AEV Critical Design Review

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Executive Summary

The goal of division C of Baker International Group is to create an autonomous Advance Electric Vehicle (AWV) as part of the Smart City Columbus, planning to make Columbus more accessible and eco friendly. Division C is determined to create the most energy efficient vehicle to help mobilize Columbus [1]. The results of this lab will allow the team to make recommendations to the Smart City Columbus.

After completing Preliminary and Advanced Research and Development, the team found that many of the original plans needed to be replaced or modified to create the best AEV. The team originally considered 5 designs, which were narrowed down to 2 designs and combined into 1 design incorporating the best aspects of the 2 designs. This design involved coaxial contra-rotating propellers and an aerodynamic shell. After testing 7 propeller configurations and the effects that the battery voltage had on the AEV, it was found that the original design needed to be changed slightly. To improve the design based on the results of the experiments, the propellers needed to be moved farther apart and facing outwards. It was also determined that the decreasing battery voltage would have no effect on the AEV. Finally, the team determined there is no correlation between the placement of the reflectance sensor at the start of the trial.

Once Performance Test 1 was completed, the team decided to remove the AEV shell due to its weight and incompatibility with repeated testing. The shell was designed to be thick enough to be 3D printed properly, but this in turn caused its benefits in aerodynamics to be outweighed by its weight. Aside from the weight of the shell, using the shell made maintaining the AEV and uploading code inconvenient and time consuming. The shell blocked most areas where a screw driver was needed to service the AEV and every time code needed to be uploaded, the cable had to bend. Once Performance Test 2 was completed, the team decided to refine the correction code, to ensure the AEV trials were more consistent. The final performance test showed that the code still needed improvement in order to reduce the time it takes the AEV to complete the performance test. Optimizing the could would also allow the total cost of the AEV to be greatly reduced, as the cost of the materials was very low compared to the costs accrued from the performance tests.

Based on the results, it was concluded that the counter rotation propellers may not be as efficient as propellers mounted side-by-side, but they are likely more efficient in reversing the the AEV. The aerodynamic shell surrounding the wires is too heavy and counters the purpose of efficiency in the AEV and therefore not needed. The propellers and the wires need to be secure to decrease error. It was determined that the counter rotating propellers, fully secured on the standoffs, is the ideal design for Smart City Columbus to make Columbus more accessible and eco-friendly.

Table of Contents

Introduction

The goal of division C of Baker International Group is to create an autonomous Advance Electric Vehicle (AWV) as part of the Smart City Columbus, planning to make Columbus more accessible and eco-friendly. Division C is determined to create the most energy efficient vehicle to help mobilize Columbus [1]. This Critical Design Review (CDR) consist of the Teams research and development, design features and changes, performance test, and final results of the AEV. The CDR will explain the experimental methodology for all the tests and labs performed by the team. It will also discuss the results of the research and development that led to basic design of the original AEV. In addition, the results will cover the advanced research and design, which was the teams specific research to discover how propeller configuration, the placement of the reflectance sensor at the start of the trial and the battery impacts the performance of the AEV. Finally, the discussion will contain an analysis of the performance tests of the AEV, demonstrating the progress of coding. The final design and costs of the AEV will then be discussed and reviewed. The CDR will also contain trends of the results and recommendations for the Smart City Columbus.

Experimental Methodology

Preliminary Research and Development

Preliminary Research and Development for the AEV was completed to determine how the AEV operated and what functions it had available to it. The research consisted of 5 experiments: Programming Basics, Reflectance Sensor Test, Data Analysis Tool, Creative Design Thinking, and Concept Screening and Scoring.

Pre R&D Experiment 1: Programming Basics

The purpose of this experiment was to demonstrate the various functions created by The Ohio State University Department of Engineering and to setup the Arduino sketchbook. This lab used a stationary AEV device to ensure the safety of those near the experiment if there was a serious error in the code (see Figure 1, on the next page).

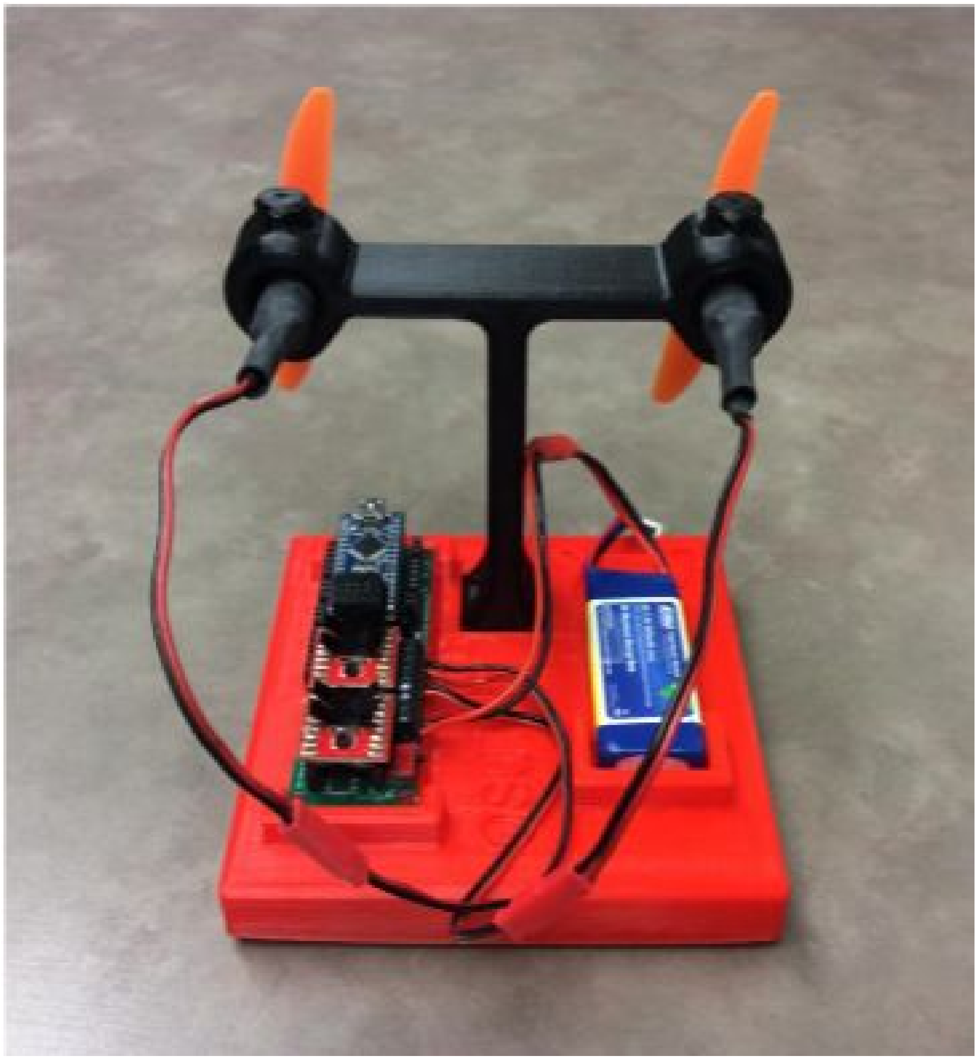


Figure 1: Stationary AEV stand [1]

In addition, this lab used the following materials:

- AEV controller (Arduino Assembly)
- 2 motors
- a USB to Micro-USB cable
- a Li-Po battery

To set up the stationary stand, the following steps were completed:

1. Motors were attached to the propellers by pushing the motor onto the propeller (see Figure 2, on the next page)

Figure 2: Proper Installation of propellers [1]

1. The motors, Arduino, and battery were placed in their respective spots according to Figure 1 (see previous page).
2. The motors' wires were connected to the 2 sets of wires furthest from the Arduino's power switch (see Figure 1, on previous page)
3. After ensuring that the motors were connected to the correct ports and that the Arduino's power switch is set to off, the battery was attached to the 2 cords closest to the Arduino's power switch

To set up the sketchbook, the following procedure was used:

1. the sketchbook needed to use The Ohio State University's function library was downloaded
2. The Arduino IDE was opened and the location of the sketchbook was set for the IDE by selecting File, then Preferences, then using the Browse button to select the location of the sketchbook
3. The Arduino IDE was restarted
4. File, sketchbook, and then AEV_Controller were selected to open multiple files that aided in coding the procedure defined in Appendix A.1 [2]
5. The procedure was implemented and uploaded to the Arduino board using these steps:
    a. The USB-Micro USB cord was used to connect the Arduino to the computer after ensuring the Arduino was turned off
    b. The proper Board, Processor, and Serial Port were selected before uploading
    c. Any bugs in the code were fixed and the program was uploaded

    d. The cable was disconnected and the Arduino was turned off
6. The Arduino was turned on and the start button on the Arduino was pressed after waiting for the yellow LED on the Arduino to stop flashing and after ensuring that team members were aware that the Arduino was being tested.

Any issues with the code, Arduino setup, or stationary AEV setup were resolved in this experiment so that these issues would be avoided in the future.

Pre-R&D Experiment 2: Reflectance Sensors

The purpose of this experiment was to ensure that the reflectance sensors were working properly and to become familiarized with the hardware of the Arduino and the sensors. The following materials were needed to complete the experiment:

- Sample AEV
- Reflectance sensors
- Zip ties
- USB-Micro USB cable
- Li-Po Battery

After collecting necessary materials, the procedure below was followed:

1. The Sample AEV was assembled and checked for loose parts
2. The Reflectance sensors were tested using the “Reflectance Sensor User Manual” [3]
3. A program was written to satisfy the procedure defined in Appendix A.2 using the fact that 0.4875 inches is equivalent to 1 mark on the sensor [2]
4. Any issues with the code or sensors were resolved before the conclusion of the experiment

The experiment served to ensure that the sensors could be easily and quickly used in future tests. It gave intuition on possible errors that may be faced in the future.

Pre-R&D Experiment 3: Performance Analysis tool

The purpose of this experiment was to demonstrate the Data Analysis Tool and Data Extraction Program in MATLAB. This lab involved the following materials:

- Sample AEV
- Reflectance Sensors
- Li-Po Battery
- USB-Micro USB cable
- Desktop Stand

The following procedure was then then performed:

1. The Performance Analysis Tool zip file was downloaded from Carmen and its contents were extracted.
2. A program was written to satisfy the procedure defined in Appendix A.3.
3. The AEV's arduino code was executed.

4. The AEV was turned off after the program completely finished executing.
5. The AEV was connected to the computer with a mini-USB cord.
6. The AEVDataExtraction program was run in MATLAB.
7. Upon being prompted, the data was saved to an excel file.
8. The excel file was opened to confirm that the data extraction worked.

The next portion of the experiment involved testing the data extraction with a specific sequence of events for the AEV to run. Once the AEV was programmed and completed its run, the previous steps were repeated plus these additional steps:

1. The excel file was imported to MATLAB.
2. A Power vs. Time plot of the AEV run was created.

This experiment displayed the abilities of the Data Extraction tool in MATLAB and its potential uses later in the project.

Pre-R&D Experiment 4: Creative Design Thinking

The purpose of this experiment was to brainstorm possible AEV designs. The designs were required to be in the form of orthographic sketches with a front, top and right side view. They were based mostly on the parts provided in the AEV kit with minimal custom parts, and every design was possible for the team to create. When creating each design, important design considerations such as energy efficiency, cost, simplicity, weight and other factors were considered to make valid and effective prototypes.

After creating prototypes, they were combined into a single prototype that inherited the best design features from each prototype. This new design was made into an orthographic drawing with a front, top, and right side view. The created designs can be found in Appendix B.

Pre-R&D Experiment 5: Concept Screening and Scoring

The purpose of this experiment was to determine which design of those created in the previous experiment would be the best in terms of important design considerations such as energy efficiency, weight, and balance. The designs previously created and the sample AEV were compared to each other using a screening matrix and a scoring matrix. The screening matrix was created as follows:

1. A list of positive design features was constructed.
2. Each design on the list was compared to the sample AEV design based on the design features.
3. Scores were summed up for each design.
4. The scores were used to suggest if the design should be considered further.

The scoring matrix was created as follows:

1. The list of positive design features from the screening matrix was used.
2. Each design feature on the list was given a level of importance as a percentage

3. The previously created designs were rated in each category and scaled to match the weighting of each corresponding category
4. The weighted scores from each category were summed for each design
5. The designs with the highest weighted score sum was deemed most effective

After scoring the designs, the one deemed most effective was constructed and used in future experiments and performance tests.

Advanced Research and Development

During advanced Research and Development, the team chose to test how minor changes in voltage affected the efficiency of the AEV,which propeller configuration was most efficient overall for the AEV and if the starting position of the reflectance sensors affected the distance travelled by the AEV. To ensure the safety of the team, others, and the AEV, multiple people were stationed along the track to catch the AEV or warn others of the incoming AEV.

Experiment 1: Battery Experiment

To test the effects of battery voltage drops, the team used a basic AEV design, a battery, a USB to Micro USB cable, Arduino Software, and MATLAB Software. The design of the AEV was not changed throughout the experiment to ensure accurate results. After assembling the equipment, the team coded the AEV to wait for 2 seconds (to average starting voltage), then to run at a speed of 40 for 3 feet using the USB to Micro USB cable and the Arduino software. Next, the team tested the AEV by having one person at the start of the track and one person in the middle to catch the AEV in case of a malfunction. Once the code was properly implemented, the team gathered data on the initial voltage and the time it took the AEV to travel 3 feet using MATLAB software designed to extract data from the AEV. The data was recorded and the procedure was repeated 5 times so that the battery would lose voltage. These 5 trials were then repeated with speeds of 50 and 60 to ensure that higher speeds did not affect changes in efficiency at varying voltages. To determine the results, the amount of time it took the AEV to travel the three feet during multiple trials was compared. Time was therefore treated as the measure of efficiency for the AEV in this experiment.

Experiment 2: Propeller Configuration Experiment

To derive the most efficient propeller configuration, the team created 7 different designs to test, all of which used the same amount of parts so that the weight of the AEV designs was held constant. Propeller designs included 5 different kinds of coaxial contra-rotating propeller designs (3 of which are shown in Figure 3, on next page), one coaxial propeller design (not contra-rotating), and one side by side design (see Appendix C for all configurations with descriptions). The team used these designs, a USB-Micro USB cable, Arduino Software, and MATLAB Software. The team then tested the total distance that each design traveled after running the AEV motors at a speed of 50 for 1 second. After each run, the data from the AEV was extracted using the MATLAB Software. Distance was therefore used as the measure of the effectiveness of each of the configurations.

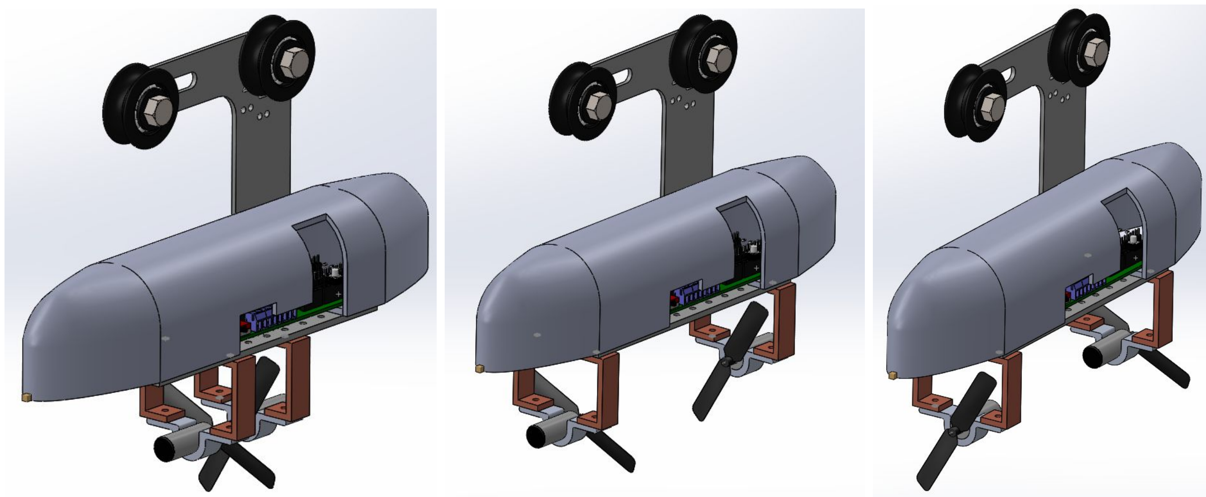


Figure 3: Three coaxial contra-rotating configurations (only configurations used in testing)

Experiment 3: Reflective Wheel Position Experiment

After working with the AEV, it was found that it was very inconsistent in the distance it traveled. In an effort to reduce this inconsistency, this experiment was developed to determine if the starting position of the wheel with reflective tape was the cause of these inconsistencies. The materials used were the AEV in its current design, a USB-Micro USB cable, Arduino Software, and MATLAB Software. The AEV was then coded to move a certain distance at a speed of 40. Before starting the code, the reflective wheel was oriented in 4 positions (see Figure 4 below).

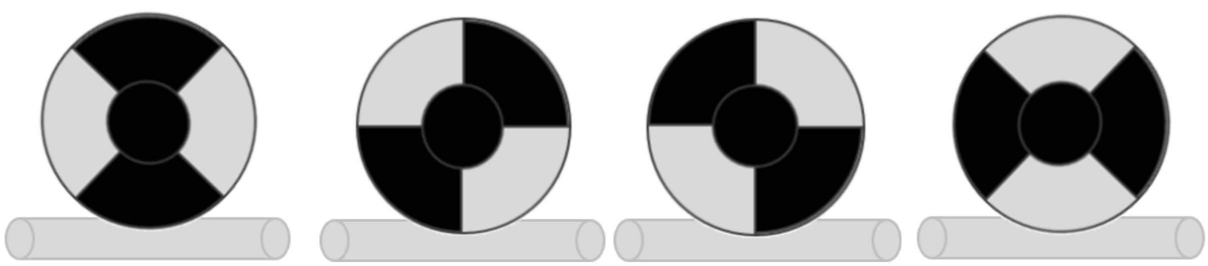


Figure 4: All wheel positions tested, relative to the track (the gray cylindrical shape)

The same code was run for each wheel position 5 times and the true distance that the AEV traveled after coasting was measured using the straight track markings. The measurement of the true distance the AEV traveled was taken from the center of the front wheel. The distances were then compared to determine if wheel position caused the previously observed inconsistencies.

Performance Tests

Performance tests were conducted periodically to examine the state of the AEV and its current design. This aided in revealing major errors that led to important design modifications.

The AEV was tested through a series of 3 performance tests that progressively increased in difficulty.

Performance Test 1:

For Performance Test 1, the AEV was tasked with starting at or behind green tape on the track, moving to the first gate, waiting for 7 seconds, and passing through. This required that the AEV stop in front of the first sensor on the gate, but ensure that it does not trigger the second sensor of the gate. After the first sensor was triggered, the gate would open after 7 seconds and the AEV was to move past the gate safely.

When preparing for this test, it was necessary to have methods to ensure the safety of colleagues and the protection of the equipment used when testing. For this reason, multiple team members were placed along the track to catch the AEV in the case of unexpected behavior. A failure to have enough team members ready to catch the AEV resulted in the AEV falling off the track and landing safely on its 3D printed standoffs with no damage to the AEV or its components. To prevent this incident from happening in the future, signals were used to ensure that all members were present and ready for each test.

Performance Test 2:

For this performance test, The AEV was tasked with completing all tasks according to Performance Test 1, but with the additional task of connecting to the caboose after passing through the gate, waiting for 5 seconds, and moving the caboose out of the loading zone. This step required the AEV to have a soft enough connection with the load so that inertia did not carry the AEV past red tape marked near the end of the track. After softly connecting with the caboose and waiting for 5 seconds, the AEV was required to pull the caboose safely out of the loading zone by pulling the caboose passed the red tape marking. The same set of safety procedures as those found in Performance Test 1 were practiced during this performance test to prevent endangering the equipment and others.

Performance Test 3:

For Performance Test 3, the AEV was required to complete those tasks found in Performance Tests 1 and 2 with the final task of moving the caboose to the gate, waiting for 7 seconds, passing through the gate, and stopping at the starting loading zone. Similar to Performance Test 1, when bringing the caboose back, the AEV was required to stop at the first sensor of the gate without triggering the second sensor, and then wait for 7 seconds. After waiting, the AEV was to move through the gate with the caboose and stop within the starting loading zone. The starting loading zone was defined as the space between the last two supporting beams holding the track up from the ceiling. Additionally, the same safety procedures followed in Performance Test 1 were used during this performance test.

Results

Preliminary Research and Development

Limitations of Arduino

Upon working with the motors for the first 2 Preliminary Research and Development experiments, it was noticed that the motors did not move fully until a certain voltage level was reached. This was especially prominent when using the "celerate" function included in the OSU Arduino library. Other issues arose when physically implementing the code. For example, using the "brake" function merely brakes the motors, but the inertia of the AEV carries it past the expected position. This becomes especially problematic when considering the charge of the battery. In order to predict how far the AEV will coast, one needs to know the speed it is traveling. When batteries lose charge, they are likely to output less power, resulting in slower speeds than expected, and less coast distance. Additionally, the reflectance sensors are imprecise and may not give distances accurate enough for precise movements.

Collecting Data from the Arduino

After completing the third Preliminary Research and Development Experiment, data was collected and formed into the graph shown in Figure 5, below.

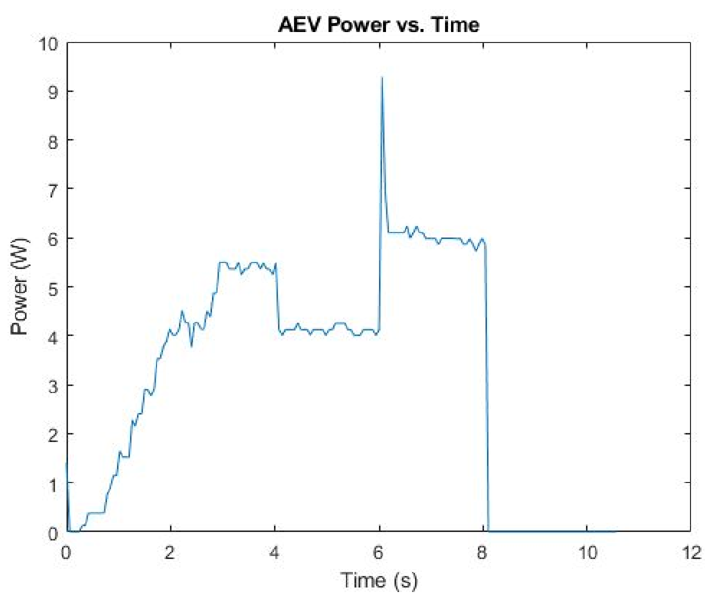


Figure 5: Power vs. Time of AEV moving forwards and backwards

Figure 5 shows the power being supplied to the motors over time as a result of the arduino code. Gradual increases in power are representative of the celerate function, constant levels of power occur when the vehicle maintains the same speed and the spike in the data occurs when the motor switches direction. The final part of the graph shows the power needed to maintain a speed in the other direction before stopping power at the end of the trial.

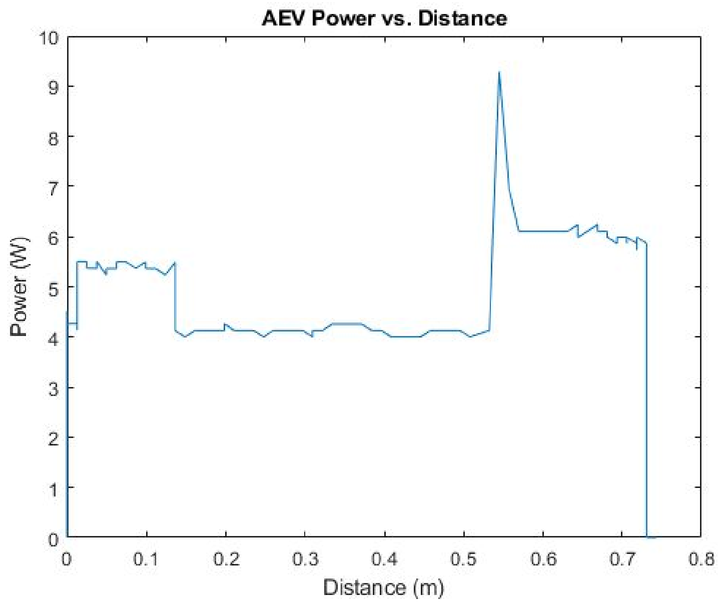


Figure 6: Power vs. Distance of AEV moving forwards and backwards

Figure 6 above shows the power supplied to the motors depending on the distance traveled according to the reflectance sensors. The beginning of the trial shows a higher voltage in order to increase the speed of the motors in accordance with the "celerate" function. After accelerating the motors to the desired speed, the power output drops as it is easier to maintain motor speed that to increase it. The spike in power usage towards the middle represents the point at which the AEV changed direction. The final part of the graph shows the power needed to maintain a speed in the other direction before cutting power at the conclusion of the trial.

Advanced Research and Development

Advanced R&D Experiment 1: Battery Voltage Experiment

The battery voltage experiment was conducted to help avoid the predicted inconsistencies of the motors. After running 3 sets of trials for each motor speed, additional trials were run for completeness of the experiment. Appendix D presents the data found from the experiment grouped by speed group. Each trial number is based on when that trial chronologically happened. Additionally, to get an accurate voltage reading, the AEV waited for 2 seconds at the start of each trial, and the voltage readings from those 2 seconds were averaged to find the voltage of the AEV before each trial.

The data above shows little to no variation in time within each speed group despite decreasing volates. Additionally, the time occasionally remained the same or decreased, meaning sometimes the AEV traveled at or above the speed of a previous trial. Interestingly, the voltage at times did not decrease at all, emphasizing that this experiment mainly tested the effects of small voltage drops. Finally, the range of each speed group's times decreased as speed increased. For example, the range of times it took the AEV to travel 3 feet at a speed of 40 was 0.271 seconds. The corresponding ranges for speeds of 50 and 60 were 0.062 and 0.002 respectively. Therefore, as the propeller speed was increased, the consistency in the time it took to travel 3 feet increased.

Advanced R&D Experiment 2: Propeller Configuration Experiment

Table 1 (below) shows the data collected from the second Advanced Research and Development Experiment. Each propeller configuration tested was given a number, and a short description of each configuration is listed in a cell below the table. The "Total Distance Traveled" column in Table 1 is defined as the number of tick marks recorded by the AEV after running at a speed of 50% for 3 seconds and coasting. Detailed descriptions and model views of each configuration can be found in Appendix C.

Table 1: total distance traveled by various propeller configurations.

Propeller Configuration	Total Distance Traveled (sensor ticks)
1	39
2	43
3	48
4	109
5	26
6	70
7	78

Firstly, the outlier of the data set is the side-by-side configuration (see Appendix C.4). It traveled the farthest out of all the designs after coasting. Configurations 1-3 are similar in distance traveled because they all use the same principle of coaxial contra-rotating propellers with one propeller's rough side facing forwards (see Appendix C.1-C.3). Additionally, the last 2 configurations traveled similar distances due to also having coaxial contra rotating propellers, but with both propeller's smooth side facing forwards (see Appendix C.6-C.7). Finally, Configuration 5 traveled the least distance since both propellers had their rough side facing forwards (see Appendix C.5).

Advanced Research & Development 3: Reflective Wheel Position Experiment

The following graph (see Figure 7, on next page) was created from data collected from the third Advanced Research & Development Experiment (see Appendix D). The Four different colors correspond to the 4 different kinds of wheel starting positions defined in Figure 4 on page 10. The equations of the lines of best fit are listed closest to their corresponding line, and each line is color coded to match the wheel position it is associated with. "True Distance Traveled" listed on the y-axis of Figure 7 is defined as how far the AEV actually traveled in inches using the measurements listed on the straight test track. Trials are numbered in chronological order.

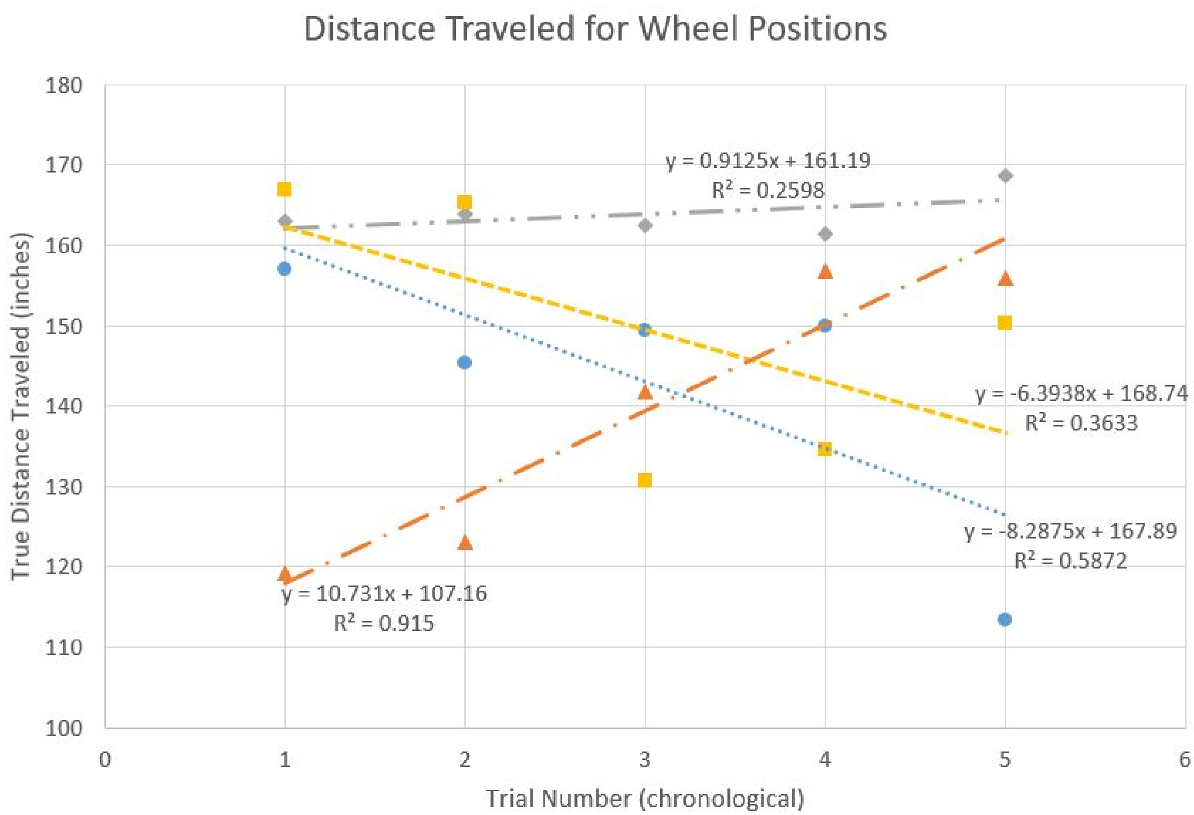


Figure 7: Trial versus true distance traveled

When examining the graph, it's clear that nearly all of the wheel positions have scattered distances. However, the "Top" wheel position had the lowest magnitude of slope out of all other configurations, but it also has the lowest R-squared value (meaning the line of best fit struggled to fit the data). Next, the "Bottom" and "Right" configurations seem to have similar trends, and similarities in their line of best fit equations confirm this. In contrast, "Left" has the highest magnitude of slope in the opposite direction of all but the "Top" starting position's line of best fit. Due to the fact that the AEV was inconsistent when testing each wheel position and in general, it was decided that a graph containing all trials and distances could help define the inconsistency of the AEV should the wheels have no role in it (see Figure 8, on next page).

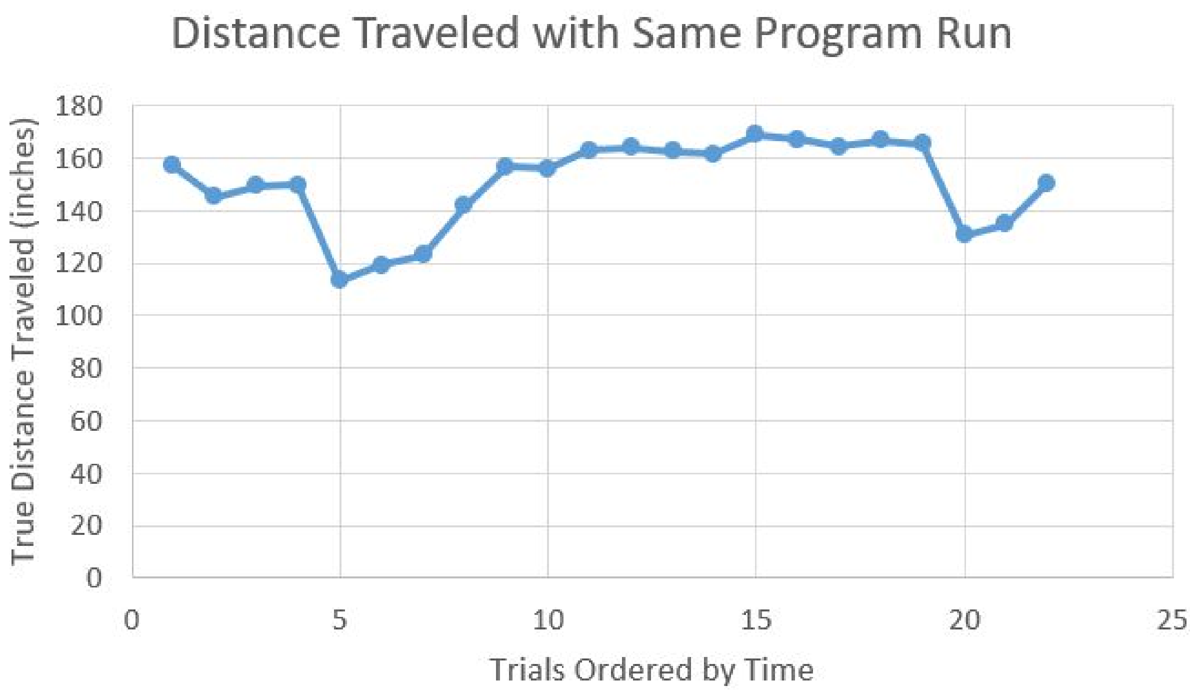


Figure 8: Graph showing distance traveled across all trials in chronological order

Viewing the graph immediately reveals the nature of the inconsistency with the AEV. Though the wheel position was changed roughly every 5 trials, it did not seem to affect the accuracy of the AEV. The main trend of the graph shows that the AEV has roughly 11 trials (trials 9-19 inclusive) where the range of the distances is 12.812 inches. Additionally, the range of all trials was 55.375 inches (over 4.5 feet). Another trend gathered from the graph was the pattern of steep drops and a gradual increase to rough consistency. Each drop was roughly 35 inches.

Discussion

Introduction

The Preliminary Research and Development experiments provided basic methods and procedures related to AEV design, construction and testing. Experiment 1 focused on the arduino library used to code all the functions of the AEV. Experiment 2 focused on using the reflectance sensors with the code as a helpful tool in allowing more precise control of the AEV's movement. Experiment 3 introduced the MATLAB tools for gathering and analyzing data after the AEV ran a piece of code. Experiments 4 and 5 were focused on the engineering design process of the AEV. These 2 experiments began with the represent part of the engineering design process, and each team member created a design for the AEV. Each design was then reviewed and a new design was created that involved the best ideas. The two designs merged were the opposing propeller design and the mystic macaw, which contained the aerodynamic shell. This design was used until the aerodynamic shell was removed after Performance Test 1.

Preliminary Research and Development of the AEV revealed that many aspects of the components the team had were imprecise or less usable than previously expected. Specifically, from Experiment 1 it was found that there is no way to measure speed directly on the AEV. However, with the reflectance sensors introduced in Experiment 2, it was easy to use distance as way of controlling when certain events would happen. Additionally, it was found that a considerable amount of power is needed to propel the AEV, even while using the larger propellers. In terms of coding the AEV, basic operations can be implemented with ease. Interfacing problems with the Arduino and the computer were also common. Selecting the wrong processor or board was a mistake made often, but was easy to fix. The data from Experiment 3 showed the power used to perform certain functions in the arduino code. The data reveals some slight inconsistencies in the power supplied to the AEV, which may have accounted for some of the problems encountered with motor speed being inconsistent between runs.

Preliminary Research and Development

Preliminary Research and Development Experiment 4 & 5 - Designing the AEV

In designing the AEV, the entire engineering design process was repeated multiple times to create a well thought out design. In starting to design the AEV, the define part of the design process was important in determining which qualities should be implemented on the AEV design. These attributes aided in creating designs as well as screening and scoring designs. When actually creating the design, the second and third steps of the engineering design process (represent and plan) were used when drawing orthographic views of the designs.

The first design had a trapezoidal base and side-by-side propellers to pull the AEV (see Appendix B.3). The base acted as a wing to help stabilize the AEV as it traveled. This first design was estimated to cost $165,620 and weigh about 0.44 pounds (see Appendix E.3). The second design, known as the “Airplane”, involved side-by-side propellers to push the AEV and an angle to give the AEV lift when moving in hopes of reducing track friction (see Appendix B.2). It was estimated to cost $167,620 and weigh approximately 0.44 pounds (see Appendix E.2). The third design, called the “Mystic Macaw”, also had side-by-side propellers, but included an aerodynamic shell to reduce the drag of the AEV (see Appendix B.4). This design’s estimated cost and weight were $169,120 and 0.51 pounds respectively (see Appendix E.4). The fourth design, known as the “Opposing Propeller” design, had a coaxial propeller configuration in which the propellers spun in opposite directions, but provided thrust in the same direction (see Appendix B.1). This design’s estimated cost and weight were $170,340 and weigh 0.46 pounds respectively (see Appendix E.1)

After creating these original designs, another design was brainstormed as a team. This design combined aspects of 2 of the designs previously created. The aerodynamic shell of the “Mystic Macaw” (see Appendix B.4) and the propeller configuration of the “Opposing

Propeller" design (see Appendix B.1) resulted in the design known as "The Bullet" shown in Figure 9 below.

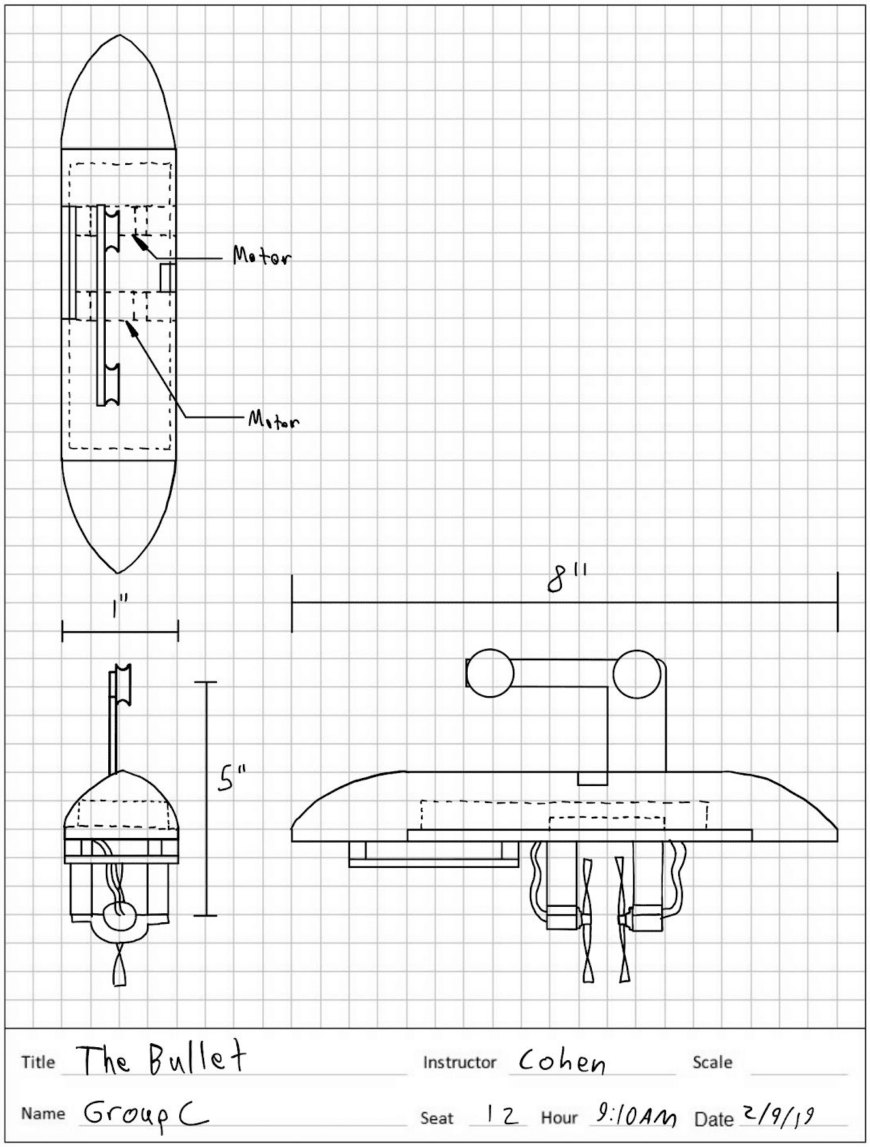


Figure 9: Orthographic drawing of "The Bullet"

This design incorporated the contra-rotating propellers with the aerodynamic shell of the Mystic Macaw Design. It will cost $176,340 and weighs approximately 0.50 pounds (see appendix E.5). The shell covers most wires attached to the Arduino and the standard battery holder. Additionally, holes were cut out of the aerodynamic shell to accommodate easy usage and modification of the Arduino without removing the shell (see Figure 10 on page 20).

After these 5 designs were created, a screening matrix was created to determine which designs were most likely to be considered for the next prototype based on a number of criteria. To determine these criteria, the first step of the engineering design process was revisited in order to match the constraints and goals assigned from the MCR[1]. The criteria created by the team were defined as follows: cost, weight, balance, simplicity, speed, aesthetics, and the time required to create the AEV. The screening matrix revealed that the opposing propeller, mystic macaw and group design (bullet) were better than the sample AEV overall, according to the screening (see Table 2, below). After determining these criterion, the final step of the engineering design process was put in to action when scoring the designs. In scoring the designs, it was determined which design was most effective (see Table 3, below).

Table 2: Screening Matrix

Success Criteria	Reference	1 (Airplane)	2 (Opposing Propeller)	3 (Tiana's)	4 (Mystic Macaw)	5 (Bullet)
Cost	0	0	+	0	-	0
Weight	0	0	-	+	-	-
Balance	0	0	+	0	+	+
Time	0	0	-	0	+	-
Simplicity	0	-	-	-	-	0
Speed (motors)	0	0	+	0	+	+
Aesthetics	0	0	+	-	+	+
Sum +'s	0	0	4	1	4	3
Sum 0's	7	6	0	4	0	2
Sum -'s	0	1	3	2	3	2
Net Score	0	-1	1	-1	1	1
Continue?	Combine	No	Yes	No	Yes	Yes

Table 3: Scoring Matrix (split to show numbers clearly)

Design	Weight	In class Prototype		1 (airplane)		2 (Opposing Propeller)	
		Rating	Weighted score	Rating	Weighted Score	Rating	Weidghted Score
Cost	20%	3	0.6	3.5	0.7	4.5	0.9
Weight	17.5%	2	0.35	4	0.7	4	0.7
Balance	17.5%	2	0.35	4	0.7	3	0.525
Time	17.5%	4	0.7	4	0.7	3.5	0.6125
Simplicity	7.5%	4	0.3	3	0.225	3	0.225
Speed(motos)	12.5%	2	0.25	3	0.375	4	0.5
aesthetics	7.5%	2	0.15	4	0.3	4	0.3
TOTAL	100%		2.7		3.7		3.7625

Design	Weight	3(Tiana's)		4(Mystic Macaw)		5(Group)	
		Rating	Weighted Score	Rating	Weight	Rating	Weight
Cost	20%	4	0.8	3	0.6	3	0.6
Weight	17.5%	4	0.7	3.5	0.6125	4	0.7
Balance	17.5%	2	0.35	4	0.7	4	0.7
Time	17.5%	4	0.7	3	0.525	3	0.525
Simplicity	7.5%	4	0.3	4	0.3	4	0.3
Speed(motos)	12.5%	3	0.375	4	0.5	4.5	0.5625
aesthetics	7.5%	3	0.225	5	0.375	5	0.375
TOTAL	100%		3.45		3.6125		3.7625

*Blue highlight signifies 1 of 2 best designs

Based off this scoring matrix, it was clear that the “Opposing Propeller” design or the “Group” design (also known as “The Bullet”) were the best designs. Since they were deemed equivalent in effectiveness, it was decided to use the “Group” design in order to test the most amount of features first (the aerodynamic shell combined with the opposing propellers).

When transitioning from the concept to prototype, it was necessary to consider the fourth step of the engineering design process, implement. After reviewing the available AEV parts, the 2” by 6” medium rectangular base was found to be most suited for the “Group” design. Additionally, custom parts were designed in SolidWorks and plans were made to re-create custom parts with the given AEV kit parts should the team not receive the grant for custom parts (see Figure 10, below).

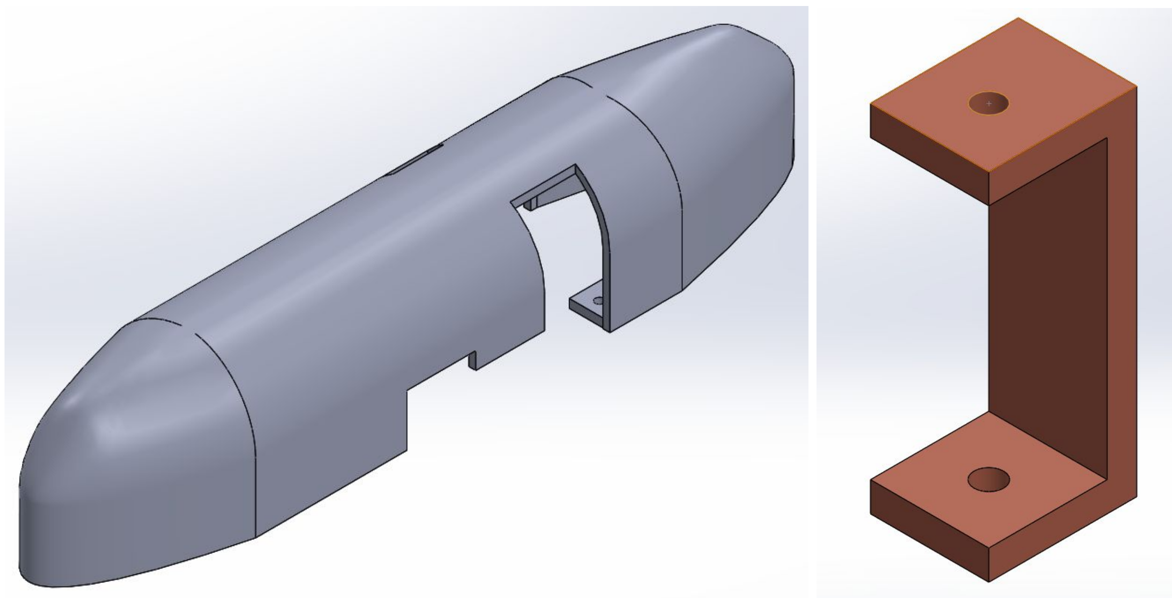


Figure 10: Custom AEV parts in SolidWorks. Left is the aerodynamic shell, right is the standoff

Advanced Research and Development

The conclusions that the team drew from both experiments were unexpected. For the battery test, the team expected that with decreasing voltage, the time it took the AEV to travel 3 feet would increase. A preliminary plan on how to counteract this effect was created by the team in advance if this were the case. However, the battery voltage did not affect the time it took the AEV to travel 3 feet, and it was found that the Arduino already has systems in place to counteract this issue. For the propeller configuration experiment, the team expected the coaxial contra-rotating propellers to outperform any other configuration in all useful ways. Those designs that did not use contra-rotating propellers were effective and surpassed contra-rotating propellers in the one dimension that was tested. A more in-depth look at each experiment allowed the team draw meaningful conclusions.

Advanced Research and Development Experiment 1: Battery Experiment

The purpose of this experiment was to determine if decreasing battery voltage caused decreased efficiency in the motors of the AEV. If this was the case, a plan would be made to counteract the decreasing efficiency of the motors. Upon completion of the Battery Experiment, it was found that small drops in voltage did not affect the efficiency of the AEV motors. Based on the data collected, the time it took the AEV to travel a certain distance remained relatively constant regardless of which speed the motors were run at. However, the faster the motors were run, the less variation in time there was, implying that the speed of the AEV became more consistent at higher motor speeds. Because the battery voltage didn't change anything about the performance of the AEV, it was concluded that the battery would not cause problems after continued use and would not be factored into the code written for the performance tests.

The error of the Battery Experiment lies in time constraints and the method of starting the AEV. In terms of time constraints, the experiment only tested small voltage drops, as large voltage drops would require enough time to run down the voltage of the battery. Larger voltage drops may have yielded more significant trends. When starting the AEV, it was required to push the start button while it was on the track. In the process of pressing the button, the AEV moved at times, and the reflectance sensors may have been triggered earlier than was intended. Though larger voltage drops could yield significantly different results, the slight movements of the AEV upon starting it would only cause slight variation in the data. This experiment should therefore be considered valid for small voltage drops.

The results of this experiment were unexpected as the decrease in voltage did not affect the time it took to travel a constant distance. After completing the experiment, it was found that the Arduino has built in code to counteract the effects of decreasing battery voltage. As such this experiment is consistent with theoretical predictions. Additionally, the AEV's speed became more consistent with higher motor speeds, aligning with the idea that at higher speeds, friction is less of a factor in slowing objects.

Advanced Research and Development Experiment 2: Propeller Configuration

When comparing the first 3 configurations tested (see Table 1 on page 14), it was clear that Configuration 3 was the most effective. This configuration had propellers facing outwards in a coaxial contra-rotating fashion and is described in Appendix C.3. However, while testing configuration 3 one propeller was facing the wrong way, decreasing the efficiency. Configuration 7 (see Appendix C.7) is the same design as configuration 3 with the propellers facing the same way, this was the best coaxial contra-rotating design for travelling in one direction. Although the data from Table 1 on page 14 showed that Configuration 4 (see Appendix C.4) was the best configuration, it only accounted for movement in one direction. As the AEV goes back through the course after picking up the load, the propellers would be facing the wrong direction, causing decreased efficiency. Due to this factor, the team opted to use Configuration 3 where one propeller was facing the wrong way so there would be an equal push pull system for both before and after picking up the load. This favored the possibility of greater efficiency when moving backwards and consistent efficiency when moving in both directions.

The obvious limit to the propeller configuration experiment is that it did not test how each configuration performed when moving backwards, but this does not affect the data previously collected. Sources of error that may have affected the results include issues when changing configurations between trials, track variability, and the fact that all configurations were not tested. When rebuilding the AEV between each trail into a new propeller configuration, the tightness of bolts and security of parts of the AEV could change through human interaction or through vibrations created when testing. It is possible that during the initial trials there was a bolt that was too tight and was creating friction for the AEV while during the final trials the bolt was loosened from the effects of the previous trials. This example suggests that the final trials should be naturally greater than the initial trials, but it's possible that the effects of changing configurations could have the opposite effect as well. Another issue with the experiment is that the track used for testing is not a uniform friction throughout, and that the wheel of the AEV has a certain tolerance to move perpendicular to the track. When using certain configurations, the AEV may have been more likely to slide to one side than another causing either increased or decreased friction, depending on the condition of the track at that point. This could skew results in either direction, but similar configurations should experience a similar error. Finally, the experiment cannot test the infinite amount of possible configurations, and it is possible that coaxial contra-rotating propellers could be enhanced further if put in a different configuration.

It was not expected that the side by side propellers would do as well as they did. Logically, since there was double the force from the propellers pushing the AEV forward, it should be expected that the side by side configuration with two propellers acting one way would perform equivalently to two coaxial propellers in a push pull system. The team's predictions were right about the contra-rotating propellers having the greatest efficiency when far apart. In addition, being further apart allowed the propeller to spin without hitting the turbulence from the opposite propeller. The team thought this configuration would be stronger due to the history from World War 2 planes. These planes had contra-rotating propellers to decrease the torque on the plane but also aid in thrust.

Advanced Research and Development Experiment 3: Reflective Wheel Position Experiment

The third Advanced Research and Development Experiment was designed to determine whether the starting position of the reflective wheel affected the consistency of the AEV. The data collected showed many contradictory trends and as such, the conclusion was drawn that the reflective wheel's starting position had no bearing on the consistency of the AEV. In this experiment, consistency was defined using the range of the distances that the AEV traveled during successive trials. When viewing data for each wheel position, the AEV was inconsistent when using the same code and same wheel starting position for 3 out of the 4 positions. This implies that the cause of the inconsistency with the AEV lies outside of the code and the wheel's starting position.

When completing this experiment, the possibility for error was high. First, the method of measuring where the AEV came to rest was imprecise, as the center of the AEV's front wheel was estimated. Additionally, the markings on the straight track had a precision of 1/16 inch, and some values were estimated or rounded. This could cause the true distance to be slightly greater or less than reported. Another cause of error lies in the way that the starting wheel position was set. To set the wheel, the AEV had to be held still while spinning the back wheel into one of the four positions (see Figure 4 on page 10). In the process of doing so, the AEV occasionally moved slightly from its starting position, and was required to be reset. This caused the wheels to not be set in the exact same way for each trial, and may have caused the data collected to be slightly inaccurate. Though these errors exist, they do not create enough error to discount the experiment.

The conclusions drawn in this experiment were unexpected, as it was predicted that the starting position of the reflective wheel would correlate to the AEV's inconsistencies in distance seen in past performance tests. However, the conclusions support the idea that the sensors are accurate and working, and that moving the AEV's wheel position does not greatly affect how far the AEV travels.

Performance Tests

Performance Test 1 of the AEV involved a very early stage version of the final AEV design. During the preparation for Performance Test 1, and the actual test, many problems were encountered, including an issue with an improperly secured motor during the test. The design of the AEV was similar to the final design, but it had the aerodynamic shell, and did not have any parts securing the the tops of the motors so they would occasionally move out of place slightly during testing (see Figure 11 on next page). During Performance Test 1, the AEV was concluded to be too heavy and not secure enough, as the motor came loose in the middle of testing. After Performance Test 1, the aerodynamic shell was removed and the propellers were secured using the small 1" by 3" rectangles provided in the AEV kit.

Figure 11: Design used for Performance Test 1

Between Performance Tests 1 and 2, the biggest change in the code was how it accounts for missing the gate area. In Performance Test 1, the code would check if the AEV was too far forward or backward and it would spin the propellers until the AEV reached that location. This method would accelerate the AEV to speeds too high to stop in the correct location if the AEV was far from the gate. In Performance Test 2 the code was changed to check the position of the AEV every 0.25 seconds with a while loop. This allowed the AEV to go back and forth until it made it to the correct spot. Along with securing the motors, changing the code between Performance Tests 1 and 2 allowed the AEV to perform more consistently. Additional Improvements in consistency were also added between Performance Tests 2 and 3.

When improving the AEV for Performance Test 3, changes in code and the magnetic connector were made. The method for getting to the correct location at the gate was rewritten to “nudge” the AEV so that every 0.2 seconds it would spin the propellers for 0.25 seconds. This allowed the AEV to travel at a more controlled speed instead of accelerating all the way to the correct position. The propellers also spun in the opposite direction well before the correct position was reached to completely stop the AEV before “nudging” it to the correct location. The code does not contain a while loop segment to make the vehicle go backwards if it goes too far, and the AEV will deliberately undershoot the location to avoid moving past the first sensor and needing to reverse. This code strategy was added to each section where the AEV stops: the first side of the gate, the caboose, the second side of the gate, and the starting position. Also during Performance Test 2, the propellers were hitting the metal connector when the AEV attempted to connect to the load. This resulted in the team moving the metal connector further out so the propellers would not tap the connector and therefore hit the load. Also, the magnet connector was designed in such a way as to cushion the connection between the AEV and load using friction (see Figure 12).

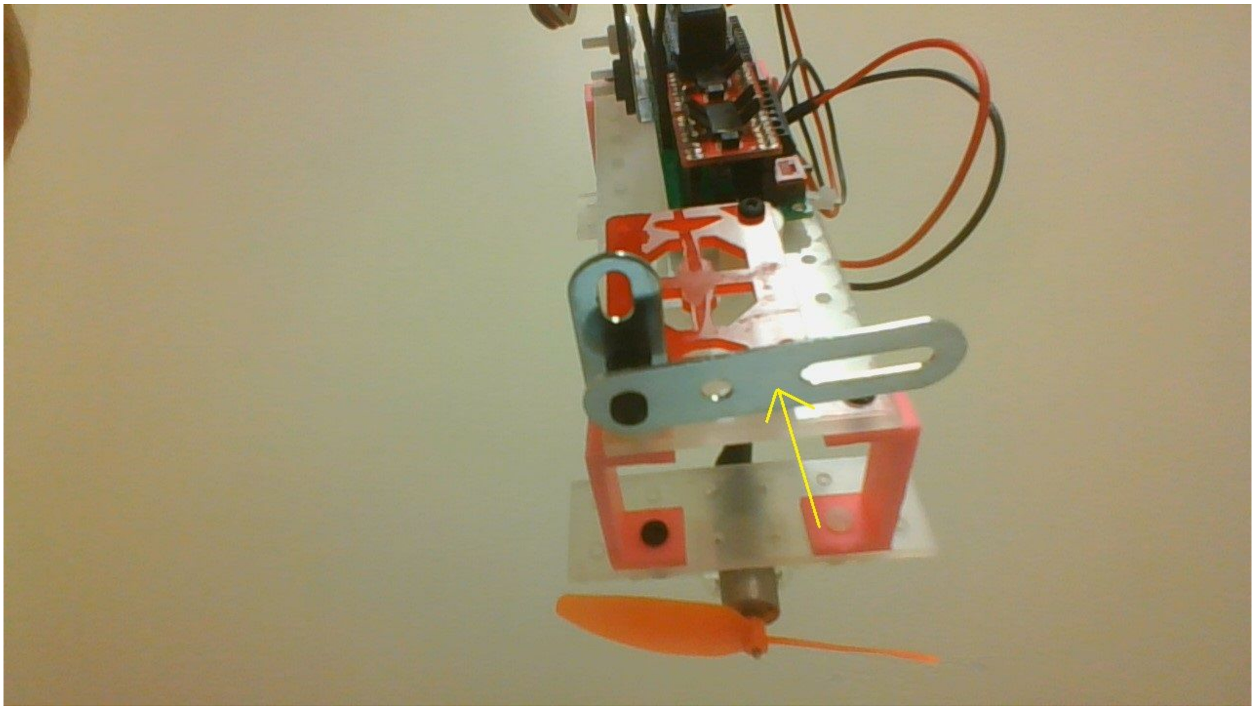


Figure 12: Magnet connector. Yellow arrow denotes load's point of contact

Performance Test 3 went well aside from hardware inconsistencies. The AEV made it to roughly the correct positions throughout the performance test, though most locations were undershot. At the beginning of the performance test, the AEV stopped too short and ended up getting stuck on the initial incline (see Figure 13, on next page). After manually pushing the AEV, it overshot the gate position likely due to the push. After passing through the gate, it nearly reached the caboose, but the minimum speed was too little to push the AEV to the caboose. Previous tests showed the AEV successfully reaching the desired positions, and these errors were classified as having something to do with the inconsistencies of the hardware and the Arduino. Additionally, the AEV successfully made it to the correct position on the other side of the gate with the load, but was moving too fast to stop safely in the final loading zone.

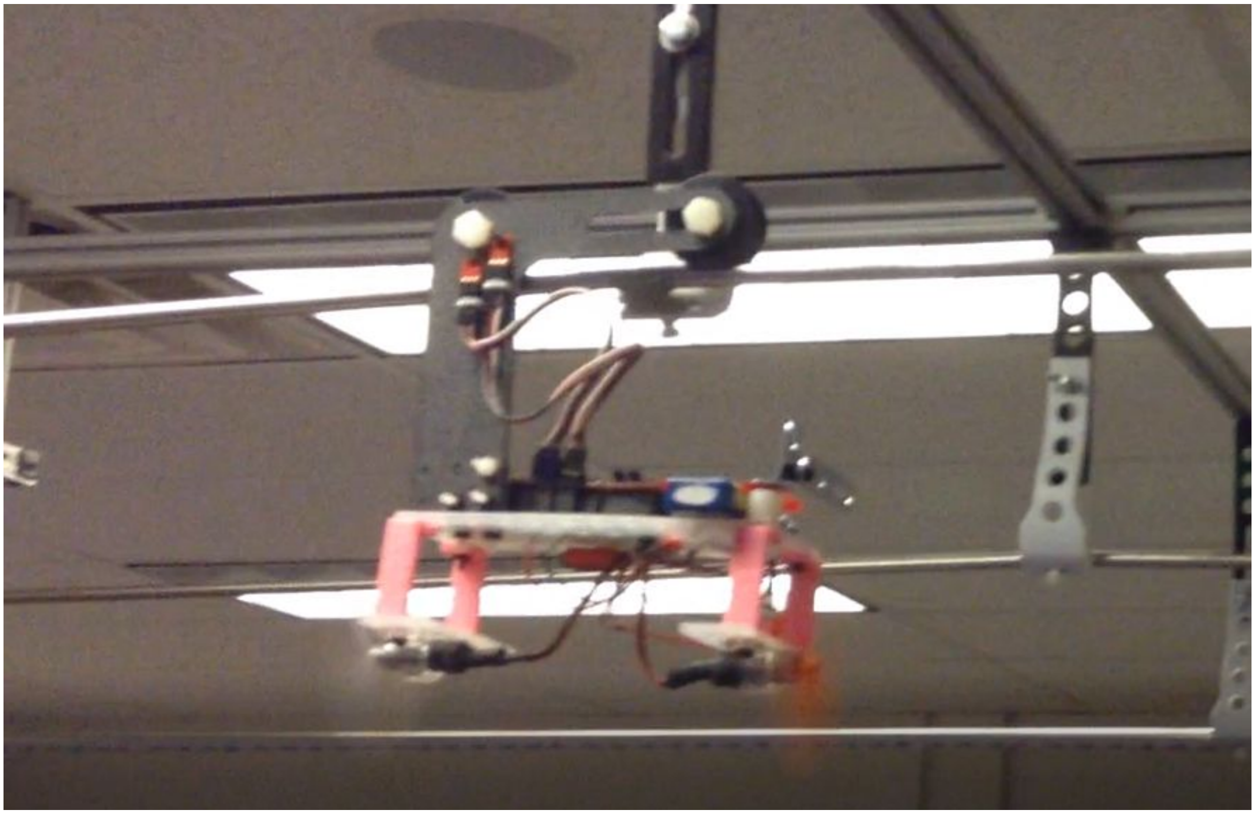


Figure 13: AEV undershoots and gets stuck on initial track incline

The changes made in the code after Performance Test 2 and during Performance Test 3 allowed the AEV to finish the test despite the vehicle undershooting targeted positions. Performance Test 3 showed that, even given inconsistent hardware problems, the AEV could be moved slightly and still work as intended. If these hardware issues were to be looked into in the future , the AEV would be even more consistent and energy efficient.

Final Design:

The final AEV design as seen in Figure 14 (on the next page), includes features from the initial design process as well as improvements made after research and performance tests. The final design features the most optimal opposing propeller design, as determined from Advanced Research and Development 2. The propeller configuration also includes extra pieces to secure the motors to the AEV from above. The final design also features a magnet connector which moves upon impact. The aerodynamic shell was removed due to its excessive weight. The final design is lightweight, efficient, and simple. Because the design is lightweight, it stops and starts moving much quicker and easier than when it still had the heavy aerodynamic shell. It also requires less energy for the motors to propel the AEV due to its weight. The final design is also propelled more efficiently due to the opposing propeller configuration. The propellers are just as efficient going forwards and backwards. The AEV is also very balanced. Initially at the start of the performance tests, it leaned to one side, but adjusting the position of the arm and shifting the battery's position in the battery holder allowed the AEV to obtain a near perfect center of balance. This was beneficial in ensuring that the AEV travelled efficiently and consistently.

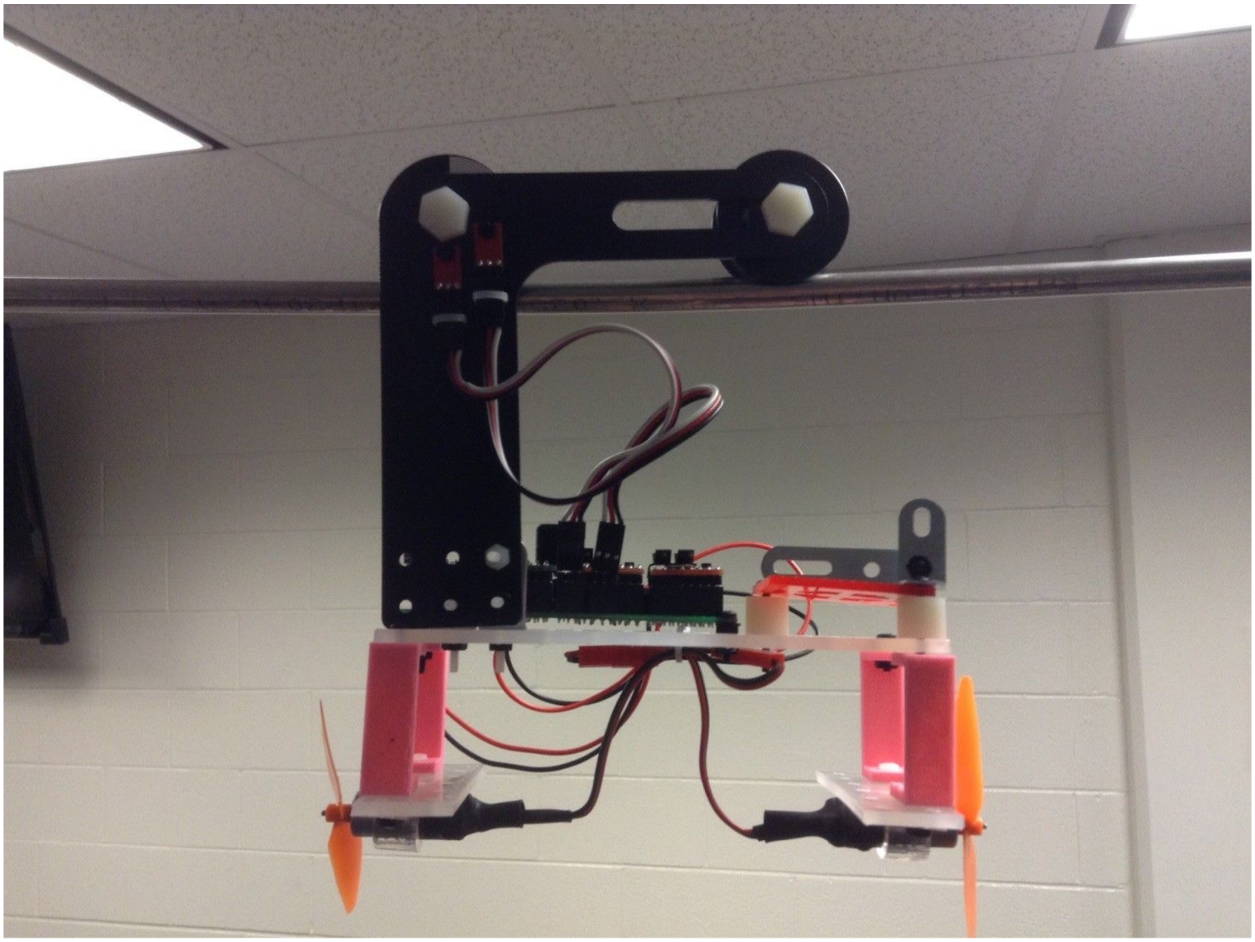


Figure 14: Final AEV Design

The final material cost of the AEV, as seen in Appendix F.2, was $151,487. This was just over 10% of the total cost of $1,466,931.25 (Appendix F.1). The total cost of the AEV was so high due to the inconsistencies in the final performance test. The AEV finished the runs, yet it had inconsistencies due to the hardware that caused it to take longer to correct itself. The actual cost of the materials for the AEV were very low due to the removal of the aerodynamic shell. The only custom parts were the 4 standoffs for the motors. If the code were improved to use less energy and take less time, the total cost of the AEV would be lessened. A big part of the cost was the safety violation as well. The $25,000 violation which occurred early on in the development process, was factored into every run. This left the costs of the runs to prices upwards of $600,000 to $800,000 (Appendix F.1). If the AEV were to complete the final performance test just 20 seconds faster, that alone could reduce the final costs by about $200,000, more than the cost of the AEV itself. If the code were to be optimized to achieve this, the vehicle could achieve much greater results, and decrease the total cost of the AEV.

Conclusions & Recommendations

Preliminary research and development revealed that there was no way to measure speed directly on the AEV and considerable amounts of power were needed to propel the AEV. The first preliminary research and development experiment helped demonstrate the various functions of the OSU Arduino library. The reflectance sensor test demonstrated how to use the reflectance sensors and their precision. The third preliminary research and development experiment explained how use the data extraction tool. The following preliminary research and development experiments showed that the best design was a mixture of the Opposing Propeller (see Appendix B.1) and the Mystic Macaw design (see Appendix B.4). Based on the preliminary experiments, it was decided that the battery needed to be tested to ensure motor consistency and that various propeller configurations should be tested to find the best for the AEV design. After These experiments and 2 performance tests, it was decided that the starting position of the reflective wheel would be tested to attempt to reduce inconsistencies with the AEV.

It was concluded during the first advanced research and development (R&D) test that there is no correlation between voltage and the efficiency of the motors. This was done by running the AEV on the track at different powers for a certain amount of distance to see how the loss in voltage related to the time it took the AEV to travel the set distance. From the second advanced R&D experiment it was concluded that contra-rotating propellers may not be as efficient as propellers mounted side-by-side, however contra-rotating propellers are more effective in reversing the direction of the AEV. This test was completed by rearranging the propellers and seeing how efficient each pairing was for one direction, using distance traveled as a measure of efficiency. According to the results from Performance Test 1, the shell was too heavy and was removed to ensure a more efficient AEV. In addition, the propellers needed to be more secure to decrease the risk of the propellers coming out of their plastic holders. It was determined that the contra-rotating propellers, fully secured and on standoffs, is the ideal design for Smart City Columbus to make Columbus more accessible and eco-friendly. During the second performance test, the AEV met all requirements and great improvements in the code were made. During the final performance test, the AEV code did not complete the course on its own. This was due to time constraints and the inconsistencies with the hardware of the AEV. With either more time, or an elimination of inconsistencies in the how the AEV run, the final design could complete the final performance test according to the requirements. This would be done by editing the code and securing down the metal connector. In the end, the cost of materials was $151,487 (see Appendix F.2), but the cost for the final test based on time and efficiently brought the cost to a little under 1.5 million dollars (see Appendix F.1). This expensive budget could be reduced with more time for research and experimentation. Since the cost of the materials is low, perfecting the performance of this design would lead to a more reasonable budget.

As far as reducing the error of each experiment, machines and other technologies could be used to aid in all experiments. The Battery Experiment could be improved by repeating the original procedure, but wearing out the batteries in between trials to induce greater voltage drops. This experiment could also be improved if the AEV could be started remotely so as not to move the AEV from its correct starting position. To improve the Propeller Configuration experiment, a design that could easily switch between propeller configurations and was equally balanced for each configuration would help to eliminate outside factors that might affect the performance of the configuration. Also, more time would allow for more configurations to be tested to find the optimal configuration for the AEV. To improve the Reflective Wheel Position experiment, more precise markings could be added to the straight track, and a laser pointer could be added to help mark where the AEV is on the straight track. To help adjust the reflective wheel to the desired position, a locking device could be added to the AEV to prevent it from moving.

Overall, the AEV could be improved by perfecting the code so that it rarely or never undershoots. This could be completed by adding more complicated functions to the code or experimenting with new strategies. Also, after multiple trials, the magnet connector would come loose. Finding an alternate way to cushion the connection between the AEV and the load would decrease the cost of maintaining the magnet connector were this idea to be used by Smart City Columbus. Though this AEV design underperformed during its final test, it passed its previous 2 performance tests meeting all requirements, and it could perform similarly on the final performance with additional improvements.

References

[1] Ohio State Fundamentals of Engineering Program, "Mission Concept Review (MCR) and Deliverables" [Course documentation]. Available: carmen.osu.edu for ENGR 1182. [Accessed Jan. 8, 2019-Present].
[2] Ohio State Fundamentals of Engineering Program, "Preliminary Research and Design" [Course documentation]. Available: carmen.osu.edu for ENGR 1182. [Accessed Jan. 8 2019-Present].
[3] Ohio State Fundamentals of Engineering Program, "User Manual - Reflectance Sensor" [Course documentation]. Available: carmen.osu.edu for ENGR 1182. [Accessed Jan. 8 2019-Present].

Appendices

Appendix A: Arduino Code for Preliminary R&D

A.1 - Exercise 1

```
celerate(1,0,15,2.5); //accelerates motor 1 0-15% in 2.5 seconds
goFor(1);             //holds the final speed for 1 second
brake(1);             //stops motor 1
celerate(2,0,27,4);   //accelerates motor 2 0-27% in 4 seconds
celerate(2,27,15,1);  //decellerates otor 2 to 15% in 1 second
brake(2);             //stops motor 2
reverse(2);           //makes motor 2 reverse, all positive values will make it move back
celerate(4,0,31,2);   //accelerates motor 1 forward to 31% in 2 seconds and motor
backwards to 31% in 2 seconds
motorSpeed(4,35);     //presets the motor to 35%
goFor(1);             //holds this 35% speed for 1 second
brake(2);             //brakes motor 2, motor 1 is still running forward at 35%...
goFor(3);             //...for three seconds
brake(4);
goFor(1);             //these lines brake all motors for 1 seconds
reverse(1);           //currently motor 1 and 2 are reversed
celerate(1,0,19,2);   //accelerates motor 1 0-19% in 2 seconds
motorSpeed(2,35);     //sets the motor speed for motor 2 to 35%
goFor(2);             //waits for 2 seconds. motor 1 is at 19% and motor 2 is at 35%
motorSpeed(2,19);     //both motors are now 19%
goFor(2);             //runs both motors at 19% for 2 seconds
celerate(4,19,0,3);   //decellerates all motors to 0 from 19%
brake(4);             //stops all motors
```

A.2 - Exercise 2

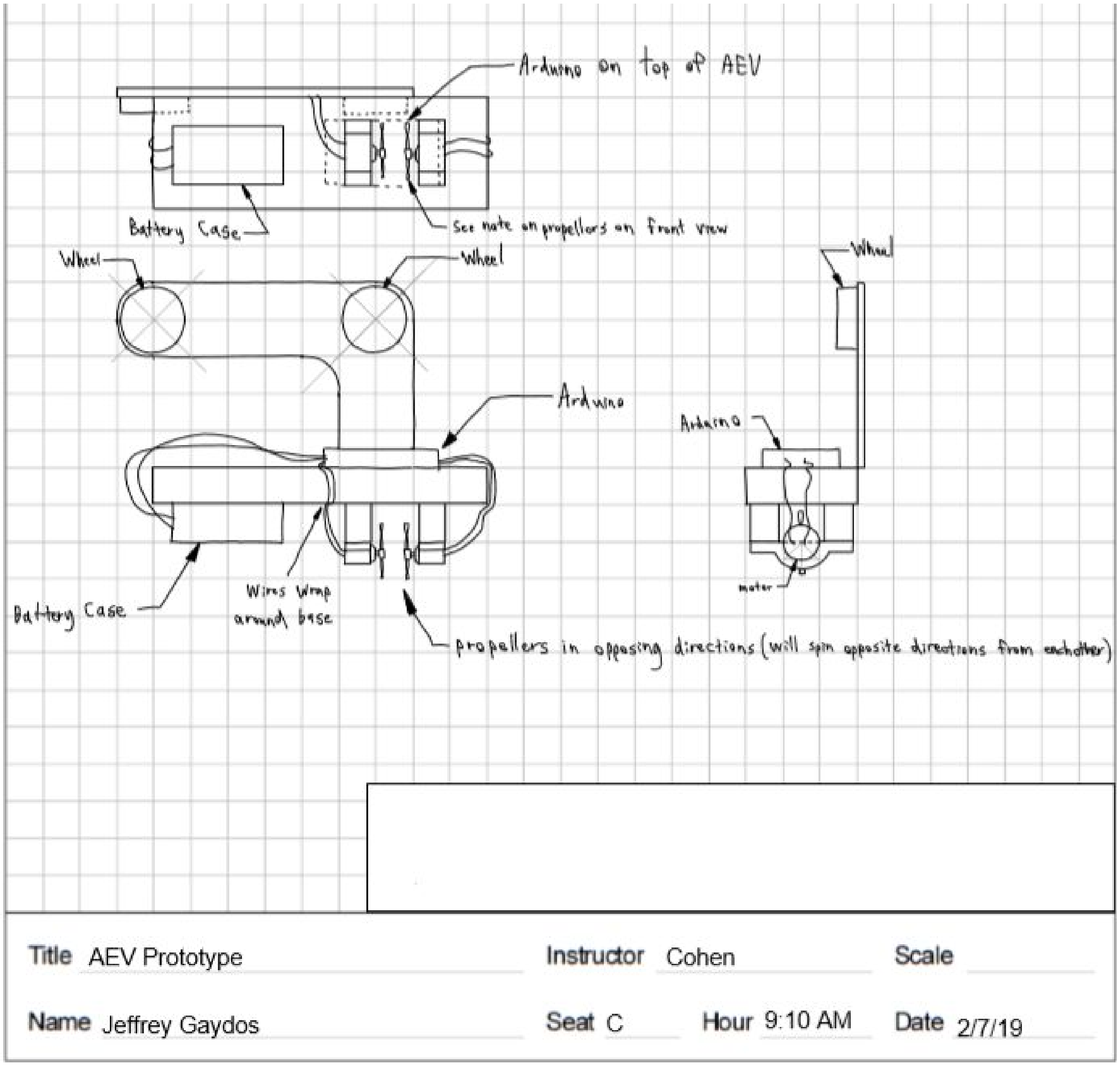
```
// Run all motors for 2 seconds at 25% power
motorSpeed(4,25);
goFor(2);
//decrease motor speeds to 20% and go 12 feet at this speed
motorSpeed(4,20);
goToAbsolutePosition(296); //goes to approximately 12', which is actually 295.3846,
rounded up to ensure it travels at least 12'
//reverse the motors and run them for 1.5 seconds at 30%
reverse(4);
motorSpeed(4,30);
goFor(1.5);
//stop all motors...
brake(4);
```

A.3 - Exercise 3

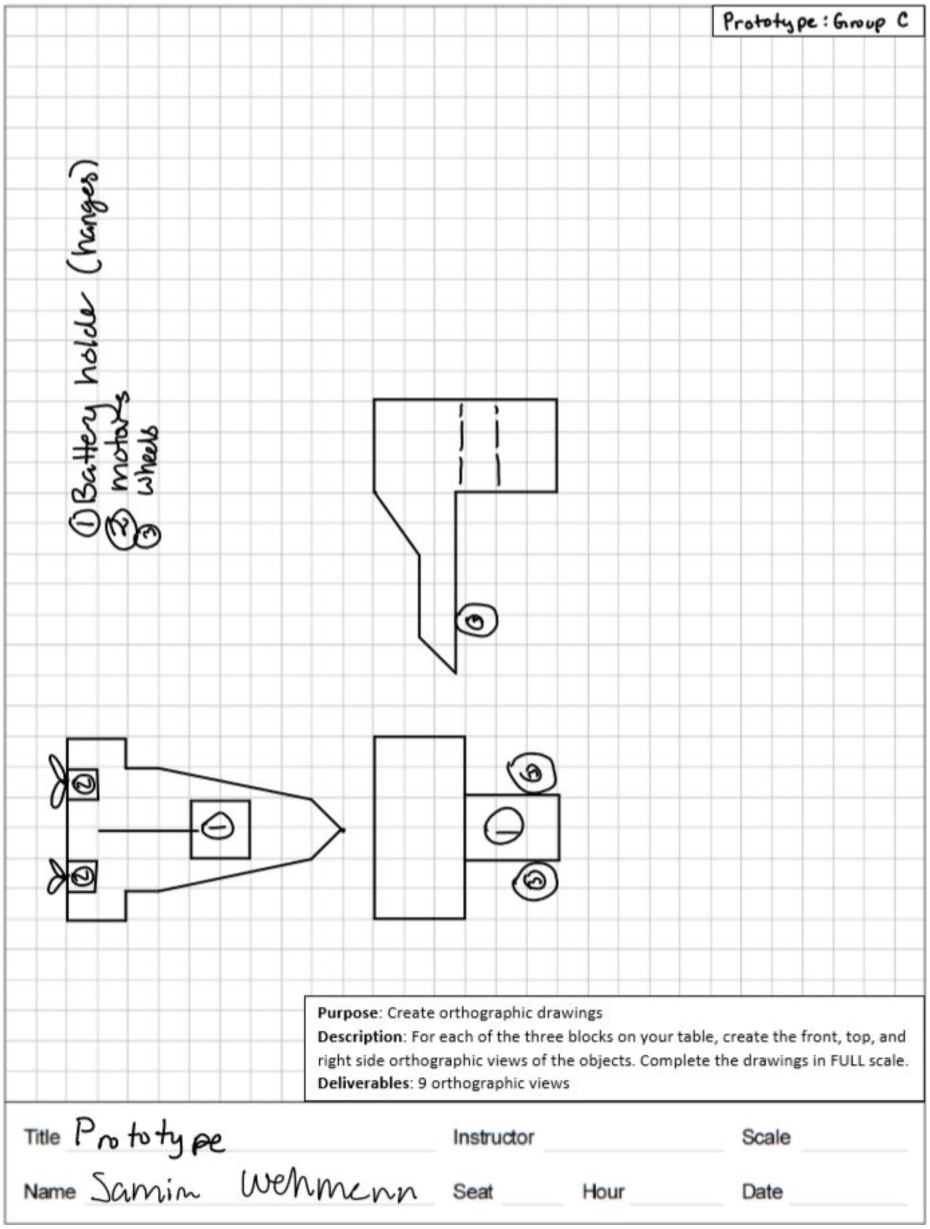
```
//accelerate all motors from 0-25% in 3 seconds
celerate(4,0,25,3);
//after accelerating, setting all motors to to 25% and waiting 1 second
motorSpeed(4,25);
goFor(1);
//running all motors 20% for 2 seconds
motorSpeed(4,20);
goFor(2);
//reverse all motors
reverse(4);
//set all motors to 25% for 2 seconds
motorSpeed(4,25);
goFor(2);
//brake all motors
brake(4);
```

Appendix B: Initial Design Sketches

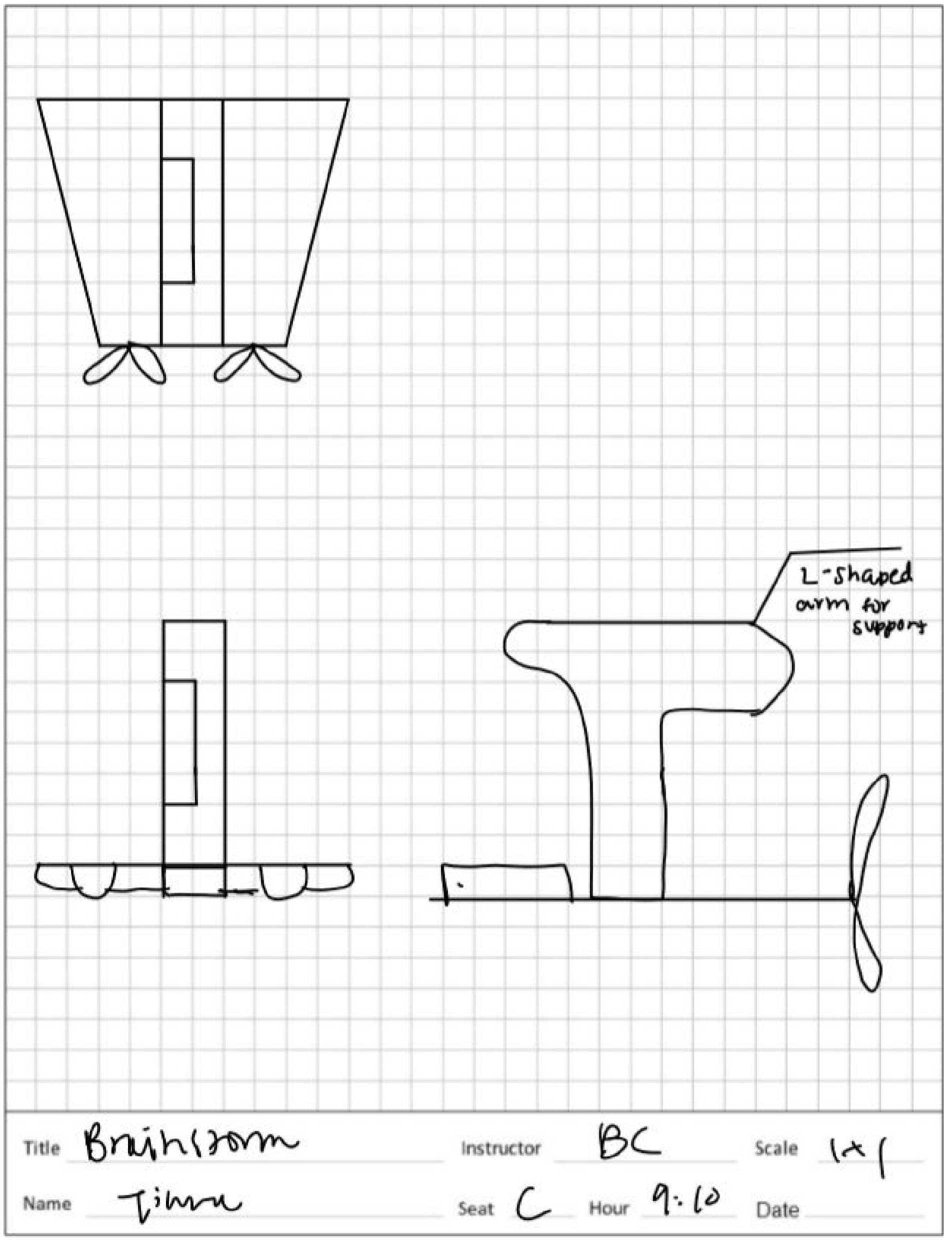
B.1 - Opposing Propellers



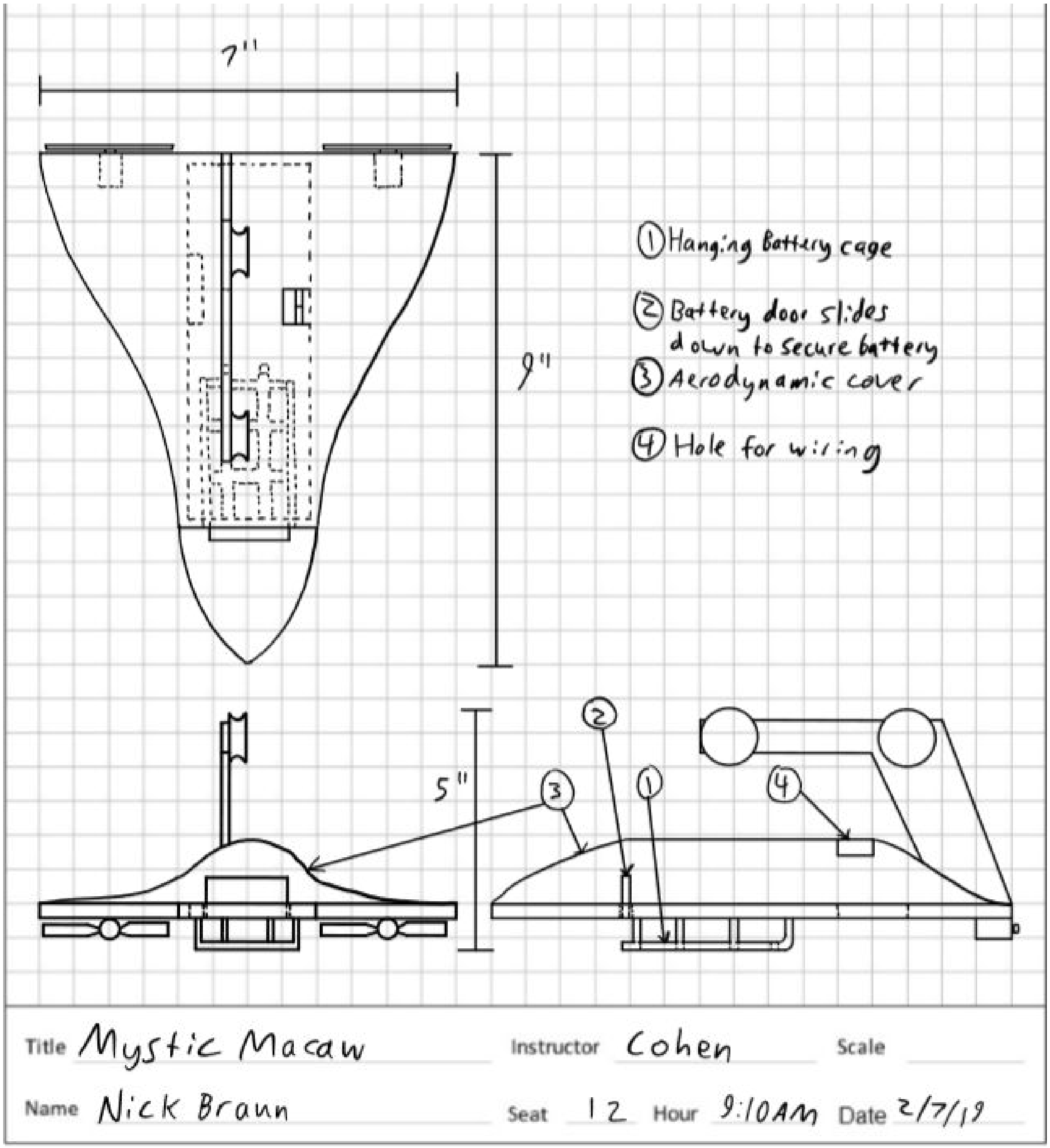
Appendix B.2 - Airplane



Appendix B.3 - Tiana's Design

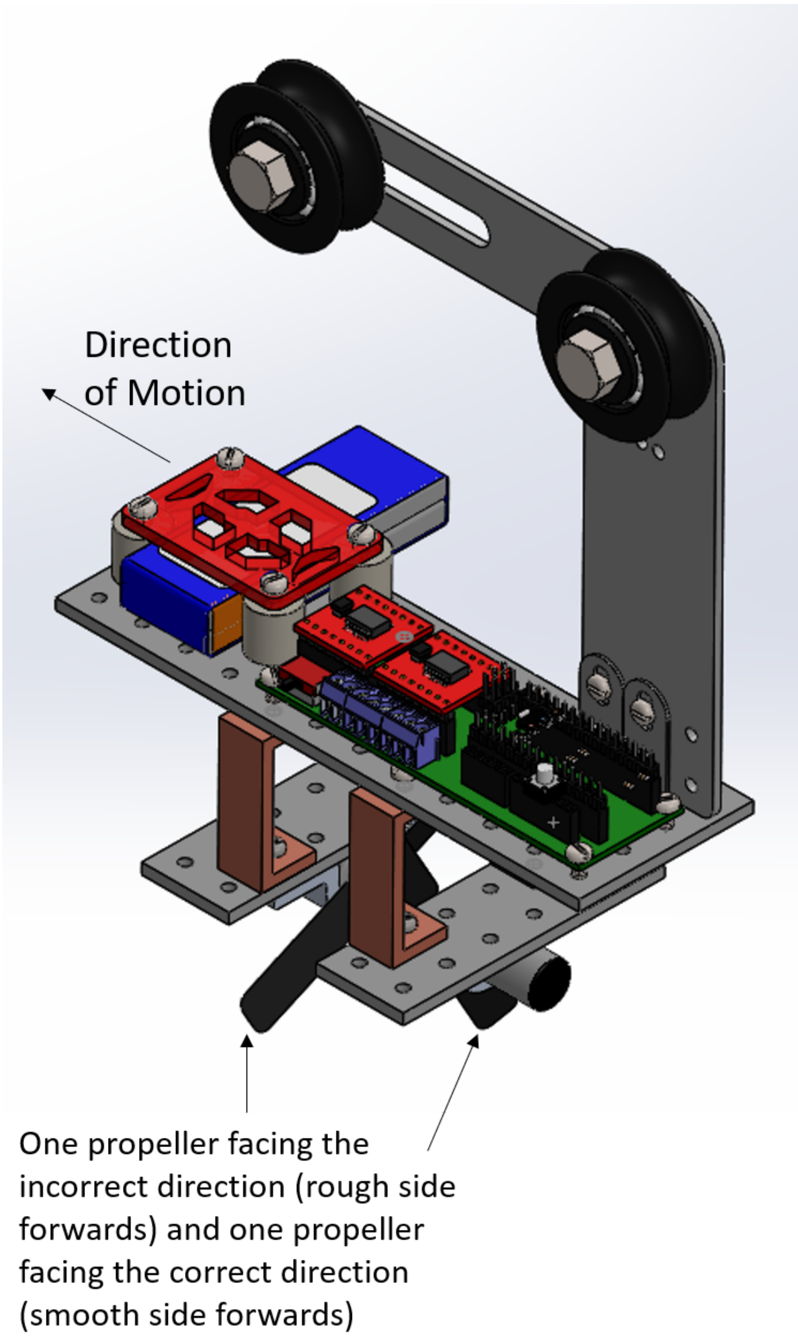


Appendix B4 - Mystic Macaw

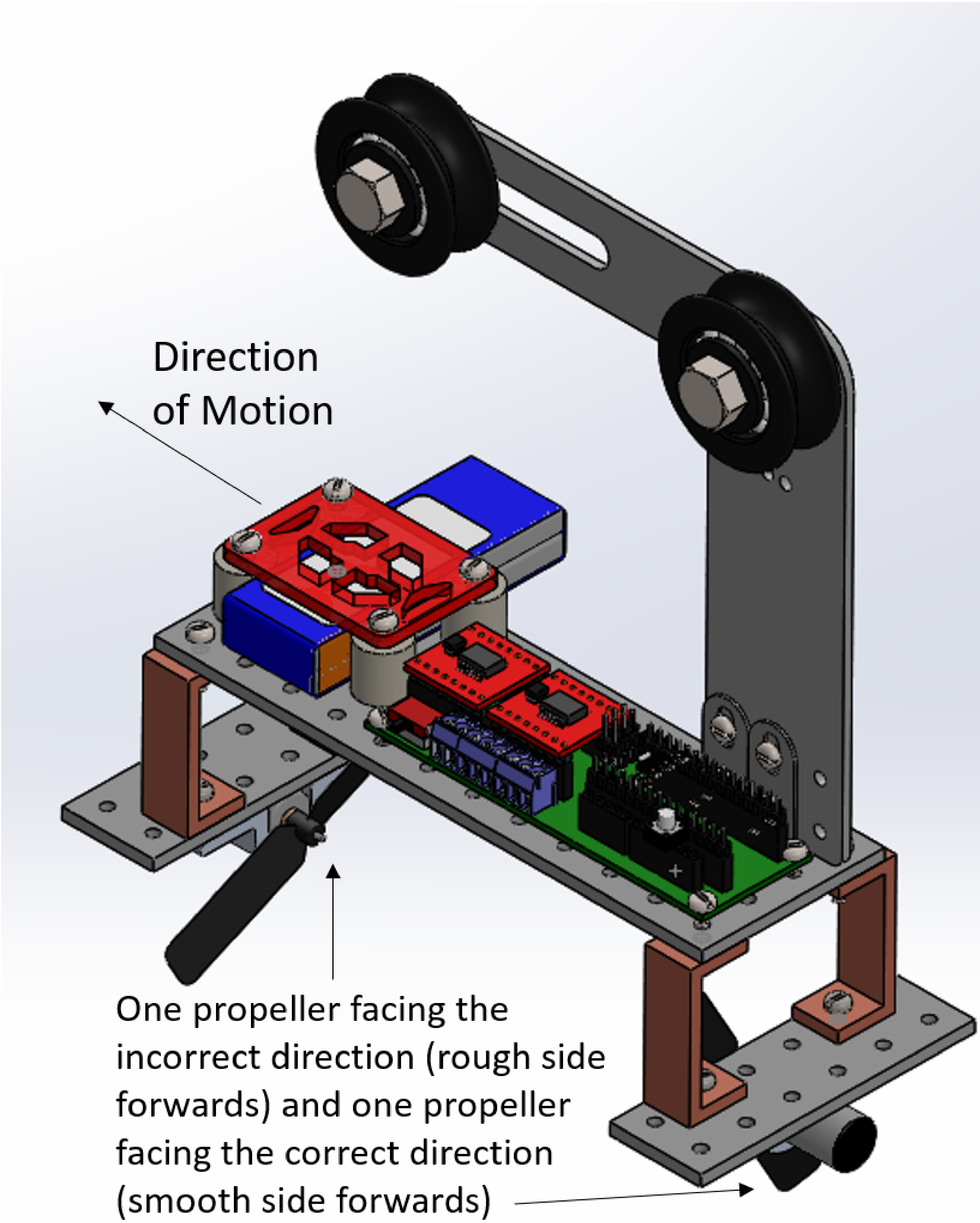


Appendix C: Propeller Configurations for Advanced Research and Development Experiments

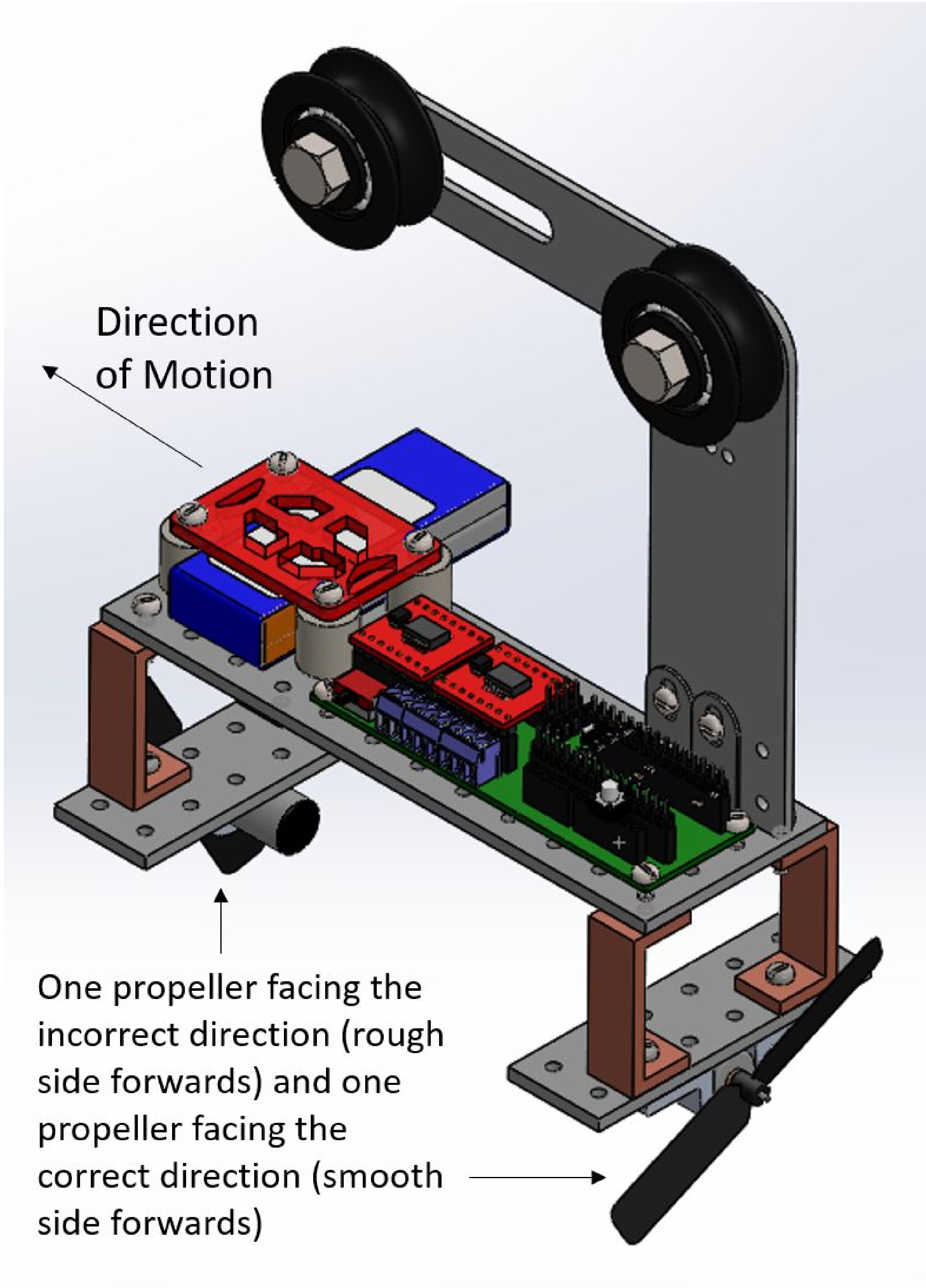
C1. Configuration 1 - coaxial contra-rotating propellers facing inwards and close together



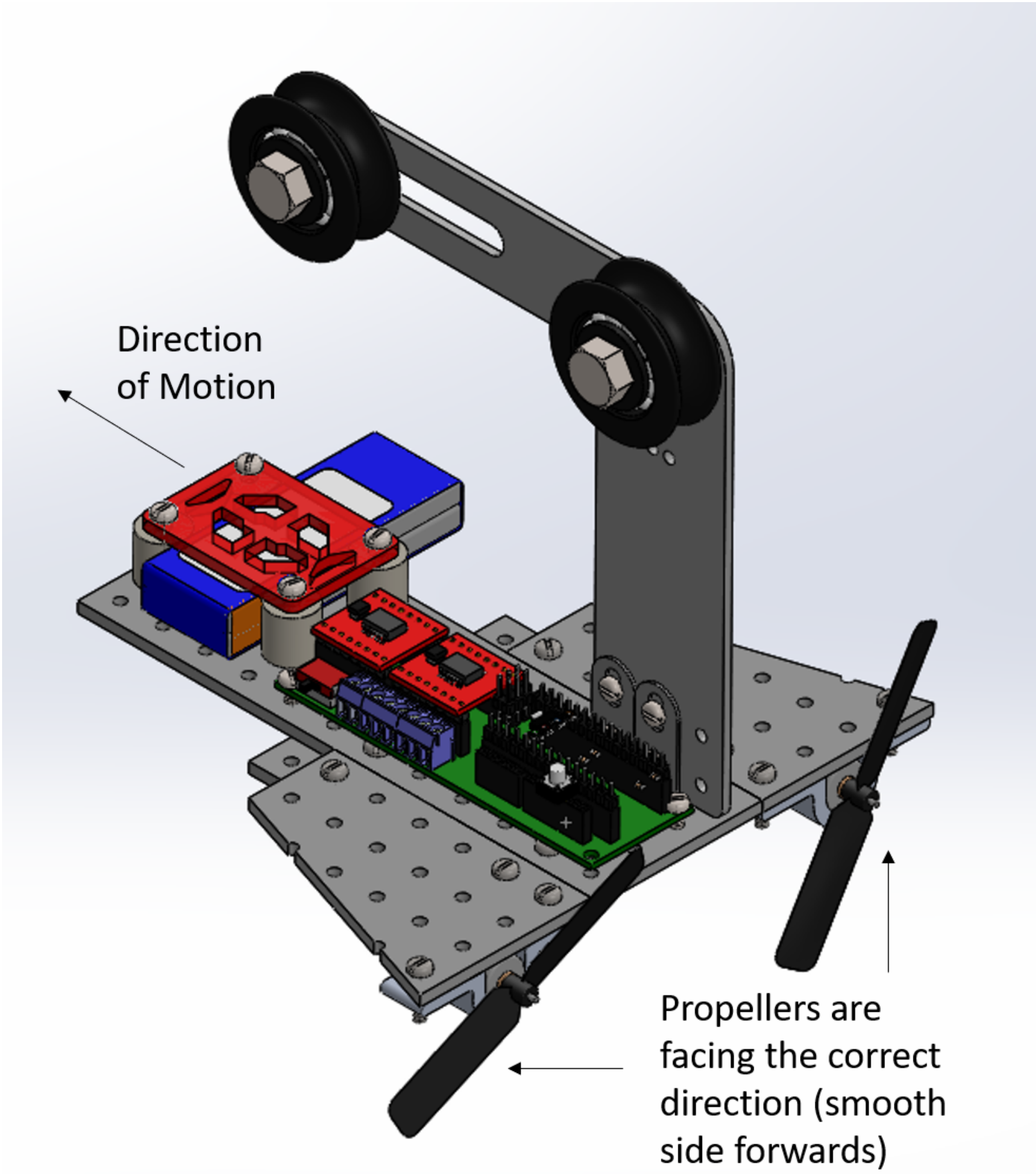
C2. Configuration 2 - coaxial contra-rotating propellers facing inwards and far apart



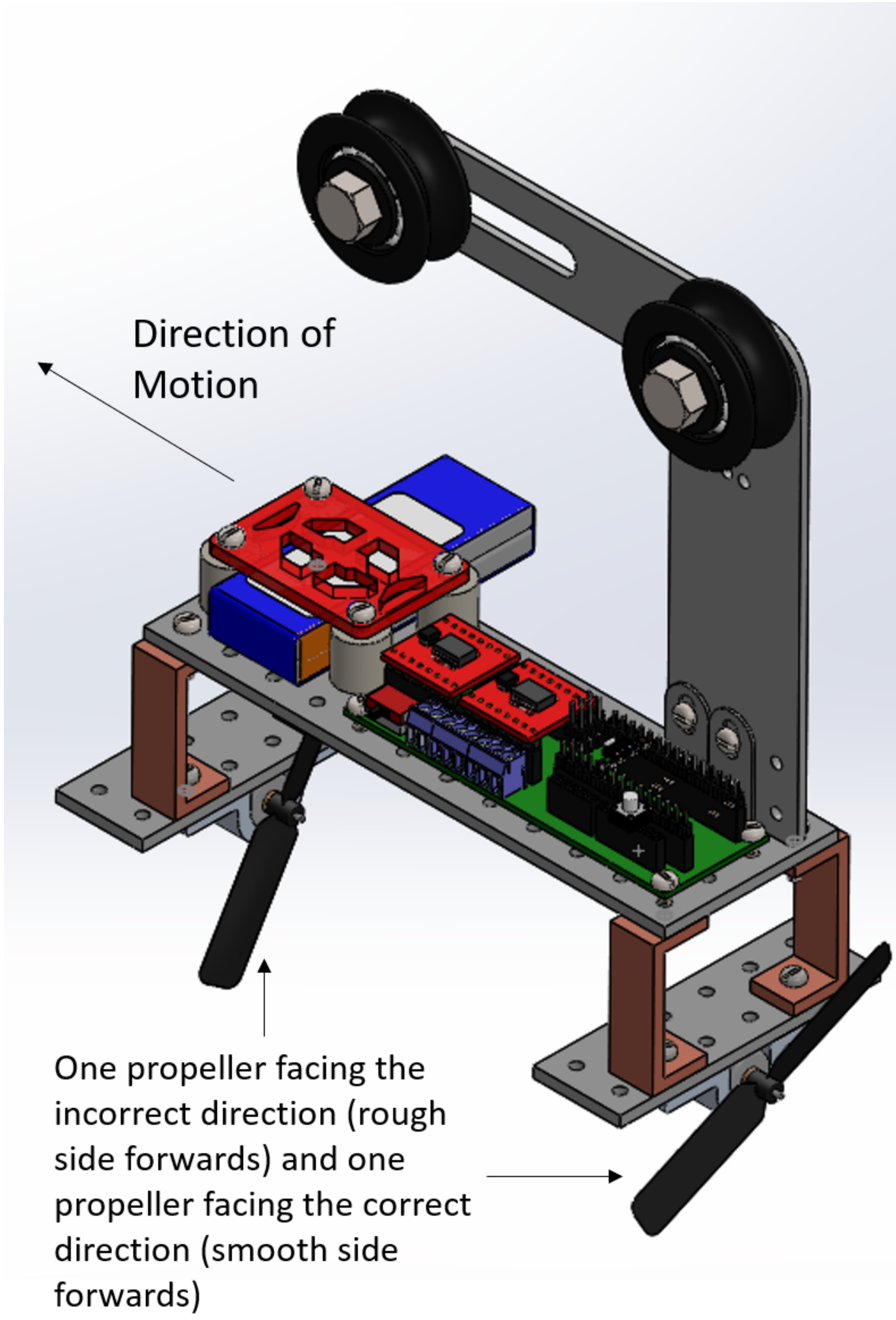
C3. Configuration 3 - coaxial contra-rotating propellers facing outwards far apart



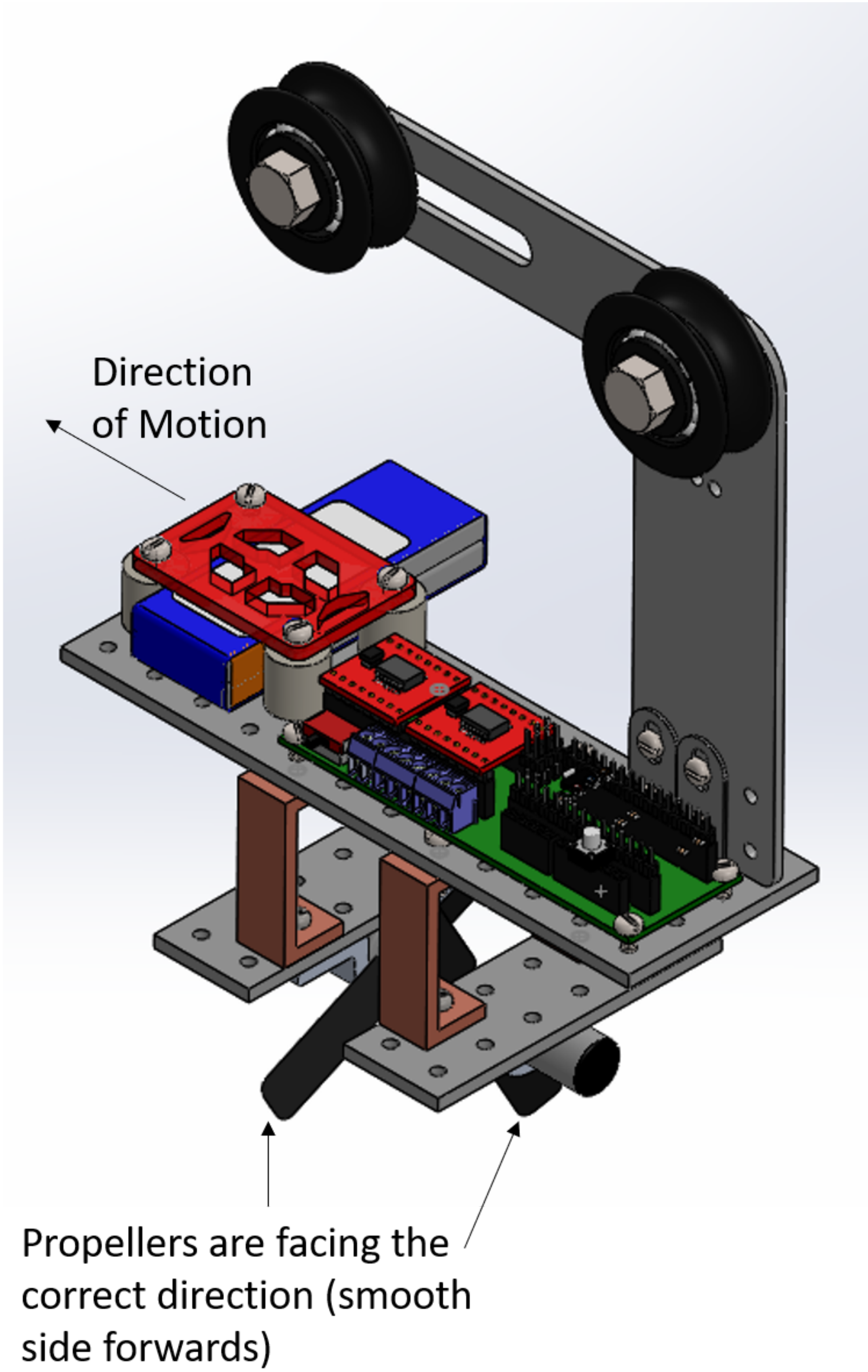
C4. Configuration 4 - side-by-side propellers



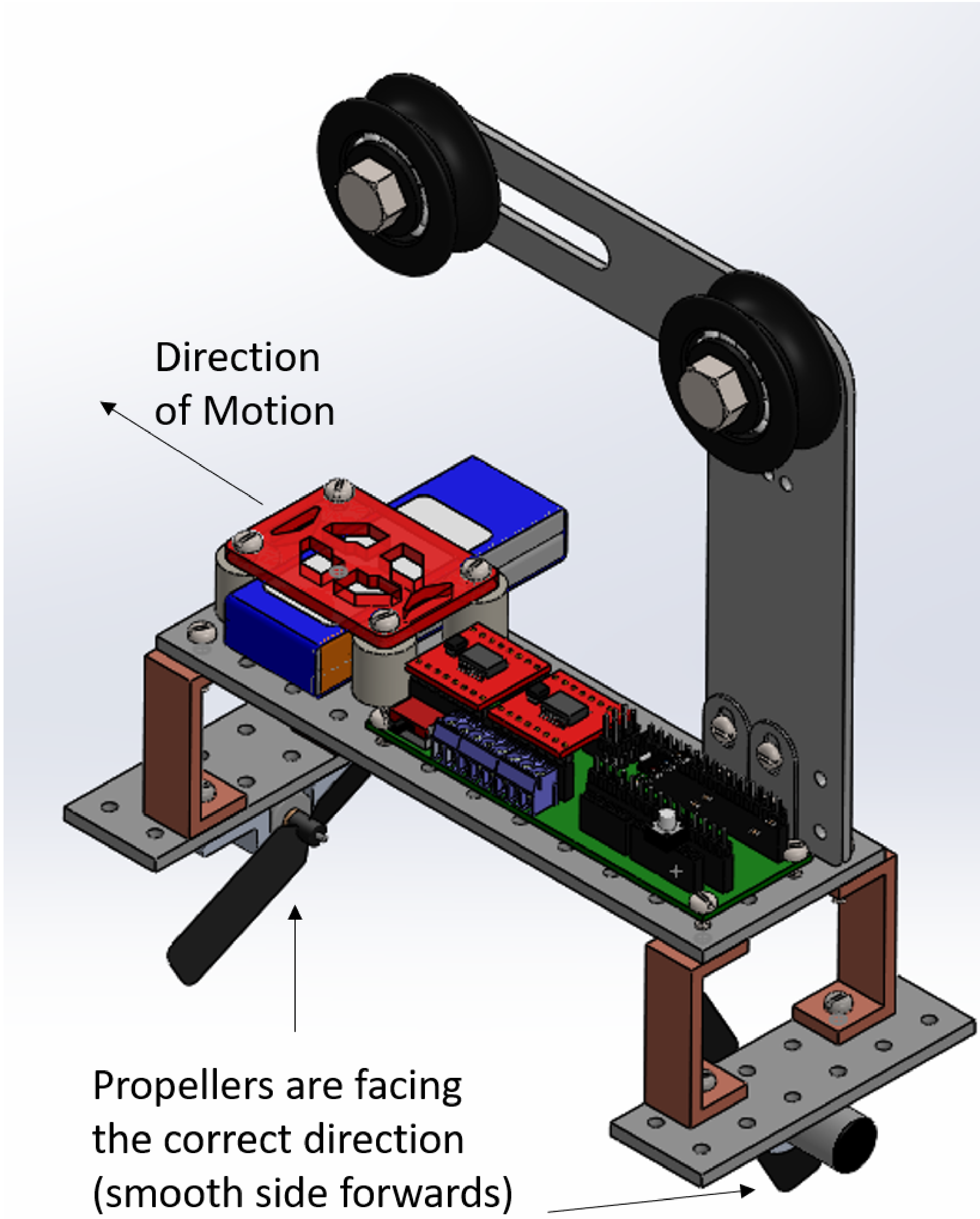
C5. Configuration 5 - coaxial non-contra-rotating propellers far apart



C6. Configuration 6 - coaxial contra-rotating propellers facing inwards close together



C7. Configuration 7 - coaxial contra-rotating propellers facing inwards far apart



Appendix D: A&D Battery Test

Time needed to run the AEV 3 ft at varying voltages and motor speeds

Trial**	Times(s)	Voltage (V)*	Power to Motors
1	3.78	9.748	40
2	3.871	9.741	40
3	3.84	9.727	40
10	3.782	9.683	40
11	3.6	9.521	40
4	2.521	9.727	50
5	2.522	9.712	50
6	2.46	9.712	50
12	2.52	9.668	50
13	2.521	9.521	50
7	1.981	9.697	60
8	1.98	9.697	60
9	1.982	9.683	60
14	1.981	9.668	60
15	1.98	9.507	60

*Voltage averaged from first 2 seconds of each trial (AEV unmoving)
**Trials disordered to organize by speed

Appendix E: Bills of Materials

E.1 - Opposing Propeller Design Bill of Materials

Component	Amount	Unit Price	Total Price	Budget Unit Cost
Arduino	1	$100.00	$100.00	$100,000.00
Electric Motors	2	$9.99	$19.98	$9,990.00
Count Sensor	2	$2.00	$4.00	$2,000.00
Count Sensor Connector	2	$2.00	$4.00	$2,000.00
2"x6" Rectangle	1	$2.00	$2.00	$2,000.00
Motor Clamps	2	$0.59	$1.18	$590.00
L-Shape Arm	1	$3.00	$3.00	$3,000.00
Wheels	2	$7.50	$15.00	$7,500.00
Large Wheel Nut	2	$1.00	$2.00	$1,000.00
Large Wheel Bolt	2	$1.00	$2.00	$1,000.00
Battery Supports	1	$1.00	$1.00	$1,000.00
Battery Risers	4	$1.00	$4.00	$1,000.00
Propellers	2	$0.45	$0.90	$450.00
Angle Brackets	10	$0.84	$8.40	$840.00
Bulk Screws and Nuts	1	$2.88	$2.88	$2,880.00
		Total	**$170.34**	**$170,340.00**

E.2 - Airplane Design Bill of Material

Component	Amount	Unit Price	Total Price	Budget Unit Cost
Arduino	1	$100.00	$100.00	$100,000.00
Electric Motors	2	$9.99	$19.98	$9,990.00
Count Sensor	2	$2.00	$4.00	$2,000.00
Count Sensor Connector	2	$2.00	$4.00	$2,000.00
T-Shape	1	$2.00	$2.00	$2,000.00
Custom Trapezoids	2	$2.00	$4.00	$2,000.00
Motor Clamps	2	$0.59	$1.18	$590.00
L-Shape Arm	1	$3.00	$3.00	$3,000.00
Wheels	2	$7.50	$15.00	$7,500.00
Large Wheel Nut	2	$1.00	$2.00	$1,000.00
Large Wheel Bolt	2	$1.00	$2.00	$1,000.00
Battery Supports	1	$1.00	$1.00	$1,000.00

Battery Risers	4	$1.00	$4.00	$1,000.00
Propellers	2	$0.45	$0.90	$450.00
Angle Brackets	2	$0.84	$1.68	$840.00
Bulk Screws and Nuts	1	$2.88	$2.88	$2,880.00
		Total	**$167.62**	**$167,620.00**

E.3 - Tiana's Bill of Materials

Component	Amount	Unit Price	Total Price	Budget Unit Cost
Arduino	1	$100.00	$100.00	$100,000.00
Electric Motors	2	$9.99	$19.98	$9,990.00
Count Sensor	2	$2.00	$4.00	$2,000.00
Count Sensor Connector	2	$2.00	$4.00	$2,000.00
T-Shape	1	$2.00	$2.00	$2,000.00
Trapezoids	2	$1.00	$2.00	$1,000.00
Motor Clamps	2	$0.59	$1.18	$590.00
L-Shape Arm	1	$3.00	$3.00	$3,000.00
Wheels	2	$7.50	$15.00	$7,500.00
Large Wheel Nut	2	$1.00	$2.00	$1,000.00
Large Wheel Bolt	2	$1.00	$2.00	$1,000.00
Battery Supports	1	$1.00	$1.00	$1,000.00
Battery Risers	4	$1.00	$4.00	$1,000.00
Propellers	2	$0.45	$0.90	$450.00
Angle Brackets	2	$0.84	$1.68	$840.00
Bulk Screws and Nuts	1	$2.88	$2.88	$2,880.00
		Total	**$165.62**	**$165,620.00**

E.4 - Mystic Macaw Bill of Materials

Component	Amount	Unit Price	Total Price	Budget Unit Cost
Arduino	1	$100.00	$100.00	$100,000.00
Electric Motors	2	$9.99	$19.98	$9,990.00
Count Sensor	2	$2.00	$4.00	$2,000.00
Count Sensor Connector	2	$2.00	$4.00	$2,000.00
T-Shape	1	$2.00	$2.00	$2,000.00
Custom Shell	1	$11.00	$11.00	$11,000.00
Motor Clamps	2	$0.59	$1.18	$590.00

Wheels	2	$7.50	$15.00	$7,500.00
Large Wheel Nut	2	$1.00	$2.00	$1,000.00
Large Wheel Bolt	2	$1.00	$2.00	$1,000.00
Battery Cage	1	$2.00	$2.00	$2,000.00
Battery Door	1	$0.50	$0.50	$500.00
Propellers	2	$0.45	$0.90	$450.00
Angle Brackets	2	$0.84	$1.68	$840.00
Bulk Screws and Nuts	1	$2.88	$2.88	$2,880.00
		Total	**$169.12**	**$169,120.00**

E.5 - The Bullet Bill of Materials

Component	Amount	Unit Price	Total Price	Budget Unit Cost
Arduino	1	$100.00	$100.00	$100,000.00
Electric Motors	2	$9.99	$19.98	$9,990.00
Count Sensor	2	$2.00	$4.00	$2,000.00
Count Sensor Connector	2	$2.00	$4.00	$2,000.00
2"x6" Rectangle	1	$2.00	$2.00	$2,000.00
Custom Shell	1	$6.00	$6.00	$6,000.00
Motor Clamps	2	$0.59	$1.18	$590.00
L-Shape Arm	1	$3.00	$3.00	$3,000.00
Wheels	2	$7.50	$15.00	$7,500.00
Large Wheel Nut	2	$1.00	$2.00	$1,000.00
Large Wheel Bolt	2	$1.00	$2.00	$1,000.00
Battery Supports	1	$1.00	$1.00	$1,000.00
Battery Risers	4	$1.00	$4.00	$1,000.00
Propellers	2	$0.45	$0.90	$450.00
Angle Brackets	10	$0.84	$8.40	$840.00
Bulk Screws and Nuts	1	$2.88	$2.88	$2,880.00
		Total	**$176.34**	**$176,340.00**

Appendix C: Performance Test 3, Arduino Code

```
void myCode()
{
  //----------------------------------------------------------------------------------------
  // myCode();
  //
  // This is the tab where the programming of your vehicle operation is done.
  // Tab _00_AEV_key_words contains a compiled list of functions/subroutines used for vehicle
  // operation.
  //
  // Note:
  // (1) After running your AEV do not turn the AEV off, connect the AEV to a computer, or
  //     push the reset button on the Arduino. There is a 13 second processing period. In
  //     post processing, data is stored and battery recuperation takes place.
  // (2) Time, current, voltage, total marks, position traveled are recorded approximately
  //     every 60 milliseconds. This may vary depending on the vehicles operational tasks.
  //     It takes approximately 35-40 milliseconds for each recording. Thus when programming,
  //     code complexity may not be beneficial.
  // (3) Always comment your code. Debugging will be quicker and easier to do and will
  //     especially aid the instructional team in helping you.
  //----------------------------------------------------------------------------------------

  // Program between here-----------------------------------------------------------------

unsigned long time;
  int iClass = 298;
  int i = 299;
  int minSpeedClass = 23;
  int minSpeed = 27;

  reverse(1);
  motorSpeed(4,40);
  goToAbsolutePosition(230);
  brake(4);

  reverse(4);
  motorSpeed(4,50);
  goFor(1.1);
  reverse(4);
```

```
brake(4);
goFor(0.5);

while (getVehiclePostion()<i) {
  motorSpeed(4,minSpeed);
  goFor(0.25);
  brake(4);
  goFor(0.2);
}
reverse(4);
motorSpeed(4,minSpeed);
goFor(0.75);
reverse(4);
brake(4);

goFor(7);
motorSpeed(4,40);
goToAbsolutePosition(510);
brake(4);

reverse(4);
motorSpeed(4,50);
goFor(1.3);
reverse(4);
brake(4);
goFor(0.5);

//time = millis();
while (getVehiclePostion()<i+342) {
  motorSpeed(4,minSpeed+7);
  goFor(0.25);
  brake(4);
  goFor(0.2);
}
reverse(4);
motorSpeed(4,minSpeed-5);
goFor(0.75);
brake(4);
reverse(4);
```

```
goFor(5);
reverse(4);
motorSpeed(4,65);
goToAbsolutePosition(455);
motorSpeed(4,55);
goToAbsolutePosition(440);
brake(4);

reverse(4);
motorSpeed(4,65);
goFor(1.25);
reverse(4);
brake(4);
goFor(1);

while (getVehiclePostion()>i+58) {
  motorSpeed(4,minSpeed+33);
  goFor(0.3);
  brake(4);
  goFor(0.1);
}
reverse(4);
motorSpeed(4,minSpeed+10);
goFor(0.75);
reverse(4);
brake(4);

goFor(7);
motorSpeed(4,75);
goToAbsolutePosition(i);
motorSpeed(4,65);
goToAbsolutePosition(i-50);
while(getVehiclePostion<150) {
brake(4);
}

reverse(4);
motorSpeed(4,30);
```

```
  goFor(2);
  reverse(4);
  brake(4);
  goFor(1.25);

  while (getVehiclePostion()>28) {
    brake(4);
  }
  reverse(4);
  motorSpeed(4,minSpeed+20);
  goFor(1);
  reverse(4);
  brake(4);

  // And here------------------------------------------------------------------------------

} // DO NOT REMOVE. end of void myCode()
```

Appendix F

F.1 - Total Budget

Capital Costs	$ 151,487		

	RUN 1	RUN 2	RUN 3
Energy Costs	$ 350,900	$ 368,750	$ 368,750
Time Costs	$ 204,900	$ 214,350	$ 214,350
Accuracy Penalty	1.111111111	1.111111111	1.111111111
R&D Costs	$ -	$ -	$ -
Safety Violations	$ 25,000	$ 25,000	$ 25,000
Run Costs	**$ 642,555.56**	**$ 672,888.89**	**$ 824,375.70**

TOTAL COST	**$ 1,466,931.25**

F.2 - Capital Costs

TOTAL AEV CAPITAL COSTS:	**$ 151,487**	**$ 80**
Standard AEV Parts Total Costs:	*$ 151,407*	*$ -*
Custom Items for AEV Total Costs:	*$ 80*	*$ 80*
Other Items used for AEV Total Cost:	*$ -*	*$ -*

modify hilighted cells

STANDARD AEV PARTS

		mass (g)	cost ($/g)	NEW Calculated Cost	# Used	Cost
Propulsion System	Arduino			$ 100,000.00	1	$ 100,000
	Electric Motors			$ 9,900.00	2	$ 19,800
	Servo Motors			$ 5,950.00		$ -
	Count Sensor			$ 2,000.00	2	$ 4,000
	Count Sensor Connector			$ 2,000.00	2	$ 4,000
	Propellers			$ 450.00	2	$ 900
Body Structure	T- Shape	30.240	$ 70.00	$ 2,328.48		$ -
	X- Shape	30.240	$ 70.00	$ 2,328.48		$ -
	2" x 6" Rectangle	21.033	$ 70.00	$ 1,619.54	1	$ 1,620
	2.5" x 7.5" Rectangle	32.868	$ 70.00	$ 2,530.84		$ -
	1" x 3" Rectangle	5.256	$ 70.00	$ 404.71	2	$ 809
	1.5" x 3" Rectangle	7.893	$ 70.00	$ 607.76		$ -
	Trapezoids (right angle)	7.893	$ 70.00	$ 607.76		$ -
	L-Shape Arm	15.374	$ 20.00	$ 338.23	1	$ 338
	T-Shape Arm	17.976	$ 20.00	$ 395.47		$ -
	Wheels			$ 7,500.00	2	$ 15,000
	Battery Clamp Narrow	3.981	$ 70.00	$ 306.54	1	$ 307
	Battery Clamp Wide	4.821	$ 70.00	$ 371.22		$ -
Brackets & Tools	Angle Brackets	0.268	70	$ 20.65	5	$ 103
	Screw Driver			$ 2,000.00	1	$ 2,000
	1/4" Wrench			$ 2,000.00	1	$ 2,000
	Motor Clamps (1/8 acrylic	3.255	70	$ 250.64	2	$ 501
	#55 A Slotted Strip, 2"	0.3708	70	$ 28.55	1	$ 29
					TOTAL:	**$ 151,407**

*(polypropylene density assumed 0.90 g/cm3)

CUSTOM PARTS

Item	*Type of material*	*Unit Cost*	*Grams*	*Cost*
Motor Clamps	3D-printing	$ 10	8	$ 88.00
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
			TOTAL:	**$ 88.00**
		Without custom:		**$ 80.00**

*4 or more parts ordered at once, change cell E4 to =L20

Custom part information			
	Type	Unit cost	
Laser Cut	PE	$70/g	+10% custom
	ABS	$20/g	+10% custom
	Wood	$50/g	+10% custom
	1/8"	$70/g	+10% custom
	1/4"	$90/g	+10% custom
3D-printing		$20/g	+10% custom
*Custom waived if 4 or more parts			

*ask CFO for more information

OTHER PARTS

Item	*Unit Cost*	*#*	*Cost*
			$ -
			$ -
			$ -
			$ -
			$ -
			$ -
			$ -
			$ -
		TOTAL:	$ -

*ask CFO for more information / prices

F.3 - PT Costs

RUN #1

ACCURACY PENALTY	
TOTAL SCORE (out of 40)	36
ACCURACY PENALTY	1.111111111

ENERGY COSTS:	
baseline fee + $500/Joule	
Baseline Fee:	$ 125,000.00
Total Joules from PT:	451.8
Cost from Joules used	$ 225,900.00
Total Energy Cost:	**$ 350,900.00**

TIME COSTS:	
baseline fee + $1.5K/second	
Baseline Fee:	$ 90,000.00
Total run time in seconds:	76.6
Cost from time used	$ 114,900.00
Total Time Cost:	**$ 204,900.00**

RUN #2

ACCURACY PENALTY	
TOTAL SCORE (out of 40)	36
ACCURACY PENALTY	1.111111111

ENERGY COSTS:	
baseline fee + $500/Joule	
Baseline Fee:	$ 125,000.00
Total Joules from PT:	487.5
Cost from Joules used	$ 243,750.00
Total Energy Cost:	**$ 368,750.00**

TIME COSTS:	
baseline fee + $1.5K/second	
Baseline Fee:	$ 90,000.00
Total run time in seconds:	82.9
Cost from time used	$ 124,350.00
Total Time Cost:	**$ 214,350.00**

Appendix G: R&D 1: Battery Testing Trials, Arduino Code

G.1 Trials 1-3

```
reverse(2);
goFor(2);
motorSpeed(4,40);
goToRelativePosition(74);
brake(4);
```

G.2 Trials 4-6

```
reverse(2);
goFor(2);
motorSpeed(4,50);
goToRelativePosition(74);
brake(4);
```

G.3 Trials 7-9

```
reverse(2);
goFor(2);
motorSpeed(4,60);
goToRelativePosition(74);
brake(4);
```

G.4 Trials 10, 15

```
reverse(2);
goFor(2);
motorSpeed(4,40);
goToRelativePosition(74);
brake(4);
```

G.5 Trials 11, 14

```
reverse(2);
goFor(2);
motorSpeed(4,50);
goToRelativePosition(74);
brake(4);
```

G.6 Trials 0, 12, 13

```
reverse(2);
goFor(2);
motorSpeed(4,60);
goToRelativePosition(74);
brake(4);
```

Appendix H: R&D 2 Trials, Arduino Code

H.1 Trial 0

```
motorSpeed(4,50);
goFor(1);
brake(4);
```

H.2 Trial 1

```
motorSpeed(4,50);
goFor(1);
brake(4);
```

H.3 Trial 2

```
reverse(2);
motorSpeed(4,50);
goFor(1);
brake(4);
goFor(2);
```

H.4 Trial 3

```
reverse(2);
motorSpeed(4,50);
goFor(1);
brake(4);
goFor(2);
```

H.5 Trial 4

```
reverse(2);
motorSpeed(4,50);
goFor(1);
brake(4);
goFor(2);
```

H.6 Trial 5

```
reverse(4);
motorSpeed(4,50);
goFor(1);
brake(4);
goFor(2);
```

H.7 Trial 6

```
reverse(2);
motorSpeed(4,50);
goFor(1);
brake(4);
goFor(2);
```

H.8 Trial 7

```
reverse(1);
motorSpeed(4,50);
goFor(1);
brake(4);
goFor(2);
```

Appendix I: R&D 2 Data

Propeller Configuration*	Total Distance Traveled (sensor ticks)
1	39
2	43
3	48
4	109
5	26
6	70
7	78

*Propellor configurations are as follows:
(1) Contra-rotating propellers 1: Motors facing inwards from AEV and are close together
(2) Contra-rotating propellers 2: Motors facing inwards from AEV and are far apart from each other
(3) Contra-rotating propellers 3: Motors facing outwards from AEV and are far apart from each other
(4) Side-by-side propellers: Motors side by side and facing the same direction
(5) Propellers facing the same direction: Motors on Standoffs in a line facing the same direction
(6) Contra-rotating propellers 4: Motors facing inwards from AEV and are close together, propeller facing proper direction
(7) Contra-rotating propellers 5: Motors facing inwards from AEV and are far apart from each other, propeller facing proper direction

Appendix J: Advanced R&D 3 Data

Trial	Wheel Starting Position	Distance
1	Right	157.06
2	Right	145.38
3	Right	149.44
4	Right	149.88
5	Right	113.38
6	Left	119.13
7	Left	123.06
8	Left	141.88
9	Left	156.75
10	Left	155.94
11	Top	163
12	Top	163.88
13	Top	162.5
14	Top	161.5
15	Top	168.75
16	Right	167.06
17	Left	164.31
18	Bottom	166.88
19	Bottom	165.31
20	Bottom	130.75
21	Bottom	134.63
22	Bottom	150.25

Appendix K: Performance Test 1, Arduino Code

```
 reverse(2);
 motorSpeed(4,50);
 goToAbsolutePosition(220);
 motorSpeed(4,0);
 reverse(4);
 motorSpeed(4,50);
 goFor(1);
 reverse(4);
 motorSpeed(4,15);
 goToAbsolutePosition(290);
 brake(4);

 if (getVehiclePostion()<304) {
  motorSpeed(4,20);
  goToAbsolutePosition(300);
  brake(4);
 } else if (getVehiclePostion()>304) {
  reverse(4);
  motorSpeed(4,20);
  goToAbsolutePosition(306);
  brake(4);
  reverse(4);
 }

 goFor(7);
 motorSpeed(4,40);
 goFor(2);
 brake(4);
```

Appendix L: Performance Test 2, Arduino Code

```
  int i = 297;

  reverse(1);
  motorSpeed(4,40);
  goToAbsolutePosition(240);
  brake;
  reverse(4);
  motorSpeed(4,40);
  goFor(1.5);
  reverse(4);
//  motorSpeed(4,22);
//  goToAbsolutePosition(290);
  brake(4);

while (getVehiclePostion()<i-1||getVehiclePostion()>-+1) {
  if (getVehiclePostion()<i-1) {
    motorSpeed(4,19);
    goFor(0.25);
    brake(4);
  } else if (getVehiclePostion()>i+1) {
    reverse(4);
    motorSpeed(4,19);
    goFor(0.25);
    brake(4);
    reverse(4);
  }
}

  goFor(7);
  motorSpeed(4,40);
  goToAbsolutePosition(500);
  brake;
  reverse(4);
  motorSpeed(4,40);
  goFor(1.5);
  reverse(4);
  motorSpeed(4,18);
  goToAbsolutePosition(520);
```

```
brake;
goFor(5);
reverse(4);
motorSpeed(4,40);
brake(4)
```

Appendix M: Team Schedule

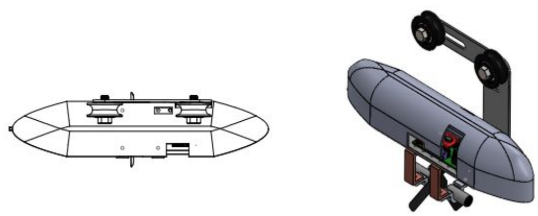
Task	Start Date	Finish Date	Due Date	Primary Person	Secondary Person	Est. Hours	% Completed
Grant Proposal	2/9/19	2/14/19	2/14/19	Jeff, Nick	Tiana, Samira	2	100
Progress Report 1	2/9/19	2/14/19	2/15/19	All		4	100
Committee Meeting	2/20/19	2/22/19	2/22/19	All		0.5	100
Advance R&D 1	2/22/19	3/1/19	3/1/19	Nick, Jeff	Samira	3.5	100
Advance R&D 2	3/3/10	3/7/19	3/8/19	Nick, Jeff	Samira	4	100
Performance Test 1	3/8/19	3/19/19	3/19/19	Nick	Jeff	2	100
GOAL: Secure wires and propellor motors	3/18/19	3/19/19	3/19/19	Jeff	Nick, Samira	0.5	100
Advance R&D Presentation	3/18/19	3/19/19	Lab 13	Samira	Jeff, Nick	2	100
Performance Test 2	3/20/19	3/28/19	3/28/19	Nick, Jeff	Samira	2	100
Advanced R&D 3	3/26/19	3/29/19	Lab 18	Jeff	Samira, Nick	2	100

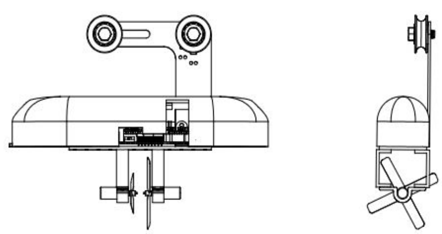
Final Deliverables	3/29/19	4/3/19	Lab 19	Nick	Jeff, Samira	5	100
Final Performance Test	4/2/19	4/5/19	Lab 21	Nick	Jeff	3	100
Oral Presentation	4/1/19	4/14/19	Lab 24	Samira	Nick,Jeff	3	100
Progress Report 2	3/3/19	3/18/19	3/19/19	Samira	Nick, Jeff	5	100
Website 3 Update	3/3/19	3/7/19	3/8/19	Samira	Nick, Jeff	2	100
CDR (draft)	3/20/19	3/21/19	Lab 14	Jeff	Nick, Samira	3	100
Team Eval 2	3/25/19	3/27/19	Lab 16	All		0.5	100
Committee Meetings 2	3/25/19	3/27/19	Lab 16	All		1	100
Progress Report 3	3/29/19	4/3/19	Lab 19	Jeff	Nick, Samira	5	100
Final Oral Presentation Draft	3/29/19	4/4/19	Lab 21	Samira	Nick, Jeff	2	100
Final Team Eval	4/15/19	4/17/19	Lab 25	All		0.5	100
CDR	3/22/19	4/17/19	Lab 25	Jeff	Samira, Nick	7	100
Final Website	4/11/19	4/17/19	Lab 25	Samira	Jeff, Nick	4	100

Cost report	4/15	4/16	4/16	Nick	Jeff	1	100
GOAL: use less than or equal to 75% of the budget	2/19/19	4/18/19	Lab 25	ALL		Throughout	100
GOAL: finish assignments 24 hours before due date	4/7/19		Lab 25	ALL		Throughout	100

Appendix N: Final Design SolidWorks

N.1 - The Bullet (Group Design) Drawing



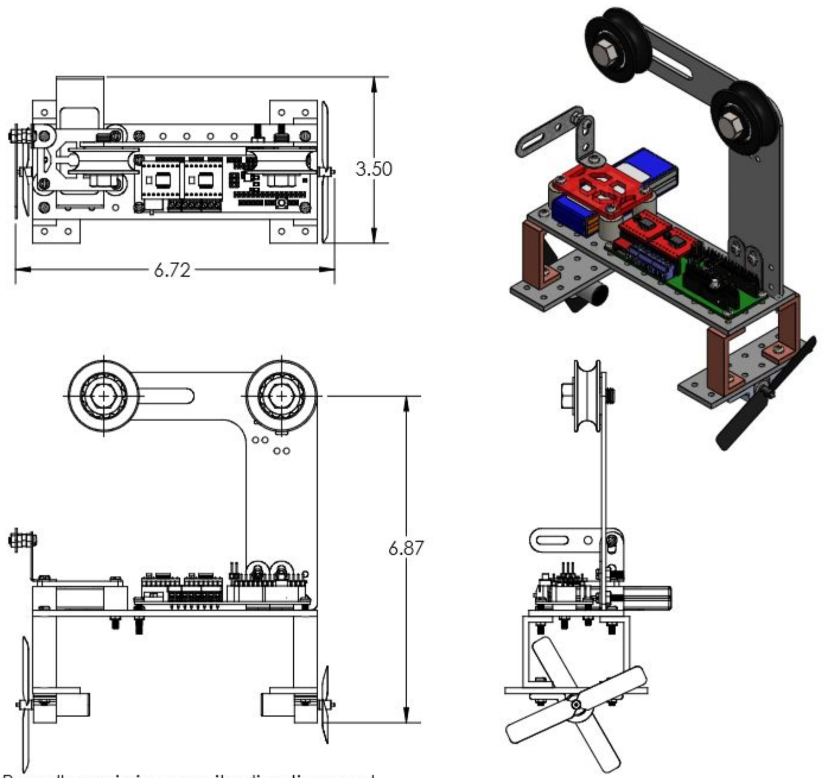


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Propellor Standoff	PLA Plastic	4
2	Medium Rectangle	PolyPropylene	1
3	AEV Arduino Assembly	Arduino Nano	1
4	Battery Pack Clamp Plate Narrow	1/8" Acrylic	1
5	Battery Spacer	1/4" Acrylic	4
6	Battery Pack	LiPo Battery	1
7	AEV Shell Printable	PLA Plastic	1
8	Motor Mount Clip	1/4" Acrylic	2
9	AEV Motor	Low Amperage Motor	2
10	Prop 3inch	Plastic	2
11	Support Arm 2 2 Sensor Holes	ABS Plastic	1
12	Pulley Assembly	Multiple Plastics	1
13	Pulley Assembly w-reflective tape	Multiple Plastics	1
14	90-deg bracket	Steel	2

Propellers spin in opposite directions and face opposite directions. Aerodynamic Shell has holes to allow for easy maintainence of the AEV.

The Ohio State University First Year Engineering	Dwg. Title: AEV Prototype	Scale: 1:4	Inst.: Cohen	Units: IPS	Dwg. No.:01
	Drawn By: Jeffrey Gaydos, Nick Braun, Samira Wehmann		Hour: 9:10AM	Seat: C	Date: 4/17/19

N.2 - Final Design Drawing



Propellers spin in opposite directions and face opposite directions. Magnet connector can move freely with friction and acts as a cushion. Wires, sensors, and zipties not shown.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Propellor Standoff	PLA Plastic	4
2	Medium Rectangle	Polypropylene	1
3	AEV Arduino Assembly	Arduino Nano	1
4	Battery Pack Clamp Plate Narrow	1/8" Acrylic	1
5	Battery Spacer	1/4" Acrylic	4
6	Battery Pack	LiPo Battery	1
7	Motor Mount Clip	1/4" Acrylic	2
8	AEV Motor	Low Amperage Motor	2
9	Prop 3inch	Plastic	2
10	Support Arm 2 2 Sensor Holes	ABS Plastic	1
11	Pulley Assembly	Multiple Plastics	1
12	Pulley Assembly w-reflective tape	Multiple Plastics	1
13	90-deg bracket	Steel	3
14	Tiny Rectangle	PolyPropylene	2
15	flat bracket	Steel	1

The Ohio State University First Year Engineering	Dwg. Title: Final AEV Design Drawing	Scale: 5:12	Inst.: Cohen	Units: IPS	Dwg. No.:02
	Drawn By: Jeffrey Gaydos, Nick Braun, and Samira Wehmann		Hour9:10AM	Seat: C	Date: 4/12/19

Appendix O: Team Meeting Notes

Date: 1/11/19

Time: 9:35-10:55 (in class)

***Members Present*:** All

Topics/Agenda: create u.osu.edu website, complete exercise 1-programing basics

Action Items with names assigned:

Jeff: complete exercise 1-programing basics

Nick: complete exercise 1-programing basics

Samira: complete exercise 1-programing basics

Tiana: complete exercise 1-programing basics

To be completed before next meeting:

Jeff: Reflection

Nick: Reflection

Samira: Meeting notes

Tiana: Website

Reflection:

Programming Arduino was explored and team members are prepared to begin the AEV project. Team members are beginning to brainstorm and think about a design that would be the most efficient for this project, as well as consider possible issues that could arise during this project.

Date 1/18/19

Time: 9:35-10:55 (in class)

***Members Present*:** All

Topics/Agenda: complete exercise 2-external sensors

Action Items with names assigned:

Jeff: setup the AEV

Nick: program the code for adruino

Samira: setup the AEV

Tiana: setup the AEV

To be completed before next meeting:

Jeff: review AEV kit checklist/update website

Nick: review AEV kit checklist/update website

Samira: review AEV kit checklist/update website

Tiana: review AEV kit checklist/update website

Reflection:

Team members tested the reflectance sensors for the AEV, and familiarized themselves with senor hardware components and troubleshooting techniques

Date 1/25/19
Time: 9:35-10:55 (in class)
***Members Present*:** All
Topics/Agenda: complete exercise 3-performance analysis tool
Action Items with names assigned:
Jeff: complete exercise 1-performance analysis tool
Nick: complete exercise 1-performance analysis tool
Samira: organize website
Tiana: organize website
To be completed before next meeting:
Jeff: Brainstorm AEV design
Nick: Brainstorm AEV design
Samira: Brainstorm AEV design
Tiana: Brainstorm AEV design
Reflection:
The AEV Data extraction program was explored and team members tested the motor of the vehicle. Team members also continued to develop and organize the website.

Date 2/8/19
Time: 9:35-10:55 (in class)
***Members Present*:** All
Topics/Agenda: complete exercise 3, test motor, evaluate potential designs
Action Items with names assigned:
Jeff: complete exercise 3
Nick: complete exercise 3
Samira: update website
Tiana: update website
To be completed before next meeting:
Jeff: work on progress report
Nick: work on progress report
Samira: work on progress report
Tiana: work on progress report
Reflection:
Team members tested and fixed the program to run the vehicle. After the first two initial attempts to run the AEV failed due to poor connectivity and motor speed the team members fixed issues with the code and with the vehicle set up. Samira and Tiana worked on the criteria to test the potential designs.

Date 2/9/19

Time: 3:00-5:30
***Members Present*:** All
Topics/Agenda: complete exercise 4, assign parts for the lab report, create grant proposal
Action Items with names assigned:
Jeff: complete exercise 4, start model on solidworks, grant proposal
*Nick:*complete exercise 4, grant proposal
*Samira:c*omplete exercise 4, grant proposal
Tiana: complete exercise 4, grant proposal
To be completed before next meeting:
Jeff: work on progress report, complete solidworks part, edit grant proposal, gather documents for community meeting
Nick: work on progress report, edit grant proposal, gather documents for community meeting
Samira: work on progress report, gather documents for community meeting
Tiana: work on progress report
Reflection:
Team members presented their individual designs then worked together to create a group design including the most efficient parts from each design. The team members worked on the grant proposal power point and determined which information is needed and which can be left out because of the 60-90 second time limit. Members also started working on their parts of the progress report. Finally, the team decided who would be representing each part of the community meetings.

Date 2/22/19
Time: 9:35-10:55 (in class)
***Members Present*:** All
Topics/Agenda: complete community meeting, discus changes with project, talk with company about what each division is researching for Advanced R&D 1 and 2.
Action Items with names assigned:
Jeff: go to budget and R&D meetings
Nick: to the he PR meeting
Samira: go the the HR meeting
To be completed before next meeting:
Jeff: update website, submit part to be 3D printed
Nick: update website
Samira: update website
Reflection:
Team members attended their assigned meetings prepared to answer the questions asked. Once the meetings were concluded, the team came back together to discuss how the meetings went and the changes that needed to be made. Most changes revolved around minor details on the website.

Problems with the computer occurred during class, so the team members decided to work on the changes another time. It was decided that team C is researching battery and propellers during advanced R&D 1 and 2.

Date 2/28/19
Time: 9:10-10:05 (in class)
***Members Present*:** All
Topics/Agenda: create procedure for testing the battery during Advanced R&D 1.
Action Items with names assigned:
Jeff: create procedure for Advanced R&D 1, testing battery
*Nick:*create procedure for Advanced R&D 1, testing battery
Samira: create procedure for Advanced R&D 1, testing battery

To be completed before next meeting:
Jeff: submit application 16, Create SolidWorks model assembly for the Prototype Vehicle
Nick: Create SolidWorks Working Drawings for the Prototype Vehicle
Samira: Create SolidWorks Working Drawings for the Prototype Vehicle
Reflection:
Team members created a procedure testing the power to voltage, power of motors, and time over a distance of 3 feet. The Teams model was based off of the example models in class, but mortified to fit the exact criteria the team wanted to test. There was not a set number of trials for the experiment. The team had their procedure approved before the end of class so the team could have maximum amount of time.

Date 3/1/19
Time: 9:35-10:05 (in class)
***Members Present*:** All
Topics/Agenda: test the batter advance R&D, update website from community meeting
Action Items with names assigned:
Jeff: test battery advance R&D
*Nick:*Test battery advance R&D
Samira: update website
To be completed before next meeting:
Jeff: N/A
Nick: N/A
Samira: N/A
Reflection:

Two team members worked on coding the program for the advance R&D test, then tested the program collecting and recording the data. The third team member worked on the updates for the website given during the community meeting.

Date 3/3/19
Time: 5:30-7:15
***Members Present*:** All
Topics/Agenda: complete updates on website, discuss the idea for progress report one, discus progress report two, write procedure for Advance R&D 2: Propellers
Action Items with names assigned:
Jeff: update website (glossary of programming functions), create procedure
Nick: update website (citations), create procedure
Samira: update website (meeting notes), create procedure
To be completed before next meeting:
Jeff: work on progress report 2 (results section)
Nick: work on progress report 2 (results section)
Samira: work on progress report 2 (introduction and future section)
Reflection:
It was determined that the team will not edit and resubmit Progress Report 1 since the grade can only be improved by 3% and the team rather focus on testing, the website, and the second progress report. In addition, the team worked on updating the website. The team updated missing documents/citations, edited the written paragraphs, and updated links. the team also made the procedure for Advance R&D 2, propellers. The team plans to get the procedure approved during the next class. Finally, the team divided the parts for the progress report 2.

Date 3/5/19
Time:9:10-10:05 (in class)
***Members Present*:** All
Topics/Agenda: Get the procedure for R&D 2 approved, start performing tests
Action Items with names assigned:
Jeff: Work on adjusting propellers, test propellers
Nick: update code for propellers, test propellers
Samira: assist on adjusting propellers, test propellers
To be completed before next meeting:
Jeff: work on progress report 2 (results section)
Nick: work on progress report 2 (results section)
Samira: work on progress report 2 (introduction and future section)
Reflection:

The team worked on comparing different positions of the propellers to determine which position would be more efficient for the AEV traveling up to the gate and proceeding from the gate. It took more time than expected to change the position of the propellers. In addition, it took multiple tries to obtain accurate results because the code would stop recording as the AEV costed. The team added a wait feature onto the code so the data could be completed. The team completed the testing of one trial.

Date 3/7/19
Time: 9:10-10:05 (in class)
***Members Present*:** All
Topics/Agenda: complete advance R&D test 2
Action Items with names assigned:
Jeff: Work on adjusting propellers, test propellers
Nick: update code for propellers, test propellers
Samira: assist on adjusting propellers, test propellers
To be completed before next meeting:
Jeff: work on progress report 2 (results section)
Nick: work on progress report 2 (results section)
Samira: work on progress report 2 (introduction and future section)
Reflection:
The team continued to test the different locations of the propellers. The distance traveled was sufficiently lower than trial one. It was determined that the propellers were attached backwards onto the motor so air was not being caught in the propeller properly. The team decided that during the lab the team would perform another test to compare how many marks the design was changed.

Date 3/8/19
Time: 9:35-10:55 (in class)
***Members Present*:** All
Topics/Agenda: create the code for the Performance Test 1
Action Items with names assigned:
*Jeff:*Work on Performance Test
Nick: Work on Performance Test
Samira: Work on Performance Test
To be completed before next meeting:
Jeff: work on progress report 2 (results section)
Nick: work on progress report 2 (results section)
Samira: work on progress report 2 (introduction and future section)
Reflection:

The team wrote the code and tested the code for the performance test. The AEV has to travel a certain distance to the gate, stop for seven seconds then proceed from the gate. The team decided to base the coding on the distance traveled so the code can be the same from the lab room to the classroom.

Date 3/18/19
Time: 4:20-6:00
Members Present**:** All
Topics/Agenda: Complete the progress report, assign roles and create PowerPoint for the Advance R&D Test Presentation
Action Items with names assigned:
Jeff: work on presentation and progress report, update website
Nick: work on presentation and progress report, update website
Samira: work on presentation and progress report, update website
To be completed before next meeting:
Jeff: be prepared to present the Advance R&D presentation, submit progress report
Nick: be prepared to present the Advance R&D presentation
Samira: be prepared to present the Advance R&D presentation
Reflection:
The team created the PowerPoint for the Advance R&D oral report. The report should be 6-8 minutes long containing the results from the test, the upcoming performance test, and the approach for the team's design. The topics to divide are; Propeller results, battery results, and approach/performance test. At the following meeting, the team will edit and submit the final PowerPoint and determine who is presenting which part.

Date 3/19/19
Time: 9:10-10:05 (in class)
Members Present**:** All
Topics/Agenda: Complete the performance test, complete advance R&D presentation slides
Action Items with names assigned:
Jeff: work on performance test
Nick: work on performance test
Samira: work on performance test
To be completed before next meeting:
Jeff: be prepared to present the Advance R&D presentation (propellers), submit slides
Nick: be prepared to present the Advance R&D presentation (intro and test)
Samira: be prepared to present the Advance R&D presentation (battery), edit slides
Reflection:

The team concluded the performance test. The team had to edit the code to rely more on coasting. During the test, the propeller broke but this did not impact the results of the data. The team obtained a new propeller and decided the shell is too much weight, causing problems with stopping. The team decided to remove the shell. In addition, the AEV was titled, so the team decided to move the L-shaped arm more towards the center to balance out the vehicle.

Date 3/21/19
Time: 9:10-10:05 (in class)
***Members Present*:** All
Topics/Agenda: Present Advance R&D, talk about next class
Action Items with names assigned:
Jeff: Present on propeller R&D test, Discuss ideas for performance test 2
Nick: Present approach and performance test, work on performance test 2 code
Samira: present battery R&D test, discuss ideas for performance test 2
To be completed before next meeting:
Jeff: N/A
Nick: N/A
Samira: N/A
Reflection:
The team presented on the results from the two advance R&D tests. In addition, the team shared how the team is approaching to the task assigned by the city of Columbus. The Team shared the results from the first performance test and discussed the changes in the design for the second performance test. After the presentation was done, the team answered questions and listened to three other Teams presentations. Finally, in the last 10 minutes of class, the team shared ideas and worked on the code for the second performance test.

Date 3/22/19
Time: 9:35-10:55 (in class)
***Members Present*:** All
Topics/Agenda: Complete performance test 2
Action Items with names assigned:
Jeff: test AEV for performance test 2
Nick:test AEV for performance test 2
Samira: *test AEV for performance test 2*
To be completed before next meeting:
Jeff: N/A
Nick: N/A
Samira: N/A
Reflection:

The team began coding the AEV for the second performance test. The AEV must travel to the gate, wait 7 seconds, go pick up a load, wait 5 seconds and proceed from loading doc. The team was having trouble with the AEV traveling up to the proper position of the gate.

Date 3/24/19
Time: 5:15-6:00
***Members Present*: All**
Topics/Agenda: Discuss the CDR and committee meetings
Action Items with names assigned:
Jeff: discuss CDR
Nick: discuss CDR
Samira: Discuss CDR
To be completed before next meeting:
Jeff: write results, executive summary and discuss of CDR, be prepared to present research and development and finances during committee meetings
Nick: write results, executive summary and discuss of CDR, be prepared to present public relations of committee meetings
Samira: write intro, conclusion and recommendations, and executive summary of CDR, be prepared to discuss human resources during committee meetings
Reflection:
The team split up roles for the CDR and discussed a due date to allow enough time for editing. The team also decided to stay in the same roles for the committee meetings. For the human resources, the team will contact Samira if the members have any concerns about another member to keep the issue confidential.

Date 3/26/19
Time: 9:10-10:05 (in class)
***Members Present*: All**
Topics/Agenda: Complete performance test 2
Action Items with names assigned:
Jeff: complete performance test 2
Nick: complete performance test 2
Samira: complete performance test 2
To be completed before next meeting:
Jeff: write results, executive summary and discuss of CDR, be prepared to present research and development and finances during committee meetings
Nick: write results, executive summary and discuss of CDR, be prepared to present public relations of committee meetings

Samira: write intro, conclusion and recommendations, and executive summary of CDR, be prepared to discuss human resources during committee meetings

Reflection:

The team had multiple issues while completing the second performance test. The AEV would go too far past the sensor at the gate, then start reversing. Once that was fixed, the AEV was not going far enough to the load, but the propellers were still moving. Increasing the speed and other changes to the code solved this. Then the AEV would land near the load, and stop, but not go again. The team focused on getting the AEV to wait and start again before worrying about getting all the way to the load. Once this was fixed, the AEV began going too far pas the first sensor of the gate again. The team did not complete the 2nd performance test.

Date 3/29/19

Time: 9:10-10:05 (in class)

***Members Present*:** All

Topics/Agenda: Complete performance test 2, have team meeting notes

Action Items with names assigned:

Jeff: complete performance test 2, present on research and development

Nick: complete performance test 2,   present public relations of committee meetings

Samira: complete performance test 2, discuss human resources during committee meetings

To be completed before next meeting:

Jeff: N/A

Nick: N/A

Samira: N/A

Reflection:

The team, present the community meetings. The website changes include descriptions for the links. The team also needs to figure out why the AEV flew off the tracks. Finally, the team is doing well working as a group. The team also completed the progress report 2. The only issues was ensuring that the AEV went the proper distance for multiple trials. The team decided that the team will test the distance traveled by the AEV at different positions to see if the AEV actually goes the distance programmed.

Date 3/28/19

Time: 9:35-10:55 (in class)

***Members Present*:** All

Topics/Agenda: Complete the Advance R&D 3 (placement of the reflector sensors), if time allows start testing for final performance test

Action Items with names assigned:

Jeff: complete A&D 3, start final test

Nick: complete A&D 3, start final test
Samira: complete A&D 3, start final test
To be completed before next meeting:
Jeff: work on progress report 3, results section
Nick: work on progress report 3, results section
Samira: work on progress report 3, intro and future section
Reflection:
The team, decided to test how the placement of the reflector sensor at the start of the trial impacted the distance and consistory traveled. The trials consisted of the sensor being on the right, left, top and bottom. It was noticed that after a certain amount of trials, there was a dip in the distance that would rise again. The conclusions showed that top configuration is most consistent. Then the team began coding for the final performance test.

Date 4/2/19
Time: 9:10-10;05 (in class)
***Members Present*:** All
Topics/Agenda: test for final performance test
Action Items with names assigned:
Jeff: work on final test
Nick: work start final test
Samira: work final test
To be completed before next meeting:
Jeff: work on progress report 3, results section
Nick: work on progress report 3, results section
Samira: work on progress report 3, intro and future section
Reflection:
The team worked on coding for the final test. The team received a fully charged battery, as opposed to the semi charged battery last meeting. The team therefore had to adjust the code for the intense increase in power. The AEV was traveling too far and too fast. Once this issue was solved, the team worked on the code coming back after the load was picked up.

Date 4/4/19
Time: 9:10-10:05 (in class)
***Members Present*:** Samira and Nick (**Jeff had an excused absence* *)
Topics/Agenda: test for final performance test
Action Items with names assigned:
Nick: work on code for final testing
Samira: work on code for final testing

To be completed before next meeting:
Jeff: work on progress report 3, results section
Nick: work on progress report 3, results section
Samira: work on progress report 3, intro and future section
Reflection:
The Team continued to work on the final code. During one of the tests, there was a metal piece on the load from another team, resulting in the damage of the Teams propeller. The team had to replace the propeller to continue with the code.

Date 4/4/19
Time: 9:35-10:55 (in class)
***Members Present*:** Samira and Nick (**Jeff had an excused absence**)
Topics/Agenda: test for final performance test and edit CDR
Action Items with names assigned:
Nick: work on code for final testing, work on CDR
Samira: work on code for final testing,work on CDR
To be completed before next meeting:
Jeff: work on progress report 3, results section
Nick: work on progress report 3, results section
Samira: work on progress report 3, intro and future section
Reflection:
The team received a battery that was 1/3 of the way charged. When testing, the AEV barely made it up the first incline. The team decided it was best to work on the CDR as the battery charged. The team edited the CDR discussing what else to add and what to take away. at 10:20 the team began testing the AEV. The AEV was slower going to the gate, but still made it. However, the AEV had trouble coming back after picking up the load. The team used trial and error for different codes adding more power to the AEV.

Date 4/7/19
Time: 5:00-7:00
***Members Present*:** All
Topics/Agenda: edit the third progress report, create the final oral presentation slide, talk about CDR
Action Items with names assigned:
Jeff: work on oral presentation, edit progress report, work on progress report, talk about CDR
Nick: work on oral presentation, work on progress report, talk about CDR
Samira: work on oral presentation, work on progress report, talk about CDR
To be completed before next meeting:
Jeff: submit progress report 3 and oral presentation

Nick: N/A
Samira: N/A
Reflection:
The team met to work on the third progress report. The team edited and added any necessary information. The team also created the draft slide for the final oral presentation, focusing on adding figures and pictures. The team created the Photoshop photo of the members on the AEV to add to the presentation.

Date 4/9/19
Time: 9:10-10:05 (In class)
Members Present**:** All
Topics/Agenda: work on the website, work on the CDR, complete Final Test
Action Items with names assigned:
Jeff: Complete final test, work on CDR
Nick: Complete final test (code)
Samira: Complete final test, work on website
To be completed before next meeting:
Jeff: work on CDR and website
Nick: work on CDR and website
Samira: work on CDR and website
Reflection:
The Team worked on the code and testing for the final performance test. The team had difficulties when it came to picking up the load, the AEV was too short. Then the team worked on editing the speed so the AEV will successfully come back with the load. During the first official final performance test, it completed the course, but did not stop at the very end. This did not allow the team to collect the data from the AEV leading to false data on the report. While waiting to test, the team worked on editing the website and the CDR.

Date 4/11/19
Time: 9:10-10:05 (In class)
Members Present**:** All
Topics/Agenda: complete Final Test
Action Items with names assigned:
Jeff: Complete final test
Nick: Complete final test (code)
Samira: Complete final test, work on website
To be completed before next meeting:
Jeff: work on CDR and website
Nick: work on CDR and website

Samira: work on CDR and website
Reflection:
The Team worked on the code and testing for the final performance test. The AEV was not going far enough to reach the gate or pick up the load. During the second final performance test, the AEV did not pick up the load and did not stop in the proper location. However, data was extracted. the time to complete the course was 76 seconds and the energy was 412 J. During the third and final performance test, the AEV did not pick up the load and again went too far for the final stopping point. However, this AEV completed the course faster then the previous two tests.

Date 4/12/19
Time: 9:35-10:55 (In class)
***Members Present*:** All
Topics/Agenda: complete group activity, turn in AEV, work on final presentation
Action Items with names assigned:
Jeff: work on final presentation, take apart AEV, complete group activity
Nick: work on final presentation, take apart AEV, complete group activity
Samira: work on final presentation, take apart AEV, complete group activity
To be completed before next meeting:
Jeff: work on CDR and website
Nick: work on CDR and website
Samira: work on CDR and website
Reflection:
The team did a group activity that they did at the beginning of the year to see how their knowledge of engineering has grown. The team also took apart their AEV and turned it in. Finally, they worked on the final presentation and decided they will be presenting Tuesday.

Date 4/14/19
Time: 5:00-7:00
***Members Present*:** All
Topics/Agenda: work on final presentation, CDR and website
Action Items with names assigned:
Jeff: work on final presentation, CDR and website
Nick: work on final presentation, CDR and website
Samira: work on final presentation, CDR and website
To be completed before next meeting:
Jeff: work on CDR, website, and presentation
Nick: work on CDR, website, and presentation
Samira: work on CDR, website and presentation
Reflection:

The team worked on the budget for the AEV to put onto the final presentation. The team also worked on the parts of the CDR and decided the team will meet Wednesday to finishing editing it. Finally, the team worked on the missing portions of the website, ensuring it was consistent throughout.

Date 4/16/19
Time: 9:35-10:05 (in class)
Members Present**:** All
Topics/Agenda: submit final presentation
Action Items with names assigned:
Jeff: submit final presentation
Nick: submit final presentation
Samira: submit final presentation
To be completed before next meeting:
Jeff: work on CDR, website
Nick: work on CDR, website
Samira: work on CDR, website
Reflection:
The team presented the final presentation over the progress of the entire project.

Date 4/14/19
Time: 7:30-12:30
Members Present**:** All
Topics/Agenda: work on final editing CDR and website
Action Items with names assigned:
Jeff: edit CDR and finish website
Nick: edit CDR and finish website
Samira: edit CDR and finish website

Reflection:
The team got together to edit the final CDR and website. The team also submitted the final everything.