THE OHIO STATE UNIVERSITY

Advanced Energy Vehicle Project

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Mission

In the Fundamentals of Engineering 1182.01 course, the team was challenged to design and create an Advanced Energy Vehicle (AEV) for a given scenario that would complete the task while running on minimal energy.

- The given scenario had a *Star Wars* theme
  - The goal was to construct an AEV that would run on a monorail to transport R2-D2 units and help the Galactic Empire rebuild their army following the destruction of the Death Star.
  - The AEV has to be very efficient because there is limited power due to the 'base' being on a remote planet.
- The team had to write a program and create an efficient, lightweight, and sleek design that would minimize the amount of energy needed to power the AEV.

Requirements

Below is a list of the tasks the AEV had to complete for the final test:

- The AEV had to start with the front wheel behind mark one on the track
- The AEV must travel to the gate and stop after only passing the first sensor
  - After stopping, the AEV must wait seven seconds in order for the gate arm to open so the vehicle can pass through
- Next, the vehicle must traverse down the track to the cargo area and connect to the R2-D2 carrier
  - The AEV must wait for 5 seconds to make sure the R2-D2 carrier is securely attached by the magnets
- During the final portion the AEV must travel backwards on the same path, pass through the same sensor operated gate as before and end where it started
  - Both wheels of the AEV be behind Mark 2

Figure 5: AEV Track

Final Design

Final Specs:

- Mass: 260g
- Total Cost: $159.30
- Energy: 958J/kg

Bill of Materials

- List of all materials used, the amount of each, and cost of each part

AEV Design Isometric View

- Isometric view of the final AEV design, used to show which parts were used and to have a formal drawing

AEV Design Orthogonal View

- Shows all views of the AEV and dimensions of the actual AEV

ITEM NO.	PART NUMBER	QTY.
1	Medium Rectangle	1
2	Support Arm 1 2 Sensor Holes V2	1
3	pan slot head_ai	7
4	pan slot head_ai	8
5	pan slot head_ai	4
6	machine screw nut hex_ai	16
7	machine screw nut hex_ai	2
8	90-deg bracket	4
9	AEV Arduino Assembly	1
10	hex bolt_ai	2
11	Rotation Sensor Board	2
12	Modified Tee	1
13	Motor Mount Clip Aluminum	2
14	AEV Motor	2
15	Prop 3inch	2
16	Battery Pack	1
17	Battery Pack Clamp Plate Narrow	1
18	Pulley Assembly	1
19	Pulley Assembly w-reflective tape	1

Table 1:Bill of Materials

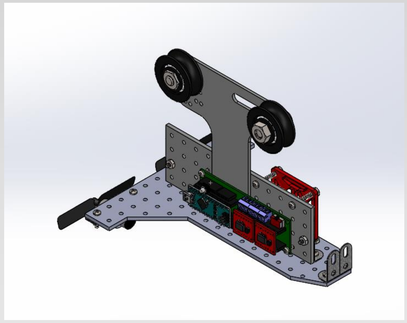

Figure 1: AEV Design Isometric View

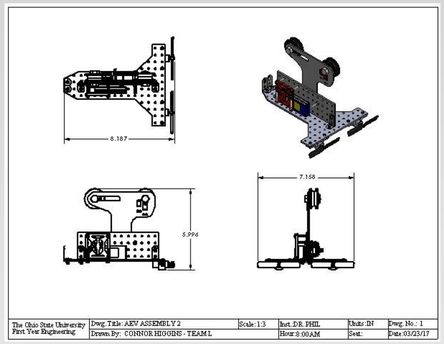

Figure 2: AEV Design Orthogonal View

Design Process

Several factors were tested throughout the project timeline, each refining the AEV design and code.

1. **Propulsion Efficiency**
   - Wind tunnel testing was utilized to measure the thrust produced at various wind speeds. From this, efficiency was measured by finding the maximum of the Propulsion Efficiency vs. Advance Ratio Graph.
   - The most efficient motor power level was 35%
2. **Brainstorming and Concept Sketches**
   - The group brainstormed potential creative designs for the AEV vehicle. Each team member created their own concept sketch to accomplish the mission.
3. **AEV Data Analysis**
   - Data recorded by the arduino while the AEV ran on the straight track was recorded. From this, the energy consumption for each phase of the code and frictional forces could be calculated.
4. **Concept Screening and Scoring**
   - The concept designs created were compared to the reference design and to each other to determine the better designs to progress and continue to develop in future labs.
   - The team decided that one design that was superior to the others to continue.
5. **Vehicle Design**
   - The vehicle design was tweaked in order to reduce energy efficiency, improve the location of the center of mass, and reduce weight.
   - The team relocated the battery and its holder from the bottom of the AEV to the location shown in Figure 1
6. **Code Design**
   - The team created a code the accomplish the full mission meeting all of the requirements. This involved testing two different command methods on tracks in two different rooms which differed in condition.
   - The team decided to use the wheel count sensors due to their consistency over other time based commands.

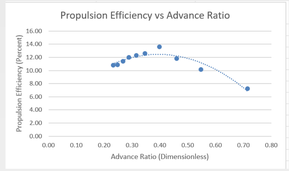

Figure 6: Propulsion Efficiency vs. Advance Ratio

Criteria	Reference Score	Design 1 Score	Design 2 Score	Design 3 Score	Design 4 Score
Balance	0	-	-	+	0
Weight	0	-	-	+	+
Cost	0	0	0	+	+
Aerodynamics	0	+	0	-	+
Durability	0	+	+	+	+
Flexibility	0	+	0	0	-
Style	0	+	+	0	+
Total +	0	4	2	4	4
Total 0	7	1	3	2	1
Total -	0	2	2	1	2
Net Score	0	2	0	3	2
Continue?		Yes	No	Yes	Combine

Table 2: Concept Screening Matrix

Criteria	Weight	Reference Score	Reference Weighted Score	Design 1 Score	Design 1 Weighted Score	Design 2 Score	Design 2 Weighted Score	Design 3 Score	Design 3 Weighted Score	Design 4 Score	Design 4 Weighted Score
Balance	0.2	3	0.6	3	0.6	1	0.2	4	0.8	4	0.8
weight	0.2	3	0.6	3	0.6	1	0.2	4	0.8	4	0.8
Cost	0.1	2	0.2	3	0.3	3	0.3	4	0.4	3	0.3
Aerodynamics	0.15	3	0.45	4	0.6	2	0.3	3	0.45	3	0.45
Durability	0.15	2	0.3	3	0.45	4	0.6	3	0.45	3	0.45
Flexibility	0.15	3	0.45	3	0.45	2	0.3	4	0.6	2	0.3
Style	0.05	3	0.15	4	0.20	3	0.15	3	0.15	4	0.20
Total Score			2.75		3.65		2.35		3.85		3.35
Continue			No		No		No		Crossbip		No

Table 3: Concept Scoring Matrix

Acknowledgements: Special thank you to professor and mentor Dr. Phillip Schlosser, GTA Clayton Greenbaum, and UTA's Hao Chen, Karen Morawski, and James Roche for all their help and support during this project

Energy Efficiency

Energy efficiency was an important component in the AEV design process

- The AEV was designed to be lightweight yet sturdy to minimize energy consumption
- Face propellers were used because they were found to be most efficient with the R2-D2 carrier
- Code that used coasting rather than motor power was implemented
- The *goToAbsolutePosition* command was used so the AEV could coast for longer periods of time and move shorter distances

Below are graphs of power vs. time and power vs. distance for the final code

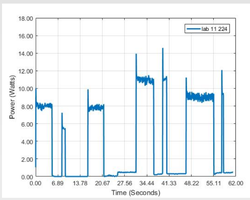

Figure 3: AEV Power vs. Time

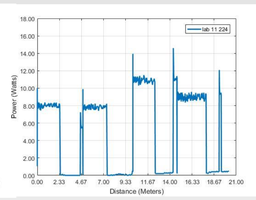

Figure 4: AEV Power vs. Distance

Takeaways

Throughout the testing process, the team learned:

- The key factors that affected energy efficiency were weight and the usage of coasting over increased motor power
- Certain commands that allowed the AEV to perform the desired task as effectively and consistantly as possible.
- Marks are more accurate and easier way to determine the distance the AEV should travel as opposed to time