Preliminary Design Review Report

Submitted to :

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Team F

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Executive Summary

This Preliminary Design Review is a report meant to show that the system under review, the AEV, is currently meeting the schedule developed by the team. The mission objectives for the team's AEV are energy management, operational efficiency and operation consistency. To achieve the objectives, the team first needs to design the AEV to use the least energy possible per mass. The AEV also needs to be coded and built to be as efficient as possible. As a matter of consistency, the AEV should be coded to perform the same on every track of the same length. The team previously submitted individual designs for the AEV and compared them to decide which would be used for the final design. All of the designs were compared to the reference model through Concept Screening Scoresheet and Concept Scoring Matrix. Two designs, Vince's and Jacob's, were chosen. After comparing the two, however, the team decided to incorporate elements from Jacob's into Vince's design to create the final design. The team again produced two variations based on this design. Model A has a 90 degree wing angle to the body, and Model B which has more broad wing angle of roughly 120 degrees.

The AEV was assembled according to Model A and tested. At first it produced inconsistent results; despite being programmed to stop after a certain number of marks, the AEV would never stop moving. Although the team checked and rewrote the code several times, the AEV still had the problem. The team realized the AEV might have technical issues with the reflectance sensors. After replacing both reflectance sensors, the AEV finally moved according to the code. The team tested the AEV again and another problem arose. When Model A rounded the turn on the track, the wings and propellers actually made contact with the track. This caused serious balance issues and interrupted the AEV's movement. Although shortening the 90 degree wings would prevent from hitting the brackets, the team did not have access to a shorter wing design. Therefore, it was decided to further the test using Model B. The propeller used by the team is pull configuration, 3 inches in diameter. Through the previous lab, it gave out the most efficient propeller from the rest. This propeller is ideal for reducing the energy used by the AEV.

Model B seemed to be more stable when speeding up at the corner. The balancing caused the AEV to move back and forth less at higher speeds compared to Model A. While Model B was nearly able to meet the task for performance testing, eventually the team encountered the same problem as before and found the AEV unable to measure distances correctly. The marks set up by the team seemed to be not working again. The team identified that it might be the battery that ran out of energy and replaced the battery immediately; however, this did not solve the problem. From the latest data the team got, some negative values showed up in relative position. It might give some clue that the sensors read the movement backwards instead of forward. Solving this problem will likely help improve the AEV's consistency overall in the future.

In conclusion, the AEV still faces some problems with moving according to the code, which is closely related to the sensors' function. The team has identified the problem but still has yet to write and implement the solution. The next test run would likely be the last necessary in order to make the AEV run with no problems. As the pull propeller configuration provided

more thrust, the AEV should likely move faster and increase in efficiency. The team is confident on this, and if the problem is solved then the AEV will not be far from reaching the mission objectives.

Introduction

The goal of the Preliminary Design Review (PDR) was to create two Advanced Energy Vehicles (AEV), that would complete the given task of trying to fetch, and transport R2D2 units. The AEV has to complete said task in a green, energy efficient, and cost effective manner. The PDR was created to summarize the findings and observations of the two prototypes built, and analyze and draw a conclusion from the data collected. The report will contain a general description of the procedure the team used to complete the lab. Then, the report will go on to the results of the lab, any observations that were noted during the process of the completing this lab, and the analysis of any graphs and tables. The discussion section will precede this section in the report; here it any common questions and and potential errors that may have caused our results to be skewed will be stated. Wrapping up the report will be the team's overall conclusion and then recommendation as we approach closer to the Critical Design Review, and the deadline.

Experimental Methodology

The Arduino is a microcomputer that the team used to program the AEV. In this lab the team got familiar with basics of getting the AEV to move, and the syntax that is needed to accomplish such task. The team found the functions celerate, reverse, goFor, and brake to be the most effective. In this lab the team was familiarized with the external sensors and how to troubleshoot those systems when there is some error occuring with them. The

System Analysis portion of the lab had to deal with the wings. The team used from the wind wind tunnel gather data about puller or. pusher propeller system. The decision was made after analyzing propulsion efficiency. Motors and propellers were installed as either push or pull configuration and with different sized blades in wind tunnels that were located at the front of the lab, with. A sheet was given to each team to record the data when the wind tunnels were in operation.

After constructing the sample AEV that was provided to team, each member was to, orthographically, draw what they thought would be the ideal design for the AEV. Figures 1-4 are the drawings of each member; also included are pros and cons of each design and a bill of materials.

With all of the basics done, the team began to analyze the AEV's system and its efficiency. In the lab the team was introduced to the EEPROM software. EEPROM Arduino fetched raw data provides physical results that is related to the team's code. After the use of this software the team realized that is software will be integral when it comes time to decide between designs. For the design analysis portion of the lab the team used the built-in analysis tools in Arduino. Using sample data that was provided, the team was able to compare and improve the AEV. Having data from the AEV that was provided the team had to then decide on what kind of design it wanted to achieve. Here the design concepts were introduced of using concept screening and concept scoring tables, figures 5 and 6, to come to decisions. The team compared each other's design and used the sample AEV that was provided as the base case. The purpose of this lab was to understand and analyze the code that was written and the design of the AEV. Two AEV's were constructed, Model A and Model B. Each with the same body, but with the placement and orientation of the wings being different. The AEV was required to approach the gate, wait, then travel to the turnaround point. Both Model A and Model B were tested using the same code, and then had their performance compared using EEPROM data and concept scoresheets.

Results

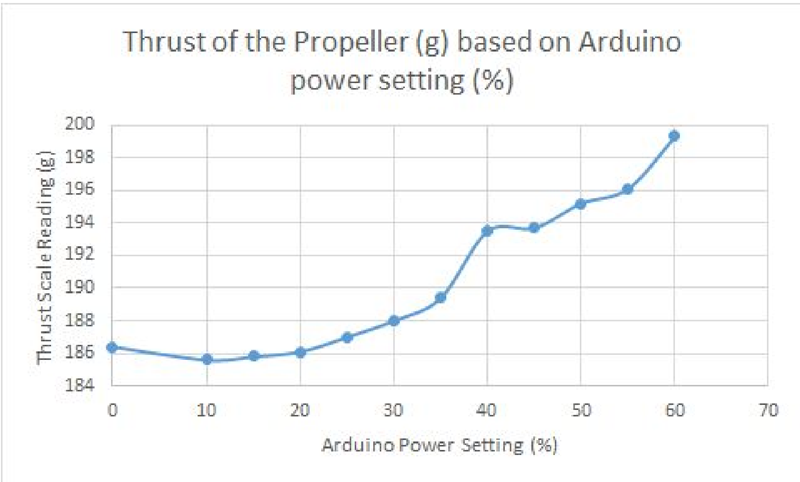
The group's two AEV designs were essentially two variations on the same model. The shared characteristics included drastically slimmed down body and wings, better positioning of the AEV and battery, and different wing orientation. The wing orientation is what separates the two designs - Model A places the wings perpendicular to the body, while Model B places the wings at an angle. The original four designs all placed emphasis on dematerialization of the body and consolidation of mass, which are both clearly reflected in these two designs. The team originally chose to move forwards with Vince's design, but decided to incorporate the vertical wings from Jacob's design after finding that vertical wings provided an increase in efficiency. It was observed, however, that vertical wings also caused issues with stability and even made contact with the track several times, and so the angled wings were proposed as an alternative.

After implementing the scenario code, the team ran both AEV models on the track and recorded the results on the concept scoresheet. Team members observed that while Model A appeared to accelerate more efficiently and ran along the track faster at equivalent motor power, it also proved to be far less stable around turns. Furthermore, this destabilization caused the AEV to rock back and forth in such a way that the wings and propellers actually made contact with the track, causing further stability problems and at one point even causing one of the propellers to fly off. Despite its superior performance in other areas, Model A clearly required significant modification in order to be a viable model. The team observed that with minor laser-cutting and adjustment of the propellers the AEV could run smoothly and be a viable alternative to Model B, but until this could be confirmed and implemented Model B was the clear solution. Although it accelerated and ran slightly slower than Model A, the model still proved to be much more stable overall.

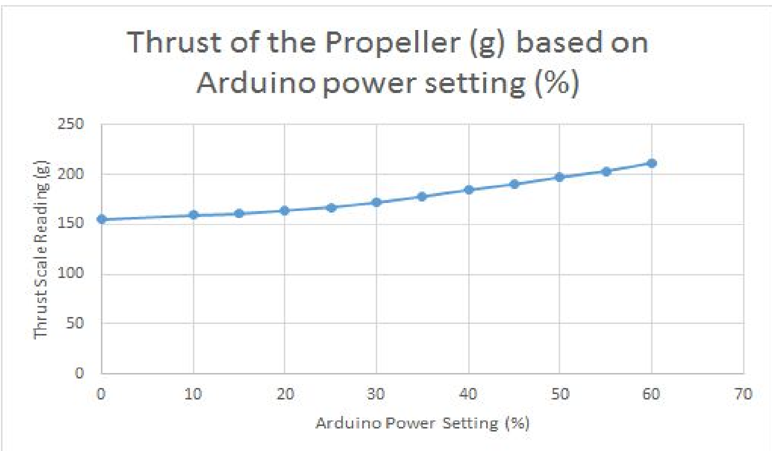
Figure 11 shows the simple concept scoresheet used by the team to record observations from the two models. Model A appeared to be superior in terms of blockage, center of gravity and environmental efficiency but also was unsuitable for use due to severe balance issues. Model B was superior in areas of balance, maintenance, durability and overall cost, as it did not require modification to fit the track. The team came up with several minor design changes to Model A that would allow it to fit the track, but unfortunately were unable to test these in time.

Provided below is the graph comparing the thrust from pusher and also puller configuration. The data can be referred to Figure (9) and Figure (10) :

Pusher :

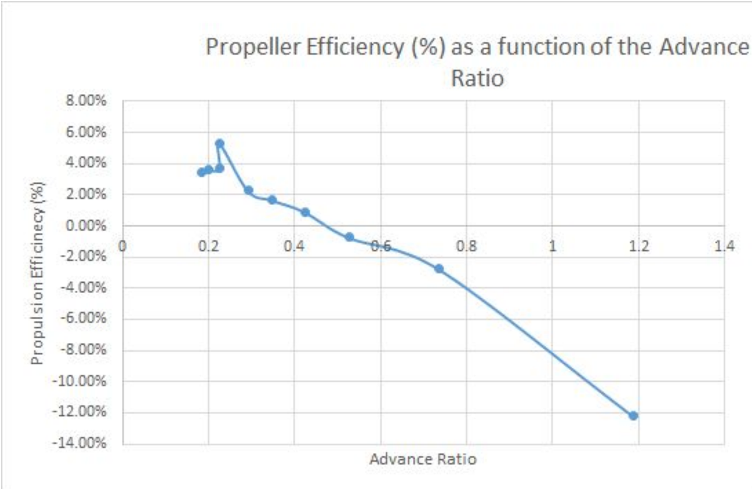


Puller:

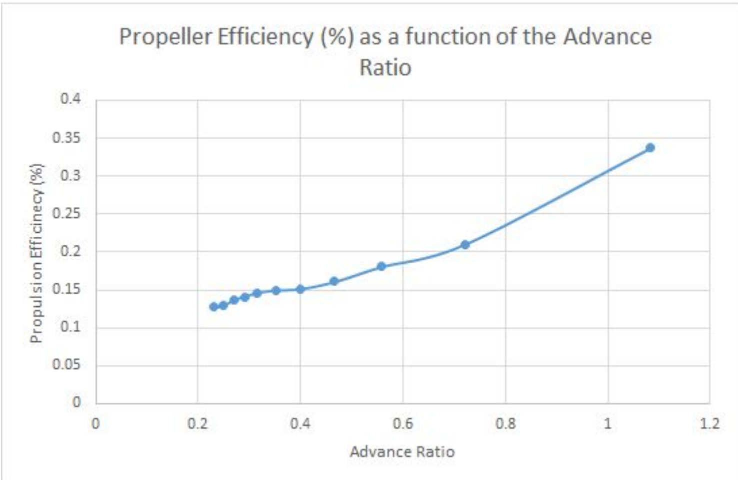


Comparing the thrust reading from two configurations, puller seems to be able to produce higher thrust reading scale. While at 60% the puller can reach more than 200 g thrust, pusher was barely keep up to 200 g. The next is the graph of system efficiency vs advance ratio by also these two configuration:

Pusher :

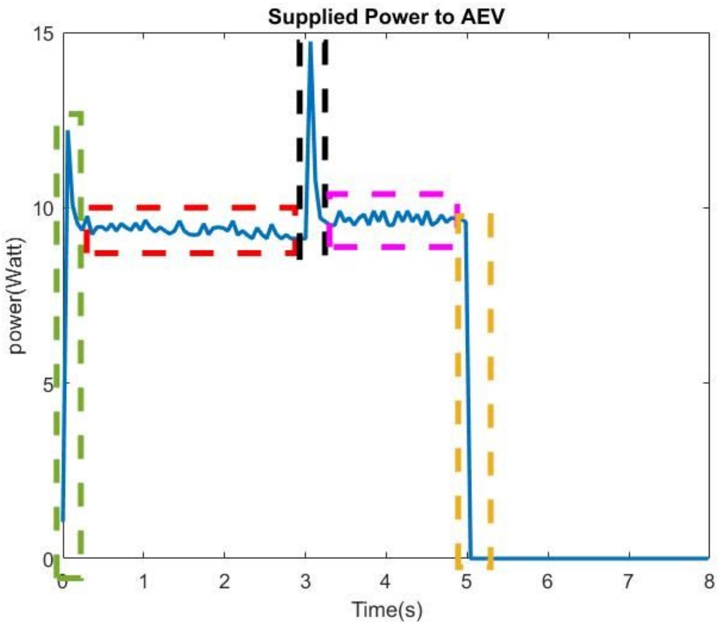


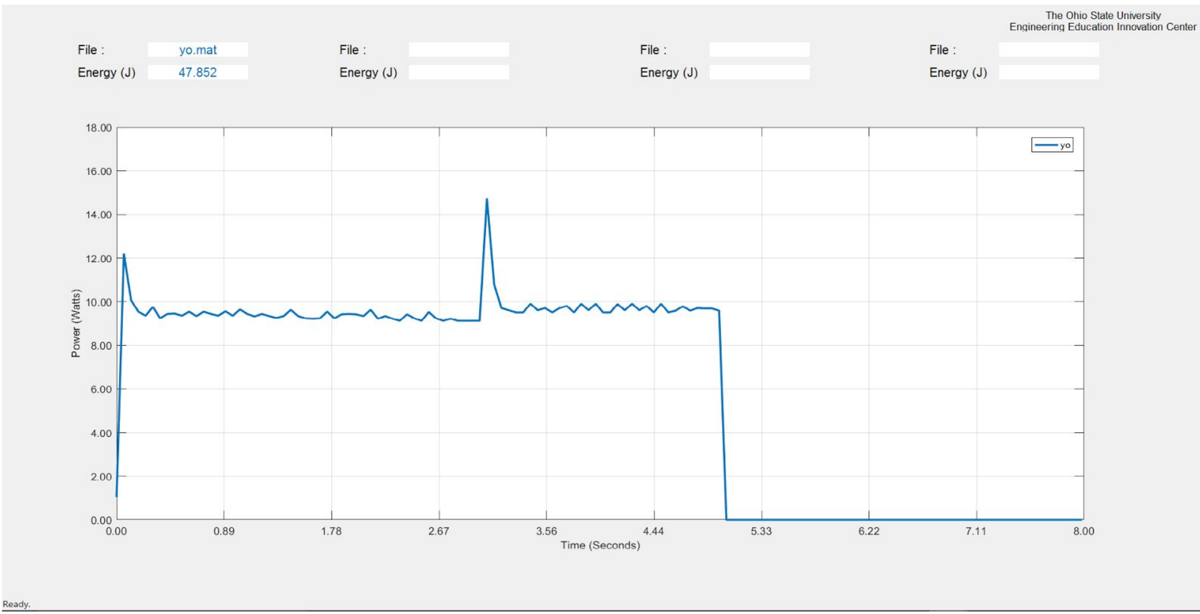
Puller :



The pusher configuration has a lower efficiency compared to the puller configuration at the approximately the same advance ratio. It showed that the same input to both of the configurations, the Puller gives out more output and in this case the thrust. As the mission objective is to have more energy efficiency, Puller would like to be choose as to carry more burden by the AEV.

Between the two 3030 wind turbine configuration, with one being of Pusher and the other Puller, in all four graphs there was a relative linear relationship between their respective axes. The wind turbine with the Puller configuration had both a higher thrust and advance ratio data than that compared to the Pusher configuration. From the result also, the team configured that Pusher would be suitable when the AEV is moving by itself. The AEV is light so even though the Pusher configuration provides less thrust than Puller, the AEV will also move fast as there is no additional weight. When the AEV moves backwards with additional weight, Puller would be more suitable in providing more thrust and efficiency.





Energy vs Time graph of the Model B

The graph above shows the average energy used by the AEV using Model B. The scenario code for both of the graph is configured using time instead of marks as the team still have a problem with the sensors. However, it also can be used as a rough idea what the energy value should be when the AEV move from the starting point and stop before the gate. As model A expected to have smaller blockage, the team also expected it to use less energy than 47.852 joule produced by Model B before stopping at the gate.

Discussion

For the AEV design, testing showed a few trends that helped to sway the AEV design choice. One such trend was the pusher vs puller efficiency. As shown in figures 9 and 10, a puller thrust system is much more efficient than a pushing one. This pushed the AEV design in a certain direction. As the AEV (as designed) did not have turning capability, we had to decide if we wanted the AEV to pull with the load or without. With the EEPROM data gathered, we determined that pulling with the load would save more energy as opposed to pulling without the load. Another trend was the Arduino power setting vs thrust provided. We saw that a certain power setting would give us the best thrust to energy used ratio. As a result of this, we would use this power setting (40%-50% power) most often for the AEV to perform it's maneuvers. The design of the AEV is directly influenced by this because we have to try to build the AEV in a way that fully utilizes the thrust the propellers give it. As the purpose of the AEV is to use the least energy to complete the task, these trends helped to focus the design on the mission.

Error came up in testing several times that could have affected the design. The reflectance sensors were giving wrong readings and having our AEV not follow the designed code. This could cause error in our EEPROM comparisons as they would not be consistent tests. Another point of error was the order in which the designs were tested. As we switched from one design to another, error could be caused in the assembly of the AEV, making them not quite the same as before. Finally error could be caused in the handling of the AEV during testing. We spotted that a propellor had come loose and fallen off and this could have affected our data.

Conclusion and Recommendations

In the AEV design project, the team designed an AEV and programmed the vehicle accordingly using Arduino. Each individual created a designed then using concept and screening matrices decided to construct two designs.

With the selecting the two designs, the team then began to discuss which propulsion system would be the most efficient. In order to decide, the team used the wind tunnel. After collecting the data and analyzing it the team decided that to maximize efficiency and not put too much strain on the AEV. The team came to the conclusion that pushing the AEV without the R2D2 and pulling the AEV back with the R2D2 attached to it would the optimal approach to this problem. Now came time to decide between the two designs. AEV in the Arduino analysis tool to help them determine which AEV was the most efficient.

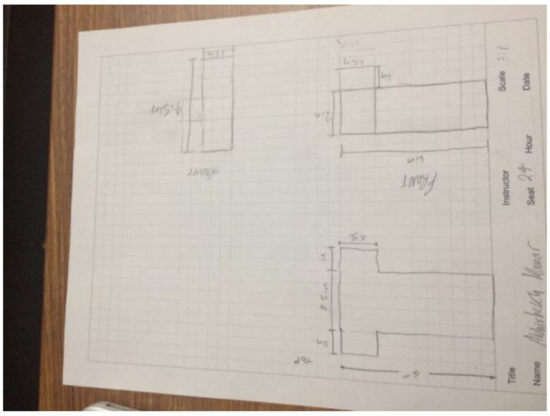
Team F will proceed with Model A after reviewing the experimental results. However there will have to be small design changes. As shown in testing, the tall vertical wings had much smaller blockage however the tips of the propellers were prone to touching the track. To remedy this, the wings will be shortened slightly. The AEV also seemed to carry unneeded mass so the body will be slimmed down wherever possible. This will improve energy usage per lbs/kg and make the AEV more efficient. Given the chance to gather data for Model A, we believe that it would have used less energy over time.

The team’s biggest error was that the sensors were very inconsistent, checking the sensors would be a way to resolve this error.

Ideally the team would have been able to get EEPROM data for both designs. However, the team ran into severe technical difficulties when it came time to test both models on the track and were unable to extract data from Model A before the end of the lab. Since the code that was written required the sensors to measure distance via marks, unfortunately the sensors were not working due to some error. And a majority of the time was spent trying to get the sensors to work. Towards the end of the lab the team decided to use time, rather than distance, to get the AEV from the starting point to the gate. In the future the team will gather data much more frequently throughout the process, especially before attempting to refine code and designs.

Appendix

Figure 1:



Abhishekh's concept AEV.

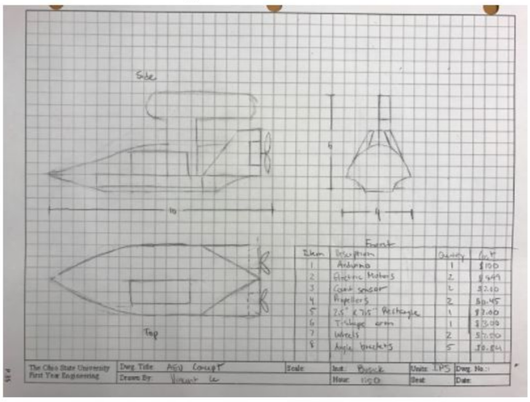
The following design is simple and light, since it is made of plastic

Bill of Materials

- 1 Arduino - $100
- 2 Wheels - $15 per
- 2 Electric Motors - $19.98 per
- 1 T-Shaped Arm - $3

Figure 2:

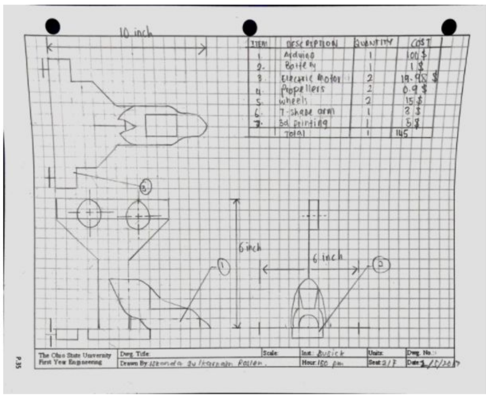
Vincent's AEV concept



Team AEV Design

- Battery + Arduino attached to arm to lessen body space required/consolidate mass
- Body is tapered to improve aerodynamics + remove unneeded mass
    - Both the triangular body and drilled arm can likely be laser-cut or 3D printed; need to find materials + potential cost
- Propellers attached in the back; inside body rather than outside
    - Improves weight distribution, easier to attach to triangular body

Figure 3:



Iskandar's Concept AEV

-Body inspired by helicopter shape.
-Aerodynamic front to reduce air resistance
-Lightweight material
-Simple design for easy built

Bill of Material

- 1x Arduino $100
- 2x Electric Motor $19.98
- 2x Propellers $0.90
- 2x Wheels $15
- 1x T- shape arm $3
- 1x Body printing $5

Figure 4:

Figure 5:

Screening and Scoring Tables

Success Criteria	Reference	Design A (Abhi)	Design B (Isk)	Design C (Jacob)	Design D (Vince)
Balanced in Turns	0	-	0	-	+
Minimal blockage	0	-	-	-	+
Center of gravity	0	-	0	+	+
Maintenance	0	+	0	+	+
Durability	0	-	0	+	+
Cost	0	+	0	-	-
Environmental	0	+	0	+	-
Sum +	0	3	0	5	5
Sum 0	7	0	6	0	0
Sum -	0	4	1	3	2
Net Score	0	-1	-1	2	3
Continue?	No	No	No	Combine	Combine

Figure 6:

Success Criteria	Weight	Reference		Design A (Abhi)		Design B (Isk)		Design C (Jacob)		Design D (Vince)	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Balanced in Turns	5%	3	0.15	2	0.15	3	0.15	2	0.1	4	0.2
Minimal blockage	15%	3	0.45	1	0.15	2	0.3	3	0.45	4	0.6
Center of gravity	10%	2	0.2	1	0.1	3	0.3	4	0.4	4	0.4
Maintenance	25%	3	0.75	3	0.75	3	0.75	4	1	4	1
Durability	15%	2	0.3	2	0.3	2	0.3	3	0.45	3	0.45
Cost	20%	3	0.6	3	0.6	3	0.6	3	0.6	3	0.6
Environmental	10%	3	0.3	4	0.4	2	0.2	3	0.3	3	0.3
Total Score			2.75		2.45		2.6		3.3		3.55
Continue?			No		No		No		Combine		Combine

Figure 7

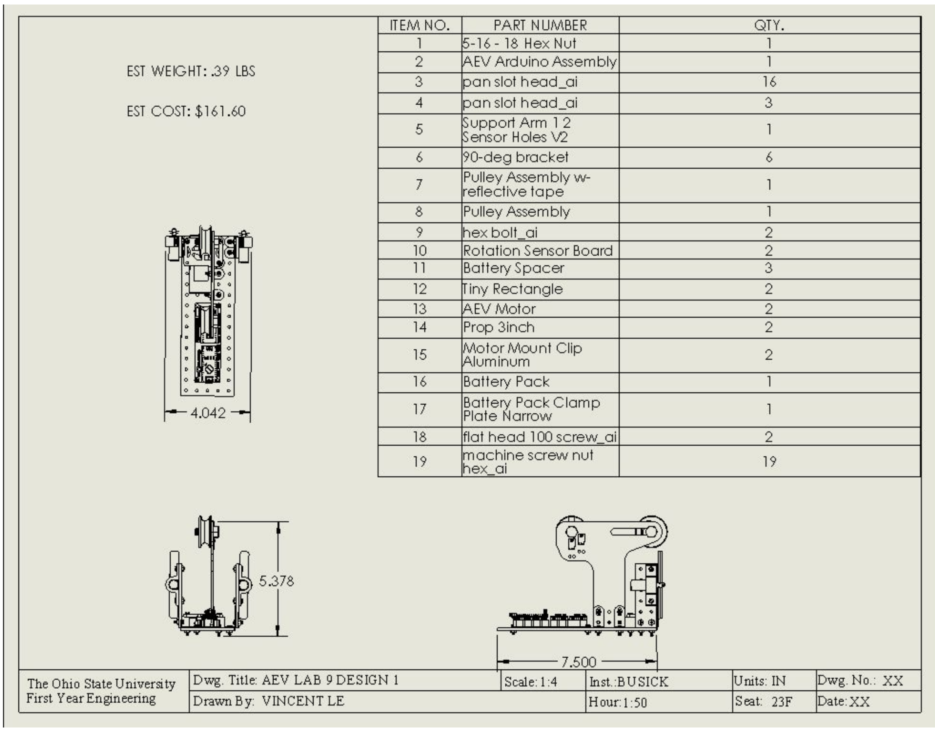
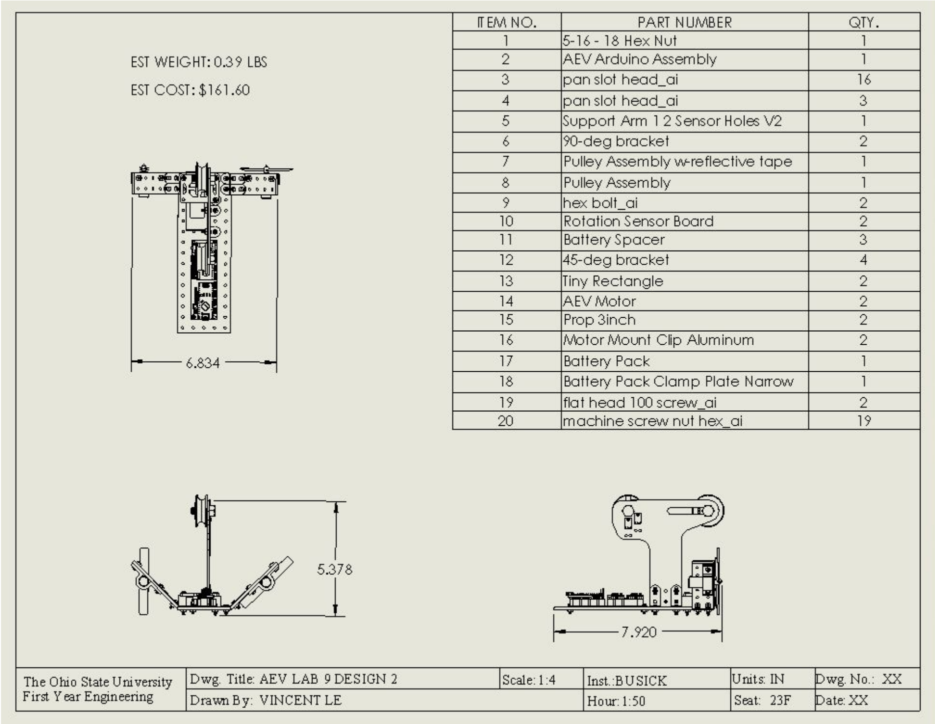


Figure 8



Propeller Data:

Figure 9

Configuration =	Push	D=3.0in	30deg	Wind Tunnel Air Speed =	2.8			
Current (amps)	**Thrust Scale Reading (g)**	**RPM**	**Arduino Power Setting (%)**	**Power Input (Watts)**	**Power Output (Horsepower)**	**Thrust Calibrated(N)**	**Propulsion Efficiency (%)**	**Advance Ratio**
0.01	186.4	0	0	0	0	0	0	0
0.1	185.6	1856	10	0.074	-0.009031478	-0.003225528	-12.20470054	1.187890307
0.22	185.8	2994	15	0.2442	-0.006773609	-0.002419146	-2.773795577	0.736380898
0.31	186.1	4191	20	0.4588	-0.003386804	-0.001209573	-0.738187533	0.526061658
0.4	187	5209	25	0.74	0.006773609	0.002419146	0.915352541	0.42325291
0.49	188	6347	30	1.0878	0.018062957	0.006451056	1.660503475	0.347364804
0.58	189.4	7544	35	1.5022	0.033868044	0.01209573	2.254562908	0.292248729
0.51	193.5	9760	40	1.5096	0.080154371	0.028626561	5.309643005	0.225893894
0.67	193.7	9760	45	2.2311	0.08241224	0.029432943	3.693794111	0.225893894
0.75	195.2	10958	50	2.775	0.099346262	0.035480808	3.580045492	0.201197701
0.79	196.1	12035	55	3.2153	0.109506676	0.039109527	3.405799633	0.183192722
0.83	199.3	13413	60	3.6852	0.145632589	0.052011639	3.951823217	0.164372207

Figure 10

Configuration =	Pull	D=3.0in	30deg	Wind Tunnel Air Speed =	2.8			
Current (amps)	**Thrust Scale Reading (g)**	**RPM**	**Arduino Power Setting (%)**	**Power Input(Watts)**	**Power Output(Horsepower)**	**Thrust Calibrated(N)**	**Propulsion Efficiency (%)**	**Advance Ratio**
0	154.8	0	0	0	0	0	0	0
0.19	159	2035	10	0.1406	0.047415262	0.016934022	33.72351465	1.083402658
0.28	160.6	3053	15	0.3108	0.065478218	0.023385078	21.06763784	0.72215015
0.38	163.8	3952	20	0.5624	0.101604132	0.03628719	18.06616856	0.55787561
0.47	167.2	4730	25	0.8695	0.139987915	0.049995684	16.09981773	0.466115097
0.57	171.8	5508	30	1.2654	0.191918916	0.06854247	15.16666003	0.400276763
0.67	177.8	6287	35	1.7353	0.259655004	0.09273393	14.963119	0.350679881
0.77	184.4	7005	40	2.2792	0.334164701	0.119344536	14.66149091	0.314735819
0.85	190.2	7604	45	2.8305	0.399642919	0.142729614	14.11916337	0.289942716
0.94	197	8203	50	3.478	0.476410486	0.170146602	13.6978288	0.2687705
1.04	203.2	8862	55	4.2328	0.546404443	0.195144444	12.90881788	0.248784068
1.13	211.5	9520	60	5.0172	0.640106032	0.228609297	12.75823231	0.231588698

Figure 11

Success Criteria	Model A	Model B
Balanced in Turns		+
Minimal blockage	+	
Center of gravity	+	
Maintenance		+
Durability		+
Cost		+
Environmental	+	
Sum +	3	4
Net Score	3	4
Continue?	No	Yes

Figure 12

Team Schedule

	Week of: March 27, 2017									
No.	**Task**	**Start**	**Finish**	**Due Date**	**Est. Time**	**Abhishekh**	**Iskandar**	**Jacob**	**Vince**	**% Complete**
1	Submit Model 3 parts for laser cutting	3/24			1 week				20min	90%
2	Complete 2 code bodies for Lab 9B	3/23	3/23	3/23	1 hour	30min	0min		30min	100%
3	Test Model 3 vs Model 2	3/27	3/27		1 hour	45min	45min	45min	45min	50%
4	Update Portfolio Website				1 hour	0min	0min	0min	5min	20%
5	Complete PDR	3/27	3/20		3 hours	1 hour	1 hour	1 hour	1 hour	100%