

AEV Critical Design Report

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Executive Summary

The motivation behind the AEV lab was to create a vehicle that would aid the rebel alliance in their pursuit of preparing their army for war after the destruction of the Death Star. This is important because without means of transportation for the R2D2 units, the empire will catch onto them and the element of surprise will vanish. The purpose of the AEV lab was to create an alternative energy vehicle to complete the MCR in a timely fashion and a goal of minimum energy consumption should be strived for. This lab was also meant to teach project management skills, teamwork and design process. These skills were taught in different labs and used throughout the entire process of the AEV creation and implementation.

In this lab the team had to draft various designs for an AEV and decide which ones to develop. The team did this by using screening and scoring matrices. These methods proved beneficial because the team was able to clearly decide which AEV would be the most efficient. The team also had to create a code in order to complete the MCR. The team did this by comparing coding techniques and trial and error test runs on the track.

The AEV was used to meet the criteria listed in the MCR by coding for the AEV to perform specific tasks needed in order to run on the track. In order to complete the MCR the AEV needed to be able to move forward, backwards and be able to stop and start. The AEV also picked up the cargo at one end of the track and returned it to the other side. The team has compared multiple AEV designs and two different codes and has decided which are the most efficient and decided to move forward with those ones.

Possible error in this lab could come from miscalculating the distance traveled in marks. If this happened the AEV would not stop at the proper location. Another error that the team encountered was having to reverse the motors in order to travel forward. Solving this error was crucial to completing the MCR and having the AEV travel properly. Another possible source of error could be uploading the code to the Arduino incorrectly. If the code is not installed correctly, then the AEV will not perform the tasks properly.

The AEV has completed the MCR at this point in time. The team fixed all problems associated with the the AEV's design that were hindering the performance. The AEV was too low to pick up the cargo and had problems with the propeller. These problems were fixed and the team was able to complete the MCR.

In conclusion, this lab has taught the team about how important and beneficial working in a team is. Without all of the team working together, the final AEV design would not have been thought of. Elements of each of the team's designs went into the final AEV design in order to create the most efficient AEV possible. This lab also displayed how a vehicle can be ran with precision with an efficient code. These ideas are closely aligned with the lab objectives because the team had to apply problem solving strategies to solve a real-world programming and design scenario, as well as working as a team to meet a deadline.

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Introduction

As the galactic empire rebuilds their empire, the rebel alliance needs to prepare for war. The rebel alliance is preparing on remote planets out of reach of the galactic empire; these planets have a limited power supply. Therefore, Team E has been contracted to design an Advanced Energy Vehicle (AEV) to transport the alliance's cargo. Teams were to create model AEVs and the top 3 would move on to the AEV Showcase to compete for the contract for construction of the AEV design. With ethics and energy management as our top priority, Team E started experimenting. These experiments included the use of laser cut pieces and propellor motors to create the model AEV, an Arduino board, the Arduino Integrated Development Editor, external sensors, and an overhead model of the track to run the model AEVs on. These experiments enabled the students to learn how to program the AEV to run on the track, work as a member of a team, apply problem-solving techniques learned in ENGR 1181, calculate the energy used by an AEV, and to work whilst under a deadline. This report contains the results of those experiments; the different AEV designs Team E came up with; and the final recommendations given by Team E.

Experimental Methodology

Over the labs that has been performed the team has gone through many steps, goals and procedures. Through the labs the team has been working on trying to make their AEV go through a course and operate fully by meeting a set of requirements. The team started out by running test runs with a test designed AEV to get used to how to run the AEV with a written code. After knowing how to operate the AEV the team began to brainstorm about the design of the AEV. Each team member then made their own design then after they looked at all the designs and brainstormed together about the type of design they felt best worked for the experiment. Below are the designs made by the team. After designs were decided upon, the team had to create a code to complete the MCR and minimize the energy usage. The team compared two different code structures to determine the most efficient one. The team continued to tweak the code to make sure the AEV would act consistently throughout every test. The team also made tweaks to the code to lower the total energy usage as well. The team was mainly focused on completing the MCR perfectly and the team was able to do that as evidenced by the Final Test Scoring Sheet located in the appendix. For specifics on individual lab procedure refer to the Lab Manual.

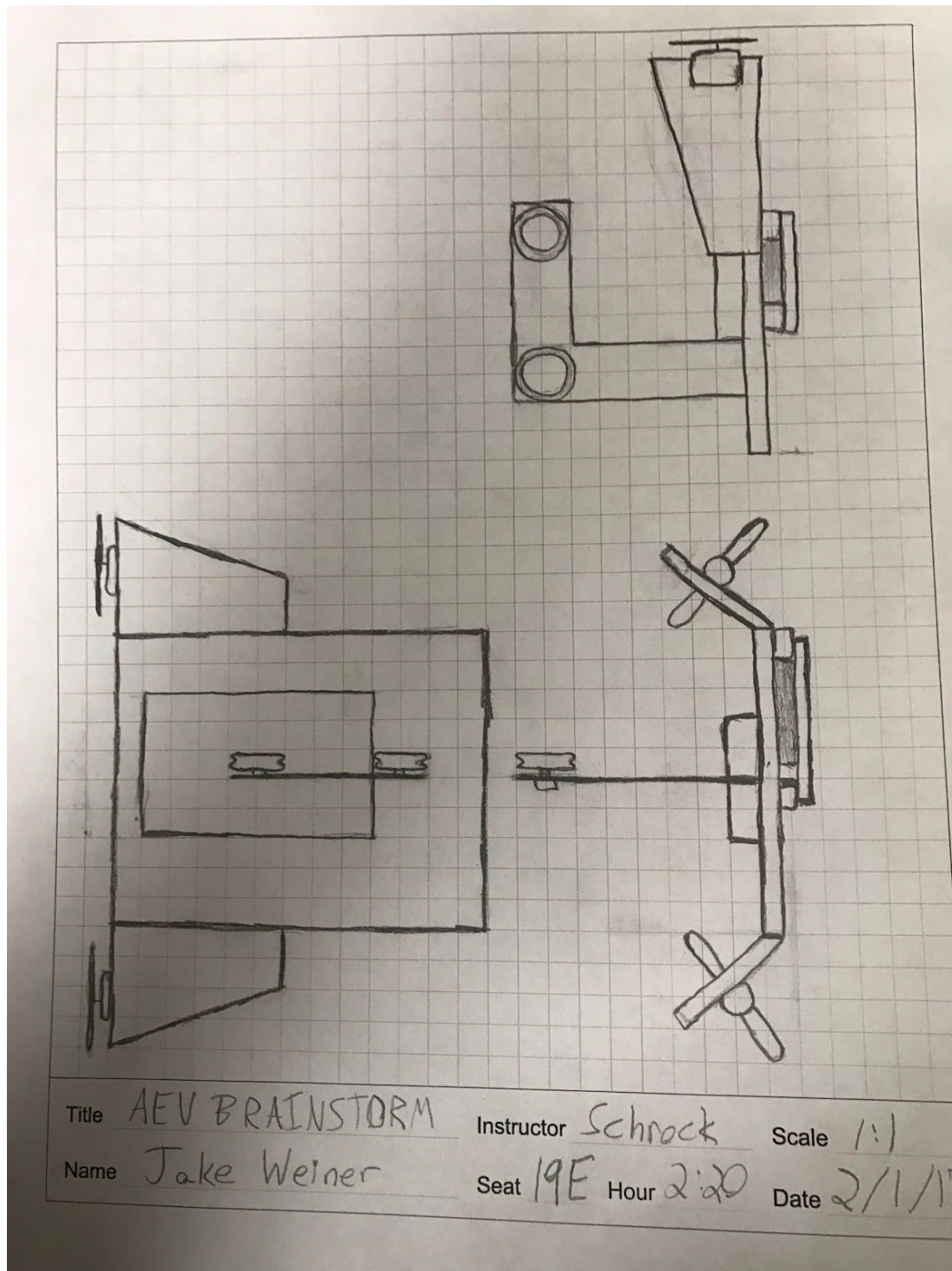


Figure 1: Jake

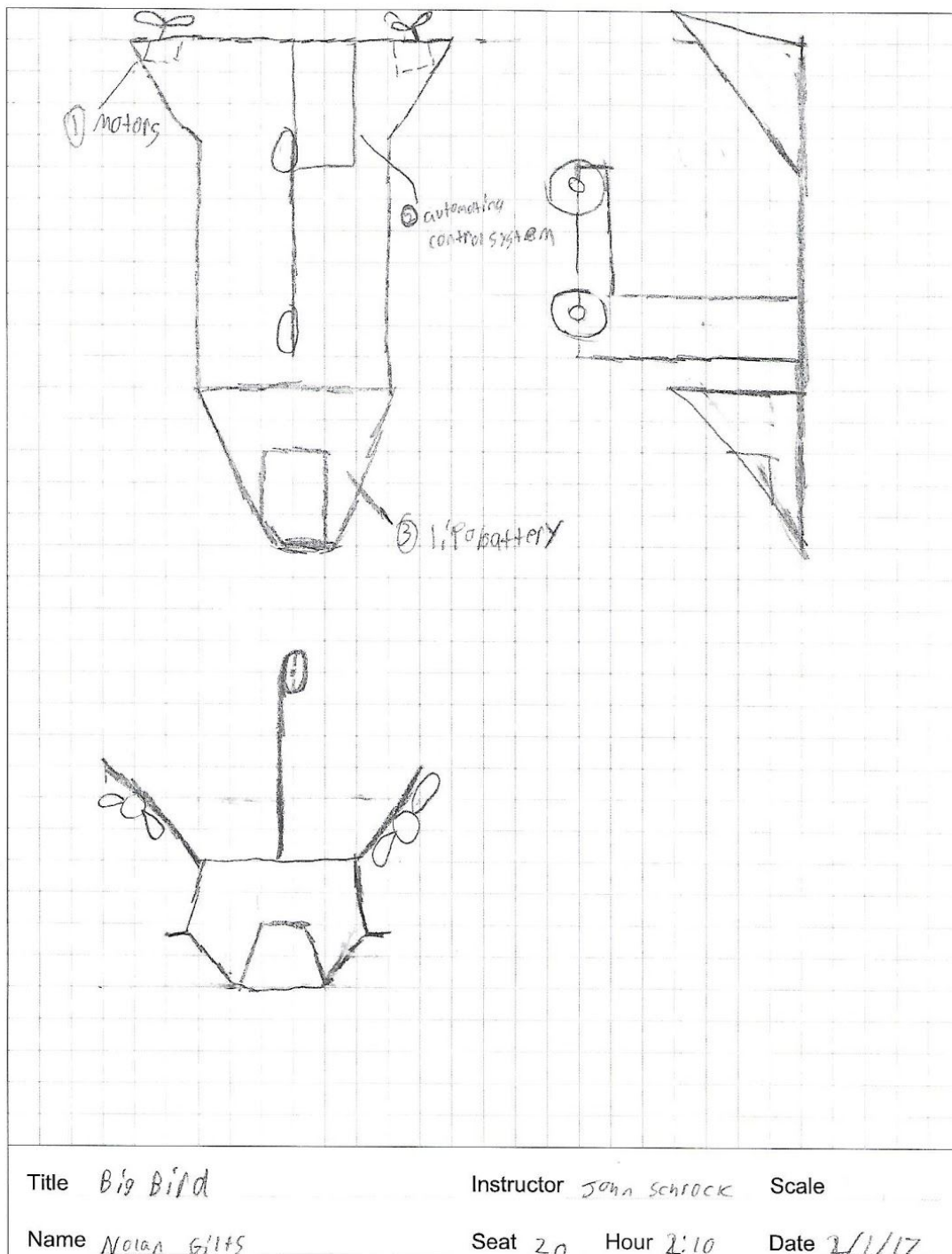


Figure 2: Nolan

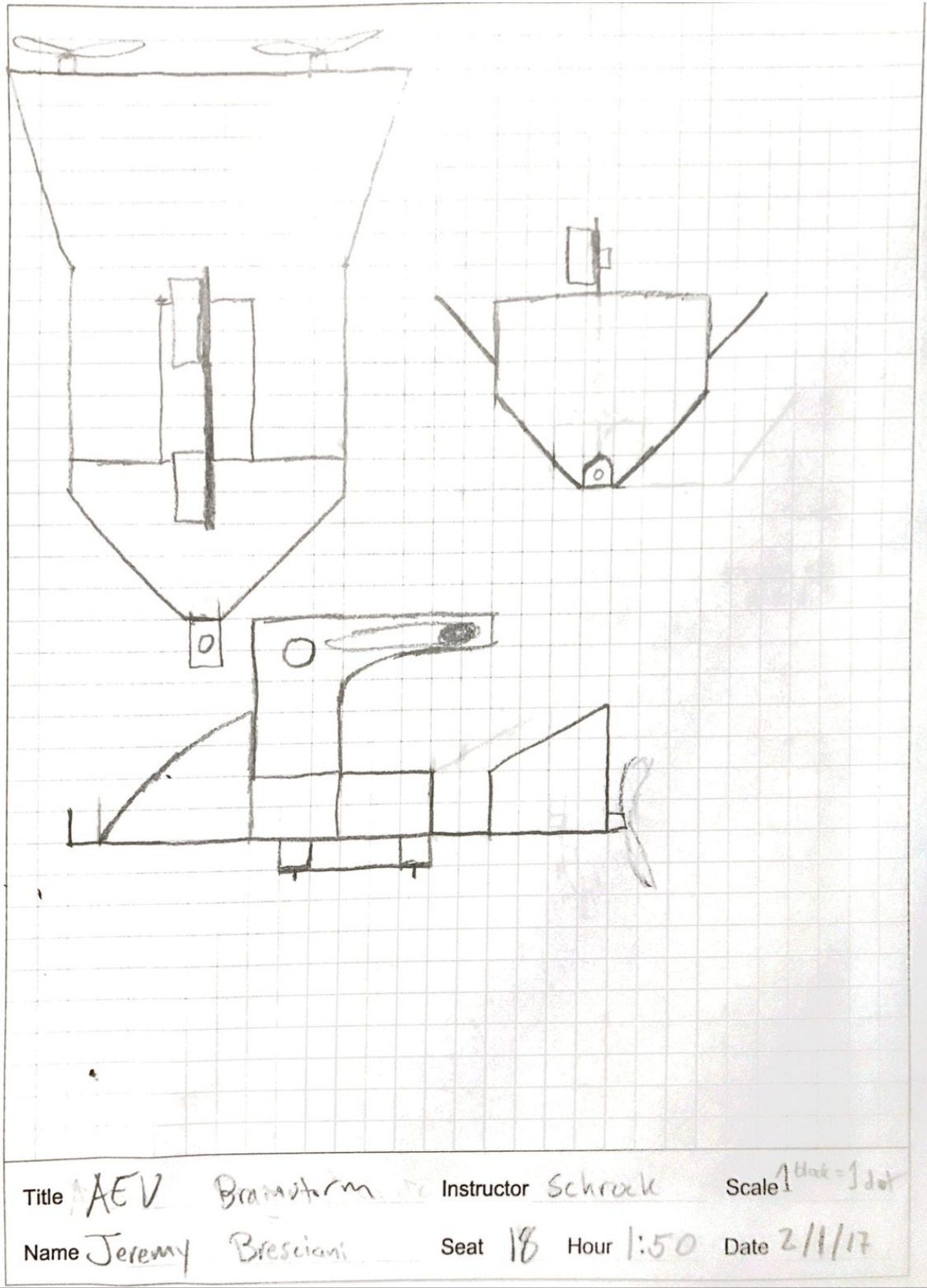


Figure 3: Jeremy

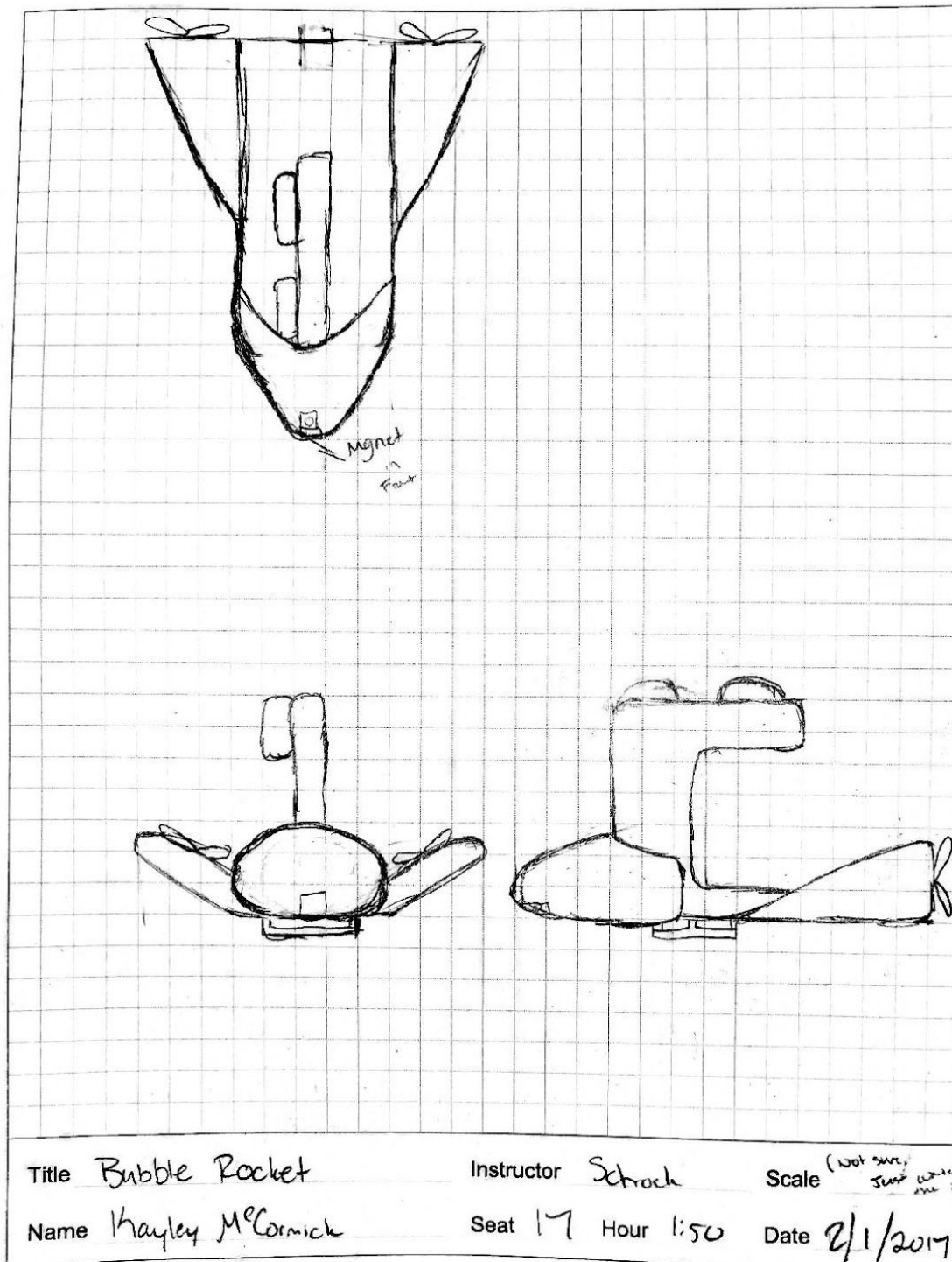


Figure 4: Kayley

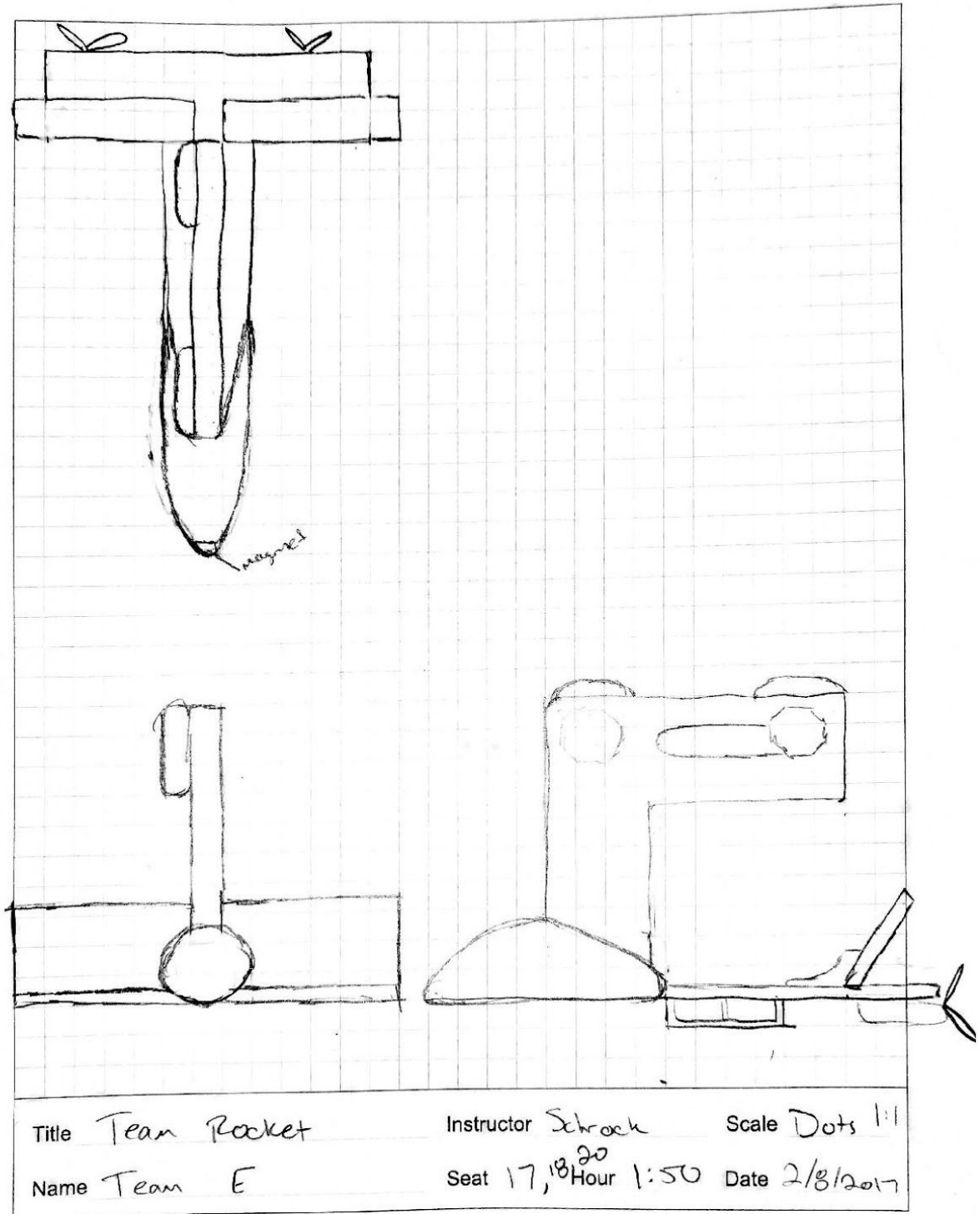


Figure 5: Group Old

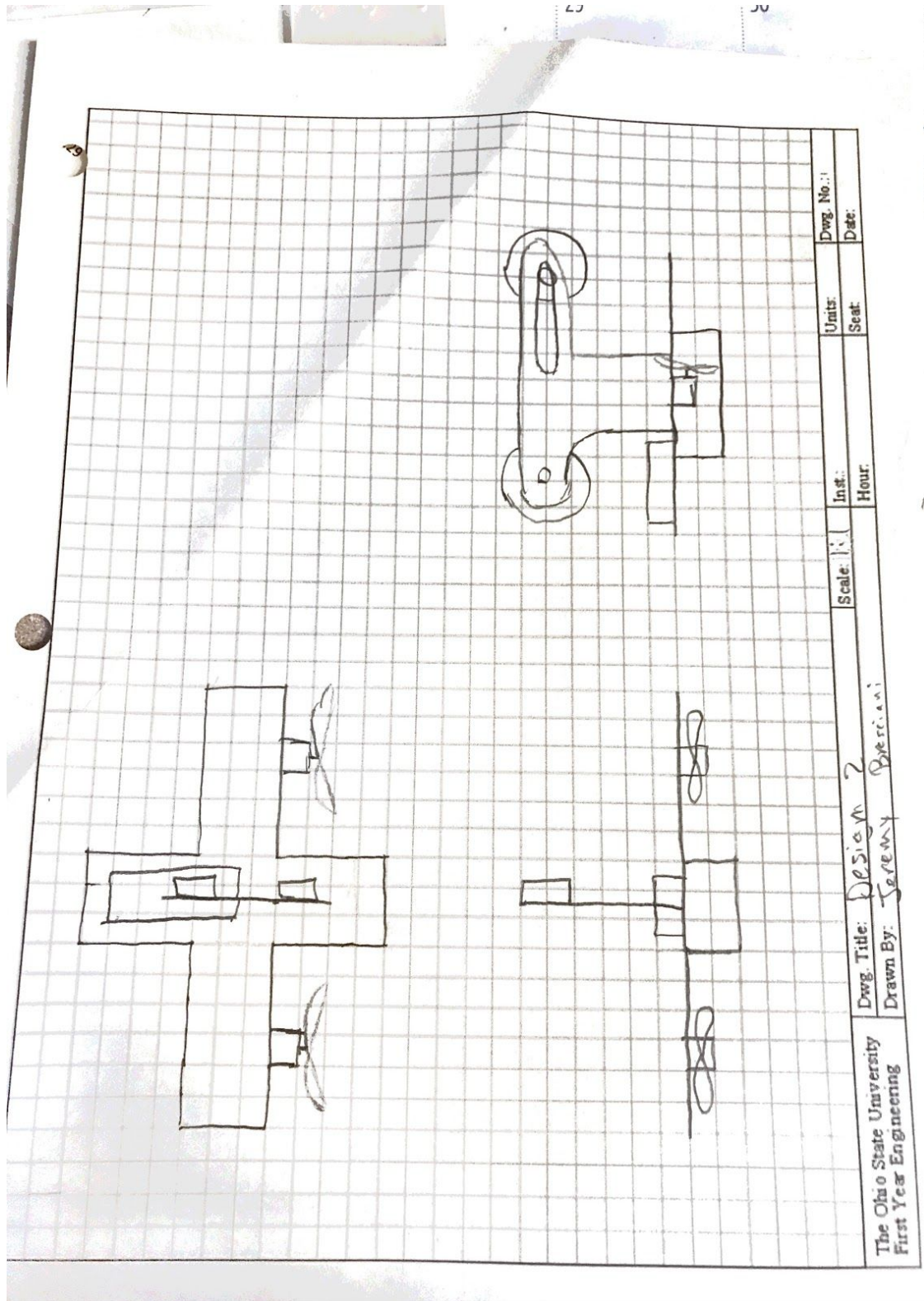


Figure 6: Design 2

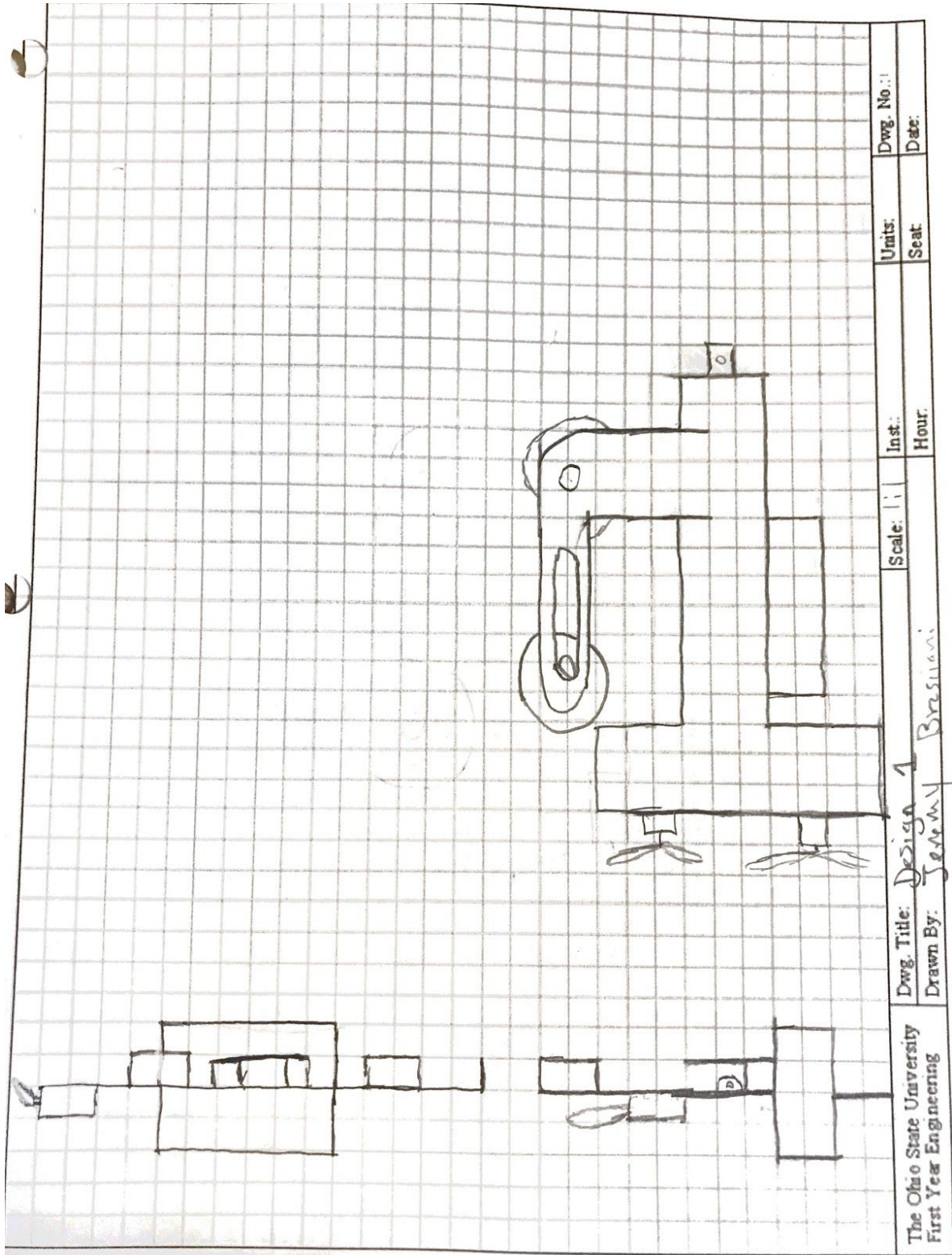


Figure 7: Design 1 (New)

The code written by the team will need to be uploaded to the AEV's arduino which is pictured below.

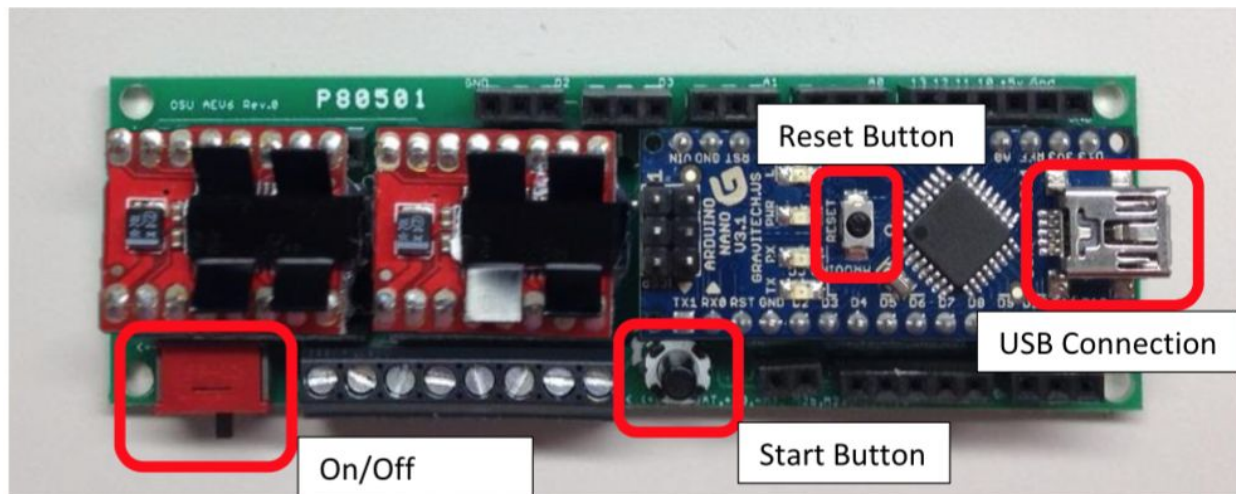


Figure 8: Arduino

After the code is uploaded to the Arduino, it will be able to run the AEV on the track to complete the MCR.

Results

After the team made all of their designs they made screening and scoring charts that would compare all the different designs and they would see which two worked the best. The team began testing after they had the two designs they felt worked best. The team decided on these designs because of their superior scores in the scoring matrix. After the team weighted the categories that were most important, it was evident which designs would be chosen. While testing the came up with another design they felt would work the best. They decided to flip the aev on its side and have a flat design. The team decided to try this out of curiosity and it actually worked well according to the decrease in energy consumption. The vertical flip also seemed to make the AEV more aerodynamic as it would coast for longer distances than it would before the flip. When they did this it increased the speed and aerodynamics of the AEV. They then ran another screening and scoring chart with the new design to make sure it would work the best and tested it. After seeing that the design was the best fit for the run they moved forward with it and made it their final design. The team then ran tests of their top two designs (as seen in figures 6 and 7) to the first gate of the track and they would pick the design that had the best runs. The team then found their final design and made their final tweaks to it. The team perfected the code for the AEV and completed the MCR exactly how it is stated in the Lab Manual, receiving all points. The team was not concerned with costs of the materials on the AEV as the team didn't purchase anything and only used what was provided by the instructional staff. The team reduced the cost of the AEV by not adding any unnecessary parts. The team experimented with different coding strategies to lower the total energy consumption. The team decided to implement more coasting into the AEV's operations, this not only used less energy because the motors were not running but it also saved energy because the

reverse motor speed could be lowered as the AEV wasn't traveling as fast. This change lowered the total energy usage by 25 Joules.

Final design:

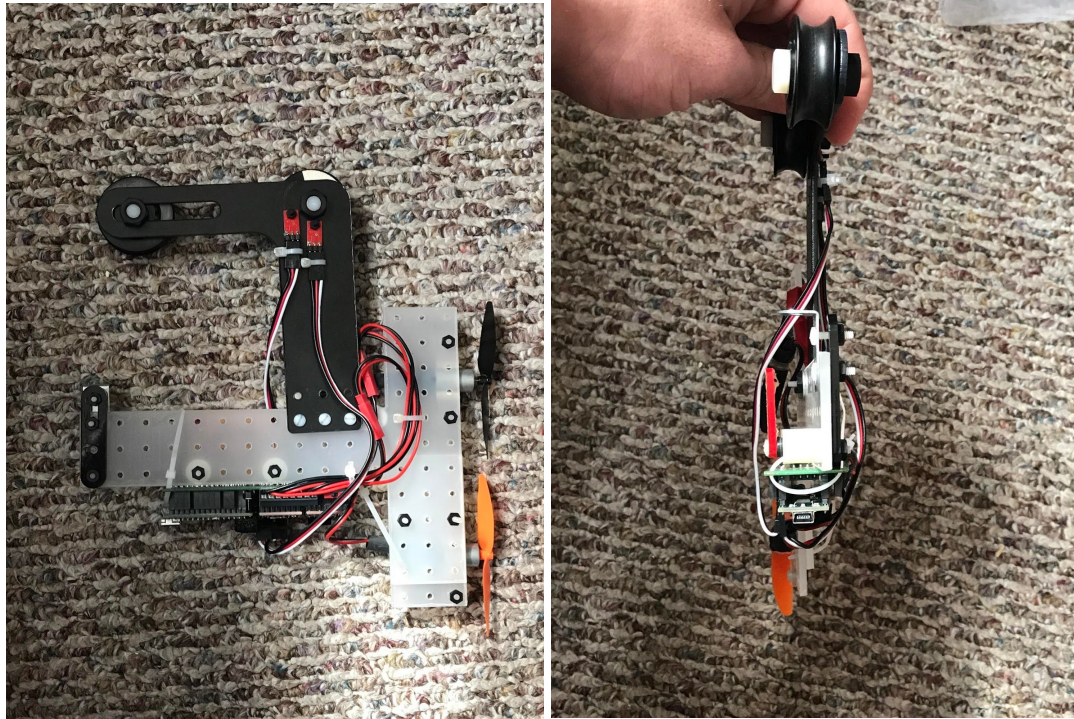


Figure 9: Final Design

The team's scoring and screening matrices are shown below. After analyzing these the team was able to come to a conclusion on which AEV would perform better.

Table 1: Concept Screening Matrix

Criteria	Reference	Jeremy	Nolan	Jake	Kayley	Group (Old)	Group (New)
Balance	0	0	-	0	0	0	-
Aerodynamics	0	+	+	0	+	0	+
Speed	0	-	0	0	+	+	+
Weight	0	-	0	0	0	+	+
Sum +'s	0	1	1	0	2	2	3
Sum 0's	4	1	2	4	2	2	0
Sum -'s	0	2	1	0	0	0	1
Net Score	0	-1	0	0	2	2	2
Continue?	Combine	No	No	No	Revise	Revise	Yes

Table 2: Concept Scoring Matrix

		Reference		Kayley's Design		Old Group Design		New Group Design	
Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Balance	34	4	1.36	4	1.36	4	1.36	2	0.68
Aerodynamics	34	2	0.68	4	1.36	4	1.36	4	1.36
Speed	16	2	0.32	3	0.48	4	0.64	4	0.64
Weight	16	2	0.32	4	0.64	5	0.8	4	0.64
Total Score		2.68		3.84		4.16		3.32	
Continue?		No		Develop		No		Yes	

Performance test 1 allowed the team to verify which AEV was the most efficient and best suited for to complete the MCR. The team decided that the design the team came up with as a group was the optimal design. After seeing both designs run on the track, the team knew which one was superior and continued using that design for the remainder of the lab. The design chosen was much more aerodynamic than the other design. After performance test 1 it became evident which AEV should be used in the coming labs. The system analysis tool allowed the team to be able to record data about how the AEV was performing. The lab taught the team how to measure the AEV's total energy usage and other pertinent stats as seen in figure 10 below, the team was able to calculate the total energy usage for the entire run to be 314 Joules.

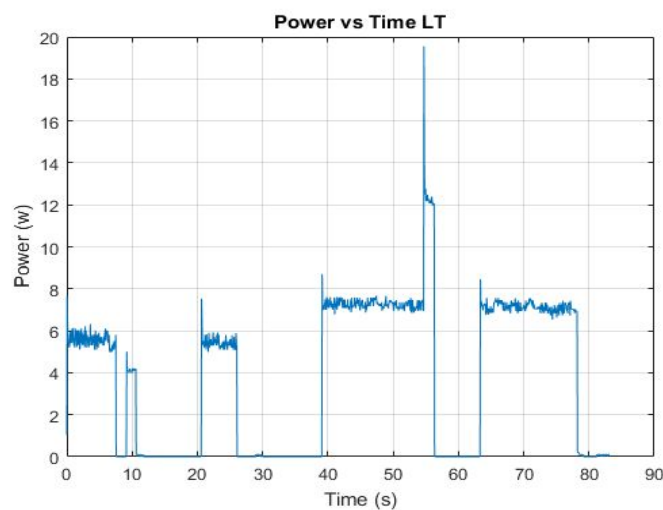


Figure 10: Power Usage

Group design A's run on the track was deemed inferior to Group Design B's run by the group. The top propeller occasionally hit the track, which was addressed by the group by adding an additional piece to the AEV to lower the propellers. Its balance was perfected by the final run and had no problems remaining straight on the track. Group Design B had a smoother run on the track, and was better balanced. Both Designs executed similar code, and made it to the gate. Neither AEV was able to stop nor turn around and return to the starting position. The group had trouble fixing this error, and will focus on this issue extensively. Although Design B's run on the track was better than Design A, the group agreed that the aerodynamics of Design A along with the 3D printed part for it outweighed the negatives. With further development, Design A will be greatly improved.

In PT1, two designs were tested: the first was a vertical design with the propellers on a vertical plane, the second was a horizontal design similar to the reference AEV with the propellers on the sides. The second design shown previously in *Figure 6* was a simplified combination of each member of Team E's initial designs. Each of those initial designs, shown in figures 1-5, were similar in their flat base and propellers on the side. The first design that Team E tested was the combined idea to flip the base piece vertical; therefore, there was no easing into that design as there was with the second design. The first design focused more on aerodynamics and a lack of air resistance compared to the second design which was solely balance and weight based.

The team's AEV ran well in the final test as it completed the MCR and earned full points as can be seen in the Final Testing Sheet in the appendix. The AEV was balanced and acted consistent with how the team was expecting it to act and similar to previous runs. The AEV was on the higher end of the energy mass ratio scores compared with the rest of the class.. The team attributes this to failing to understand how to calculate the AEV's energy until week 11. Had the team figured this problem out earlier, greater strides in energy consumption could have been made.

Arduino Code

```
reverse(4);           reverses the AEV's motors so it will run forward
motorSpeed(25);       sets the AEV's motors to 25 percent
goToRelativePosition(-402); travels 402 marks
reverse(4);           Reverses the motors to have the AEV stop
motorSpeed(40);       Sets motors to 40 percent
goFor(.5);            runs the previous command for half a second
brake(4);             shuts all motors off
goFor(7);             AEV will stop for 7 seconds
reverse(4);           reverses motors to have the AEV travel forward again
motorSpeed(25);       runs motors at 25 percent
goToRelativePosition(-448); travels 448 marks
reverse(4);           reerses motors to have the AEV travel backwards
motorSpeed(40);       sets the motors to 40 percent
goFor(.5);            runs the previous command for half a second
brake(4);             shuts motors off
goFor(5);             runs previous command for 5 seconds
motorSpeed(30);       sets motors to 30 percent
goToRelativePosition(402); travels 402 marks
reverse(4);           reverses the AEV's motors
motorSpeed(40);       Runs the motors at 40 percent
goFor(.5);            Runs the previous command for half a second
brake(4);             Shuts motors off for 4 seconds
```


<code>goFor(7);</code>	stops the AEV for 7 seconds
<code>reverse(4);</code>	Reverses all motors
<code>motorSpeed(30);</code>	sets the motors to 30 percent
<code>goToAbsolutePosition(0);</code>	brings the AEV back to the start
<code>reverse(4);</code>	Reverses the AEV's motors
<code>motorSpeed(40);</code>	sets the motors to 40 percent
<code>goFor(.5);</code>	runs the previous command for half a second
<code>brake(4);</code>	shuts off all motors

Discussion

A source of possible error in this lab could come from miscalculating the distance traveled in marks. This problem could happen if the wrong conversion factors were used or an error was made in calculations. If this happened the AEV would not stop at the proper location thus not being able to trigger the gate to open and the entire attempt would be ruined. Another error that the team encountered was having to reverse the motors in order to travel forward. The AEV was originally traveling backwards so the team implemented a reverse code on the motors and the AEV traveled forward. This allowed the AEV to complete the mission as planned. Solving this error was crucial to completing the MCR and having the AEV travel properly. Another possible source of error could be uploading the code to the Arduino incorrectly. This could happen by misspelling a function or having the wrong comm port selected. If the code is not installed correctly, then the AEV will not perform the tasks properly.

The idea that the 3030 pusher is a more efficient propeller than the the other propeller is at lower percentages of power is consistent with what was learned in lab in the first lab the team concluded that the 3030 pusher propeller was more efficient than the others so this idea compared to theory was correct. The following graphs show that at the lower power settings, the 3030 pusher propeller provides more thrust than the 3020 pusher propeller.

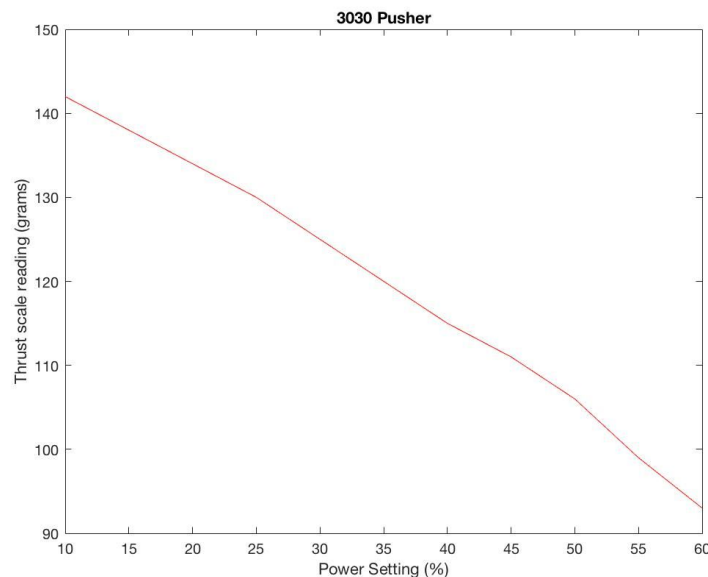


Figure 11 3030 Pusher Graph

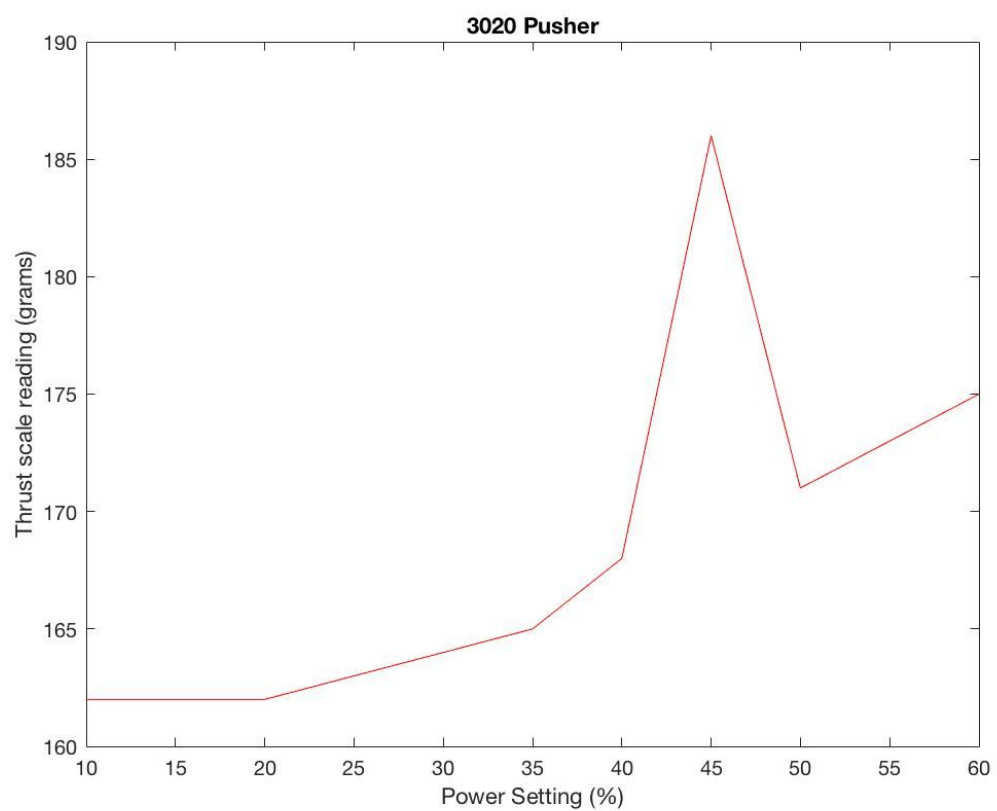


Figure 12: 3020 Pusher Graph

Conclusion & Recommendation

The AEV project consisted of designing and programming an AEV to complete the MCR. The team had to work together to come up with a design for the AEV and also come up with the optimal code necessary to run the AEV and complete the MCR. This lab has taught the team about problem solving, working in a team, design process and coding techniques. These skills will be crucial as the team moves forward in their academic career and job field. These are all conclusions drawn from this lab. Similarly, conclusions can be made about how to efficiently create an AEV. The team learned how important weight, design and power input can be when designing anything for industry. The results of this lab were concluding that the team's fully functioning AEV needed 314 Joules of energy to complete the MCR and it had an energy mass ratio of 1.28. These numbers are a little high compared to the rest of the class but the team was more focussed on completing the MCR completely rather than optimizing energy. Error can be resolved in this project by being careful when assembling the AEV, when uploading code to the AEV's Arduino and carefully doing calculations for the AEV's code. All of these problems could contribute to the AEV not functioning properly and receiving data that is not ideal. The team thought that using the data analysis tool was difficult and recommend that the lab 4a and 4b are split up to allow more time for learning how to analyze the data from the AEV. This problem led the team to have difficulty completing the lab and recording solid data for the lab. The team was ultimately able to choose the final AEV design by comparing each design with screening and scoring matrices and also by observation of the AEVs running on the track. The team has one of the best AEV designs because it was able to complete all steps in the MCR perfectly and earn full points on the final testing as seen in the appendix.

Appendix

Schedule

Task	Nolan Gilts	Kayley McCormick	Jeremy Bresciani	Jake Weiner	Start Date	Due Date	% Completed
Project Portfolio	70%			10%	3/24/2017	4/21/2017	80
Lab 8 PT1	25%	25%	25%	25%	3/2/2017	3/7/2017	100
Lab 9 PT2	25%	25%	25%	25%	3/2/2017	3/22/2017	100
PDR	25%	20%	35%	30%	3/2/2017	3/24/2017	100
Extra Credit Video	5%	5%	5%	5%	3/2/2017	4/21/2017	20
3D Printed Part		20%		80%	3/2/2017	3/21/2017	100
Oral Presentation Draft	10%		80%	10%	3/30/2017	4/5/2017	100
Oral Presentation	20%	10%	50%	20%	4/12/2017	4/19/2017	100
Final Project Report	20%	10%	50%	20%	4/6/2017	4/19/2017	100
Lab 10 PT3	25%	25%	25%	25%	3/22/2017	3/31/2017	100
Lab 11 PT4	25%	25%	25%	25%	3/31/2017	4/7/2017	100

Weight, Cost and BOM:

Material Name	Weight	Cost	Description	Quantity
Arduino	██████	\$100	"Brain" of the AEV	1
Electric Motors	██████	\$9.99	Run the propellers	2
Count Sensor	██████	\$2	Counts the marks as AEV runs	2
Count Sensor Connector	██████	\$2	Connects Sensor to Arduino	2
Propellers	██████	\$.45	Spin to make the AEV accelerate	2
Base	██████	\$2	Body of AEV, holds all the parts together	1
L-Shape Arm	██████	\$3	Holds the wheels and connects them to the body	1

Wheels	██████	\$7.50	Allows AEV to run on the track	2
Battery Supports	██████	\$1.00	Holds the battery in place	2
Angle Brackets	██████	\$.84	Allow pieces to attach perpendicularly	8
Motor Clamps	██████	\$.59	Hold the motors	2
Bulk Screws and Nuts	██████	\$2.88	Used to attach all pieces together	1
Total	348.4 g	\$153.16	████████████████████	██████

Team's Final Testing Sheet



ADVANCED ENERGY VEHICLE

Lab 11: Performance Test 4 – Final Testing

AEV Final Testing Scoresheet

Team/Team Name: E Instructor: Schrock Class Time: 7221

This sheet must be filled out and signed by a member of the Instructional Staff by the end of Lab. The Instructor/TA must watch the AEV complete the operational objectives and will record the results below.

		Run 1			Run 2		
Procedure		Yes	No	PTS Earned	Yes	No	PTS Earned
Team shows proper testing procedure (up to 10 points)		✓		/10			/10
AEV starts and travels to first gate		✓		/4			/4
Gate Routine	Stops before gate	✓		/4			/4
	Waits 7 seconds	✓		/4			/4
	Travels through gate	✓		/4			/4
AEV starts and travels to loading zone and waits for 5 seconds		✓		/4			/4
AEV connects to cargo & travels to gate (crashes into cargo-deduct <= 2)		✓		/4			/4
Gate Routine	Stops before gate	✓		/4			/4
	Waits 7 seconds	✓		/4			/4
	Travels through gate	✓		/4			/4
AEV starts and travels to starting point		✓		/4			/4
Total Points Earned				52/50			
Total Score = Total Pts Earned * Δt					Max Total Score		

Track Layout: inside
(Inside or Outside)

Mass of AEV: 245
(in kilograms)

Total Energy: 314
(Joules)

Total Time Run1: 82
(seconds)

Total Time Run2: _____
(seconds)

Delta Time Run 1:

$$\Delta t1 = 1 + \frac{150 - \text{total time}}{150}$$
 = _____

Delta Time Run 2:

$$\Delta t2 = 1 + \frac{150 - \text{total time}}{150}$$
 = _____

Energy/Mass: 1.28
(Joules per kilogram)

Your final score will be based on the **Energy/Mass ratio** (how efficient is the team's AEV) and the **Total Score** (time and distance requirements).

Instructor / TA Signature: AEV Date: 4/12

Final Design Solidworks Model

