Report of Progress

Situation

Since the start of the Advanced Electric Vehicle (AEV) project, five labs have been completed on the following topics: programming basics, reflectance sensors, data analysis tool, creative design thinking, and concept screening and scoring. The programming and reflectance sensors labs taught team members how the movement of the AEV works. Team members programmed electric motors to spin propellers like the ones used on the AEV and tested the reflectance sensors to determine which way the AEV is travelling. The data analysis lab showed team members how to extract and analyze data relating to AEV movements, such as time, distance, energy, and power. The last two labs involved brainstorming AEV designs as well as scoring and screening processes to choose the design the team will produce.

Results and Analysis

Each lab allowed team members to learn various functions of the AEV and potential design limitations. During the programming lab, Arduino code was run on electric motors attached to propellers. Upon watching the code execute, team members noticed that the propellers took longer than expected to accelerate to the desired speed. When applying code to the AEV in the reflectance sensors lab, a similar issue was noted: Arduino commands take a few moments to fully execute. The brake command is expected to quickly terminate all AEV movements, however, this command simply stops supplying power to the motors while the AEV coasts slowly to a stop. A full list of commands used in each lab can be found in Appendix A. Throughout the first two labs, learning how to transfer code from the computer to the Arduino could have been better explained. Several errors can occur when transferring code and fixing these errors once does not prevent them from reoccurring. Emphasizing how to check for these errors and solve them could have saved the team valuable time during each lab.

Along with testing various Arduino commands on the AEV, the team also tested the data analysis tool. This tool allows the team to collect data about the AEV including the time, distance, energy used, power used, and various other variables that aid in understanding the performance of the AEV. To test the data analysis tool, the AEV had to run on the track. During the first run on the test track, the AEV did not run because the zip ties interfered with the track. Once the zip ties were snipped, the AEV ran well, but it was slightly unbalanced. After the code was activated, the AEV took several seconds to start moving. The AEV's movements were also not precise. Turning around took a few seconds since the motors had to reverse direction and accelerate once again back to the desired speed. Comparing these observations to the data collected by the data analysis tool helps understand the AEV more accurately. Figures 1 and 2 show the Energy v. Distance and Energy v. Time plots, respectively. In Figure 1, the AEV continually uses more energy until it has traveled one meter. After one meter, the AEV is no longer receiving power from the motors and using energy. Without power from the motors, the AEV coasts to a stop.

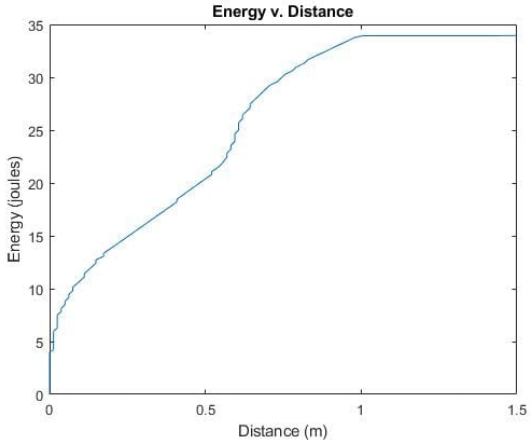

Figure 1. *AEV's energy and distance travelled during data analysis lab*

In Figure 2, the AEV continually uses more energy as time passes. Once eight seconds have passed, the AEV energy levels off. As with the Energy v. Distance plot, the leveling off of the energy is a result of the AEV coasting to a stop. After gaining a deeper understanding of the functions and limitations of the AEV, the team could start brainstorming designs.

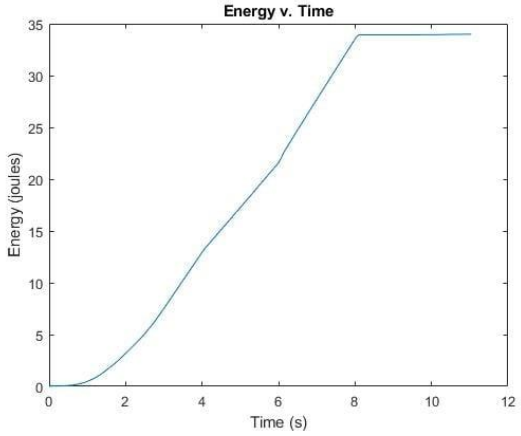

Figure 2. *AEV's energy and time elapsed during data analysis lab*

The creative design thinking lab was a pivotal point for the team. The team created individual designs which can be referenced in Appendix B. Tatum's design focused on aerodynamics with a body shape similar to a plane or rocket. Paige's design was motivated by reducing the amount of materials and weight with angled wings for aerodynamics. Miho and Rachel's designs were based off of the sample AEV. Miho made changes to the battery holder and the arm for the wheels. Rachel's design added wings to make a cross-shaped base. All the designs differed in shape, which means each design also differed aerodynamically. The designs with wings, like Tatum, Rachel, and Paige's, scored higher in the speed and aerodynamics categories, but the designs without wings, like Miho's, scored higher in the materials and cost categories. When evaluating designs for the screening and scoring lab, the team compared the different designs heavily to figure out what design would work best. The team created a concept sketch, shown in Appendix B, that combined Paige and Miho's designs, along with a few aspects from other designs. The final design combined ideas such as wing shape, symmetric weight distribution, and cost. To see the full design comparisons, see the screening and scoring matrices in Appendix C.

Takeaways

The Preliminary R&D provided an important takeaway for the team: the first design is not always the best. After using and testing the sample AEV, the team realized the flaws with the design. The new team AEV features angled wings to increase aerodynamics and a T-shaped arm in the center of the vehicle to more evenly distribute the weight. While testing the AEV on the track, the team also discovered that the AEV moves in the direction of the propellers instead of in the opposite direction of the propellers. This knowledge affected how each piece of the team AEV will be connected to the base. As more testing and researching occurs, the team anticipates many additional revisions before a final design is created.

Future Work

Situation In the upcoming weeks, the team will complete their grant proposal, start advanced research and development, and attend a committee meeting. The grant proposal is a 60 to 90 second presentation in front of the Smart City Grant Staff to propose a supplemental part for the team's AEV design. If the team's part is one of the top three parts presented, the team will receive additional funding. The advanced research and development will test various AEV components, such as the battery, reflectance sensors, servos, and prototyped parts, to better understand each component's function and contribution to the

overall AEV design. After completing the grant proposal and advanced research, each team member will be a representative for one of the following committees: human resources, research and development, and public relations. Each committee will meet with the Smart City Grant Staff to discuss the team's progress and possible improvements that the team can make in upcoming weeks.

Upcoming Goals

As advanced research and development begins, the team will start understanding how various parts affect the AEV and will brainstorm at least three ways to improve the AEV by the next progress report. To determine which components improve the AEV most significantly, the team will investigate the following: the relationship between battery voltage and distance travelled, how reflectance sensors can increase accuracy, how servo motors compare to electric motors, and if prototyped parts perform better than the provided parts. To better prepare for the upcoming tasks, the team will create a weekly plan before leaving lab on Friday at least twice before the next progress report. These weekly plans will layout the work assigned to each team member and deadlines created by the team, and the team will decide if the plans are helpful based on how quickly and completely tasks are completed.

Upcoming Schedule

Committee Meeting

In the upcoming committee meeting, the representatives for each committee will be as follows: Paige with human resources, Tatum with public relations, and Miho and Rachel with research and development. Paige will prepare to discuss planning, team roles, and team interaction with the team meeting minutes, team working agreement, and team schedule. Tatum will prepare to discuss the documentation and website organization with the previous website updates. Miho and Rachel will prepare to discuss the progress of the AEV with team meeting minutes and the first progress report. The preparation for each meeting should be approximately 30 to 60 minutes depending on the amount of materials and discussion topics for the meeting.

Advanced Research and Development

Before the next progress report, four labs of advanced research and development will be completed. Prior to each lab, team members must brainstorm topics to test and write an experimental procedure to follow during lab. Every week, all team members will brainstorm and decide on a topic to investigate no later than the Sunday after the previous lab. Two people every week will be assigned to complete the methodology, which should take about one to two hours depending on the difficulty of the lab. The remaining two people will determine how the data collected from the previous lab will be used to improve the AEV, which should take about 30 to 60 minutes. The first week, Tatum and Paige will focus on writing the lab procedure, and Miho and Rachel will focus on other weekly tasks. Every week, the roles will alternate so that every team member has a chance to write lab procedures and interpret results.

Meeting Minutes

As seen in Appendix D, meeting minutes are completed after each team meeting. Every week, the team should have at least one team meeting to decide the next topic to investigate in lab. The person completing and uploading the meeting minutes will alternate each week. The rotation of meeting minute responsibility will be Miho, Paige, Rachel, and Tatum. Once four weeks has passed, the rotation will start again with Miho. Completing the meeting minutes and uploading them to the website will take approximately ten minutes every meeting.

Appendix A: Code

Table A.1. *Code to test electric motors in programming basics lab*

Code	Comments
celerate(1,0,15,2.5);	// Accelerate motor one from start to 15% power in 2.5 seconds.
motorSpeed(1,15); goFor(1);	// Run motor one at a constant speed (15% power) for 1 second.
brake(1);	// Brake motor one.
celerate(2,0,27,4);	// Accelerate motor two from start to 27% power in 4 seconds.
motorSpeed(2,27); goFor(2.7);	// Run motor two at a constant speed (27% power) for 2.7 seconds.
celerate(2,27,15,1);	// Decelerate motor two to 15% power in 1 second.
brake(2);	// Brake motor two.
reverse(2);	// Reverse the direction of only motor 2.
celerate(4,0,31,2);	// Accelerate all motors from start to 31% power in 2 seconds.
motorSpeed(4,35); goFor(1);	// Run all motors at a constant speed of 35% power for 1 second.

brake(2);
motorSpeed(1,35);
goFor(3);
	// Brake motor two but keep motor one running at a constant speed (35% power) for 3 seconds.

brake(4); goFor(1);	// Brake all motors for 1 second.
reverse(1);	// Reverse the direction of motor one.

celerate(1,0,19,2);
motorSpeed(2,35);
goFor(2);
	// Accelerate motor one from start to 19% power over 2 seconds.15.Run motor two at 35% power while simultaneously running motor one at 19% power for 2 seconds.

motorSpeed(4,19); goFor(2);	// Run both motors at a constant speed (19% power) for 2 seconds.
celerate(4,19,0,3);	// Decelerate both motors to 0% power in 3 seconds.

brake(4);	// Brake all motors.

Table A.2. *Code to test sensors and AEV in reflectance sensors lab*

Code	Comments
reflectanceSensorTest();	// Tests sensors to determine if they are working
motorSpeed(4, 25); goFor(2);	// Run all motors at a constant speed of 25% power for 2 seconds
motorSpeed(4, 20); goToAbsolutePosition(295);	// Run all motors at a constant speed of 20% and using the goToAbsolutePosition function travel a total distance of 12 feet (from the starting point)
reverse(4);	// Reverse motors
motorSpeed(4, 30); goFor(1.5);	// Run all motors at a constant speed of 30% power for 1.5 second
brake(4);	// Brake all motors

Table A.3. *Code to test AEV in data analysis lab*

Code	Comments
reflectanceSensorTest();	// Tests sensors to determine if they are working
motorSpeed(4, 25); goFor(2);	// Run all motors at a constant speed of 25% power for 2 seconds
motorSpeed(4, 20); goToAbsolutePosition(295);	// Run all motors at a constant speed of 20% and using the goToAbsolutePosition function travel a total distance of 12 feet (from the starting point)
reverse(4);	// Reverse motors
motorSpeed(4, 30); goFor(1.5);	// Run all motors at a constant speed of 30% power for 1.5 second
brake(4);	// Brake all motors

Table A.4. *Code to plot AEV data in data analysis lab*

Code	Comments

data = table2array(DataonTrack);	% Downloads data from excel file of data extraction tool
time = str2double(data(9:193, 7)) power = str2double(data(9:193, 13)) energy = str2double(data(9:193, 15)) distance = str2double(data(9:193, 10))	% Creates all of the necessary vectors from the downloaded data

plot(time, power);
title('Power v. Time');
xlabel('Time (s)');
ylabel('Power (watts)');
	% Power v. Time Plot

plot(distance, power);
title('Power v. Distance');
xlabel('Distance (m)');
ylabel('Power (watts)');
	% Power v. Distance Plot

plot(time, energy);
title('Energy v. Time');
xlabel('Time (s)');
ylabel('Energy (joules)');
	% Energy v. Time Plot

plot(distance, energy);
title('Energy v. Distance');
xlabel('Distance (m)');
ylabel('Energy (joules)');
	% Energy v. Distance Plot

Appendix B: Design Sketches

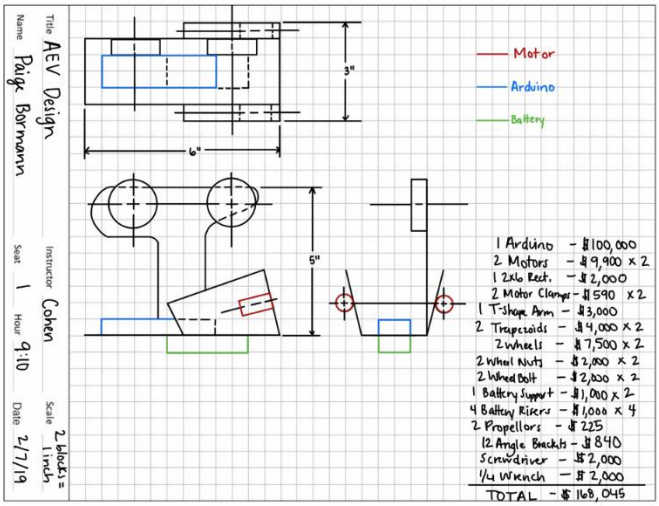

Figure B.1. *Paige Bormann's AEV design*

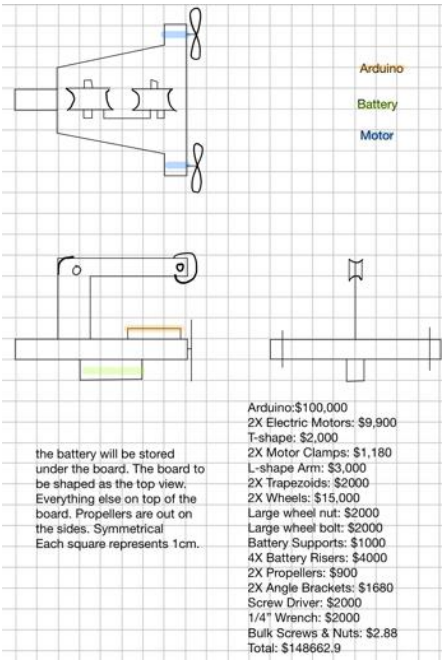

Figure B.2. *Miho Kaburagi's AEV design*

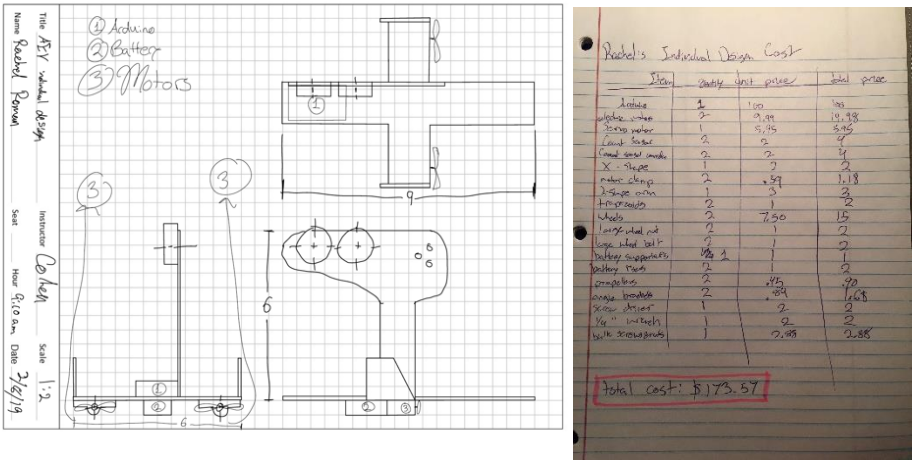

Figure B.3. *Rachel Roman's AEV design*

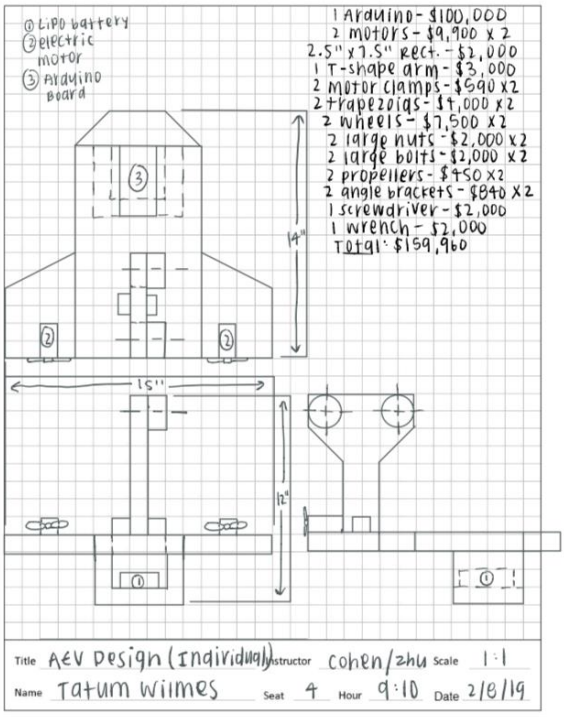

Figure B.4. *Tatum Wilmes' AEV design*

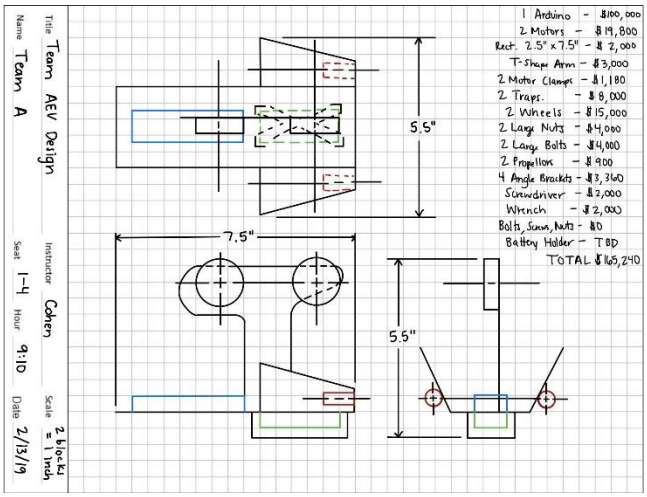

Figure B.5. *Team AEV Design*

Appendix C: Concept Screening and Scoring Spreadsheets

Table C.1. *Screening Matrix*

Success Criteria	Reference	PB Design	MK Design	RR Design	TW Design
Weight	0	+	0	+	0
Aerodynamics	0	+	+	+	+
Flexible	0	0	0	0	0
Amount of Materials	0	-	-	-	-
Speed	0	+	+	+	+
Cost	0	-	-	-	-
Sum +'s	0	3	2	3	2
Sum 0's	0	1	2	1	2
Sum -'s	0	2	2	2	2
Net Score	0	1	0	1	0
Continue?	No	Yes	No	Yes	No

Table C.2. *Scoring Matrix*

		Reference		PB Design		MK Design		RR Design		TW Design	
Success Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Weight	15%	2	0.3	1	0.15	4	1.2	3	0.45	2	0.3
Aerodynamics	20%	2	0.4	4	1.6	1	0.2	2	0.4	3	0.6
Flexible	5%	2	0.1	3	0.15	1	0.05	2	0.1	4	0.2
Amount of Materials	20%	2	0.4	3	0.6	2	0.4	1	0.2	4	0.8
Speed	15%	2	0.3	1	0.3	2	0.6	3	0.9	4	0.6
Cost	25%	2	0.5	2	0.5	4	1	1	0.25	3	0.75
Total Score			2		3.3		3.45		2.3		3.25
Continue?			No		Combine		Combine		No		No

Appendix D: Team Meeting Minutes

Date: 11 – Jan – 2019
Time: 9:35am – 10:55am
Location: HI 224
Members Present: Paige Bormann, Miho Kaburagi, Rachel Roman, Tatum Wilmes
Topics Discussed: AEV Website & Arduino Programming
Objective: The main focus of this meeting was to learn about the AEV project requirements and to experiment with programming the Arduino board.
To-Do/Action Items: Post meeting minutes to u.osu.edu (PB), Website Update (ALL)
Decisions: No decisions made during the meeting.
Reflections: We had a hard time deciding if or when we should meet. Next lab, we should discuss a plan for meeting outside of class.

Figure D.1. *First team meeting minutes*

Date: 17 – Jan – 2019
Time: 9:10am – 10:05am
Location: HI 308
Members Present: Paige Bormann, Miho Kaburagi, Rachel Roman, Tatum Wilmes
Topics Discussed: AEV Website & Roles
Objective: The main focus of this meeting was to update the website and assign roles in the project.
To-Do/Action Items: Post meeting minutes to u.osu.edu (TW), Assign Roles (ALL), Website Update #1 (ALL)
Decisions: Tatum and Paige will be the primary programmers. Miho will primarily work on documentation and Rachel will primarily update the website.
Reflections: We were able to set roles based on experience and interest. However, we will contribute to all roles.

Figure D.2. *Second team meeting minutes*

Date: 31 – Jan – 2019
Time: 9:10am – 10:05am
Location: Drackett Tower Lobby
Members Present: Paige Bormann and Rachel Roman
Topics Discussed: AEV sample design
Objective: The main focus of this meeting was to build and put together the sample AEV.
To-Do/Action Items: Build the sample AEV
Decisions: Rachel and Paige decided on how the AEV should be built. They made decisions as to how the structure and function would work together.
Reflections: We were able to see more clearly how the AEV will function after building. The objective of this project is more clear now.

Figure D.3. *Third team meeting minutes*

Date: 1 – Feb – 2019

Time: 9:35am – 10:55am
Location: HI 224
Members Present: Paige Bormann, Miho Kaburagi, Rachel Roman, Tatum Wilmes
Topics Discussed: AEV Website & Preliminary R&D 3
Objective: The main focus of this meeting was to test the Performance Analysis Tool and update the website.
To-Do/Action Items: Website Update 2 to u.osu.edu (TW), Retest the reflectance sensors (PB), Write code for Preliminary R&D 3 (RR), Data Analysis Test (MK)
Decisions: Tatum decided to make a separate tab on the website for contact information. The team decided to meet during the week.
Reflections: We were able to come up with a plan on how we want to execute the project.

Figure D.4. *Fourth team meeting minutes*

Date: 3 – Feb – 2019
Time: 3:30pm-4:15pm
Location: HI 316
Members Present: Paige Bormann, Miho Kaburagi, Rachel Roman, and Tatum Wilmes
Topics Discussed: Preliminary R&D 3
Objective: The main focus of this meeting was to finish preliminary R&D 3.
To-Do/Action Items: Finish preliminary R&D 3
Decisions: Due to the lack of equipment to finish the assignment we decided to use open lab to finish it by 2/8.
Reflection: We were able to come up with a plan to complete the assignment by the due date.

Figure D.5. *Fifth team meeting minutes*

Date: 4 – Feb – 2019
Time: 6:00 pm-7:00 pm
Location: HI 346
Members Present: Paige Bormann, Rachel Roman, Tatum Wilmes
Topics Discussed: AEV Website & Preliminary R&D 3
Objective: The main focus of this meeting was to test the Performance Analysis Tool and update the website.
To-Do/Action Items: Website Update 2 to u.osu.edu (TW), Figure out Preliminary R&D 3 (PB)
Decisions: Tatum decided to make a separate tab for progress reports and design updates. The team decided to meet at the TA office hours.
Reflections: We were able to come up with a plan on how we want to execute the project.

Figure D.6. *Sixth team meeting minutes*

Date: 8 – Feb – 2019
Time: 9:35 am-10:55 am
Location: HI 224
Members Present: Paige Bormann, Rachel Roman, Tatum Wilmes, and Miho Kaburagi
Topics Discussed: Data Extraction and AEV Design

Objective: The main focus of this meeting was to finalize the data collected and discuss the design of the AEV
To-Do/Action Items: Website Update 2 to u.osu.edu (TW), Figure out Preliminary R&D 3 (PB), Discuss different designs (ALL)
Decisions: We decided that we need to meet during the week to finish up exercise 4 and 5. We decided that the base for our wheels would be the more symmetrical one, and that there would be angled, wing-like structure on the sides of the AEV.
Reflections: We were able to have a better understanding of the AEV project after running it on the track. It is more clear to us now what we should be designing and what objectives we are pursuing.

Figure D.7. *Seventh team meeting minutes*