Along the way some issues with coding were experienced. These issues were resolved by decreasing the time in which the vehicle is accelerating from 1.5 seconds to .5 seconds. Also, the time in which the vehicle was at 25% speed was changed from 8 seconds to 7 seconds. The errors encountered that lead to this change were the vehicle running into the gate and not stopping at the correct time to allow the gate to open.

The second prototype was not able to be tested due to issues that occurred in collecting data with prototype 1. The design for prototype 2 however was once again a design similar to the one that will be used for the final design. For this design a custom designed part was used for the base. Some errors were realized and a plan on changes that needed to be made was set into place.

Conclusion and Recommendation - Adam Boes

The group completed several tasks including testing the propellers, creating designs, and performing a concept screening and scoring. The 2510 propellers were used initially after they were tested in the wind tunnel and had more efficient results. However, when they were used in test runs they did not provide enough thrust to move the AEV along the track. When the 2510 propellers were replaced with 3030 propellers, the a significantly greater amount of thrust was created and the AEV was propelled along the track without issue. To help create a design to use for the vehicle, each group member brainstormed individually and sketched a design that could be used. The group took everyone's ideas into account before working together to create another design. Each draft, the four individuals and one group, underwent a concept screening and scoring. It was found that none of the designs met enough standards to continue building upon them, so a new design was created instead. The group has learned to work through the design process after sketching designs, analyzing them, and selecting the best for completing the mission concept. The team has worked together on the various aspects of the project and throughout the design process, building teamwork skills. Finally, the project has been documented through progress reports and the project portfolio. This has helped the team learn how to properly track and document a project as it is developed.

From the results in labs, the group determined what propellers and design should be used as the project moves forward. The 3030 propellers were used instead of 2510 propellers to create the power needed to move the AEV along the track. It was also found that the propellers are more efficient when they have a puller orientation, so it is recommended the Rebel Alliance use a 3030 puller propeller. After examining each design along with its concept screening and scoring, it is advised that the original sketches are not used for the AEV. The new design that has a vertical base and a pocket to hold the battery would be the best design to use for the vehicle. Further testing must be done to find if this design is actually more efficient than the second prototype. The group had predicted it would be much more efficient, but it did not appear to be the case in the initial test runs after the second prototype moved much faster using the same amount of power. This must be examined further to determine if the new design is more beneficial.

One possible way to resolve error is to mark the exact placement of each part of the AEV after the initial test run and ensure that it is put together the same way and everything remains in the same place throughout all of the test runs. This would solve any issues with the balance of the vehicle changing between repetitions and trials. The group could also make sure to do trial runs and the final test on the same track in the same room so that the rail will be identical and there would be limited difference in wind within the room. The only remaining issue with this is that the vents could be blowing more air on one day than another, but this is outside of the control of the group and would not likely have a great impact on the AEV. The only task not completed was Performance Test 1 because the second prototype's data from its test run was not analyzed. The group started off behind with the test because it did not get very much done on the first day due to the time it took to finish the LPQ. A lot of time was spent the following period constructing the AEV because it had been taken apart previously, and then the group struggled to create the proper code to make the vehicle run to the gate and stop. Once the AEV was constructed and the code was successful for the first prototype, the group analyzed the data from that run and did not have enough time to complete the second.

Conclusion and Recommendation - Spencer Lohmeier

At this point in the project many tasks have been completed in order to improve the quality and design of the AEV. Some tasks include propeller testing, design creation, concept screening and scoring, as well as test runs. Beginning with the design creation, all members of the group were tasked with the responsibility of brainstorming and drawing up two possible designs for the AEV. From these designs and a group base design, concept screening and scoring was performed on each design. From the results of the concept screening and scoring, the group has decided that a new design concept needed to be brainstormed. Some potential issue areas that were discovered through the concept screening and scoring were ability to travel in both directions on the track, air resistance and weight. With these results, the design that presented the highest score was a vertical base design. This design would have motors with propellers on opposite ends of the AEV. This way at all times, the vehicle is taking advantage of the pusher and puller method of a propeller. Through tests that were performed on the propellers it was discovered that the puller method was the most efficient. With this information in mind the group wanted to make sure that the puller method was being used at all times, as well as that the group recommends to the Rebel Alliance that a puller propeller method be used to transport R2D2.

Through test runs the group come across some important recommendations that it would like for the Rebel Alliance to consider. As a group it was determined that the vehicle should only be on 25% power when going from the start to the gate for a total of 7 seconds. When the AEV is on 25% power for more than 7 seconds the AEV had issues with crashing into the gate. Also after the AEV has passed through the gate, it is recommended that the vehicle only accelerate for a total of 0.5 seconds. Any time greater than this value will cause the vehicle to crash into the cart carrying the R2D2 and not allow for a good connection to the cart.

In a task similar to this one there is always room for error. One major area of error is wind resistance in the room of testing. Wind resistance is completely out of the control of the group when testing. A way to make sure that the same effects are experienced on all test runs is to only test in one room. This resolution will also be a good resolution to solve the problem of friction between the wheels of the vehicle and the track. This makes sure that all factors that go into making the vehicle act differently will remain constant.

Conclusion and Recommendations - Aaron Mckinley

Throughout the project the group has performed many tests and analysis on different parts that make up the AEV vehicle.The reason for this is to combine all aspects of the testing into one vehicle that is at max the max power efficiency possible. There have also been a few tests analyzing the overall success of some basic AEV designs made. Combined with brainstorming on a number of ideas and concepts related to the project, each design was able to go through a concept screening and scoring system put together by the entire group. The scoring system is based on all the aspects that the group deems crucial to the overall effectiveness of the AEV: air resistance, aesthetic appearance, weight, and the ability for the vehicle to move down both directions of the track. The group was able to come to a unanimous decision over some aspects of the vehicle after this testing. One fact was that the most efficient shape for the vehicle was one with a vertical base and with one propeller on either side to decrease size and air resistance. This is because the testing showed that the pull method on a propeller was more powerful and efficient than the push method, so the vehicle should be able to perform the pull method with at least one motor at all times.

There are a few recommendations that can be made after testing to make the AEV more efficient. There were two different approaches that could be used to completing the mission with the code. One method was to have the motor run for a certain amount of time, then brake all motors after that time and let the aev roll the exact distance to the sensor gate. The other method is to use the relative position command that measures the mark being traveled on the wheels. The group chose to test the time method, and wa able to perfectly time the AEV up to the sensor gate. To get the AEV to roll into the sensor gate, the vehicle was programmed to run both motors at 25% power for 7 seconds at the beginning to give it a boost to the sensor gate halfway through the track. Another recommendation is to have the vehicle accelerate in a slower amount of time on the second half of the track, else the AEV could crash into the R2D2 unit on its approach.

This testing has multiple instances where error could occur. One area that affects the vehicle on every run is the air resistance as the vehicle moves. The group has tried to design an AEV that reduces the amount of air resistance, but there will always be some to cause friction on the vehicle. Another way to account for this air resistance when testing is to always test the AEV in the same room, to reduce variation in winds and keep the entire testing system constant. One other small source of error is the friction of the wheels on the track. The same approach can be used for this as the other source of error. All testing should be done in the same room on the same track to keep all results as consistent and precise as possible.

Conclusion and Recommendations - Christian Considine

The team tested two designs in the performance tests. One was a design which was similar to the final design the group came up with for the AEV vehicle after each individual constructed their own design. The final piece was a vertical piece that was in the shape of an upside down T that would have to be printed with a 3D printer, thus could not be tested in this part of the experiment, especially because some of the dimensions were incorrect and needed to be fixed and resubmitted. The similar design was tested in the performance tests during this week. Many tests were needed in order for the AEV to come to a stop at the right place. The variations in some of the runs should how adjusting the position of the wheels helped to increase the efficiency, as most of the weight of the AEV was on the back of the vehicle. As a result, the front wheel was brought closer to the back wheel to balance out the amount of weight each wheel holds. This also shows how balance front to back may have more of an influence on the efficiency that the group expected, although more tests will be needed to prove this theory. One test that did help support this claim was that the second design, which had more weight in the front, performed better than the first design using the same code. One possible reason for this was that the second design included both motors in the same configuration, which, if in puller configuration, could explain the higher efficiency. The other explanation was that the weight distribution front to back (heavier in the front) was more efficient than having the weight in the back. As a result, the final AEV will be designed to keep the front to back weight distribution to be centered in the middle.

There are a few recommendations in the continuation of the design of the AEV. First, one recommendation is that the percent power and acceleration should be kept low. At the higher percent power, even at less time going at that power, the power used spiked and increased much more compared to a lower percent power. The second recommendation is that the AEV needs to be much more balance, particularly front to back. The weight should be concentrated between the front and back. If there is any imbalance, the excess weight should be moved to the front rather than the back (based on the results from the performance tests). Finally, using the GoToAbsolute position and GoToRelative position functions needed to be considered as possible replacements for the current code. This isn't so much a recommendation as much as it is an option the group should test to see if it makes the AEV more consistent and/ or more efficient.

The group was unable to complete the full performance test for the second design. The group tested the second design multiple times with adjustments to the code, but the group was never able to successfully stop in front of the gate, wait for the gate to open, and continue to the end of the track, like what was done for the first prototype design. One reason this was not completed was that the AEV varied too much in the first design in terms of where it ended and it was hard to adjust the code to perfectly account for the AEV going to far or not far enough in the previous run. As a result, much of the time was spent trying to adjust the code before the group finally realized that the weight distribution on the wheels was off and decreasing the efficiency and consistency of the AEV. The front wheel position was adjusted to help solve the inefficiency which allowed for a quicker success in the performance test of the first prototype. Despite this adjustment, too much time had been wasted on completely a good run for the first prototype and not enough time was left to test and adjust the code for the second prototype.

Appendix

Schedule

Performance Test	Task	Start	Finish	Due Date	Adam	Aaron	Spencer	Christian	% Complete
2	Develop 2 Codes	3/22/17	3/28/17	3/28/17		x		x	10
3	Choose efficient code	3/28/17	4/3/17	4/5/17	X		X		0
3	Complete scenario efficiently	3/30/17	4/5/17	4/5/17	X	X	X	X	0
4	Final testing	4/6/17	4/11/17	4/12/17	X	X	X	X	0
4	Choose a code and finalize it	4/11/17	4/12/17	4/12/17	X	X	X	X	0
n/a	Develop oral presentation	4/10/17	4/17/17	4/18/17	X	X	X	X	0

Concept Screening

	Prototype 1	Prototype 2 (Reference)	Sketch A	Sketch B	Sketch C	Sketch D
aerodynamic	+	0	+	+	+	+
cost efficient	-	0	-	-	-	-
balanced (Front to Back)	0	0	-	-	+	+
balanced (L to R)	-	0	0	0	0	0
durablility	0	0	+	-	-	0
simplicity/ plausiblity	-	0	-	0	0	0
efficiency (power)	+	0	-	-	-	0
efficient backwards	+	0	-	-	-	-
# of 0	2	10	2	3	3	5
# of +	3	0	3	2	3	3
# of -	3	0	5	5	4	2
Total	0	0	-2	-3	-1	1
Decision	Test	Test	Eliminate	Eliminate	Eliminate	Elimintate

Concept Scoring

Weight	Prototype 1 Score	Prototype 2 Score	Sketch A Score	Sketch B Score	Sketch C Score	Sketch D Score
15%	5	2	3	3	3	3
5%	4	5	2	2	2	2
10%	4	4	2	2	4	4
15%	3	4	4	4	4	4
5%	3	3	4	1	1	3
10%	4	5	1	3	3	3
20%	4	3	0	1	1	1
20%	5	3	0	0	0	0
100%	32	29	16	16	18	20

Weighted Concept Scoring

	Weighted scores	Proto. 1 (Ref) WS	Proto. 2 (Ref) WS	A WS	B WS	C WS	D WS
aerodynamic	15%	0.75	0.3	0.45	0.45	0.45	0.45
cost efficient	5%	0.2	0.25	0.1	0.1	0.1	0.1
balanced (Front to Back)	10%	0.4	0.4	0.2	0.2	0.4	0.4
balanced (L to R)	15%	0.45	0.6	0.6	0.6	0.6	0.6
durablility	5%	0.15	0.15	0.2	0.05	0.05	0.15
simplicity/ plausiblity	10%	0.4	0.5	0.1	0.3	0.3	0.3
efficiency (power)	20%	0.8	0.6	0	0.2	0.2	0.2
efficient backwards	10%	1	0.6	0	0	0	0
Total	100%	4.15	3.4	1.65	1.9	2.1	2.2

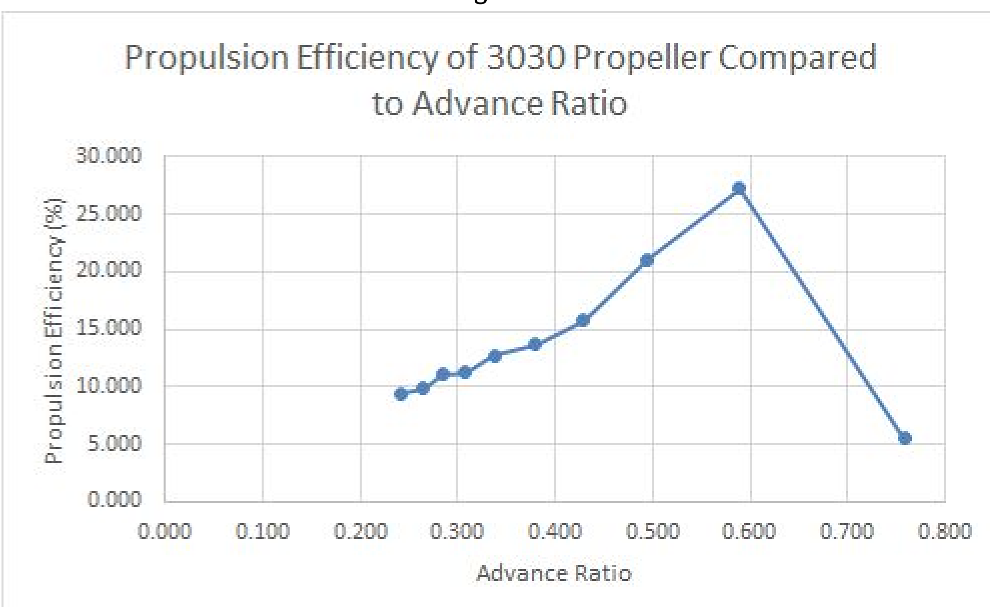
Table 1

Current	Thrust Scale Reading	RPM	Arduino Power Setting
amps	*grams*	*RPM*	*%*
-0.1	142	0	0
0.8	146	3113	15
0.18	148	4011	20
0.28	151	4780	25
0.38	153	5508	30
0.48	156	6221	35
0.58	160	7005	40
0.68	163	7664	45
0.77	168	8323	50
0.88	171	8922	55
0.99	176	9760	60

Table 2

Current	Thrust Scale Reading	RPM	Arduino Power Setting
amps	*grams*	*RPM*	*%*
0.01	158	0	0
0.22	157	2950	15
0.32	157	4100	20
0.44	158	4875	25
0.5	158	6300	30
0.58	160	7325	35
0.65	162	8650	40
0.67	166	9760	45
0.76	168	10900	50
0.79	170	12050	55
0.83	172	13233	60

Figure 2



Code 1

```
reverse(2);
celerate(4,0,25,.5);
goFor(7);
brake(4);
goFor(13);
celerate(4,0,40,.5);
goFor(5.5);
```

```
brake(4);
```

Code 2

```
celerate(4,0,25,.5);
goFor(7);
brake(4);
goFor(13);
celerate(4,0,25,.5);
goFor(5.5);
brake(4);
```