Preliminary Design Report

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Executive Summary

The purpose of the AEV (Advanced Energy Vehicle) labs was to develop a working model that will eventually complete the objectives presented in the Mission Concept Review. The overall objective for the labs was to acquire the skills necessary to program and create a unique AEV that could potentially fulfill the MCR. Over the course of the semester, the team has tested for various components including efficiency of the AEV, design and effectiveness of push vs. pull propellers, and the proper way to program the Arduino controller. The labs have helped the team to better understand and draw conclusions in the previously stated fields. The motivation behind the project itself is/was to encourage problem solving, critical thinking, and innovation in developing engineers.

The Mission Concept Review (MCR) in the AEV Lab Manual outlined the actual task to be completed by the AEV, along with any and all constraints. The necessity of the AEV was indicated in a scenario found at the beginning of the MCR. Essentially, there is a load that must be retrieved transported along a curved track with a gate bisecting the pathway. Within the MCR, it was explicitly stated that energy is a resource that must be conserved. The team's finalized AEV design will complete the task via the execution of a program by the Arduino controller.

In the initial labs, the team drafted several prototype concepts for the AEV. These designs were compared and the group then decided on a final design that implemented the best aspects from each individual's concept. The team also tested various propeller designs for efficiency, coming to the to the conclusion that the 3020 propeller is the most efficient propeller to use. The team learned how to utilized Arduino's ability to collect data during its operation. This allowed (and will continue to allow) the team to quantitatively observe and analyze the performance of the AEV.

In actuality, it is the team's recommendation that a direct drive model be constructed. This hypothesis was proposed because of the experienced inefficiency of using two motors with propellers. Further testing will be needed to verify that a direct drive model is more efficient and more easily controlled than an AEV model utilizing the 3020 propellers. Once the parts have been manufactured, the team is prepared to do this analysis. A specific problem that the team needs to resolve is that the current motion sensors in use are tracking distances inconsistently.

For the rest of the semester, the team plans to further develop the two Arduino programs for Lab 9's analysis as well as construct the direct drive AEV and then compare it to the developed propeller-based AEV. It is the team's ultimate goal to have a working solution for the task specified in MCR with an AEV that implements direct drive.

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Introduction

The general purpose of the AEV labs completed since the start of the semester was to develop a preliminary design of an AEV with the intended function of completing the task outlined in the Mission Concept Review.

The AEV must be programmed to traverse the track and return to its starting position with a load. In the center of the track, the AEV must stop for approximately 7 seconds to trigger the lowering of a gate that will allow the AEV to pass. This same gate must be lowered on the way to the load and on the way back to the initial position. The MCR also states that the AEV must conserve power, so resource efficiency is a large concern of the team. The AEV must complete its task within 2.5 minutes. In the team's experience through the lab, this is more than ample time; therefore, time complexity was not a noteworthy consideration to make.

Experimental Methodology

Overall, the lab procedures provided the team with instructions to adequately develop a working AEV model. The arc of the project began with an introduction to the Arduino controller, the Arduino programming environment, and the MCR. The team used the reference design (sample AEV) to learn what the project would entail. A wind turbine was used by the instructional staff to collect data on the two provided types of propellers (the "3030" and the "3020"). The team then proceeded forward by brainstorming prototype AEV designs and eventually choosing one to act as a working model. This choice was informed by using two different methods of concept evaluation, one being more quantifiable than the other. A specific algorithm was implemented and used by the team's new AEV to provide the opportunity to learn how to use the provided AEV Analysis Tool (a GUI and program written in MATLAB). After the aforementioned introductory lab material, the team began actually working directly on fulfilling the MCR.

For an entirely comprehensive coverage of the experimental methodology, refer to the source material in use by Engineering 1182 students: the *Advance [sic] Energy Vehicle Design Project Lab Manual*.

Results & Discussion

For Performance Test 1, the sample AEV and the team's custom model chosen from the concept scoring and screening test were utilized. The sample AEV consists of two motors supported by wings that extend from the main body of the vehicle. The team's custom model also consists of two motors, but they are supported by the vehicle's main T shaped body (see Figure 1 in the Appendix). The battery and arduino are positioned between the motors, the battery resting on top and the arduino suspended underneath. The four prototypes that the team rendered were all similar in design to each other and the sample AEV. After reviewing each design the team decided to focus on minimizing the weight of the vehicle and to utilize a compact design, leading to the final model. See Tables 1 and 2 in the Appendix for the *Concept Screening Scoresheet* and *Concept Scoring Matrix*, respectively.

During Performance Test 1, the team observed that the custom model behaved very similarly to the sample AEV. Both the first model and the sample AEV consumed comparable amounts of power as shown by Figure 2 below, being that they utilized the same Arduino program with the same power settings.

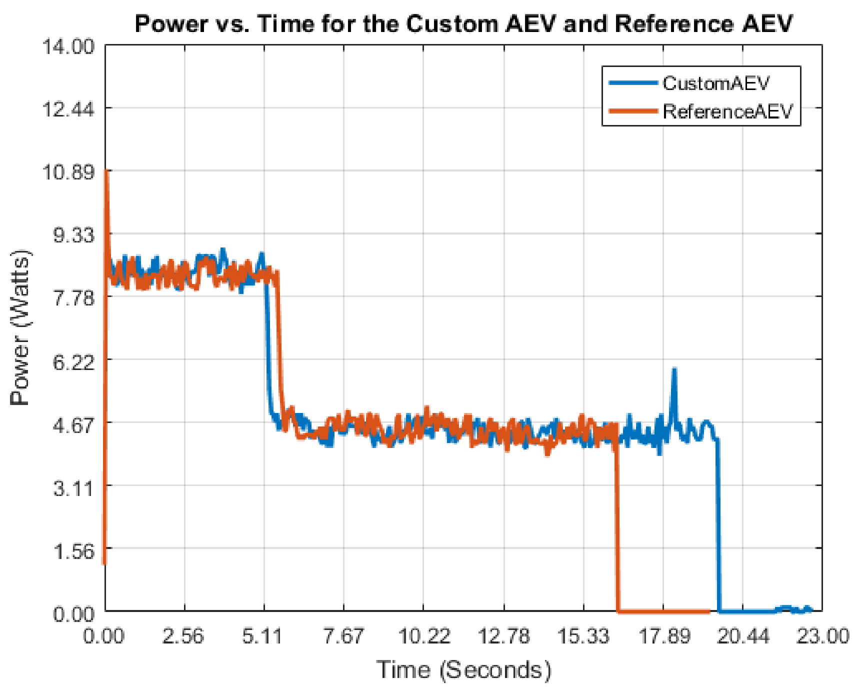

Figure 2: Power over Time Comparison

Both vehicles behaved in a manner similar to what the team had anticipated. The performance test reinforced the team's belief that the team should further develop the concept for a direct drive vehicle. Using the data collected from System Analysis Tests 1 and 2, the team concluded that the 3020 propeller was a superior model as shown by Figures 3, 4, and 5 on the following pages.

Figure 3 shows a consistently high thrust output for the 3020 when used to push a load, reaching approximately 60 grams at a power setting of 10% and seeing little improvement as more power was given to the motor.

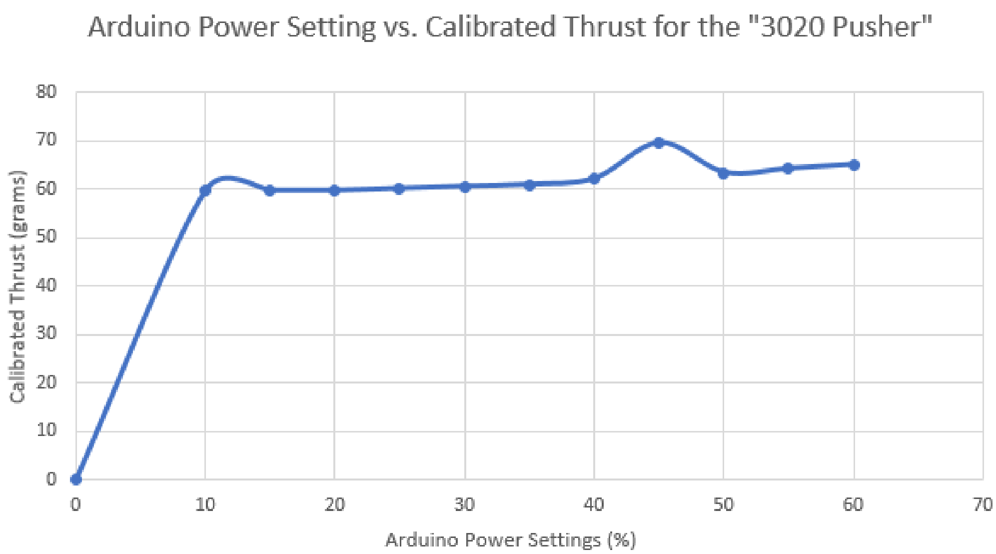

Figure 3: Arduino Power Setting vs. Calibrated Thrust for the 3020 when pushing a load

Figure 4 shows a gradual increase in thrust for the 3030 when used to pull a load, but only reaches a thrust output of 18 grams.

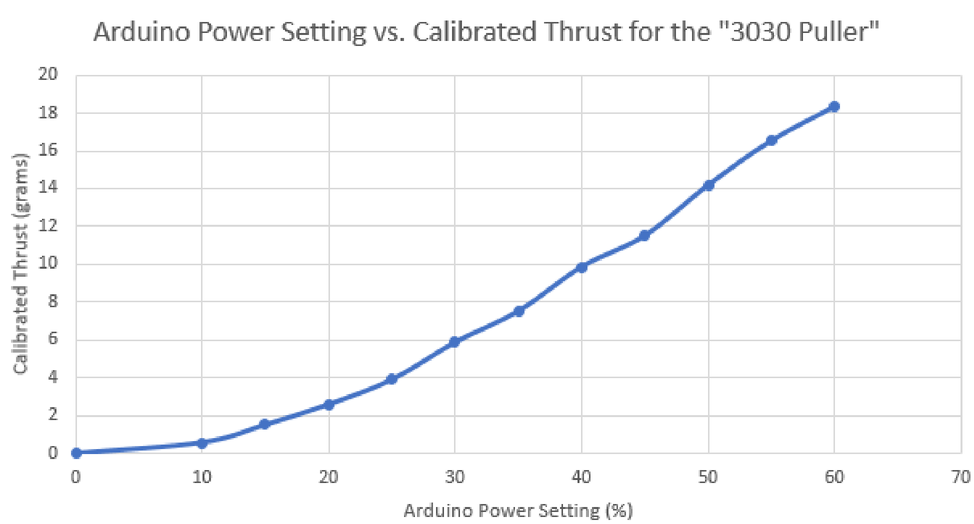

Figure 4: Arduino Power Setting vs. Calibrated Thrust the 3030 when pulling a load

Figure 5 shows that to maximize the efficiency of a propeller, the advance ratio should not exceed approximately 0.75. These results were replicated for both propeller types. (See Equation 1 in the Appendix for the components of the propeller advance ratio and a sample calculation.)

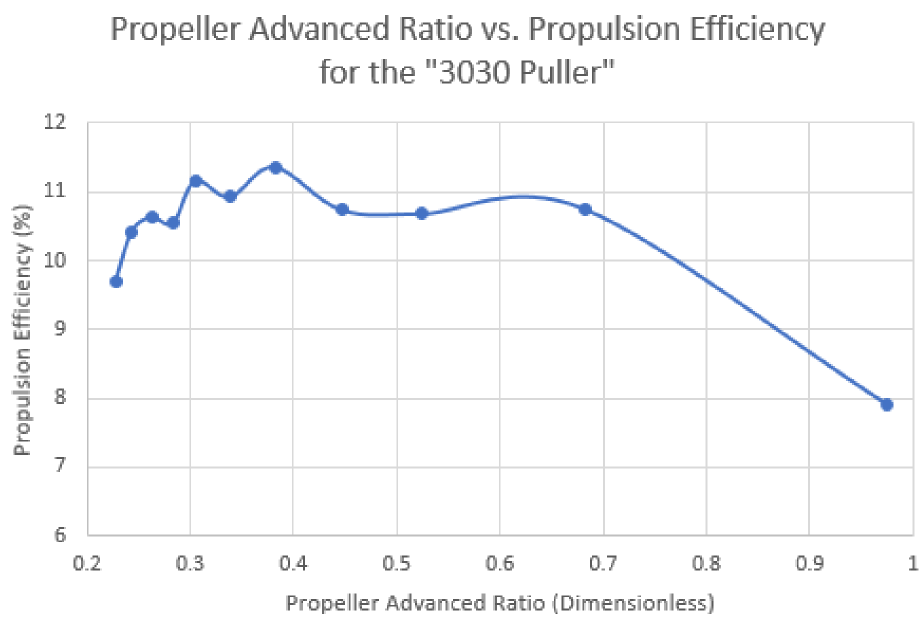

Figure 5: Propeller Advance Ratio vs. Propulsion Efficiency for the 3030 model when pulling a load

Conclusion & Recommendations

The parts needed for the approved direct drive AEV were delayed by uncontrollable factors on the team's part. This has delayed the timeline outlined in the previously submitted proposal for the direct drive, so only data based on the propellered AEV is available in this Preliminary Design Review.

Several important lessons were learned about the propellered AEV throughout the labs. For example, the direction of each propeller type greatly affects the efficiency of the propellers (as seen in the Results & Discussion section of this report). The issue is that, because the AEV will travel in both directions, a propeller will be extremely inefficient when traveling in one direction.

Hardware seems to be another issue for the group—the sensors which measure distance are not functioning properly. They work inconsistently and sometimes overcount distance and sometimes undercount. It is for this reason that the group attempted to use a code reliant on time. Consistency was again an issue. The most efficient method, which is to coast the majority of the way, is difficult given the inconsistencies of propellers mixed with long-run timing. The method the group attempted was to accelerate quickly then rapidly decelerate at the gate. The timing again needs to be precise, and was done by trial and error. The group failed to produce a program that made the AEV cross the gate. It is for this reason the group will troubleshoot the issues with the sensors, and begin coding using distance measurements. It is highly recommended that using strictly time based Arduino command are not used in the future. Finding out a way to make the distance tracking sensors work with consistency is imperative to the future success of the project.

The lessons learned with the propellered AEV have been valuable, and the group is confident that the objective could be completed with this design. However, the direct drive AEV has more potential and is the more attractive option. If there are no more unforeseen setbacks, preliminary testing will begin the week of March 26th. The current testing plan for comparing the propeller-based AEV with the direct drive AEV will include examining how much power is consumed during a finite distance travelled. If for some reason the team finds the direct drive model is not effective, the team will return to the propellered model with confidence.

Appendix

Tables & Figures

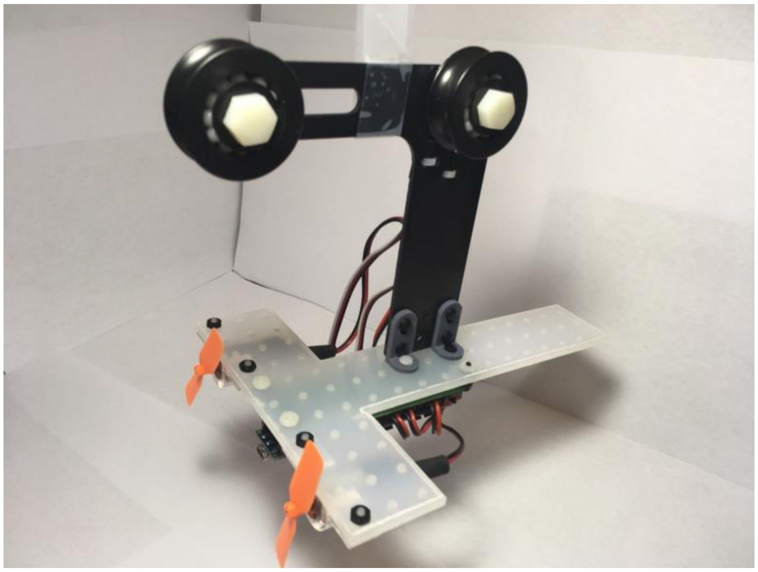

Figure 1: Sample Design Used in Testing for Group F

Table 1: Concept Screening Scoresheet

Success Criteria	Reference	Brian's Design	Zach's Design	Rafe's Design	Kenny's Design
Balanced in Turns	0	-	+	0	0
Minimal Blockage	0	-	-	0	0
Center-of-Gravity	0	+	+	+	+
Maintenance	0	0	-	0	0
Cost	0	0	0	0	0
Efficiency	0	0	+	-	-
Sum +'s	0	1	3	1	1
Sum 0's	6	3	1	4	4
Sum -'s	0	2	2	1	1
Net Score	0	-1	1	0	0
Continue?		no	yes	no	no

Table 2: Concept Scoring Matrix

		Reference		Brian's Design		Zach's Design		Rafe's Design		Kenny's Design	
Success Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Balanced in Turn	20%	3	0.6	2	0.4	5	1	3	0.6	3	0.6
Minimal Blockage	15%	3	0.45	2	0.3	1	0.15	3	0.45	3	0.45
Center-of-gravity	20%	3	0.6	4	0.8	5	1	4	0.8	5	1
Maintenance	10%	3	0.3	3	0.3	1	0.1	2	0.2	3	0.3
Cost	10%	3	0.3	3	0.3	3	0.3	3	0.3	3	0.3
Efficiency	25%	3	0.75	3	0.75	4	1	2	0.5	1	0.25
Total Score	**100%**		3		**2.85**		**3.55**		**2.85**		**2.9**
Continue?					**No**		**Develop**		**No**		**No**

Table 3: Final Projected Schedule for Team F

No.	Task	Start	Finish	Estimated Time	Zach Ahern	Brian Cekada	Kenny Kelley	Rafe Sanders	% Complete
1	Custom AEV Construction	3/7/17	3/8/17	0.5 h		0.25 h		0.25 h	100
2	Custom AEV Testing	3/7/17	3/8/17	1.0 h	0.25 h		0.25 h		100
3	Sample AEV Construction	3/7/17	3/21/17	0.5 h		0.25 h		0.25 h	100
4	Sample AEV Testing	3/7/17	3/21/17	1.0 h	0.25 h		0.25 h		100
5	Direct Drive AEV Construction	3/28/17*	3/28/17*	1.0 h	0.5 h	0.5 h			0
6	Direct Drive AEV Testing	3/28/17	3/31/17	2.0 h	1.0 h		1.0 h		0
7	Develop Arduino Program A	3/22/17	3/28/17	1.5 h			1.5 h		50
8	Develop Arduino Program B	3/22/17	3/28/17	1.5 h			1.5 h		0
9	Final Testing and Refinement	3/31/17	4/12/17	6 h					0
		* Assumes acquisition of necessary parts on/by 3/24/17							

Sample Calculations

Equation 5:

$$\text{Propeller Advance Ratio}$$
$$= (velocity(m/s) \div ((RPM \div 60) \times Diameter\ (m))) \times 100$$
$$= ((2.8) \div ((3000 \div 60) \times .08)) \times 100 = 0.7$$