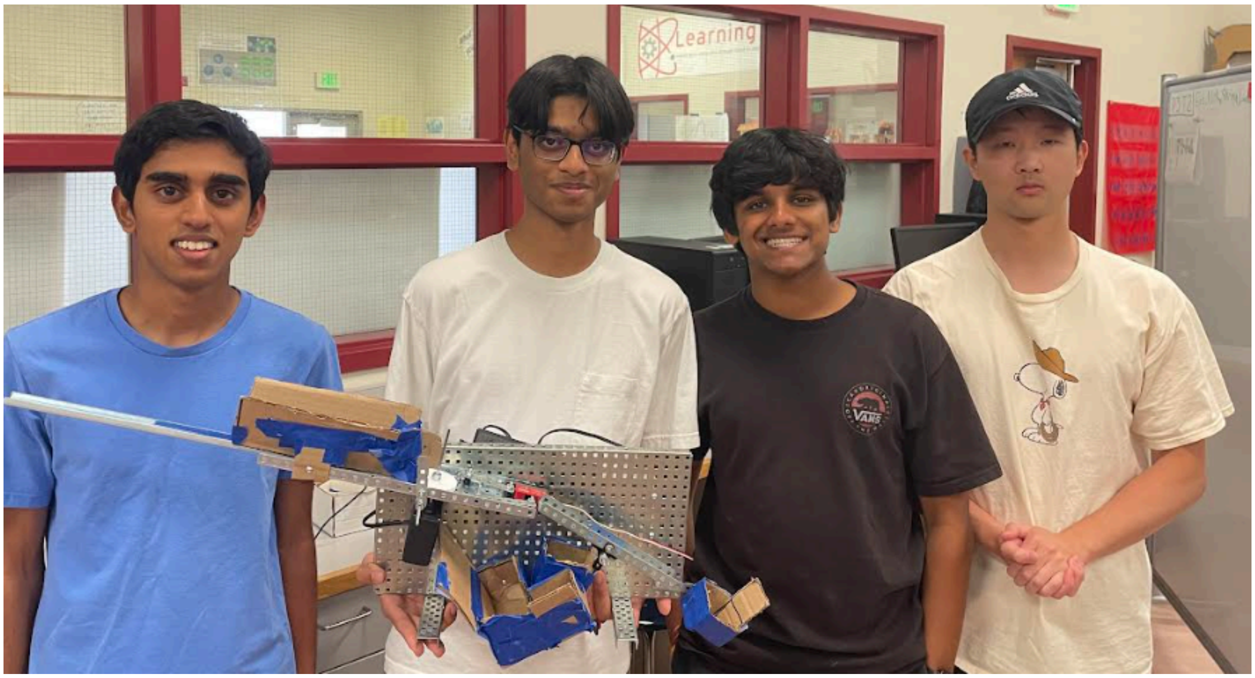
Material Sorting Project



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Principles of Engineering

Amador Valley High School

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Design Brief

Client	National Recreation and Park Association (NRPA)
Target Consumer	Society
Designer(s)	Akhil Bejjanki, Ryan Vir, Janav Rakesh, Luke Chen
Problem Statement	The National Recreation Park Association (NRPA). needs a new sorting facility that will separate recycling material from the dumpsters.
Design statement	Design and model a device that efficiently separates recyclable materials into different bins/groups.
Criteria	1. Sorting process must be fully automated using at least one sensor. 2. Separate 15 marbles into three different groups/bins 3. Must have one functional part custom-made
Constraints	1. Only utilizes one baseplate 2. 2 minute max for completion of sorting process 3. No float/water separation strategies

Team Norms + Gantt Chart

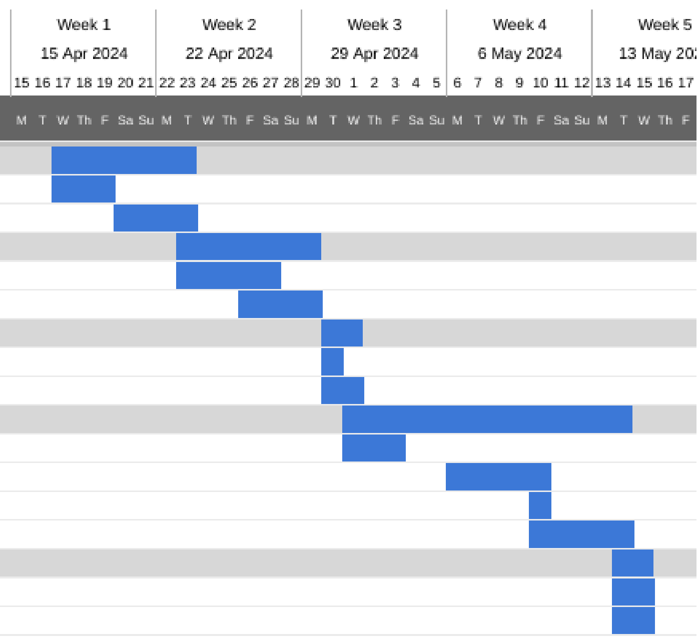
Team Norms:

1. **Be respectful and actively listen to others' ideas**
2. **Stay on task and be productive in class**
3. **Communicate absences**
4. **Get approved for changes and give feedback**
5. **Finish your responsibilities**

Gantt Chart

Project Start Date: 4/17/2024 (Wednesday) Week: 1

WBS	Task	Lead	Start	End	Days	Work Days
1	**Define Problem**		Wed 4/17/24	Tue 4/23/24	7	5
1.1	Identify all parts of problem		Wed 4/17/24	Fri 4/19/24	4	3
1.2	Research materials/ideas		Sat 4/20/24	Tue 4/23/24	4	2
2	**Generate Concepts**		Tue 4/23/24	Mon 4/29/24	7	5
2.1	Brainstorming initial sketches		Tue 4/23/24	Sat 4/27/24	1	4
2.2	Generate Pseudocode		Fri 4/26/24	Mon 4/29/24	1	2
3	**Develop Solution**		Tue 4/30/24	Wed 5/01/24	2	2
3.1	Decision Matrix/Group Agreement		Tue 4/30/24	Tue 4/30/24	1	1
3.2	Create Final Sketch/Approval		Tue 4/30/24	Wed 5/01/24	1	2
4	**Construct and Test**		Wed 5/01/24	Tue 5/14/24	14	10
4.1	Build our input/store marbles		Wed 5/01/24	Fri 5/03/24	1	3
4.2	Sorting the marbles with sensor		Mon 5/06/24	Fri 5/10/24	1	5
4.3	Build the final sorting place		Fri 5/10/24	Fri 5/10/24	1	1
4.4	Implement the code & test		Fri 5/10/24	Tue 5/14/24	1	3
5	**Evaluate Solution**		Tue 5/14/24	Wed 5/15/24	2	2
5.1	Prepare for presentation		Tue 5/14/24	Wed 5/15/24	1	2
5.2	Document all findings/report		Tue 5/14/24	Wed 5/15/24	1	2



While working on our design, we fell behind when it came to constructing our input as we underestimated the difficulty of the task. Marbles were easily getting jammed and we had to modify our input multiple times. By spending more time on the project after hours, we were able to get back on track and finish our design.

Brainstorming + Initial Research

Marble Type	Steel	Aluminum	Wood	Opaque Plastic	Clear Plastic
Special/Unique Qualities	- magnetic - silver - partly reflective	- silver - lighter weight	- light brown - light weight	- white - light doesn't pass through well	- see through color - highly reflective

Material Research Summary: Each material differs from the others in a practical way allowing our team to sort it using specific sensors, magnets, or a weight mechanism.

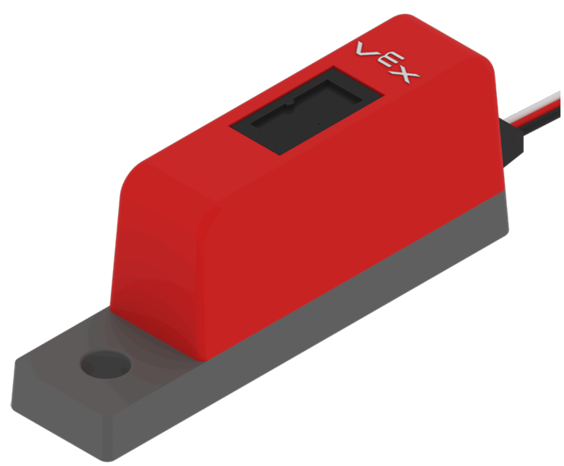
Specific methods used in industries:

1. Magnetic Seperation → Magnets can separate iron, steel, and other ferromagnetic metals from other basic metals.
2. Density Seperators → Screens materials based on density, size, or shape (shape or size isn't applicable to our goals as all marbles are the same shape/size.

Vex Sensor Research → Line Tracker Sensor

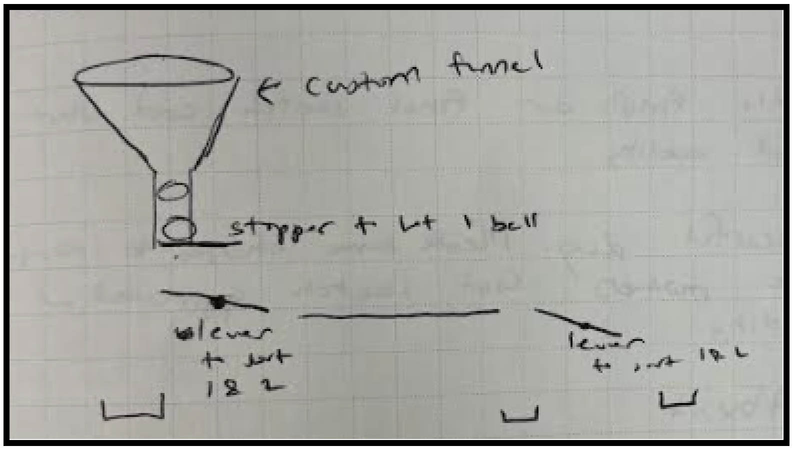
The Line Tracker consists of an infrared light sensor which functions by illuminating a surface and picking up infrared radiation. Based on the intensity, the line tracker is able to detect reflectivity.

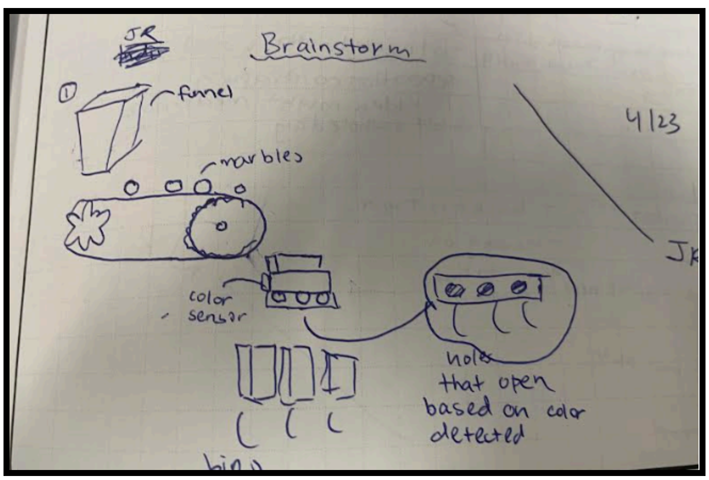
The sensor would easily able to differentiate between clear plastic and other marbles because clear plastic has high reflectivity.

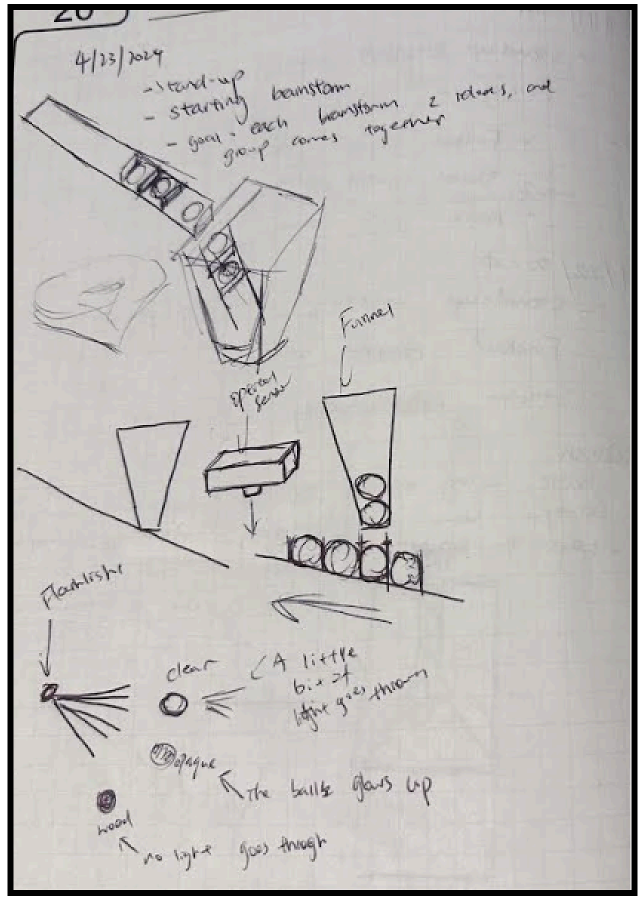


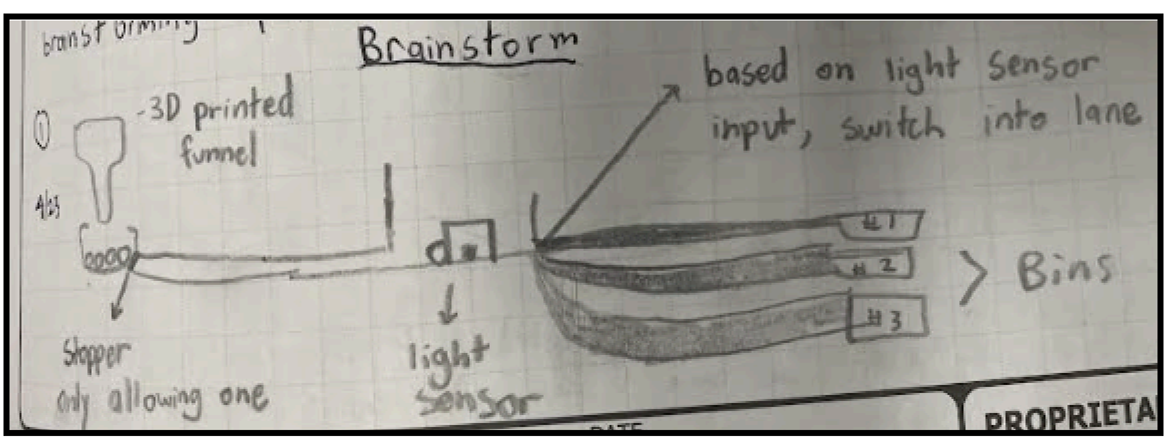
Brainstorming Sketches

Apart from the initial research, here are ideas that were sketched from each of our group members. These were just initial ideas that were not chosen, but displays our different thinking.



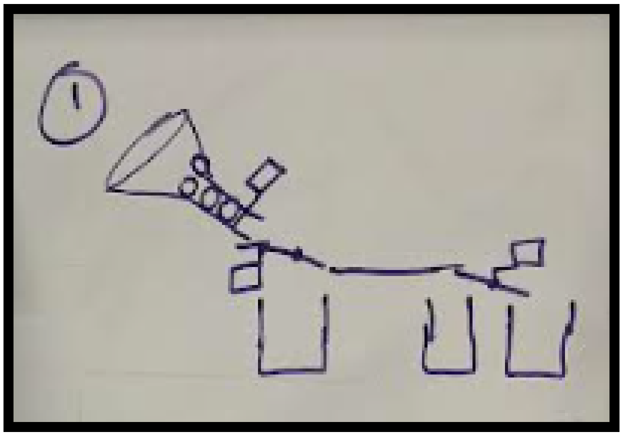


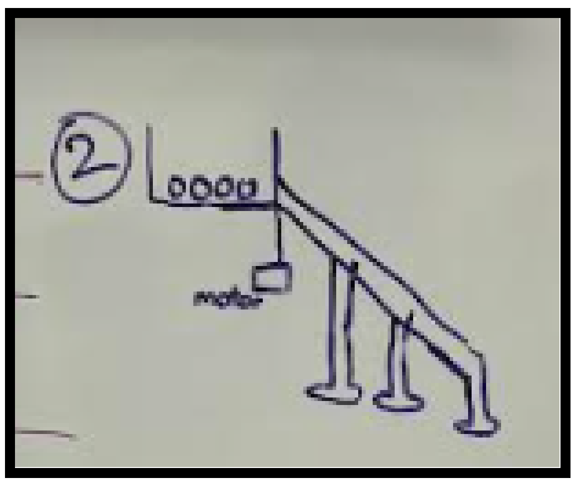


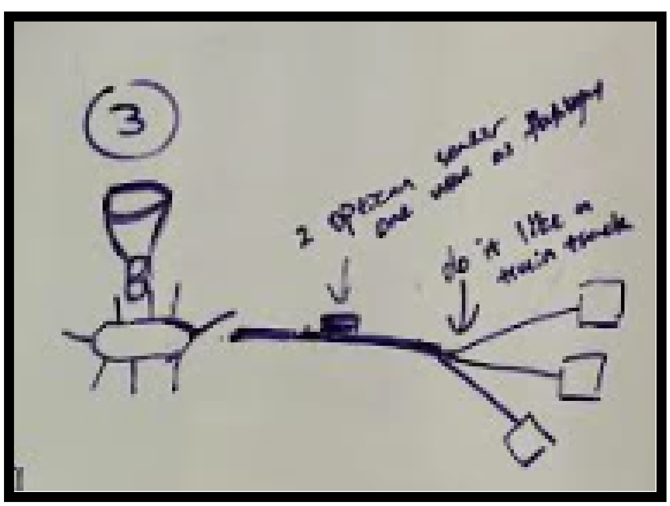


Generating Concepts: Initial Sketches

Note: Numbers next to each sketch represents their name used on the decision matrices







Decision Matrices & Justification

Input

	Speed	Accuracy	Complexity	Code Simplicity	Total Score
#1	4	4	2	3	13
#2	3	4	2	3	12
#3	2	2	1	4	9

We judged all input systems on speed, accuracy, complexity, and code simplicity. For the input design the 2 clear favorites were design 1 and 2. Both designs were quite evenly matched up among all criteria. Both designs required stoppers indicating some code difficulty and general complexity; and with its complexity both designs proved to be quite accurate. It came down to the speed of both inputs: design 1's funnel shape enabled it to win the speed category compared to design 2's box shape which was likely clutter prone.

Sorting Mechanism

	Efficacy (x2)	Speed	Complexity	Total Score
#1	4	2	3	13
#2	1	3	2	7
#3	3	3	4	13

Note: Efficacy was worth twice the score of the other categories because accuracy is the most important component in sorting.

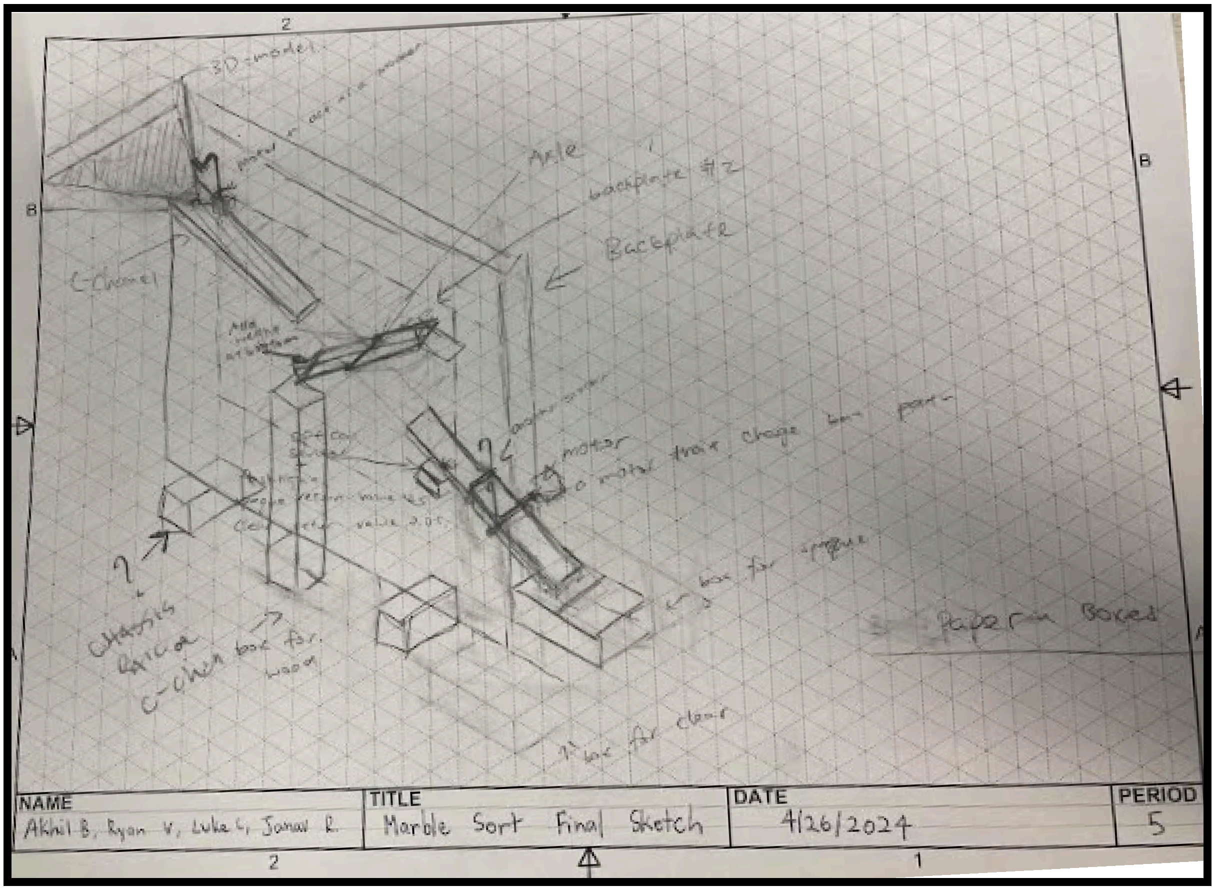
For the sorting mechanism we judged by efficacy (2x), speed, and complexity. We used fewer categories for this matrix as these are what we believed to be the most important qualities of the designs. Design 1 was the most efficient due to its use of motorized sorting compared to designs 2 which relied on weight which was a big variable and design 3 which was quite complex which would likely affect its efficacy. Designs 2 and 3 earned the highest scores for speed as the sorting was kept to one “component” whereas design 1 relied on 2 contraptions to differentiate between the 3 types of marbles. Finally for complexity Design 3 earned the highest score followed by Design 1 and then Design 2. Design 1 had only one motorized component meaning it was less complex and easier to build. Similarly Design 2 relied on only several motorized components with simple motorized functions. However Design 3 required multiple motor functions in order to change the complete direction of rails making it the most complex. After tallying up all the points Design 1 and Design 3 came to a tie. In the end we decided meshing both ideas to come up with our final sorting mechanism.

Output

	Accuracy	Complexity	Space	Total Score
#1	3	5	3	11
#2	4	4	1	9
#3	5	3	3	11

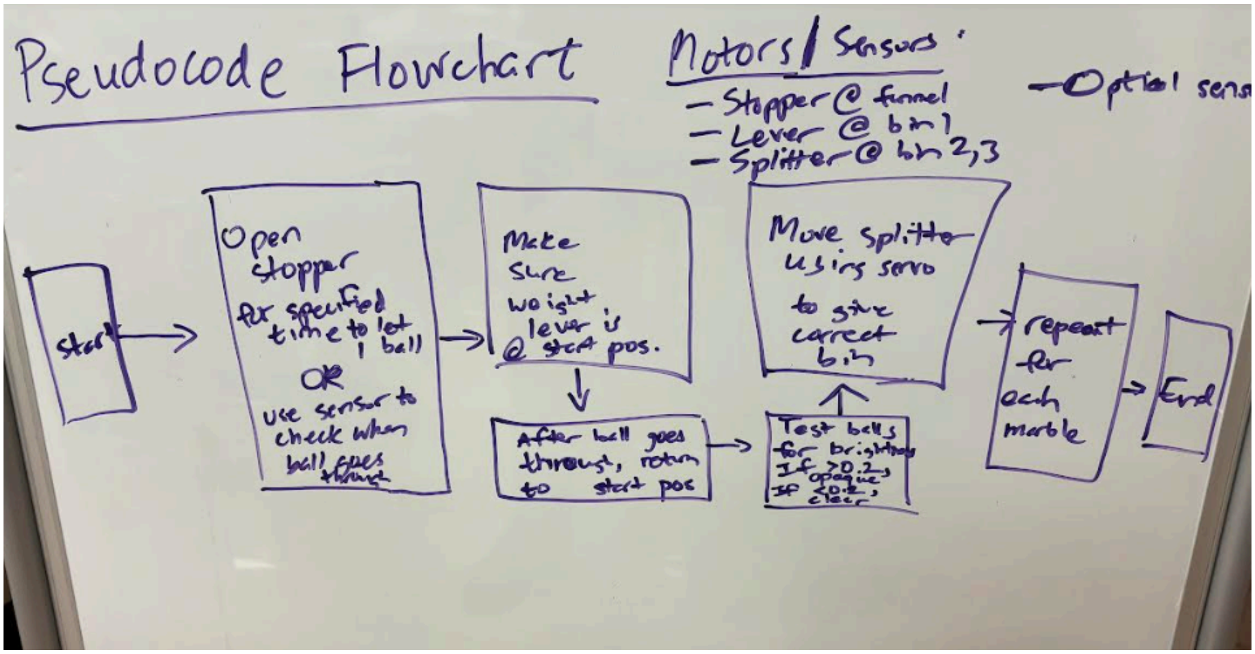
For the output we judged each design on accuracy, complexity, and space. Design 3 scored the highest on accuracy closely followed by Design 2 and Design 1. Design 3’s advanced sorting system functions by switching tracks directly to the bins, which in theory would lead to a 100% accuracy for the output. Design 2 and 1 both have pretty accurate sorting systems with a simple fall into the bins, but not as accurate as Design 3. For complexity Design 1 scored the highest followed by Design 2 and then Design 3. Design 1 just requires basic bins for the marbles to fall in earning it the highest score for complexity. Designs 2 and 3 require a bit of guidance towards the bins earning slightly lower scores on complexity. Finally for space Designs 1 and 3 scored the highest followed by Design 2. All Designs don’t have much space, but Designs 1 and 3 have much more space compared to Design 2’s narrow tube into the small circular bins. After totaling up the scores we had another tie between Design 1 and 3, so we decided to use a combination of both Designs; taking the best out of both.

<u>Final Sketch</u>



The final sketch was chosen through the scores based on the decision matrices. Since there were ties for a couple of the scores, we decided to combine the components in our final sketch. We decided to move on with both the weight system and a sensor-based system,

Pseudocode + Final Program




```
turn = False
def returnInput():
    global turn
    turn = True
    wait(1, SECONDS)
    brain.screen.clear_screen()
    brain.screen.print(trackerA.reflectivity(PERCENT) * 6)
    brain.screen.next_row()
    if (trackerA.reflectivity(PERCENT)) <= 7:
        brain.screen.print("Clear")
        motor_1.spin_to_position(7, DEGREES)
    elif (trackerA.reflectivity(PERCENT) * 6) >= 250:
        brain.screen.print("Wood")
        motor_1.spin_to_position(-25, DEGREES)
    else:
        brain.screen.print("Opque")
        motor_1.spin_to_position(35, DEGREES)
    turn = False
    wait(0.7, SECONDS)
    motor_1.spin_to_position(0, DEGREES)

def initialize():
    motor_5.set_position(0, DEGREES)
    motor_5.spin_to_position(0, DEGREES)
    motor_5.set_velocity(50,PERCENT)
    wait(0.5, SECONDS)
    while True:
        if bumperH.pressing():
            break
        if turn == True:
            continue
        motor_5.spin_to_position(180, DEGREES)
        motor_5.spin_to_position(0, DEGREES)
        returnInput()
        # wait(2, SECONDS)
```

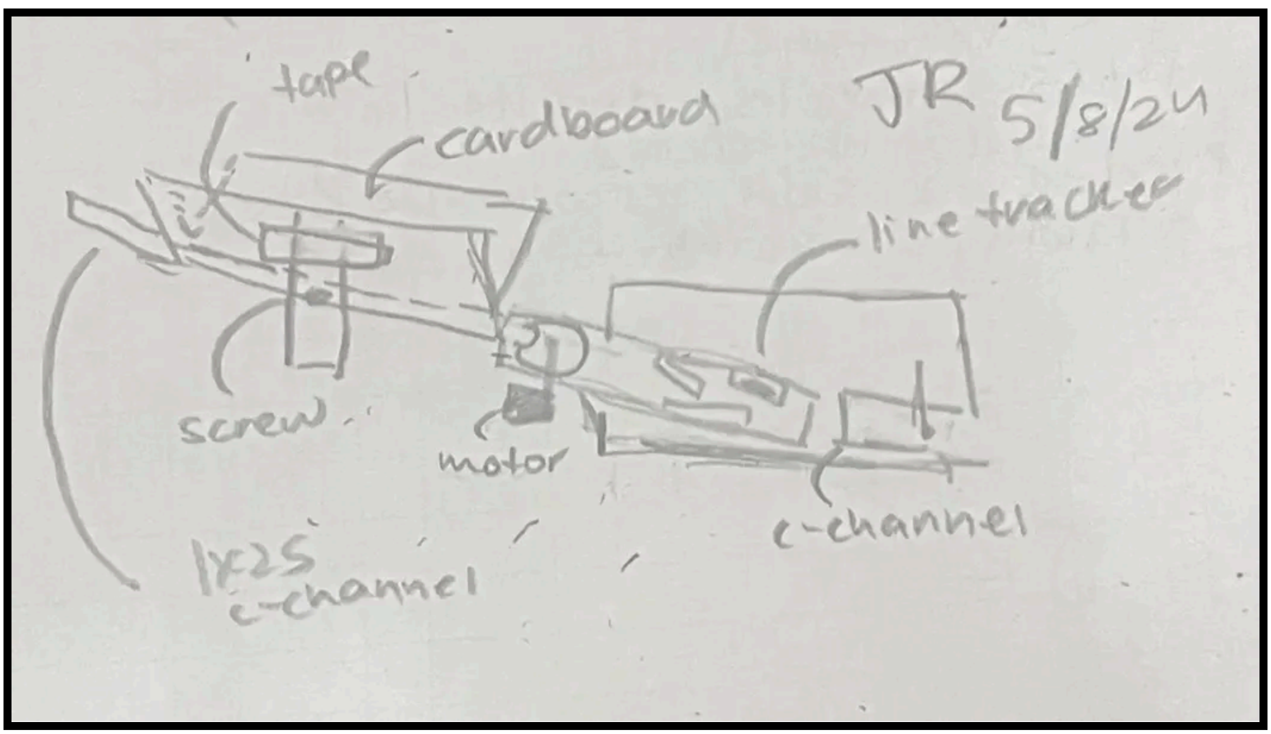
```
def when_started1():
    motor_1.set_position(0, DEGREES)
    motor_1.spin_to_position(0, DEGREES)
    motor_1.set_velocity(100, PERCENT)
    # while True:
        # motor_1.spin_to_position(5, DEGREES) #downwards
        # wait(3, SECONDS)
        # motor_1.spin_to_position(-5, DEGREES) #upwards
        # wait(3, SECONDS)
        # motor_1.spin_to_position(0, DEGREES) #blocking marble
        # wait(3, SECONDS)

    bumperH.pressed(initialize)

when_started1()
```

Design Modification

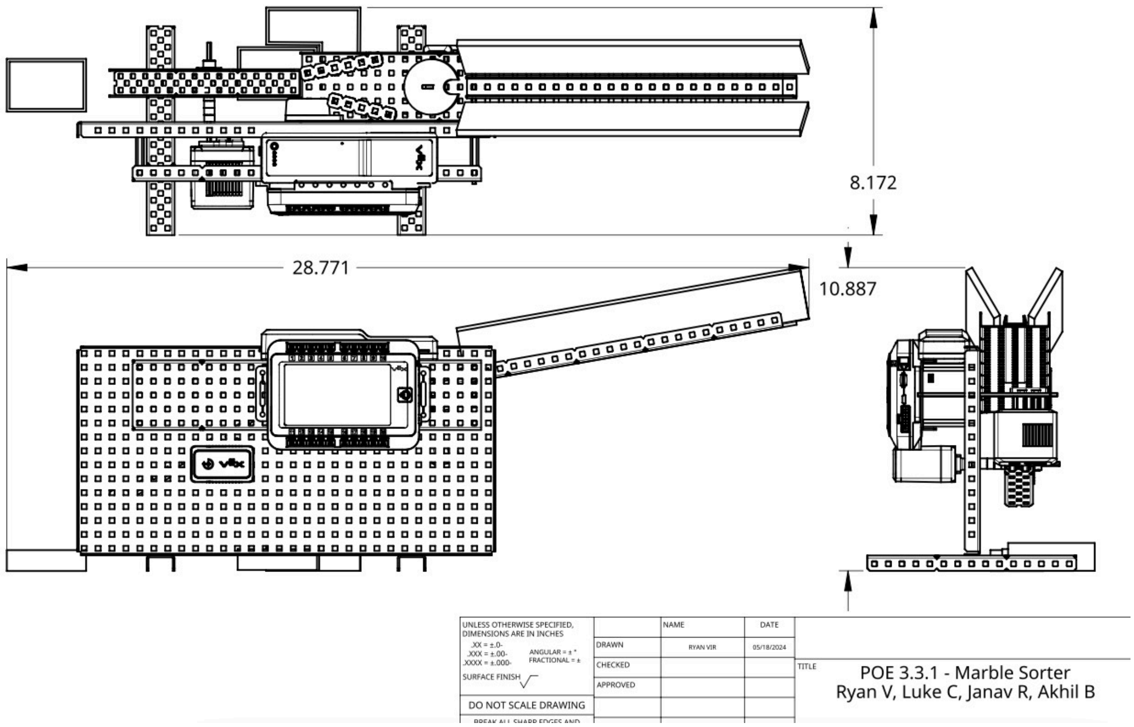
Problem: Many problems arose from the original design shown in the final sketch. Most importantly, the marbles would often get jammed and stuck in our 3D printed input. It didn't allow any marbles to pass through to the rest of the design and get sorted. Also, even if the marbles successfully made it past the input, there was still no efficient way to include a stopper.

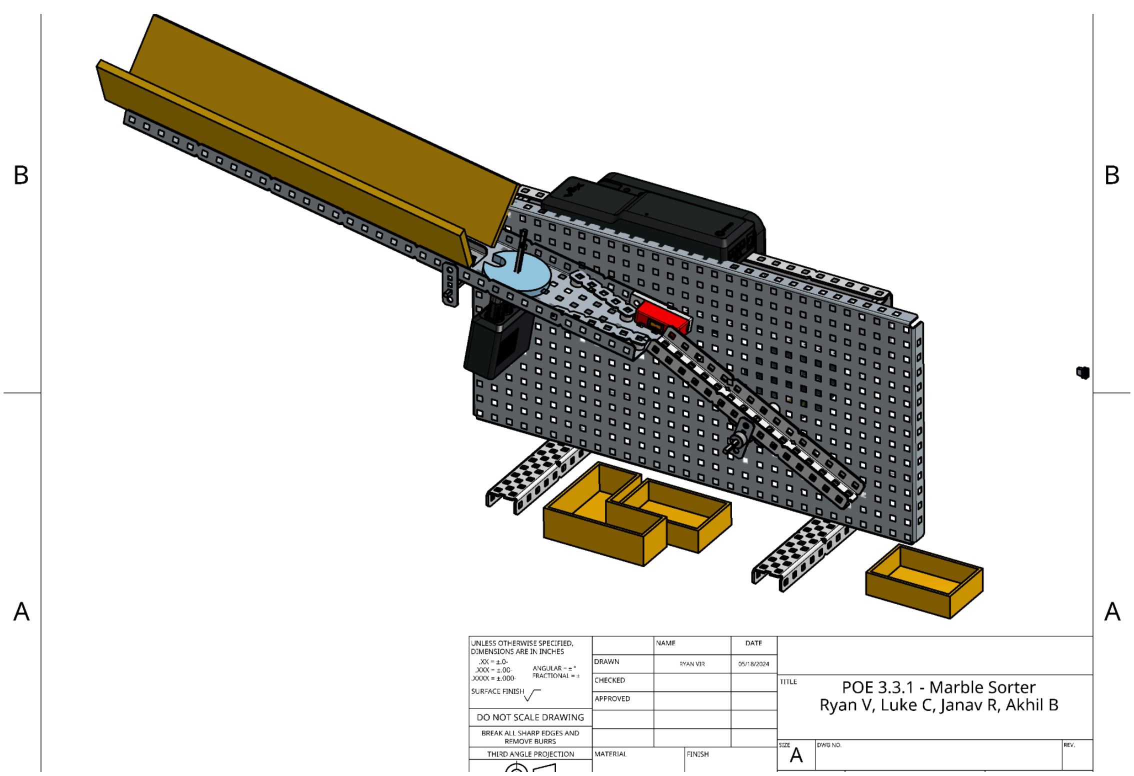
Proposed Solution: Our new solution for our input utilized a linear slide that would also use cardboard to make sure no marbles fell off the sides. This modification would not only fix the current jamming problem, but it would also make sure each marble is lined up 1 by 1 leading directly to the stopper. With the new input, the weight-mechanism was also not necessary as the sensor would be able to directly identify and sort each type of marble.

Design Sketch



3D Models


8.172
28.771
10.887
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES
NAME
DATE
DRAWN
RYAN VSR
05/18/2024
CHECKED
APPROVED
SURFACE FINISH
DO NOT SCALE DRAWING
TITLE
POE 3.3.1 - Marble Sorter
Ryan V, Luke C, Janav R, Akhil B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UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES
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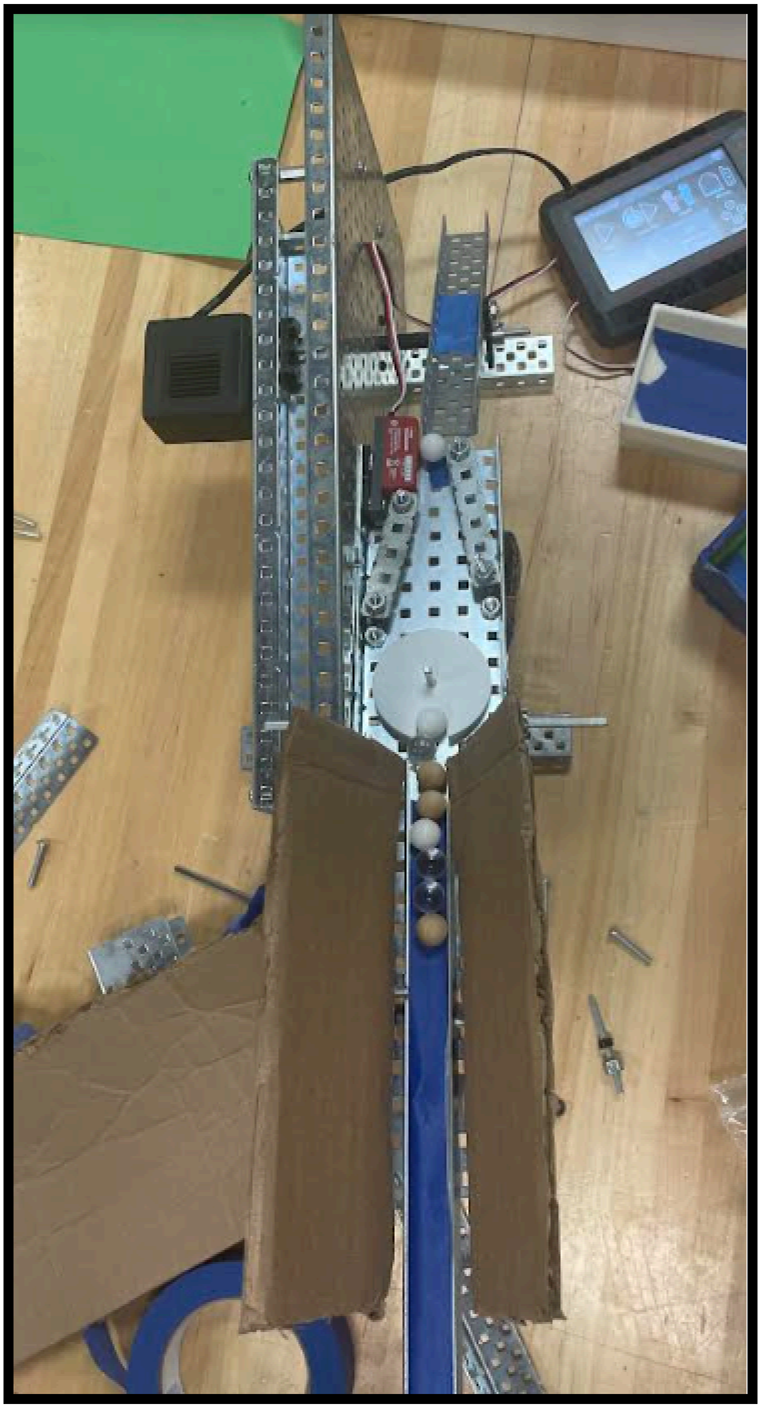
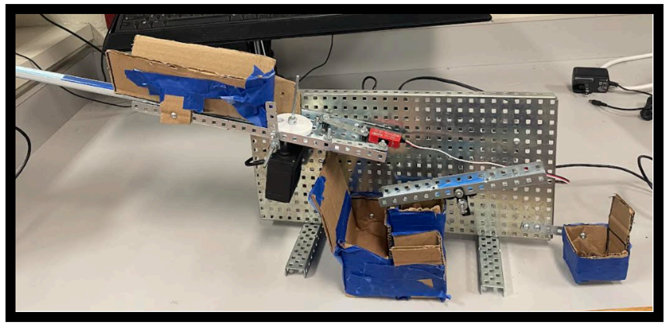
SURFACE FINISH
DO NOT SCALE DRAWING
BREAK ALL SHARP EDGES AND REMOVE BURRS
THIRD ANGLE PROJECTION
MATERIAL
FINISH
TITLE
POE 3.3.1 - Marble Sorter
Ryan V, Luke C, Janav R, Akhil B
SIZE
A
DWG NO.
REV.

Final Design

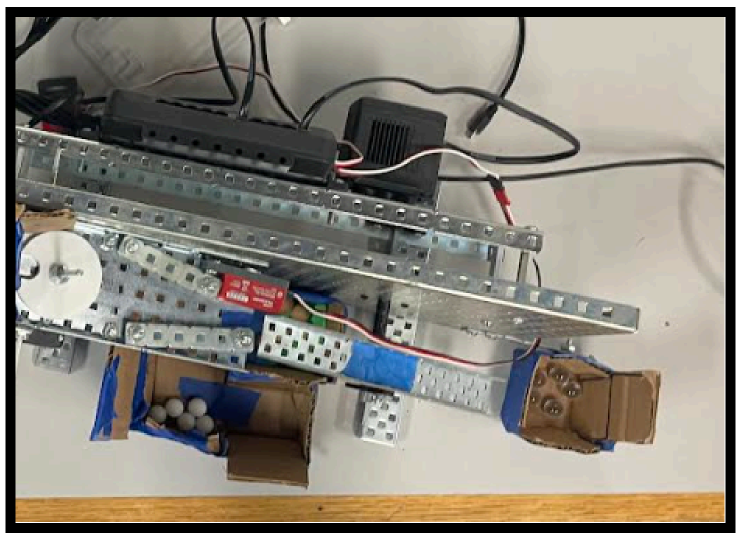
Top View



Front View

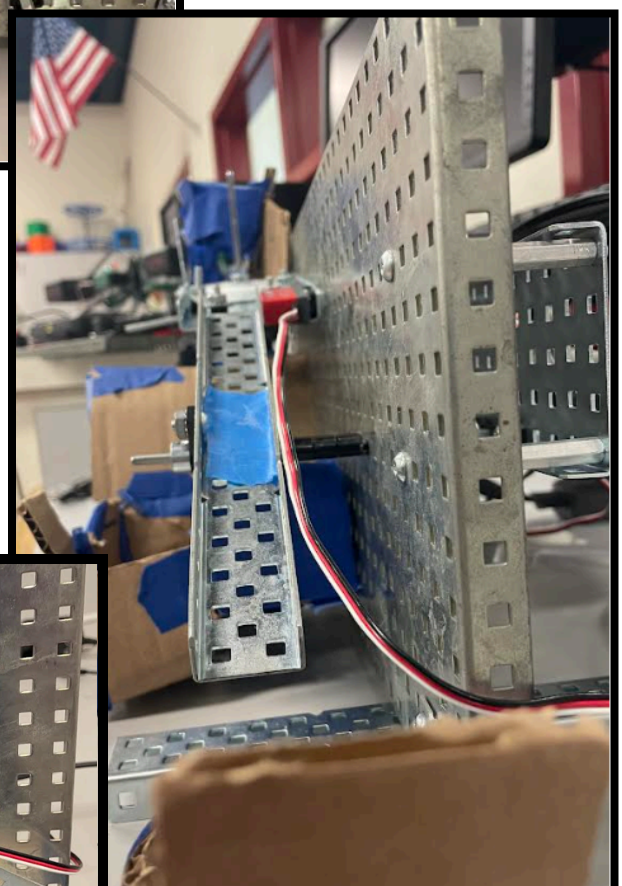


Brains and Motors are shown



Detailed View of Marble Sort Process

Side View



C-Channel acting as stopper

Group Reflections:

Akhil:

In general, our team did a great job in accomplishing our objectives as we sorted 13 out of the 15 marbles in under two minutes while also fitting all the criteria and constraints. However, we could have done many things differently to have a more efficient design. During our brainstorming process, we rushed through some of our ideas and didn't necessarily take into account other factors that could hinder the performance of the design. For example, we didn't mention the specifics of our input and how it would be incorporated with a stopper. This led to us spending more time building and trying to explore new ideas which put us on a time crunch. Also, one other aspect of our design solution that I would have done differently was modeling our input. Instead of using cardboard, 3D printing a more efficient design would be more appealing to the clients. Nonetheless, our results still fulfilled the problem statement except for coming two marbles short. While working with a group, I learned the importance of communicating efficiently in order to achieve a certain task. We were able to bounce ideas off each other and finish our design despite also having to miss some clases due to AP tests. Overall, I would say that this project was a success.

Luke:

Although our design did have several minor flaws, it did accomplish our objectives, to sort the 15 marbles, fairly well. We definitely underestimated the accuracy or the reliability of all the sensors, as a result giving us very little time to work on the input. I would try several things differently with our solution. I would make sure our ideas are practical, rather than theoretical. We also need to make sure to do some testing before proposing or deciding on a final solution. Our results are not 100% accurate; occasionally, several balls fail to be sorted correctly. Through this project, I learned I need to consider many other components. For example, we failed to consider the screws and the metal surfaces could obstruct a marble's traveling path. Most of our initial ideas failed, so we had to change them. Many of our initial brainstorming ideas did not work out, so we had to rework several aspects of our design. Additionally, all of us had AP exams during the project, but we effectively communicated to ensure timely completion and accountability. As I see it, the project was not to provide a task but to present a challenge to push teams to bring out the best of each other.

Janav:

Looking back at our objectives relative to the constraints and criteria I think we were pretty successful in accomplishing our objectives. We were able to meet all constraints and criteria except for the fact that we only sorted 13/15 marbles. I would do several things differently with our design solution. First, I would try using CAD for designing our input and output devices as using cardboard and tape proved to be very messy and was likely unappealing to our clients. I would also research and test on how we would minimize friction in our input system, so we could reduce the about of marbles getting stuck when we drop them in. Though our machine was able to occasionally sort the marbles with a 100% accuracy we failed to fulfill the problem statement as in our demonstration we failed to effectively sort all marbles translating into a failure in designing a machine for the NRPA to sort recycling materials. Throughout the design process I learned quite a lot. This project to prove arguably the hardest project I've ever had to work on. Due to the strict criteria and tough constraints developing a solution to the problem was not a very straightforward process. Throughout the design process our design almost completely changed from our initial final sketch. Many of our initially brianstormed ideas failed to work when it came to prototyping, so we had to rework many parts and conduct robust brainstorming to solve these problems during different stages of the design process. Along with this many of our team members had AP testing over the final 2 weeks of the project. This made it essential that we maintained communication to ensure we were able to finish on time and everyone was held accountable. The purpose of this project was not to be easy, but to be a tough challenge that would push us as a team to look for the best in eachother to engineer the best possible solution while working through the highs and lows.

Ryan:

This project was really fun as we got to put together everything we have learned combined with VEX to solve an interesting and practical problem. Our team collaborated effectively and efficiently throughout the engineering process. We applied our engineering skills to a new challenge and found it fun to use VEX again, again developing a solution that operates autonomously.

Looking back, one area for improvement would be dedicating more time to the decision-making process in designing the solution. Many of our initial designs had to be changed because they did not have a lot of research behind them to work well. We jumped into the building and had to spend a lot of time tweaking our designs. Our team worked well with communication and used each member's strengths and weaknesses, which allowed us to divide tasks in a good way. Each of us worked on different components of the product, working together to ensure they worked together well.

However, in future projects, I would consider organizing our group in a more collaborative manner. Instead of working separately and combining efforts at the end, we could work together on various parts throughout the process. Although our current method was successful, a more collaborative approach might make integration of the project components better.

Our final product addressed the problem statement and our client's problem well, though we did not sort all 15 in the final demonstration.

Conclusion Questions

1. The most challenging aspect of this project was definitely time management and accounting for problems. Throughout this project we had many hiccups that we didn't really account for while getting the timeline ready for this project. We thought we had given ourselves enough time on each stage of our gantt chart, but clearly not. From the get go, we faced many obstacles. Our conceptualized final idea didn't even physically work and we were forced to start brainstorming again, backtracking everything again. Also certain parts of the project seemed more challenging than others, which sucked up time and reduced the quality and attention to detail to other components. For example, we were so focused on the sorting system for several days that we were in a time crunch to get the input working. We failed to account for the importance of every component. Without a proper input all the work we put into the sorting system wouldn't matter.

2. There are several creative design changes we would make if we could start over. One problem we faced was with getting marbles stuck in the input systems. We could solve this by 3-D modeling the input instead of using cardboard. Due to time constraints and being a last minute change we did not have the time to 3-D print our input change. By 3-D modeling a v shape with a base the same size as the 1x25 c-channel we can minimize the friction from the holes of c-channel and screws below. Another problem was with the detection and sorting of the opaque plastic. Whenever an opaque plastic was detected due to having the biggest drop to the c-channel the marble would often bounce onorthodoxly, requiring a bigger box to accommodate the bouncing. We could solve this problem by changing the code to account for this. Once an opaque marble is detected the velocity of the motor can slow down so the marble has a smoother fall and doesn't bounce and after x time for the marble to get in the bin it returns to its original velocity until another opaque marble is detected.