Critical Design Report

Submitted To

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Engineering 1182

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4/19/17

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Abstract

The purpose of the lab was to design a vehicle to aid the rebels in transporting R2D2 across multiple locations. The vehicle would have to be both lightweight and energy efficient in order for the mission to function at an optimal level. The vehicle also has to be able to move on multiple terrains due to there being many different planets that the vehicle will be operated on.

The group took many insights away from the results of their experiments. The group decided that the ep - 3030 pull propeller is the most effective in terms of thrust and efficiency. The 3030 pull had a thrust value of 18.49 grams which was much higher than the other types of propellers. Also, the group decided that the AEV should be very aerodynamic in order to ensure that a minimal amount of energy would be needed to make the vehicle move from one location to another. Multiple lab tests also determined that the AEV used the least amount of energy while it was coasting. When the AEV is coasting, the motors are turned off which leads to a much greater energy efficiency rating. The vehicle's code is strongly focused on using a maximum amount of coasting in order to keep the AEV running efficiently and correctly. The only problem that was encountered while using the coasting method was that at times the AEV would barely miss its target location. To combat this, testing was used to create a code that would insure the most accurate travels for the vehicle. Finally the AEV is very cost efficient. The vehicle uses the bare minimum in terms of parts so it will be able to be purchased and built in a very cost and time efficient manner.

With all the data and results taken into consideration it is highly recommended that the rebels use this group's AEV. The AEV is very cost and energy efficient which will allow for rapid use and production.

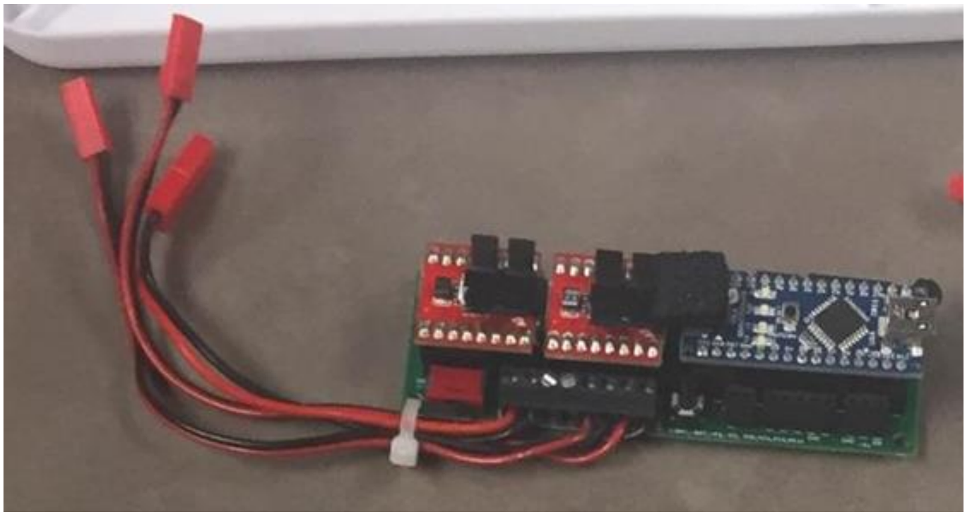
Introduction

This report will discuss the reasons why the team made certain design and code decisions. Data will be provided to further explain how the team got to their decision. The report shows how the team had to work together to overcome challenges throughout the semester. The main purpose of the project was to create a vehicle for the rebels that is both cost and energy efficient. The vehicle also must be able to run on multiple terrains as well due to there being many different surfaces that the AEV will need to traverse.

This report will discuss how each lab was conducted and what information was obtained from the results of the labs. The team reflects on the meaning behind the results in terms of the design process, team dynamic, and why the project is important. Then the team looks back on the results obtained during the project and make recommendations based on the observations for future teams to consider.

Experimental Methodology

Lab 1 was focused on getting the group used to the Arduino and its many different components. During this lab, a sample code was given to the group in order to see how different commands impact how the motors could be used to control the AEV. This lab taught the group the simple motor commands that could be implemented on the Arduino.

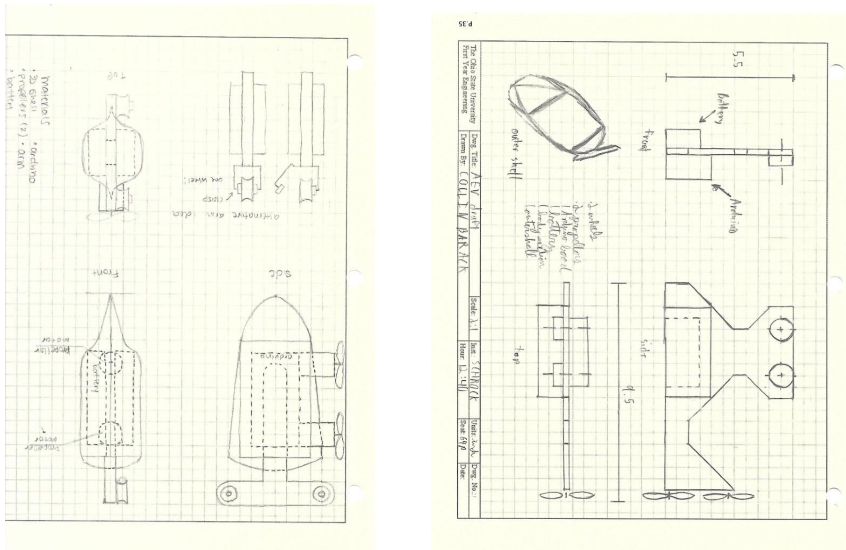


Graphic 1: The Arduino microcontroller .

Lab 2’s primary focus on helping the group understand the different ways in which the vehicle can track its distance and location. Two sensors attached the Arduino to a wheel that was partially covered in reflective tape, allowing the Arduino to read the location of the vehicle and whether it was moving forwards or backwards by the use of a reflectance sensor. Different position based commands could then be implemented that would allow the motor commands from the previous lab to execute until the vehicle made it to a certain relative or absolute position on the track.

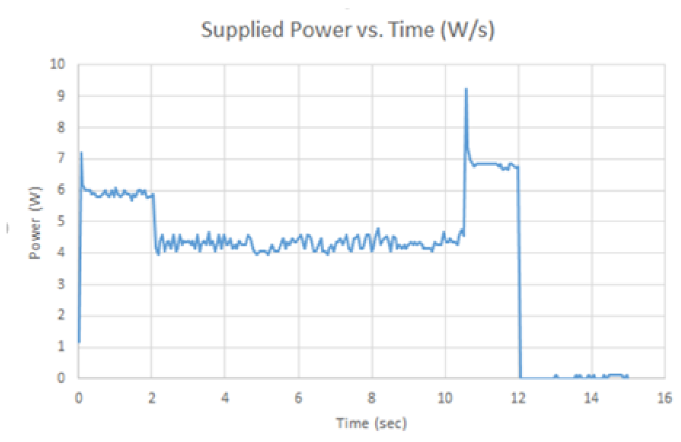
Graphic 2: The reflectance sensor

In Lab 3, the group created concept designs for the AEV. Each member created a design, two of which are shown in graphic 3 which can be seen on the next page. These designs would later be compared and ranked according to the team decided parameters. Then a final design would be chosen to move forward with.



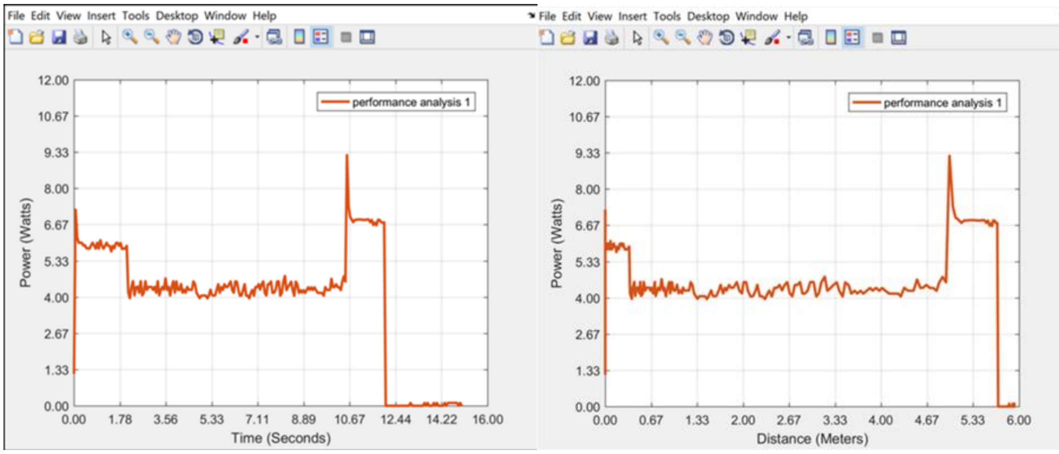
Graphic 3: The Toughy model (left) and the Barack-o-flocka-flame model (right)

In Lab 4, the group built the basic AEV model and intended to test the design with a basic code. The code was uploaded to the AEV and then the vehicle was tested on the track. During the run, the AEV ran to the gate and stopped at the first sensor. This code and design would then be used as a baseline run that other designs and codes could be tested against in the future. Lab 5 educated the team on the process of gathering and interpreting data from the AEV after a successful run. This process would allow the team to empirically compare the energy usage and efficiency of different designs.



Graphic 4: Initial power vs time graph for sample AEV and code

The graph depicts the supplied power verses time extracted during the test AEV run. This standard AEV only ran up to the gate and was mainly used as a benchmark for future testing.



Graphic 5: The standard AEV's power usage over time from a test code run (left), and the standard AEV's power usage over distance (right).

Lab 6 gave the team ways to rate proposed designs in the form of a concept screening matrix. This process involved the group creating different categories that each vehicle could be judged on; such as weight and efficiency. Each category was then given a weighted value and the different AEVs were then scored based on the given weights for each category. The top design was then chosen to move forward with. The remaining labs were all used to determine the most efficient code that would allow the selected AEV to complete the course while meeting the multiple requirements. These figures 1 and 2 can be seen under results.

Results

From the various data that was obtained the group decided that the ep-3030 pull propeller would be used in order to make the AEV run in the most efficient manner possible. The 3030 pull propeller exhibited the highest thrust with a value of 18.49 grams.

	Reference A	Liz-dog	Toughy	Barack-o-flock-flame	god
Stays on the track	0	0	0	0	0
Weight	o	-	+	+	0
Ability to carry trailer	o	+	0	0	0
Cost	o	0	+	+	0
Aesthetic	0	+	+	-	0
Durability	0	0	-	-	++
Total +	0	2	3	2	2
total 0	6	3	2	2	5
total -	0	1	1	2	0
Net	0	1+	2+	0	2+
Continue?	no	revise	revise	no	no

Figure 1: Concept Screening Matrix

The second task was designing a vehicle for the group to move forward with. As seen in Figure 1, the group created a concept screening matrix in order to score all of the different created designs. Many things were taken into account while judging the vehicles such as weight and cost. The Toughy model scored the highest on the scale so it was chosen. As seen in figure 7 (Appendix A), the Toughy model was loosely based off of a sunfish. This design had a long arm which would allow the vertical attachment of all the necessary components such as the battery and the Arduino. This design scored highly because it was lightweight, compact, and very cost efficient.

	weight %	Reference A	score	Liz-dog	score	Toughy	score	Barack-o-flock-flame	score	god	score
Stays on the track	10	3	30	3	30	3	30	3	30	3	30
Weight	30	2	60	2	60	5	150	4	120	2	60
Ability to carry trailer	15	3	45	4	60	2	30	3	45	3	45
Cost	20	2	40	2	40	4	80	4	80	2	40
Aesthetic	5	1	5	4	20	5	25	1	5	2	10
Durability	20	3	60	2	40	2	40	2	40	4	80
Total +	100		240		250		355		320		265

Figure 2: Concept Scoring Matrix

As seen in figure 2, the Toughy model blew away all of the other designs in the concept scoring matrix by obtaining a final value of 355. This was 35 points higher than the next closest design which further influenced the group to move forward with the sunfish design that was presented in the Toughy model. Also, the concept scoring matrix had a strong emphasis on weight, cost, and durability which is why they were given the highest weight values. The mass of the vehicle was given a weighted value of 30 because a lightweight design would allow maximum energy efficiency and coasting. The cost and durability were both given a weighted value of 20 since the vehicle would need to be durable and cheap in order to maximize its use on different terrains and locations.

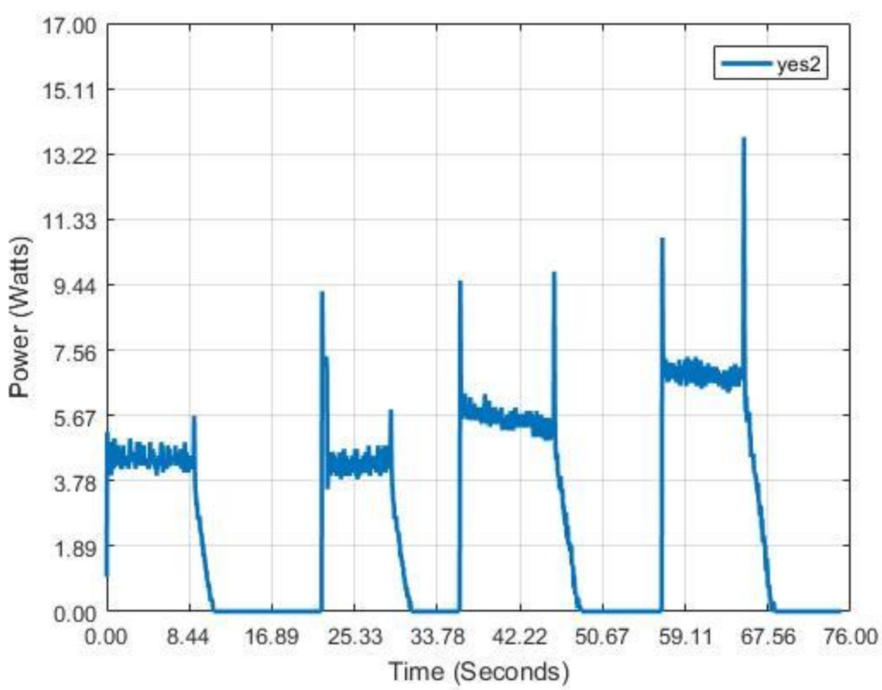


Figure 3: Matlab generated graph of Power vs. Time.

Figure 3 which can be seen on the previous page, represents the four phases of the code that was used to propel the vehicle around the track. Each of the four spikes and drops in the power correspond to a different ¼ of the track. Coasting was used to get the vehicle from one location to another. This is why after a set amount of time that all of the power is cut off to the motors. The coasting method allowed the vehicle to be extremely energy efficient for its weight. An initial power would start the vehicle and after some time the power would be cut. In Figure 3, the first spike and drop in power correlates with the vehicles initial start then stop at the first gate. The second spike corresponds to the AEV starting again and traveling through the gate and picking up the trailer. More power was needed to start the vehicle after it had stopped at the first gate because the vehicle constantly kept getting stuck on part of the track while waiting for the gate to open. The third and fourth spikes represent the ride back after the trailer had been picked up. Both sections required that the vehicle use a higher power than on the ride to the trailer. This was because the trailer weighed 150g which nearly doubled the total weight of the system because the groups vehicle weighed 214g.

ENGR 1182 - AEV Final Test Results

Section 32466 (12:45)

Enter scores in blue fields

% increase of 16' track: 19%

Team	Inside / Outside	AEV Mass (g)	Total Energy (J)	Run Time (s)	Delta t	Energy / Mass (J/g)	Points Earned (out of 50)	Normalized Energy Used	Normalized Ratio	Normalized Score
P	Outside	214.0	206.20	71.0	1.5	0.964	38	206.2	0.96	39.44

Figure 4: Data from the final AEV test run

As seen in figure 4, the groups vehicle used a total of 206.20 joules of energy in order to complete the entire track. This figure also shows that the vehicle had a mass to energy ratio of 0.964 J/g. This meant that the vehicle was very energy efficient because it was using less than 1 joule of energy per gram of weight. Overall, the groups vehicle was extremely energy efficient and used a very minimal amount of energy in order to complete the required task.

Discussion

One trend that seemed to occur throughout the experiment was that there was a direct correlation between a lightweight AEV, and using a low amount of power. The starter AEV that was given to the group was very heavy and required a lot more power to move along the track. However, the groups chosen AEV was much lighter which allowed for less power to be used to propel the vehicle along the track. Another trend that seemed to occur a lot during the lab was that the coasting method was efficient but hard to keep consistent. The vehicle would sometimes stop at the sensor in front of the gate but during other runs, it would over or undershoot the desired location by a couple of inches. This directly came into play during the groups final test run. As seen in figure 3 the groups final run did not necessarily go as planned. The vehicle was working perfectly fine during testing, but during the final run it coasted too far both times that it was supposed to stop at the gate. This led to one of the team members having to stop the vehicle with their hand which negatively affected the overall performance of the vehicle.

Even though the group was able to make an energy efficient and lightweight AEV there were still many errors that were encountered during the process. The first error that was encountered by the group was that one of the motors in the initial kit was broken. The motor would not run regardless of which port it was connected to or which code was being used. This error was resolved by getting a new motor that worked properly. The next error the team faced was that the given Arduino was faulty. The code would not upload to the AEV, and after a long period of trial and error, a new Arduino was obtained and the drivers on the computer were updated. The biggest problem that group faced was an error that would occur while using the reflectance sensor on the final vehicle design. The groups final design only used one sensor which meant that the vehicle could not tell what direction it was going in. This meant that position commands that the group used to control the location of the AEV had to be counted as cumulative distance whether going forward or backward. The problem that arose was that the vehicle would occasionally run and never stop, whereas other times it would execute the code and correctly run on the track. After two weeks of troubleshooting, it was determined that this was due to the relationship between using only one sensor and how it can read location based on what part of the wheel it was facing, and will only run correctly if the sensor starts facing the reflectance tape on the wheel. This occurs due to the fact that while using binary code, reading values from 0 to 1 is not considered the same as reading values from 1 to 0.

Recommendations and Conclusion

Even though the group's vehicle had a few errors, the team still recommends that the rebels go through with using the project because they can easily be fixed. The group first recommends that they should use two sensors instead of one. The AEV is less reliable with only one sensor, and must start in a certain position to work properly. Also, the group recommends that the rebels use a more refined method in order to stop the vehicle. Coasting should still be used to propel the vehicle but something like a servo motor would make stopping the vehicle much easier and would barely raise the energy usage of the vehicle. This addition could greatly improve the reliability of the vehicle because the only problem that the vehicle has would be solved. The rest of the vehicle should remain the same because as seen in the results, the current design is very aerodynamic and efficient. The energy to weight ratio of 0.964 J/g is more than low enough to justify that the vehicle is very efficient when utilized correctly.

During the time of the project, the team learned how to code using the Arduino software and how to use Solidworks and apply that knowledge to build a physical AEV. The team also became adept at problem solving and working forward without giving up. These compare to the lab objectives by solving the issues posed in each lab within an allotted amount of time. The results also reflect this by showing in concrete evidence that the team is progressing forward.

Appendix A

Task	Teammates	Start Date	Due Date	Time Needed	Percentage Completed
Preliminary Design Report	All	3/23/2017	3/24/2017	2 Hours	100%
Correcting AEV code	Madison Hudak (Coder)	3/24/2017	4/17/2017	55 minutes	100%
Fix sensor	Collin Barack (Builder)	3/24/2017	4/17/2017	55 minutes	100%
CDR	All	4/1/2017	4/19/2017	18 days	100%
Project Portfolio	All	4/1/2017	4/21/2017	20 days	100%

Appendix B

Figure 5: Sunfish AEV design

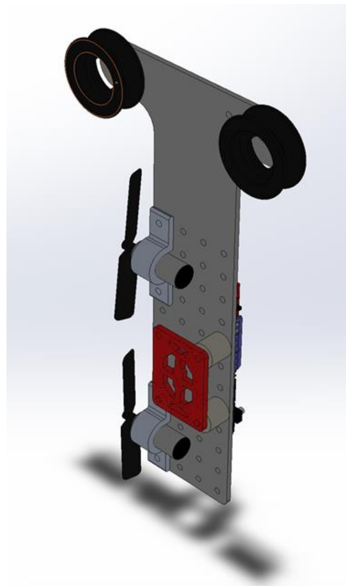
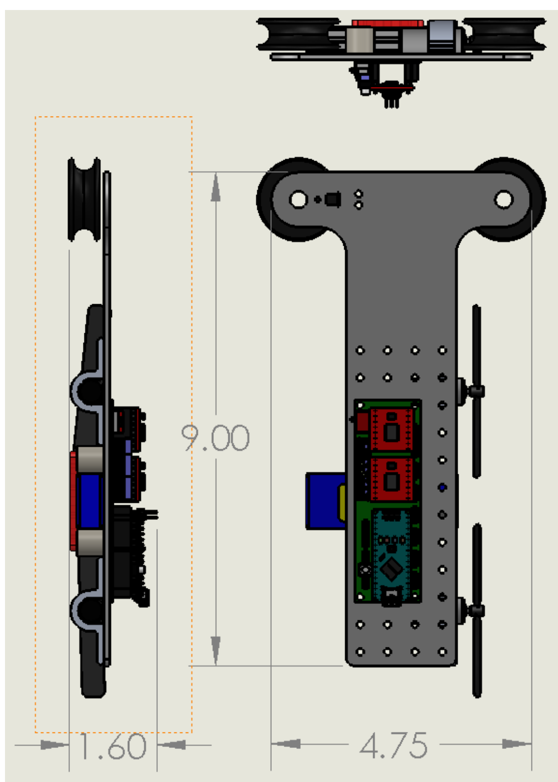


Figure 6: Sunfish AEV orthographic drawing



Approximate weight: 0.25 lbs.

Cost: $153

Materials:

ITEM NO.	PART NUMBER	QTY.
1	proto Support Arm 2 2 Sensor Holes	1
2	AEV Arduino Assembly	1
3	Battery Pack	1
4	Prop 3inch	2
5	AEV Motor	2
6	Motor Mount Clip Aluminum	2
7	Battery Spacer	2
8	Battery Pack Clamp Plate Narrow	1
9	Housing	2

Figure 7: Sunfish Origins Orthographic drawing

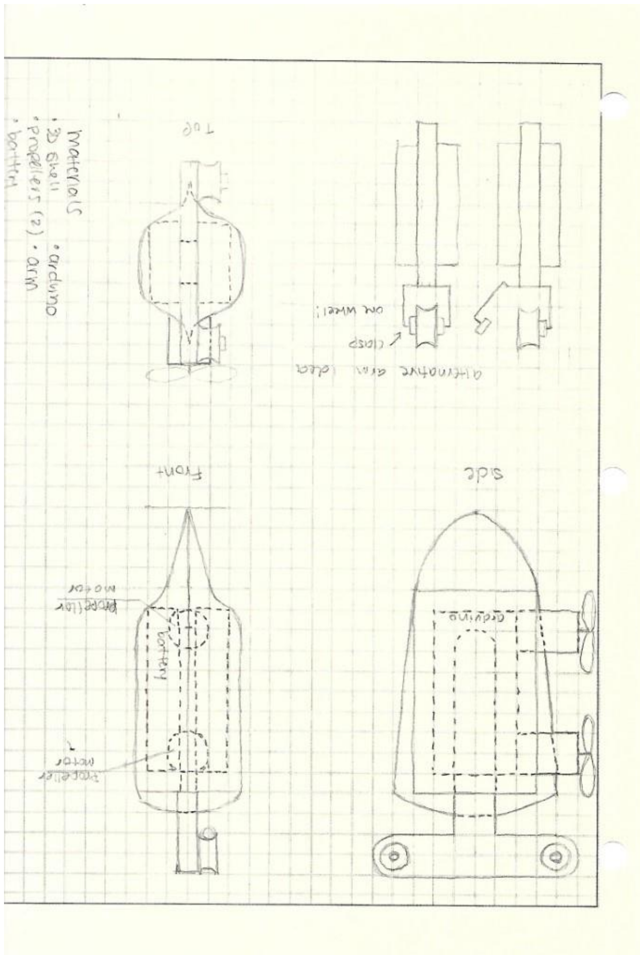
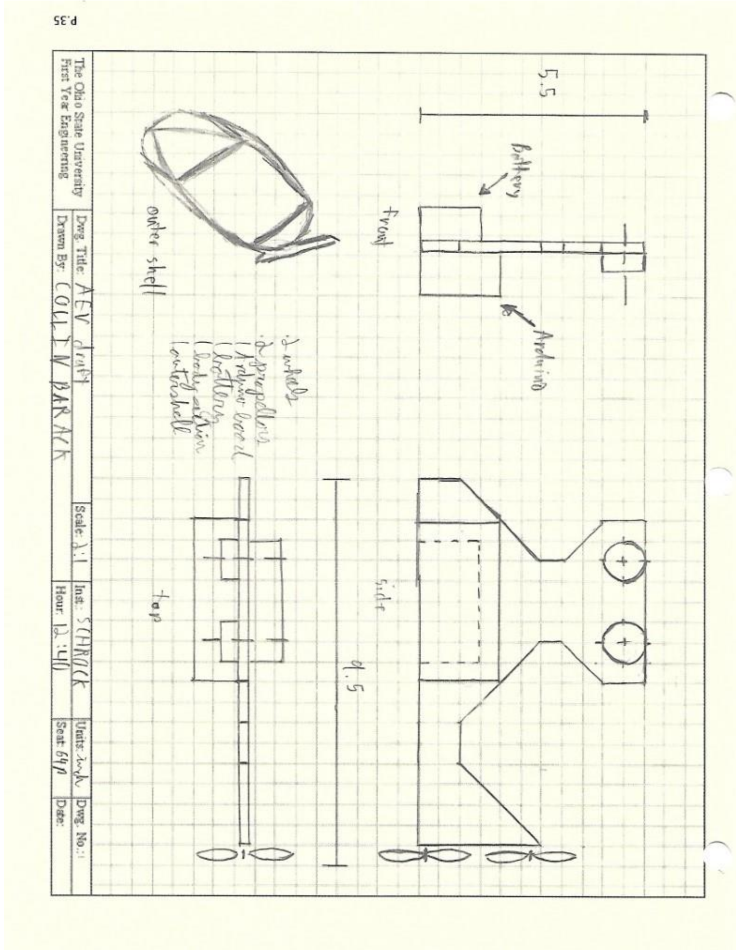


Figure 8: Barack-o-flock-o-flame orthographic drawing



P.35
5.5
battery
front
Arduino
outer shell
side
top
9.5
The Ohio State University
First Year Engineering
Dwg Title: AEV draft
Drawn By: COLLEEN BARACK
Scale: 2:1
Inst: SCHRACK
Hour: 12:40
Units: inch
Dwg No.:
Date:

Appendix C

```
// Phase 1
reverse(4);
motorSpeed(4,20);
goToAbsolutePosition(-169);
reverse(4);
celerate(4,20,0,2);
motorSpeed(4,0);
goFor(11);
reverse(4);

// Phase 2
motorSpeed(4,30);
goFor(.5);
motorSpeed(4,20);
goToAbsolutePosition(-424);
reverse(4);
celerate(4,20,0,2);
motorSpeed(4,0);
goFor(5);

// Phase 3
motorSpeed(4,45);
goToAbsolutePosition(-705);
reverse(4);
celerate(4,40,0,6);
motorSpeed(4,0);
goFor(5);
```

```
reverse(4);

// Phase 4
motorSpeed(4,50);
goToAbsolutePosition(-953);
reverse(4);
celerate(4,45,0,6);
motorSpeed(4,0);
goFor(1);
```