Watts Scientific

Division F

Progress Report 1

Week 5

Team members: Madison Morgan, Tessa Gilmore, Norbert Ung and Keith Cummings

February 6, 2018

Weeks 1 – 4

Situation

The past few weeks Group F has been completing preliminary research for the AEV. The topics investigated during this preliminary research were: Programming Basics, Reflectance Sensors, Creative Design Thinking, Design Analysis Tool, and Concept Screening and Scoring. Programming basics was done so the team could get comfortable with the Arduino syntax and function calls. The Reflectance Sensor Test was used to set up the sensors which enabled the Arduino to count the distance traveled by the AEV in marks. Creative Design Thinking allowed the team members to each brainstorm their own initial AEV concept design. The Design Analysis tool gave the team a way to track the AEV power against time, as well as distance against time. This was an important to research as the Design Analysis tool will be beneficial for AEV analysis in the upcoming investigations. Lastly, the Concept Screening and Scoring exercises were used to determine which team members concept sketches would be used going forward in the advanced research stage.

Results and Analysis

Programming Basics:

The electric motors seemed to have a delay where the propellers didn't spin after the code began. However, the Arduino still counted this time of resistance towards the total seconds programmed. Team F first tested for resistance with "celerate(1,0,35,10); brake(5);" line of code as outline in Appendix A. Then to determine the delayed time increment, used a 10 second test. It was determined that 1 second passed before sound was heard and 3 seconds passed until movement of the motors was tracked, resulting in a total 4 seconds of delay time.

Because the time programmed for the AEV to run was different than the time the motors actually rotated, writing the final code will take further consideration and may require other programming commands for accurate control. Another factor to take into consideration for the final code is stopping distance. Because the brake function does not stop the AEV immediately, the stopping distance will have to be measured once the motor power is cut to determine how much time is needed to stop the vehicle. This was discovered during the Reflectance Sensors investigation.

Creative design thinking:

First, each team member designed their own version of the AEV. Each one used a different shape and layout and had different goals in mind. Pictures of each design are located in Appendix C. Madison's design used the cross-shaped base for inherent balance and placed the motors on the top of the base with the rest of the features rather than hanging underneath with the battery. The goal was to reduce the amount of materials used compared to the sample AEV, which was accomplished by only using the cross-shaped base and no trapezoidal "wings". The reduced materials would also allow for less battery use as the motors would not need to move such a large mass.

The AEV concept drawn by Tessa used the larger T-shaped base and no "wings". The designs goal was to create an AEV that used less material while still maintaining enough space to have all parts equally balanced. The two propellers, motors, and battery sat on the underside of the base. This allowed for more balance as the lower the center of mass is, the more stable the AEV will be on the track. Creating the most stable AEV will allow for the safest possible design and will ensure passengers are transported unharmed.

The AEV prototype designed by Keith was based on two principles: minimizing weight by using smaller structural materials and separating the two motors as much as possible. By creating a wider base with the 1×3 wings, the design was meant to increase lateral roll stability by creating a larger moment of inertia. Using the smaller 2×6 base piece would reduce the overall mass of the AEV, decreasing power use.

Norbert's strategy was a sleek design that reduced weight from the original AEV. The "wings" were moved to the bottom which allowed the AEV to have a more aerodynamic design unlike the large and bulky sample AEV. The use of the T-shaped base reduced weight and made a slimmer design. The trapezoidal "wings" were moved closer to the battery to allow for less wind drag when traveling on the track. The engines for the propellers were relocated to the base instead of on the "wings". Reducing bulk and using a slimmer design would make the AEV more aerodynamic and allow for smoother travel along the track.

After comparing the four individual designs, a team design was created. The goal of the initial team concept design was to limit the total mass and amount of materials used. The cross-shaped was the only base component used and was chosen to maintain balance within the design. The battery was placed on the bottom parallel to the Arduino, which was placed on the top. Placing the battery on the underside of the AEV would lower the center of mass to stabilize the small design. The motors were located on the shorter ends of the cross, another component to ensure balance. The only difference in materials used compared to the sample AEV was the removal of the "wings" and the change to a smaller base. It was estimated that this reduce in used materials would also reduce the cost compared to the sample AEV.

Data Analysis tool:

The Team AEV was then supposed to undergo a couple test programs while data for battery power, time, and distance traveled were recorded. However, upon arrival and mounting of the propellers it was discovered that the motor placement on the AEV base did not allow for enough clearance for the propellers to fully rotate. As time was limited it was decided that the sample AEV would be used for the tests and failure of the team AEV was recorded.

In the Power vs. Time graph, located in Appendix B, power increased at a linear rate from time = 0 seconds to time = 3 seconds. The power then remained constant for 1 second, followed by a 5% decrease in power. The vehicle then remained at 20% power for 2 seconds until the reverse function was applied. The power spiked at time t = 6 seconds due to the need to fight the forward momentum and reverse the AEV. After the vehicle was reversed, the power remained at 25% for about 2 seconds, until the brake function was applied, travelling another 2 meters before coming to a complete stop.

In the Power vs. distance travelled graph, the motor power increased from 0 watts to about 4.89 watts or by 25%. Shortly after, the power was cut to 20% for approximately 1 meter. Then, the direction was reversed and the motors increased to 25% power again. After about 0.35 meters, the brake function was applied and slowed the AEV for the rest of the run until its came to a full stop.

Concept screening and scoring:

The team AEV design had an unforeseen issue with the propellers not having enough clearance to rotate fully, therefore the design initially tested on the track for the Concept Screening and Scoring lab was the sample AEV. The AEV was evenly balanced and did not threaten to tilt to one side at all however because of its large mass and size, the AEV did not start immediately with the program and more time was taken for the AEV to stop. This resulted in a larger brake distance that was deemed undesirable.

The criteria chosen for screening and scoring were, balance/stability, mass of material, clearance, aerodynamics, durability, and clutter. The concept screening spreadsheet displays how each individual design and the team design compared with the sample AEV: a positive sign meant that the design performed better than the sample AEV in that criteria and a negative sign meant that the design performed worse. The concept scoring spreadsheet is simply a more precise measurement of performance. Weighted importance is added as a percentage and multiplied by the score given out of 5. Scores are then added up to determine the final score of the design and compared.

Madison's design ran into the same issue as the team AEV; the propellers did not have enough room to spin, which greatly hindered the AEV. Tessa's Design did not allow for enough room for all the required equipment of the AEV, also hindering the AEV. These conclusions were also enforced by their final scores which were lower than the sample AEV. However, Keith's design scored better than the sample AEV in the balance/stability, mass of material, and aerodynamic criteria resulting in a final score higher than the sample. Similarly, Norbert's design scored better than the sample AEV in balance/stability and aerodynamics, also resulting in a higher final score.

The only drawback in both passing designs was their clutter scores. The clutter was due to having a small base and having to carefully place all equipment in a balanced fashion. However, because clutter was rated as the least important criteria, the scores were still more than high enough to allow for Keith and Norbert's designs to be carried forward into the advanced R&D labs.

Takeaways

- Position control of motor operation using the reflectance sensors will be necessary due to internal motor resistance creating a lag in operation time
- Propeller clearance was an unforeseen complication, confounding several initial designs that were otherwise compact and balanced
- Clearance, balance and a light, aerodynamic design were the primary criteria in evaluating concepts
- Less supervisor instruction during project periods would allow the team to spend more time investigating research topics

Weeks 5 – 7

Situation

Over the next three weeks, Division F will conduct in-depth research into motor configuration and motor quantity. A third topic – the effect of track variance – will be examined if time permits. These investigations, combined with the other teams of Watts Scientific, will allow for more informed design decisions. We will focus on the two aspects of motor design to explore if efficiency gains can be made by altering number or placement of the motors. Multiple arrangements and numbers of motors will be tested to evaluate power efficiency and other performance metrics. This will potentially pay dividends by possibly reducing construction and power costs for the AEV.

Weekly Goals

1. Begin research into topics: Motor configuration, motor quantity, and track comparisons
2. Prepare grant proposal and meet with other teams
3. Begin research into motor configuration and gather materials and set up a time to start testing
4. Collect data and analyze results. Present data to the whole group.
5. Begin research into motor quantity testing. Collect data and results are presented to the whole group.
6. Begin research into track comparisons. Collect multiple data from runs and calculate deviations from times.
7. Present results to the whole group and decide which configurations would produce the best results.

Weekly Schedule

Task	**Due Date**	**Time Needed**	**Teammates(s)**
Further testing of AEV designs • Applies to current design if it fails.	2/18/2018	As needed	Everyone
Necessary coding for AEV • All labs and pre-testing should be done	2/13/2018	As needed	Everyone
Decision on research on testing for certain parts of the AEV • Review aR&D lab manual and consult with other groups on what topics to explore	2/7/2018	1 hr	Everyone
Motor configuration testing • Team comes up with 4-5 different motor configurations • Perform test runs and collect data • Answer progress report questions	2/21/2018	3 hrs	Everyone
Motor quantity testing • Team comes up with 2-3 motor setups • Perform test runs as done with Analysis Lab • Collect data and review data to see which motor setup is best • Answer progress report questions	2/21/2018	3 hrs	Everyone
Track comparisons • Team tests the AEV 5 times on each track • Perform test runs and collect data with different tables • Answer progress report questions	2/26/2018	3 hrs	Everyone

Appendix A-Arduino Codes

Function Call	Function
celerate(m,p1,p2,t);	Accelerates or decelerates motor(s) m from start speed (%) p1 to end speed (%) p2 over a duration of t seconds
motorSpeed(m,p);	Initializes motor(s) m at their percent power p
goFor(t);	Runs the motor(s) at their intialized state for t seconds
brake(m);	Brakes motor(s) m. Note: Just stops the motors from spinning
reverse(m);	Reverse the polarity of motor(s) m
goToRelativePosition(n);	Continues the previous command for n marks from the vehicle's current position. n can be positive or negative with positive meaning the vehicle is moving forward, negative meaning the vehicle is moving backward
goToAbsolutePosition(n);	Continues the previous command for n marks relative to the overall starting position of the AEV

Figure 1. Arduino function calls.

<u>Programming Basics Lab Code:</u>

```
celerate(1, 0, 15, 2.5);        // Accelerates motor 1 from 0 to 15% power in 2.5 seconds
goFor(1);                       // Runs motors at initialized power for 1 second
brake(1);                       // Brakes motor 1
celerate (2, 0, 27, 4);         // Accelerates motor 2 from 0 to 27% power in 4 seconds
goFor(2.7);                     // Runs motors at initialized power for 2.7 seconds
celerate(2, 27,15,1);           // Decelerates motor 2 from 27 to 15% power in 1 second
brake(2);                       // Brakes motor 2
reverse(2);                     // Reverses polarity of motor 2
celerate(4, 0, 31, 2);          // Accelerates both motors from 0 to 31% power in 2 seconds
motorSpeed      (4, 35);        // Runs both motors at 35% power
goFor   (1);                    // Run motors at initialized speed for 1 second
Brake(2);                       // Brakes motor 2
goFor   (3);                    // Runs motor at initialized state for 2 seconds
```

```
Brake(4);                       // Brakes both motors
goFor(1);                       // Runs motors at initialized power for 1 second
reverse(1);                     // Reverses polarity of motor1
celerate(1, 0, 19, 2);          // Accelerates motor 1 from 0 to 19% in 2 seconds
motorSpeed    (2, 35);          // Initializes motor 2 at 35% power
motorSpeed    (1,19);           //Initializes motor 1 at 19% power
goFor   (2);                    // Runs motors at initialized state for 2 seconds
motorSpeed(4, 19);              // Initializes both motors to run at 19% power
goFor(2);                       // Runs motor at initialized power for 2 seconds
celerate(4,19,0,3);             // Decelerates both motors from 19 to 0% power in 3 seconds
brake(4);                       // Brakes all motors
```

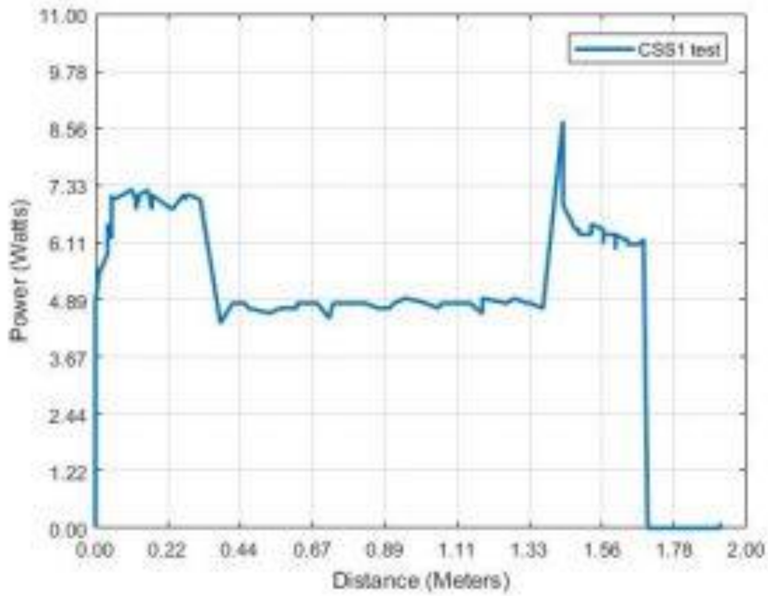
Reflective Sensor Test Code:

```
motorSpeed(4,25);               //Initializes all motors at 25% power
goFor(2);                       //Runs motors at initialized speed for 2 seconds
motorSpeed(4, 20);              // Initializes all motors at 20% power
goToAbsolutePosition(12);       //Continues previous command for 12 marks relative to overall
                                starting position
reverse(4);                     //Reverses polarity of all motors
motorSpeed(4,30);               // Initializes all motors at 30% power
goFor(1.5);                     //Runs motors at initialized power for 1.5 seconds
brake(4);                       //Brakes all motors
```

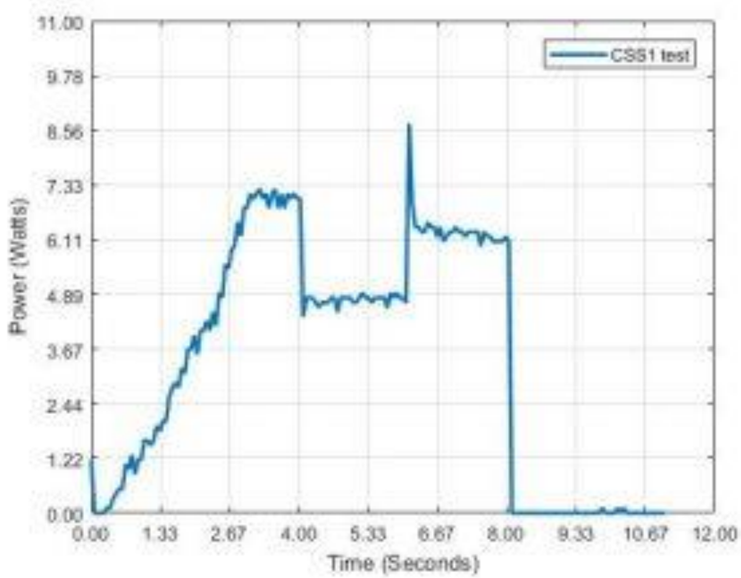
Data Analysis Tool Lab Code:

```
reverse(4);                     //Reverses polarity of all motors, used to counteract direction of
                                motors on AEV
celerate(4,0,25,3);             // Accelerates all motors from 0 to 25% power in 3 seconds
motorSpeed(4,25);               // Initializes all motors at 25% power
goFor(1);                       // Runs motor at initialized power for 1 seconds
motorSpeed(4,20);               // Initializes all motors at 20% power
goFor(2);                       // Runs motor at initialized power for 2 seconds
reverse(4);                     //Reverses polarity of all motors
motorSpeed(4,25);               // Initializes all motors at 25% power
goFor(2);                       // Runs motor at initialized power for 2 seconds
brake(4);                       // Stops all motors from spinning
```

Appendix B – Data Analysis Graphs

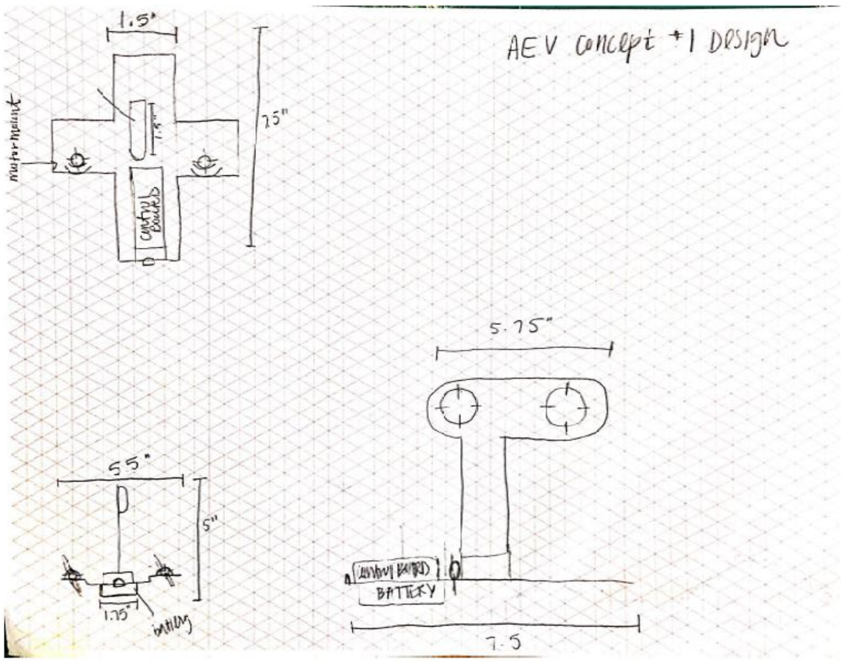


Graph 1. Graph of Distance(meters) vs. Power(watts) for Data Analysis Lab.

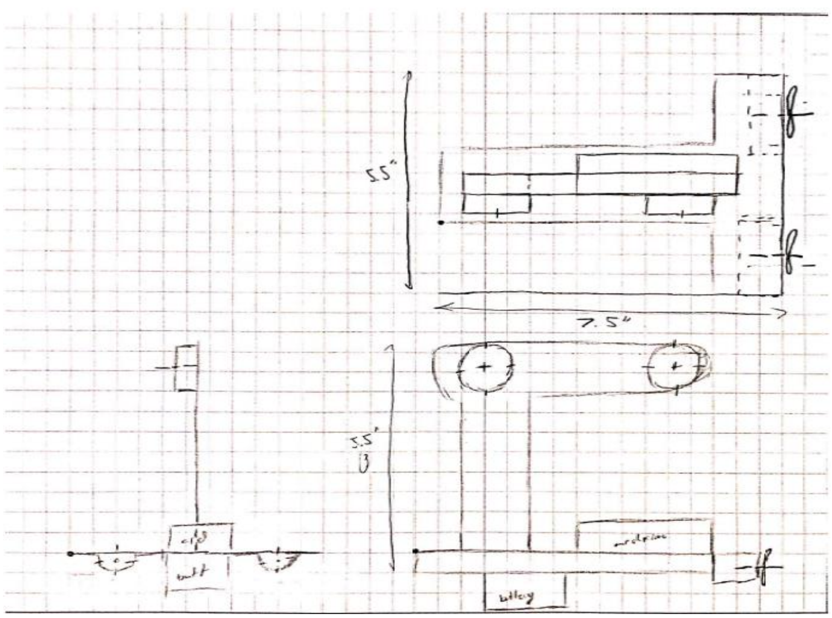


Graph 2. Graph of Time(seconds) vs. Power(watts) for Data Analysis Lab.

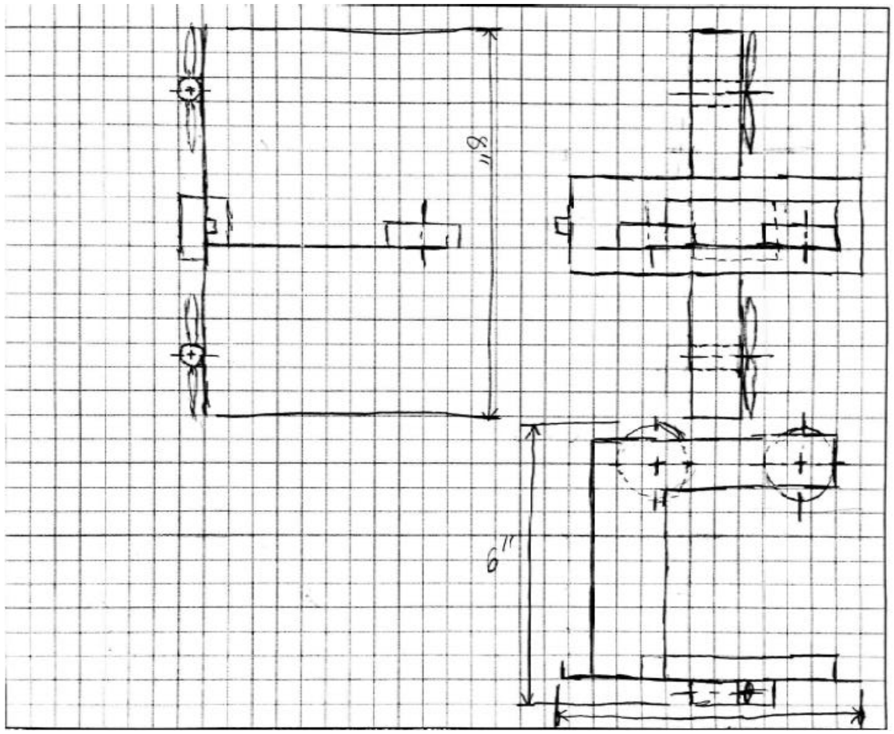
Appendix C-Team Concept Sketches



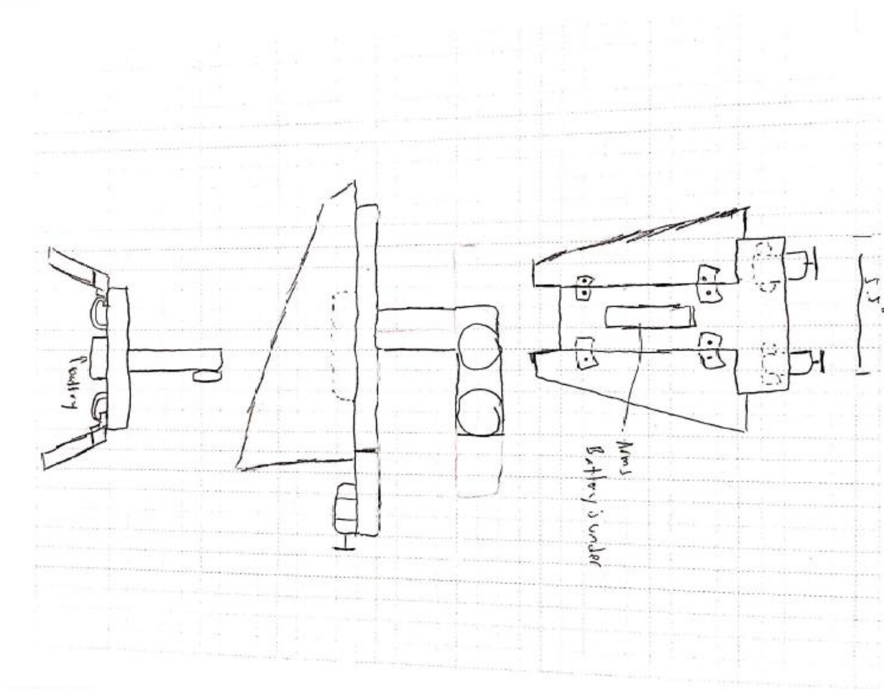
Concept 1. Maddie's Initial Design Concept.



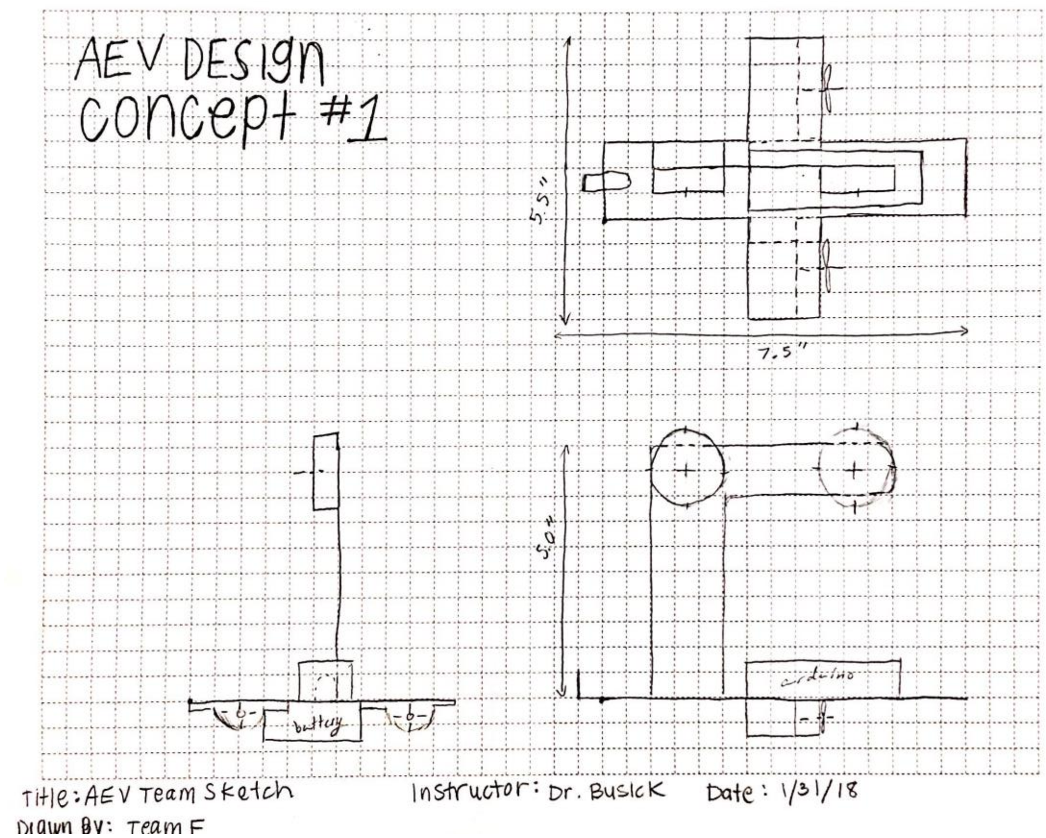
Concept 2. Tessa's Initial Design Concept.



Concept 3. Keith's Initial Design Concept.



Concept 4. Norbert' Initial Design Concept.



Concept 5. Division F Initial Team Design Concept.

Appendix D-Concept Screening/ Scoring Matrices

Division F Concept Screening Matrix						
Success Criteria	Reference Design	Tessa Design	Madison Design	Norbert Design	Keith Design	Team Design
Balance/Stability	0	-	+	+	+	+
Mass of materials	0	+	+	0	+	+
Clearance	0	0	-	0	0	-
Aerodynamics	0	-	-	+	+	-
Clutter	0	-	-	-	-	-
Durability	0	+	+	0	-	+
Sum +'s	0	2	3	2	3	3
Sum 0's	5	1	0	3	1	0
Sum -'s	0	3	3	1	2	3
Net Score	0	-1	0	1	1	0
Carry Forward?	**No**	**No**	**No**	**Yes**	**Yes**	**No**

Concept Screening Matrix.

		Division F Concept Scoring Matrix											
		Reference		Tessa Design		Madison Design		Norbert Design		Keith Design		Team Design	
Success Criteria	Weighted Importance	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Balance/Stability	20%	2	0.4	1	0.2	4	0.8	5	1	5	1	4	0.8
Mass of materials	15%	3	0.45	4	0.6	4	0.6	3	0.45	5	0.75	4	0.6
Clearance	27%	3	0.81	3	0.81	1	0.27	3	0.81	3	0.81	1	0.27
Aerodynamics	15%	3	0.45	2	0.3	2	0.3	4	0.6	4	0.6	2	0.3
Durability	13%	3	0.39	4	0.52	4	0.52	3	0.39	2	0.26	4	0.52
Clutter	10%	3	0.3	1	0.1	2	0.2	2	0.2	2	0.2	2	0.2
Total Score	100%		2.80		2.53		2.69		3.45		3.62		2.69
Carry Forward?			**No**		**No**		**No**		**Yes**		**Yes**		**No**

Concept Scoring Matrix.

Appendix E-Team Meeting Minutes

Date: 1/17/18
Time: 5:00 – 7:00 PM (In person)
Members Present: Keith Cummings, Madison Morgan, Norbert Ung, Tessa Gilmore
Topics Discussed: Team introductions, Website Update 1, Initial AEV setup

Objective:
The objective of this meeting was for the team to get to know each other, assign initial responsibilities, discuss the upcoming first set of deliverables and build the initial setup for the AEV.

Progress Prior to Meeting:
- Company landing page was created (Maddie)

To Do / Action Items:
- Set up TA's as administrators for the website (Maddie)
- Set up team member contact page on website (Norbert)
- Each team member will fill in their own contact info on webpage
- Upload minutes to Carmen (Keith)
- Upload website link to Carmen (Keith)

Decisions:
- Initial prototype of the AEV was built according to sample documentation
- Team roles:
- KC: Team notetaker
- MM: Website manager
- NU: Lead programmer
- TG: Transporter
- The team developed an outline for our approach to designing the AEV, which is on the website

Reflections:
- TG: Our team should work on taking better pictures during construction revisions

Date: 1/31/2018
Time: 5:30-7
Members Present: All members Present
Topics Discussed: Website update 2, Creative Design Thinking

Objective:
To compile individual team concepts into one initial AEV design concept for further testing. Also, organize jobs for website update 2.

To Do / Action Items:
– Upload pictures under "Team Contact Information"(All)
– Create new team design(All)
– Sketch new team design-(Tessa)
– Upload reflectance sensor picture/info(Keith)
– Work on Website 2 update(Maddie and Norbert)

Decisions:
– Use cross shape base for design
– No wings on design
– Battery location moved

Reflections:
-Be thorough in documentation as research in lab progresses (pictures, sketches, notes, etc.)