ME 2110-Section A01

Final Report

Group 3:

Hunter Schaufel

Cole Sosnowski

Neel Maity

Josh Zeisloft

Submitted to: Kristi Mehaffey

TA: Jesse Goodwin

Date: 04/23/2021

Table of Contents

Abstract

The customers, Lebron James and the Looney Tunes characters, require a method to consistently win a basketball-inspired competition against a malicious artificial intelligence (AI). The goal is to develop a system that will meet the customer's need to excel in the basketball competition, and be able to quantitatively rank performance. Multiple design tools are employed to define the critical engineering requirements and functions needed to win the competition and to generate a wide range of potential solution types to fulfill these functions. The importance of maximizing average point value attained and launch consistency, demonstrates that movement consistency of the system is critical to earn points in all tasks. The final system took these criteria into account, and was able to perform well due to the emphasis of those key findings. In conclusion, the client's goal was best achieved by prioritizing requirements to avoid disqualification and maximizing functions that attain points within the game, while still keeping the system reliable. This goal was met through the use of the final design, as the required point values were able to be scored reliably throughout the design and testing process, as well as the final competition.

I. Introduction

The customers, Lebron James and the Looney Tunes characters, need a method to autonomously score points in a basketball themed competition. To compete in the competition, the system must start at rest inside a 20 x 20 x 18 inch space, shown in Figure 1, then complete the Launch, Pass, Jumpshot and Dunk tasks, each scoring the points outlined in Table 2. The Launch task, max 1 point, requires the system to start movement after a button press. Failing to do so will result in disqualification. The Pass task requires a preloaded ball to hit the side of Target Zone 1, scoring a max of 3 points. The Jumpshot task has the system launch a preloaded ball into Target Zone 1, scoring a max of 8 points. The Dunk task consists of two parts: collecting three balls off of PVC pipes, spaced various lengths away at different heights, and scoring them into the Dunk Target Zone, an arrangement of Solo cups, scoring a max of 30 points. This competition has foreseeable design challenges, the largest being repeatability. Mechanisms can be powered by motors, rubber bands, mousetraps, air cylinders, and gravity, but mousetraps and rubber bands are prone to releasing slower or less forcefully due to wear over extended use. This will impact how a mechanism powered by these sources operates on the field over multiple runs. Because the customers require repeatable scoring, the wear on these power sources poses a threat to fulfilling the customer’s needs in the game.

II. Problem Understanding

The most important customer requirements for the system are those that must be met to avoid disqualification. The House of Quality (HOQ), shown in Figure 3, weighs these requirements the highest, followed by Completing Launch Task due to its ability to disqualify, though it provides little score. The HOQ also demonstrates that the three most important engineering requirements are Average Point Value Attained, Launch Consistency, and Ball Handling Precision. The machine must maximize points earned to win consistently for the customer, and launch consistency is required to score any points, while ball handling precision increases point value attained because the most points are earned by placing balls in target zones. The roof of the HOQ demonstrates synergy between the system’s accuracy in ball placement and success in the Dunk and Jumpshot tasks in the game. The more accurate the system is, the more points it will attain. Therefore, the spec sheet, shown in Table 4, defines the minimum accuracy of the system’s ball placement as +/- 1.725” horizontally for the Dunk task and +/- 6.25” horizontally for the Jumpshot task. In addition, the spec sheet establishes a minimum machine starting position tolerance of +/- 0.25” horizontally. In a worst-case scenario, the combined tolerances of machine starting position and ball placement will sum to +/- 1.975” and +/- 6.5”, matching the diameters of the cup and bucket target zones, respectively. In addition, the HOQ’s roof highlights the tradeoff between maximizing point-gaining functionality and minimizing robot size. Hence, the spec sheet defines a demand to keep overall dimensions of the system within 19.5” x 19.5” x 18”, leaving 0.25” of clearance around all sides for alignment and helping to enforce the placement tolerance. At the same time, the spec sheet establishes the wish to achieve 3 and 8 points in the pass and jumpshot tasks, respectively: based on the maximum points achievable in these tasks. The spec sheet establishes a wish to achieve at least 28 points in the dunk task based on a prediction of landing all three field items in the yellow zone. This was decided based on the customer's need to score consistently: landing all three balls in green would require extreme precision, while scoring all three balls in the more numerous yellow cups is more likely, and therefore a more realistic way to achieve the 22 points required to win consistently.

The Function Tree, pictured in Figure 5, shows some of the easier functions to accomplish are Accept Input to Begin Routine and Relay Input. Per the competition rules, these two tasks only require a button to be pressed and the Arduino to signal to move any mechatronics component. Both the Pass and Jumpshot tasks require the system to remain inside the foul line, so the system must launch the pre-loaded balls, driving the design of the system. However, the tasks Collect Stock Items and Score Stock Items in Target Zone 2 are harder to achieve due to their limiting constraints. These two tasks are more open-ended and allow for many different solutions. Additionally, the margin of error for these two tasks is much smaller because the cups in the target zone have a significantly smaller diameter rim. As shown in the Morphological Chart in Table 6, the functions for Hit Target Zone 1 and Launch Ball into Target Zone 1 have similar options, suggesting one mechanism for both tasks. The Score Stock Items In Target Zone 2 function, however, considers more complex options like an Extend & Drop mechanism to meet the constraints of that task.

III. Design Overview

The preferred design alternative, the Final Design, combines a ramp, slingshot, and linear slide mechanism within the robot frame to accomplish all four tasks. As shown in Figure 7, the base is designed to be stationary, launching field items and extending components to complete the tasks and score 29 points. The ramp, shown in Figure 8, enables the machine to complete the

Pass Task and score 3 points by restraining the pre-loaded ball with a solenoid, then releasing it, allowing the ball to roll towards Target Zone 1. While this mechanism did not change after Sprint 1, it was lowered before Sprint 2 to prevent the ball from bouncing when it rolls off the ramp, thereby improving Pass consistency. The slingshot, shown in Figure 9, scores 8 points for the Jumpshot task by pulling back a lever with a rubber band, restrained by a latch bracket. The ball gets hit by the lever when released, and travels towards Target Zone 1. This mechanism was incredibly reliable during Sprint 1 so no changes were made since its construction. The linear slide mechanism, shown in Figures 7 and 10, is powered by rubber bands to quickly extend, then uses a rotating basket to score 17 points for the Dunk task. Once the latch bracket releases, the linear slides quickly extend causing the basket, shown in Figure 10**,** to hit the 12" PVC pipes, catch the money balls, and knock the yellow stock item off, scoring 1 point. When the linear slides extend past a certain point, the fixed-length fishing wire engages, causing the basket to rotate back, the two money balls to roll out onto the ramp in Figure 10, and finally land in the orange zone, scoring 8 points each. Many changes were made to this mechanism between sprints. Prior to Sprint 1, the basket only aimed to knock the stock items off and could not consistently collect them. Before Sprint 2, the rotating basket and a second linear slide set were added to reliably collect the money balls and deposit them into the red zone. Before the Final Competition, the latch bracket was moved due to reliability concerns and a ramp was added, enabling scoring into the orange zone. The robot costs $98.43, as seen in Table 11, the Bill of Materials. The drawer slides are by far the most expensive item, costing almost $60. Hence, costs were minimized elsewhere, for example, replacing half of the bricks with a cheaper option. In order to operate autonomously, the robot runs on a scripted code sequence displayed in Figure 12. The robot checks the state of the button repeatedly and uses a debouncing function to ensure an intentional press. It activates the solenoid and moves the Jumpshot latch motor, enabling these mechanisms to score. The program deactivates both of these components, then activates the linear slide latch motor to release the linear slide mechanism. The program ensures all components are disengaged and waits for the button state to change again.

IV. Alternative Designs

Multiple alternative designs were created to help develop ideas and visualize differing mechanisms. The cannon design, pictured in Figures 13 and 14, accomplishes the Jumpshot and Pass tasks by utilizing the same rotating pneumatic cylinder mechanism. At the start, the cylinder faces forward and two balls are loaded in the chamber. The robot shoots the first one to complete the Pass task, then the DC motor rotates the assembly up and fires again, scoring the Jumpshot task. This solution cuts down on complexity by incorporating two of the tasks into a single system. For the Dunk task, it features a slide system which expands as the wheel drives, using the linear slides for stability. The basket knocks over the PVC pipes and the balls fall into the back. Once the basket has traveled far enough to collect both money balls, the solenoid releases the rubber band that is connected to the back of the basket, as seen in Figure 15. This causes all three balls to be launched out of the basket and into the solo cups. The driving design, pictured in Figures 16 and 17, combines the Pass and Jumpshot mechanisms as well, but they are powered by a mousetrap held back with a solenoid. The two balls are located at different lengths down the arm, so the Jumpshot ball lands in the target zone, while the Pass ball hits the side. This design utilizes a motor-powered, 4-wheel-drive chassis to knock the balls off the PVC pipes in hopes of bouncing into the Solo cups. Finally the pitchfork design, displayed in Figures 18, 19, 20, and 21, utilizes a similar Jumpshot and Pass mechanism to the final design - a slingshot and ramp - but differs in its stationary pitchfork and single set of linear slides. The dunk mechanism for the pitchfork design aims to knock the balls off of the PVC pipes and push them towards the dunk zone cups. Additionally this design uses a slimmer frame design compared to the others. A first level evaluation matrix was initially used when evaluating the best alternatives, as seen in Table 22. This matrix uses the cannon design as a datum to compare the three additional designs. As displayed in the matrix, the Final Design and Pitchfork Design both rank high with a marginal improvement compared to the datum, while the Driving Design was shown to be worse by comparison. Measuring the criteria in terms of importance using a third level evaluation matrix, shown in Table 23, allows a more accurate rank to be seen. It shows the preferred design to be the Final Design, over the other three alternatives. The strengths of this design come from its ability to complete the Jumpshot task consistently, as well as its higher scoring potential for the Dunk task, ensuring it will be able to achieve the required 22 points of the competition.

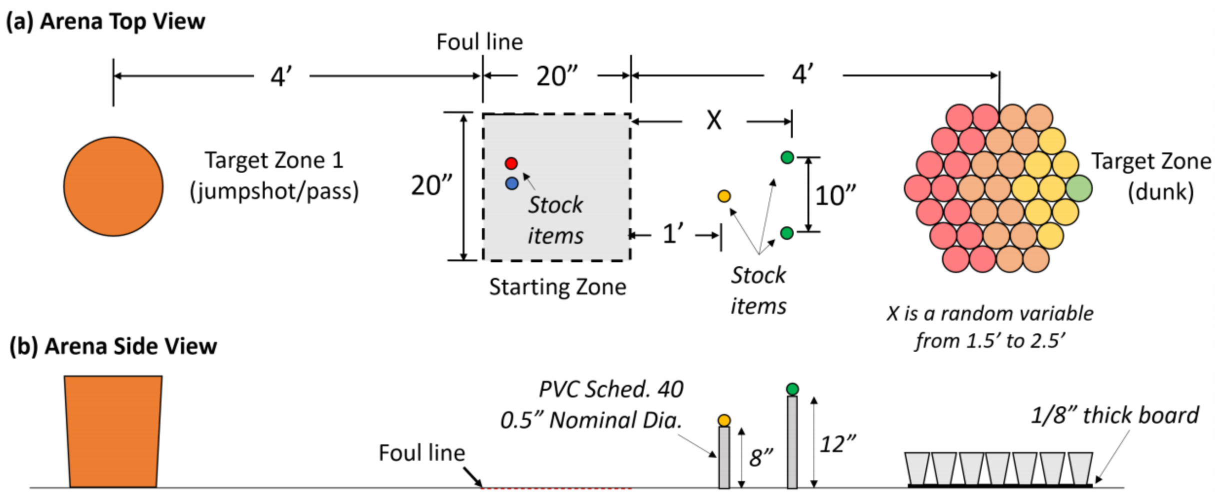
V. Discussion

The performance of each iteration of the robot in all three competitions was excellent. The specific point breakdown is outlined in Table 24, where the robot scored over the needed points to get 100% in every competition except for the final competition, where the final score was an 85%. The performance in the final competition was less than ideal, due to the motor responsible for releasing the linear slides not actuating, due to a slipping in the mount on the D-shaft. This meant that no points were scored in the Dunk task, making it impossible to get the 22 points needed for that run. This error occurred due to numerous test runs in the days before, which caused the mount to slowly wear down. The issue was resolved in the following runs by placing the release lever so it barely retained the slides, therefore allowing the shaft to slip a bit and still release. The final score of 85% is a passing grade, however, the specification sheet outlined a 100% actuation rate for every sub-system in the robot. This "fluke" only happened once during testing the day of the final competition, and was therefore ignored. All tests of the machine's performance in the days before, outlined in Table 25, clearly show this specific error never occurred. It was therefore never considered as a failure mode. Obviously, the true performance is never as reliable as the test runs, which was accounted for in the design of the system by planning to score over the required 22 points. However, his specific error did not allow for that redundancy since only a max of 12 points can be scored without the Dunk task. The assumption that enough testing had been done to eliminate all potential problems was incorrect, and with more testing, the latch arm issue would have been found, like many others that had been discovered previously. In the HOQ, both "Consistently Performs Tasks" and "Is Aesthetically Pleasing" were weighted too low. The consistency of performing each task is integral to the success of the robot in competition, and therefore should have been a larger concern from the beginning of the design phase. As for the aesthetics of the robot, a large portion of the grade for the Design Review comes from how the robot looks, so giving it an importance rating of 3 is inappropriate, and some effort should have been made to beautify the robot and make it unique. Strengths of the robot were made clear in the consistency of the Jumpshot task and in the ease of setup. Having a robot that was easy to set up came from the decision to have a stationary frame, allowing all mechanisms to be reset by pushing them back into the frame, instead of by moving the entire robot. As for the consistency of the Jumpshot mechanism, the strategy of rapid prototyping and testing quickly brought forth a design that never missed in all 3 competitions. The Dunk mechanism showed the most weaknesses in this design. Early on, the decision to use linear slides limited how far the mechanism could extend, especially when rubber bands were used. However, to ensure the rubber bands would not wear over time, they were replaced before each run to ensure consistency. Another weakness of the overall system was how close the total cost of the robot was to the limit, as shown in the Bill of Materials in Table 11. This limited potential improvements to the robot that would have allowed for more reliable mechanisms, such as using pulleys to extend the slides. This is mainly due to the steep price of the slides which, again, was decided early on and took up more than half the budget. If more time was allotted, the final design could be improved by creating a system to make the slides reach their full extension through the use of the string and pulley system aforementioned. This would have allowed for the ability to score more points by reaching the green cup.

VI. Conclusion

The machine achieved 12 points in the first run of the final competition, and the expected 29 points in the following two runs, resulting in an average score of 23.3 points overall. The Dunk release mechanism failed during the first run in competition, costing the run 17 points. In comparison with performance in prior sprints, shown in Table 24, the Pass and Jumpshot mechanisms continued to earn max points in two of three runs in Sprint 1, in all runs in Sprint 2, and in all runs in the final competition. This indicates a pattern in the machine performance: the independently-scoring Pass and Jumpshot mechanisms consistently compensated for the highly variable Dunk mechanism. The key to the Pass and Jumpshot mechanisms' consistency was the robot's stationary design, as there were very few changes in variables that could negatively impact the performance of these mechanisms between runs. For this reason, the stationary design of the machine was ultimately the right choice to score consistently in the competition. With the competition completed, one key takeaway is the value of prototyping early and often with low-fidelity materials to confirm a solution works before investing time in a CAD-modeled design. The Dunk mechanism went through at least one iteration before Sprint 1, another before Sprint 2, and a final iteration before the final competition. In each iteration, time was saved by testing concepts in cardboard before moving to slower-to-manufacture materials. The value of this iterative process was reflected in judge comments from the Design Review, such as, "Great iterative design-build-test strategy," and, "they showed the evolution of their design." In conclusion, in the Final Competition, the design failed to achieve the client's goal of scoring consistently due to the Dunk mechanism release issue. However, because the Pass, Jumpshot, and Dunk mechanisms scored consistently in all testing and sprints leading up to the Final Competition, the machine did demonstrate its ability to achieve the client's goal of scoring consistently in a basketball-themed competition.

Appendix



Source: ME 2110 Final Project Description

Figure 1: Competition Layout

Table 2: Competition Point Breakdown

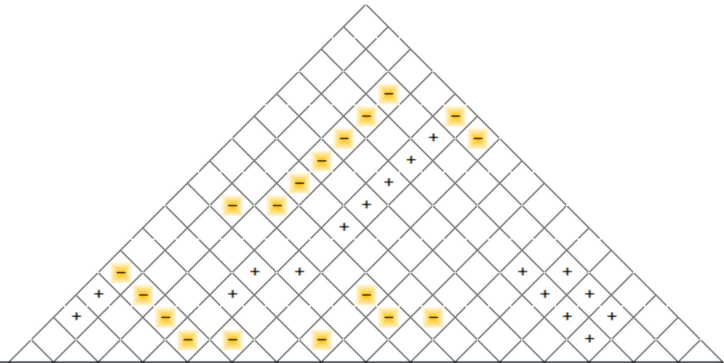
Task	Competition Point Value
Launch	1 (successful deployment)
Pass	3 points/item (hits target zone) 1 point/item (leaves starting zone)
Jumpshot	8 points/item (lands in target zone) 3 points/item (hit target zone but not in target zone) 1 points/item (leaves starting zone)
Dunk	6 points/item (green zone) 5 points/ item (yellow zone) 4 points/item (orange zone) 3 points/item (red zone) 1 point per item (not in a zone but off of PVC stand) *Money balls count 2x points per zone*

Project: ME 2110 - A01 Group 3 Final Competition
Revision:
Date: 22-Apr-21

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



		Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Direction of Improvement	▼	◇	▼	▼	▲	▼	▼	▼	▲	▲	▲	▲	▲	▲	▲	◇
Category	Weight	Engineering Requirements / Customer Requirements (Explicit and Implicit)	Volume Limit	Energy Source Limit	Cost Limit	Weight Limit	Average Point Value Attained	Time Limit	Max Setup Team	Max Setup Time	Pass Distance	Launch Consistency	Pass Consistency	Jumpshot Consistency	Dunk Consistency	Movement Consistency	Ball handling precision	Motor Speed
Competition Tasks	9	Completes Launch Task					●					●						
	6	Completes Pass Task					●				●		●					
	7	Completes Jumpshot Task					●				○			●			●	
	8	Completes Dunk Task					●				○				●		●	
Regulations	10	Meets Sizing Requirements	●			▽												
	10	Operates Autonomously						○				○						
	10	Remains Still Before Start & After End		●				○				●						
	10	Is Affordable			●													
	7	Is Safe to Operate		○												●		○
Miscellaneous	5	Consistently Performs Tasks						○				●	●	●	●	●	●	●
	4	Is Easy to Pick Up	○			●												
	6	Is Easy to Set Up							●	●								
	3	Is Aesthetically Pleasing	▽			▽												
		Target	Fits within 19.5x19.5x18" box	Be deactivated & static at end of round	Additional Parts < $100	Weigh < 30 lbs	Score > 25 points on average	Complete tasks in < 1 minute	Takes 2 or less people to set up	Takes < 3 min to set up	Launch pingpong balls >4ft	Complete successful deployment >100% of the time	Hits target zone >70% of the time	Lands in target zone >70% of the time	Lands in yellowgreen zone >70% of the time	Stays behind foul line in >95% of trials	Ball placement accuracy is +/- 6.25 in. (jump) & +/- 1.725 in. (dunk) in x and	Motor speed <= 60 rpm
		Max Relationship	9	9	9	9	9	3	9	9	9	9	9	9	9	9	9	9
		Technical Importance Rating	105	111	90	49	270	75	54	54	99	246	99	108	117	108	180	66
		Relative Weight	6%	6%	5%	3%	15%	4%	3%	3%	5%	13%	5%	6%	6%	6%	10%	4%
		Weight Chart																

Figure 3: House of Quality

Table 4: Specification Sheet

			Issued:	2/19/2021
		Specification		
		For: ME 2110 Final Project Device		
		Function: Score points during autonomous operation.		
Changes	**D/W**	**Requirement**	**Resp.**	**Source**
		Geometry		
4/19/2021	D	In starting position, outer extremities fit within a 19.5"x19.5"x18" space	Hunter	Competition Description Source: ME 2110 Website, linked here
4/22/2021	W	~~In starting position, outer extremities are within 12"x12"x12"~~	Hunter	Team Decision: A system that fits in the 12” x 12” x 12” max dimensions will be easier to transport and position on field.
4/22/2021	W	System can successfully knock balls off of pvc pipes when pvc pipes are located at any point 2 feet +/- 0.5 feet away from starting zone.	Hunter	Competition Description Source: ME 2110 Website, linked here
4/22/2021	W	System can successfully knock balls off of pvc pipes of heights 8" and12", respectively.	Hunter	Competition Description Source: ME 2110 Website, linked here
2/18/2021	W	Accepts 1 stock item at a time of diameter 1.57” and weight 0.095 oz.	Hunter	Competition Description Source: ME 2110 Website, linked here
		Kinematics		
2/18/2021	D	Be deactivated & static within 1 minute of beginning operation	Cole	Competition Description Source: ME 2110 Website, linked here
4/19/2021	D	~~Begins operation starting from rest~~	Cole	Competition Description Source: ME 2110 Website, linked here
2/18/2021	D	Operation includes perceptible motion	Cole	Competition Description Source: ME 2110 Website, linked here

Table 4: Specification Sheet Continued

		Energy		
2/18/2021	D	Runs entirely on energy provided by a combination of the following: electricity supplied by the controllers, 5 mousetraps, mechatronics kit components, 5 #64 rubber bands, and gravity.	Neel	Competition Description Source: ME 2110 Website, linked here
4/22/2021	D	Where motors are used, the motor used is model number DK-37R545123000-41K produced by Dakemotor.	Hunter	ME 2110 Website Motor Spec Sheet, linked here
4/22/2021	D	Where motors are used, the system must by operate using a max motor speed of 60 RPM and a max motor torque of 5 kilograms-force per centimeter.	Hunter	ME 2110 Website Motor Spec Sheet, linked here
2/18/2021	D	Compressed air is used only to power pneumatic actuators.	Neel	Competition Description Source: ME 2110 Website, linked here
		Safety		
2/18/2021	D	The system does not present a pinch, shear, wrap or crush hazard to operators, or users are unable to access such hazards on the system.	Josh	Indiana Constructors, Inc. [1]
		Production		
2/18/2021	D	All actuators used in the system were provided in the ME 2110 mechatronics kit.	Hunter	Competition Description Source: ME 2110 Website, linked here
		Transport		
2/18/2021	D	System weighs less than 51 lbs.	Cole	OSHA [2]
2/18/2021	W	Weigh < 30 lbs	Cole	Team decision: 30 lbs is a more comfortable weight to carry when transporting the system.

Table 4: Specification Sheet Continued

		Operation		
2/18/2021	D	Completes tasks in < 1 minute.	Neel	Competition Description Source: ME 2110 Website, linked here
2/18/2021	D	Takes 2 or fewer people to set up	Neel	Competition Description Source: ME 2110 Website, linked here
2/18/2021	D	Takes < 3 min to set up	Neel	Competition Description Source: ME 2110 Website, linked here
2/18/2021	D	Translates 1 stock item a minimum horizontal distance of 4 feet from starting location.	Josh	Competition Description Source: ME 2110 Website, linked here
2/18/2021	D	System activated by pushbutton supplied in ME 2110 mechatronics kit	Josh	Competition Description Source: ME 2110 Website, linked here
2/18/2021	D	Complete successful deployment 100% of the time	Hunter	Team decision: failure to complete deployment results in overall failure to complete competition.
2/18/2021	D	Hits target zone >70% of the time	Cole	Team decision: achieving 70% of total possible points is minimum allowable to complete competition.
2/18/2021	D	Lands in target zone >70% of the time	Neel	Team decision: achieving 70% of total possible points is minimum allowable to complete competition.
2/18/2021	D	System stays behind foul line in 100% of trials.	Josh	Team decision: failure to stay within Starting Zone results in overall failure to complete competition.
2/18/2021	D	The arena and components are unharmed on visual inspection after the system has completed each run.	Josh	Competition Description Source: ME 2110 Website, linked here

Table 4: Specification Sheet Continued

4/22/2021	D	~~Linear horizontal system movement on the playing field is accurate to within +/- 1.975 inch of the point initially aimed for.~~	Neel	Team Decision: Maximum allowable system position tolerance is +/- 1.975" based on radius of rim of Solo cup.
4/22/2021	W	~~Linear horizontal system movement on the playing field is accurate to within +/- 1.0 inch of the point initially aimed for.~~	Hunter	Team decision: A tolerance of 1.0" leaves a safe margin of error to drop a field item inside the rim of a Solo cup.
4/22/2021	W	System starting position is accurate to within +/- 0.25 inches left-to-right and back-and-forth.	Hunter	Team decision: enables consistent scoring despite tolerance stacks between starting position and ball placement.
2/18/2021	W	Scores > 25 points in average of three trials	Hunter	Team decision: Achieving 25 points on average leaves safe margin of error to achieve maximum 21 points for Sprint 2.
4/22/2021	W	Scores a minimum of 3 points in the Pass task.	Hunter	Competition Description Source: ME 2110 Website, linked here
4/22/2021	W	Scores a minimum of 8 points in the Jumpshot task.	Hunter	Competition Description Source: ME 2110 Website, linked here
4/22/2021	W	Scores a minimum of 28 points in Dunk task.	Hunter	Competition Description Source: ME 2110 Website, linked here
2/18/2021	W	Translates 1 stock item >= 4 feet horizontally and >=14.5 inches vertically with a left-to-right and back-forth accuracy of +/- 6.25 inches as measured off of the point initially aimed for.	Hunter	Competition Description Source: ME 2110 Website, linked here
2/18/2021	W	Translates 1 stock item >= 4 feet horizontally and >= 5 inches vertically with a left-to-right and back-forth accuracy of +/- 1.725 inches as measured off of the point initially aimed for.	Cole	Competition Description Source: ME 2110 Website, linked here
4/19/2021	W	~~Removes field item resting on PVC cylinder~~	Cole	Competition Description Source: ME 2110 Website, linked here

Table 4: Specification Sheet Continued

4/19/2021	W	~~Autonomously retrieves field item.~~	Cole	Competition Description Source: ME 2110 Website, linked here
		Schedules		
2/18/2021	D	By March 19, 2021, the system achieves an average point value of >= 6.3 points over three consecutive trials in the following sections: Launch, Pass, Jump Shot, and Dunk	Neel	Sprint 1 Description: 9 points is the max score in Sprint 1, so 70% of this max average score is 6.3 points.
2/18/2021	D	By April 16, 2021, the system achieves an average point value of >= 14.7 points over three consecutive trials in the following sections: Launch, Pass, Jump Shot, and Dunk	Neel	Sprint 2 Description: 21 points is the max score in Sprint 2, so 70% of this max average score is 14.7 points.
2/18/2021	W	By March 19, 2021, the system achieves an average point value of >= 9 points over three consecutive trials in the following sections: Launch, Pass, Jump Shot, and Dunk	Josh	Sprint 1 Description
2/18/2021	W	By April 16, 2021, the system achieves an average point value of >= 21 points over three consecutive trials in the following sections: Launch, Pass, Jump Shot, and Dunk	Josh	Sprint 2 Description
		Costs		
2/18/2021	D	Total cost of additional parts is <= $100	Hunter	Competition Description Source: ME 2110 Website, linked here
		Maintenance		
4/22/2021	W	All critical components (defined as components required to complete a task) EITHER show no signs of wear after a minimum of 10 consecutive runs OR come with at least one replacement part that can be replaced in 3 minutes.	Hunter	Team Decision: 3 minutes is setup time between runs in competition.
2/18/2021	D	System functions without critical failure over three consecutive runs of all operations, with critical failure meaning a part fails and therefore renders an intended function of the overall system inoperable.	Josh	Team Decision: Three trials allowed during Sprint 1 and 2, so the system must repeat all tasks three times consecutively.

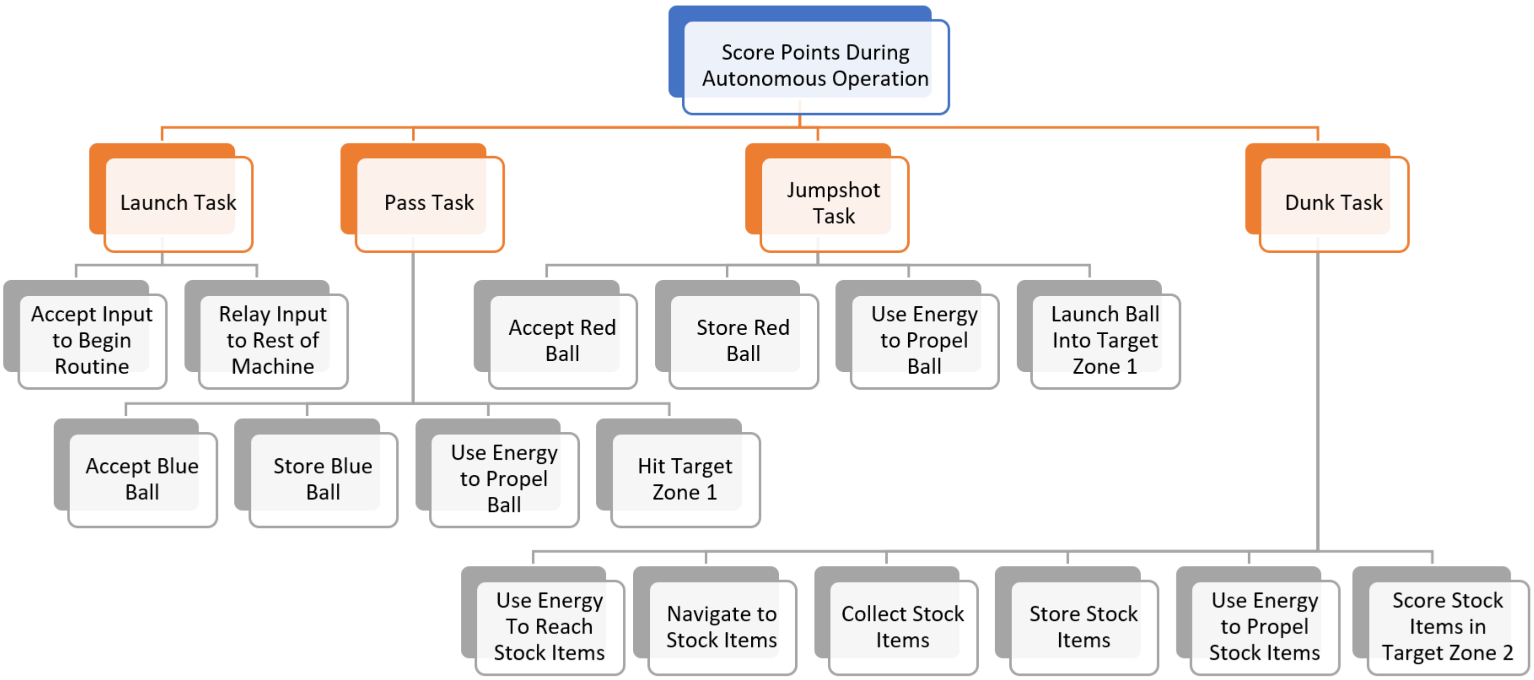


Figure 5: Function Tree Diagram

Table 6: Morphological Chart

Function	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Accept Input to Begin Routine	Push Button						
Relay Input to Rest of Machine	Arduino						
Accept Blue Ball	Opening from Top	Opening from Side	Trapdoor	Ramp	Claw		
Store Blue Ball	Cup	Bucket	Funnel	Net	Plate with Small Hole	Gate	
Use Energy to Propel Blue Ball	Rubber Bands	Pneumatic Cylinder	Mousetraps	Gravity	Motors	Solenoids	
Hit Target Zone 1	Linear Puncher	Rotary Launcher	Drop and Bounce	Ramp	Punch & Roll	Sling Shot	
Accept Red Ball	Opening from Top	Opening from Side	Trapdoor	Ramp	Claw		
Store Red Ball	Cup	Bucket	Funnel	Net	Plate with Small Hole	Gate	
Use Energy to Propel Red Ball	Rubber Bands	Pneumatic Cylinder	Mousetraps	Gravity	Motors	Solenoids	
Launch Ball into Target Zone 1	Linear Puncher	Rotary Launcher	Drop and Bounce	Sling Shot	Cam Mechanism	Deformed Material	

Table 6: Morphological Chart Continued

Use Energy to Reach Stock Items	Rubber Bands	Pneumatic Cylinder	Mousetraps	MG Gravity	Motors	Solenoids	
Navigate to Stock Items	Linear Extension	Drivetrain	Rotating Arm	Seperate Robot	Folding Frame	Ramp	
Collect Stock Items	Claw	Scoop	Push and Catch	Push from Stand	Sweep In		
Store Stock Items	Cup	Bucket	Funnel	Net	Plate with Small Hole	Gate	
Use Energy to Propel Stock Items	Rubber Bands	Pneumatic Cylinder	Mousetraps	MG Gravity	Motors	Solenoids	
Score Stock Items in Target 2	Linear Puncher	Rotary Launcher	Drop and Bounce	Sling Shot	Ramp	Extend & Drop	Trapdoor

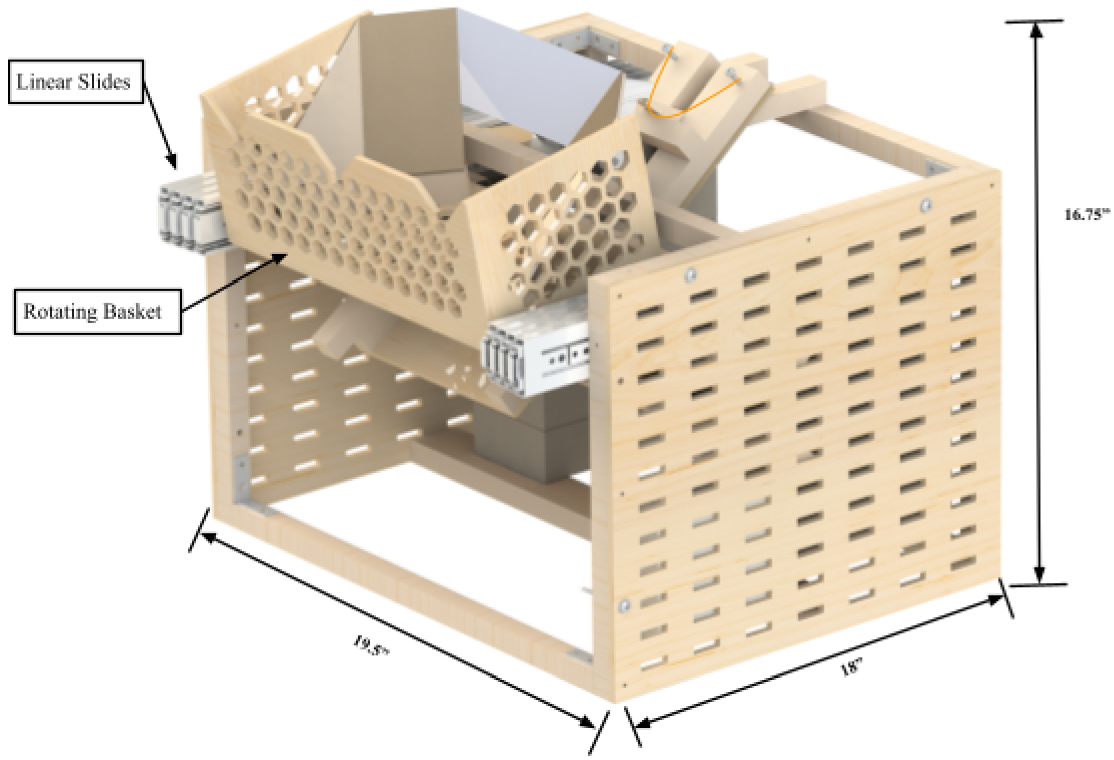


Figure 7: Final Design Starting Setup

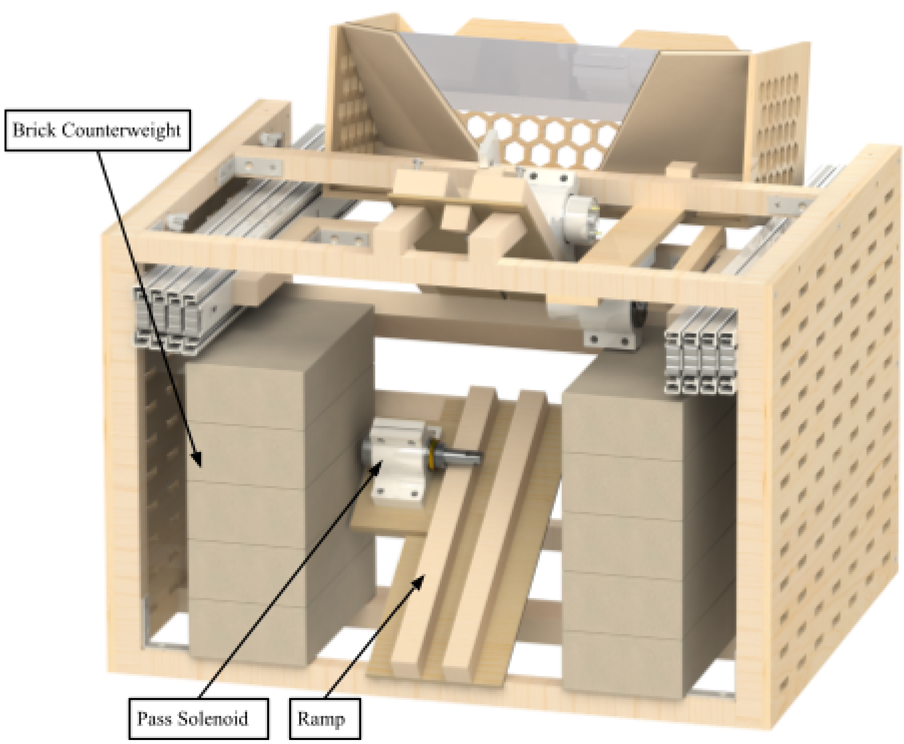


Figure 8: Back View of Final Design

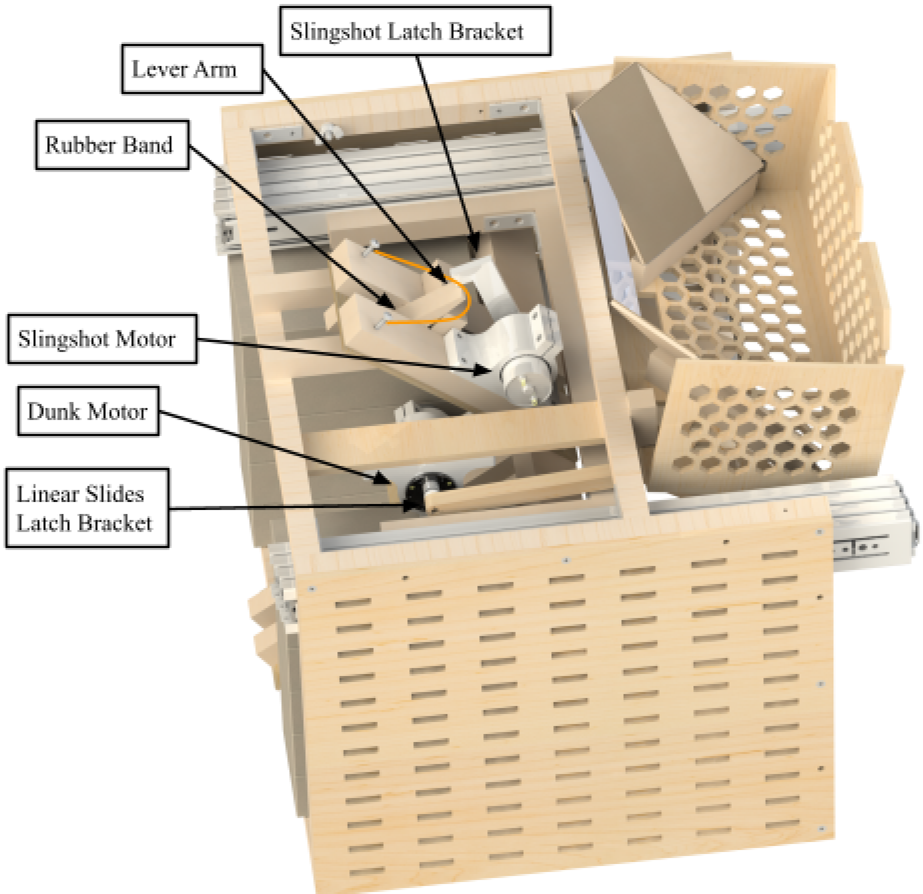


Figure 9: Top View of Final Design, Highlighting the Slingshot

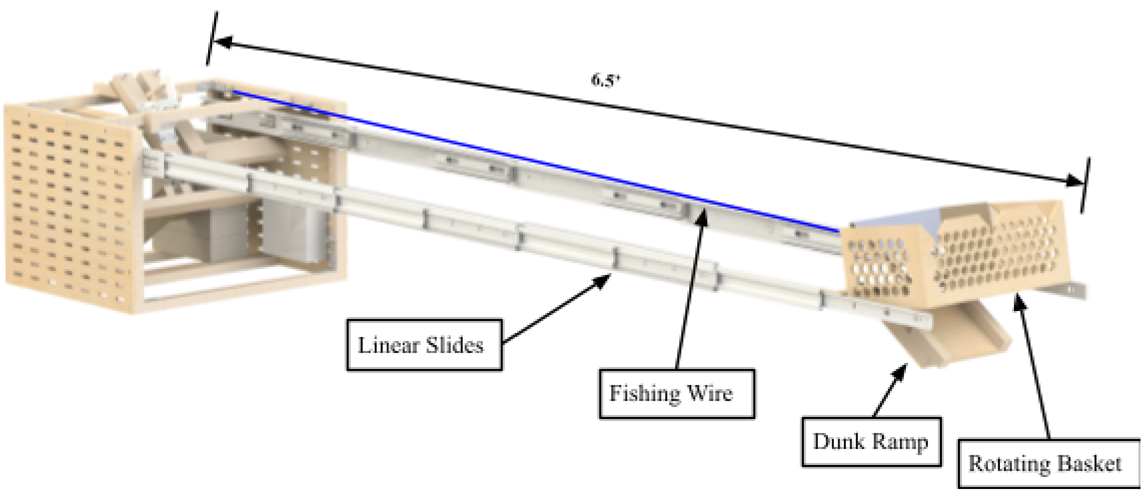


Figure 10: Final Design Deployed Position

Table 11: Bill of Materials

Part Name	Vendor	Part Number	Manufacturer	Unit Quantity	Unit Cost	Quantity Used	Cost	Link
7 in. x 3.5 in. x 1.75 in. bricks	Home Depot	1004885873	Pavestone (Quikrete)	1	$0.25	5	$1.25	Link
7 in. x 3.5in. x 1.75 in. bricks	Home Depot	163156	Pavestone (Quikrete)	1	$1.18	5	$5.90	Link
18 in. Full Extension Side Mount Ball Bearing Drawer Slide Set	Home Depot	302867747	Everbilt	2	$14.98	4	$59.92	Link
3D printed jumpshot latch	Team Design	N/A	Idea Lab Printer	1 kg	$51.93	0.006	$0.31	
3D printed linear slide latch hub	Team Design	N/A	Idea Lab Printer	1kg	$51.93	0.003	$0.16	
6-32 x 3/8" Steel Button Head Screw	Ace Hardware	N/A	Hillman	1	$0.40	6	$2.40	
6-32 Kep Nut	Ace Hardware	N/A	Hillman	1	$0.25	6	$1.50	
#64 Rubber Bands	Amazon	N/A	Business Source	380	$7.19	0.0132	$0.09	Link
3/4" Dowel	Home Depot	100536762	Waddell	36"	$3.14	5.106	$16.03	Link
1/4" MDF	Home Depot	354221	Home Depot	2'x4'	$8.42	0.15143	$1.28	Link
1/8" Plywood	Home Depot	165891	Columbia Forest Products	4'x8'	$33.24	0.01955	$0.65	Link
						Total Cost	$98.43	

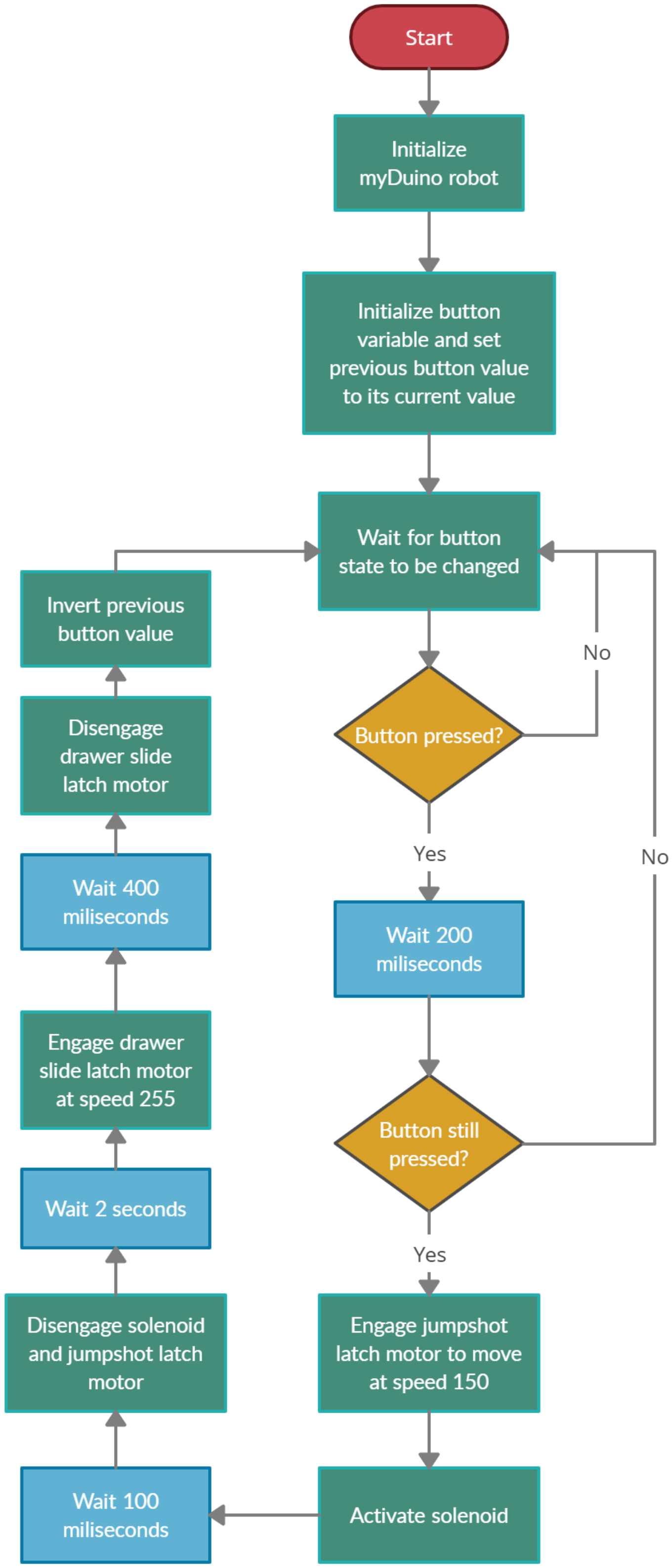


Figure 12: Robot Code Flow Chart

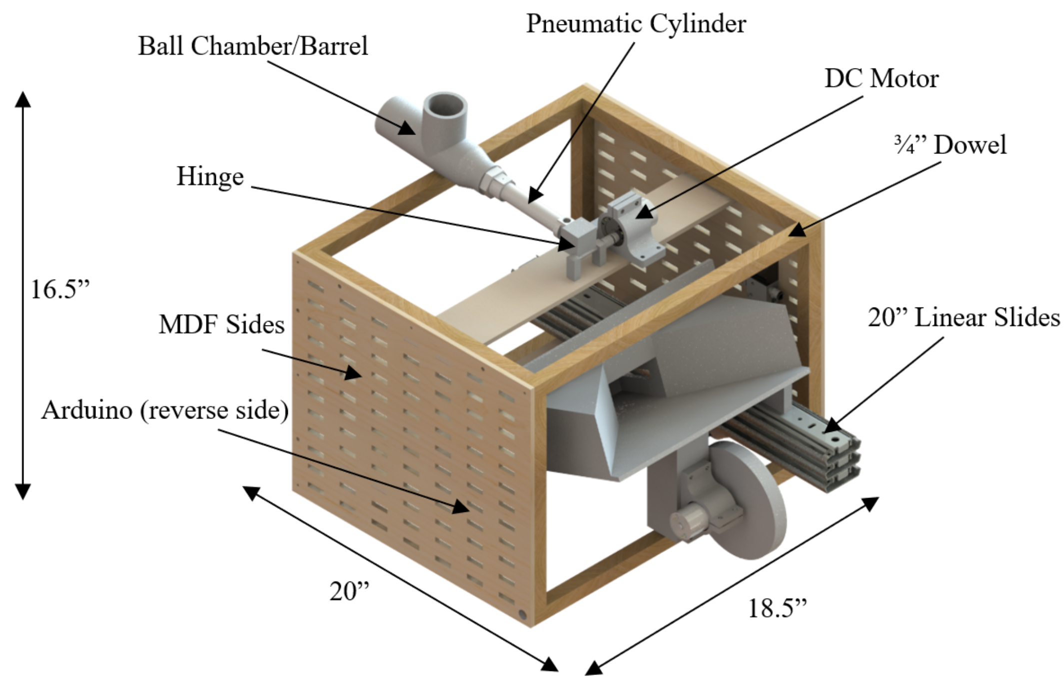


Figure 13: Cannon Design Starting Setup

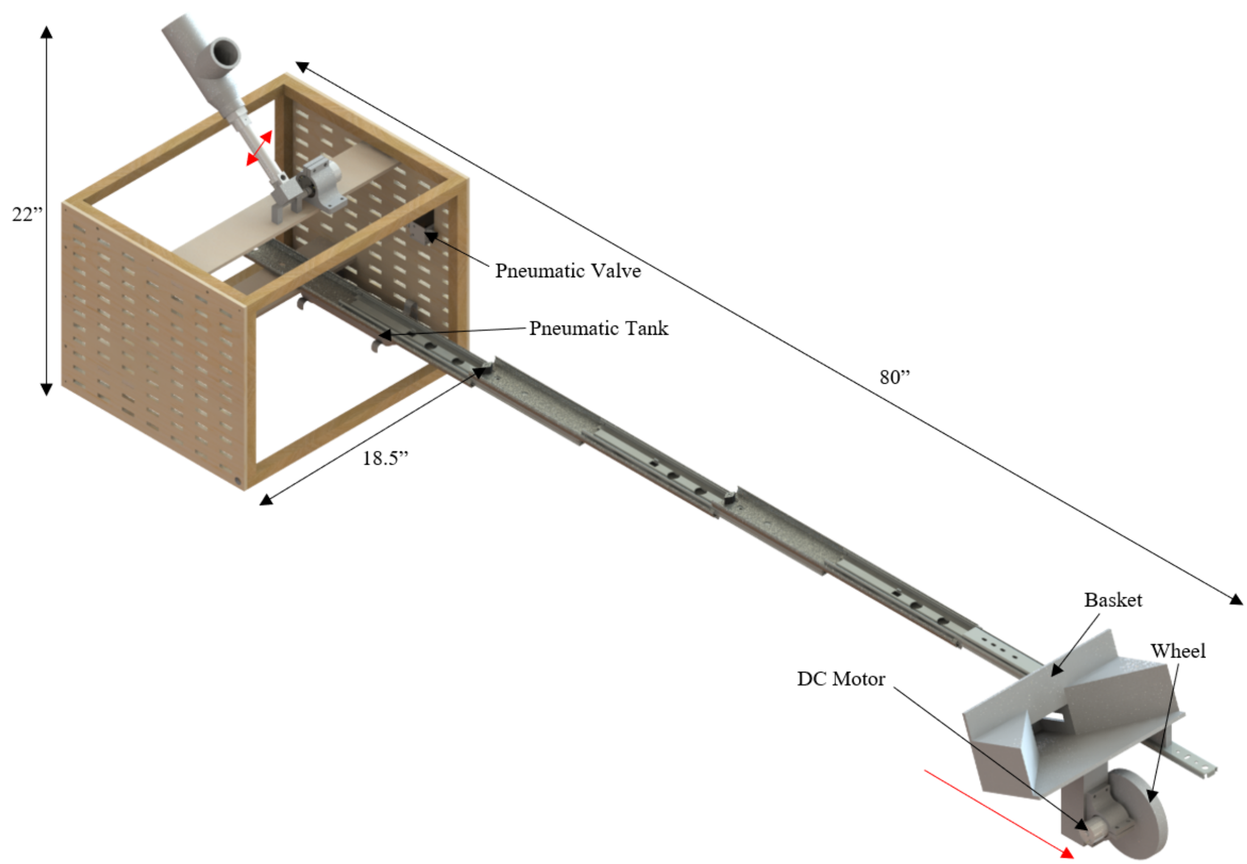


Figure 14: Cannon Design Operating Setup

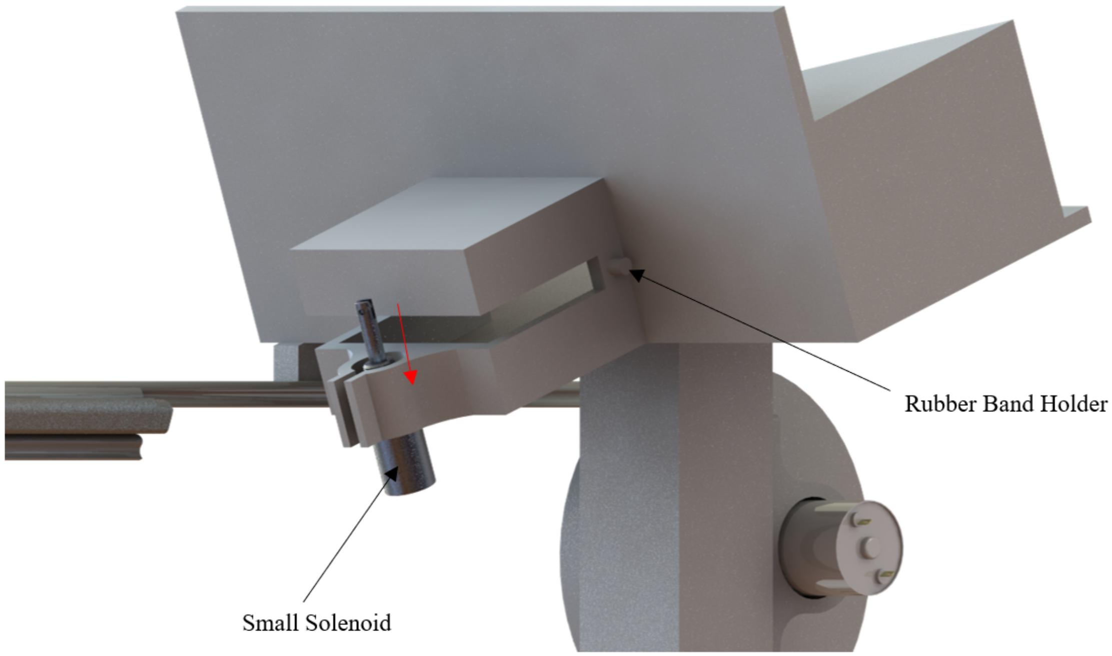


Figure 15: Cannon Design Basket Backside

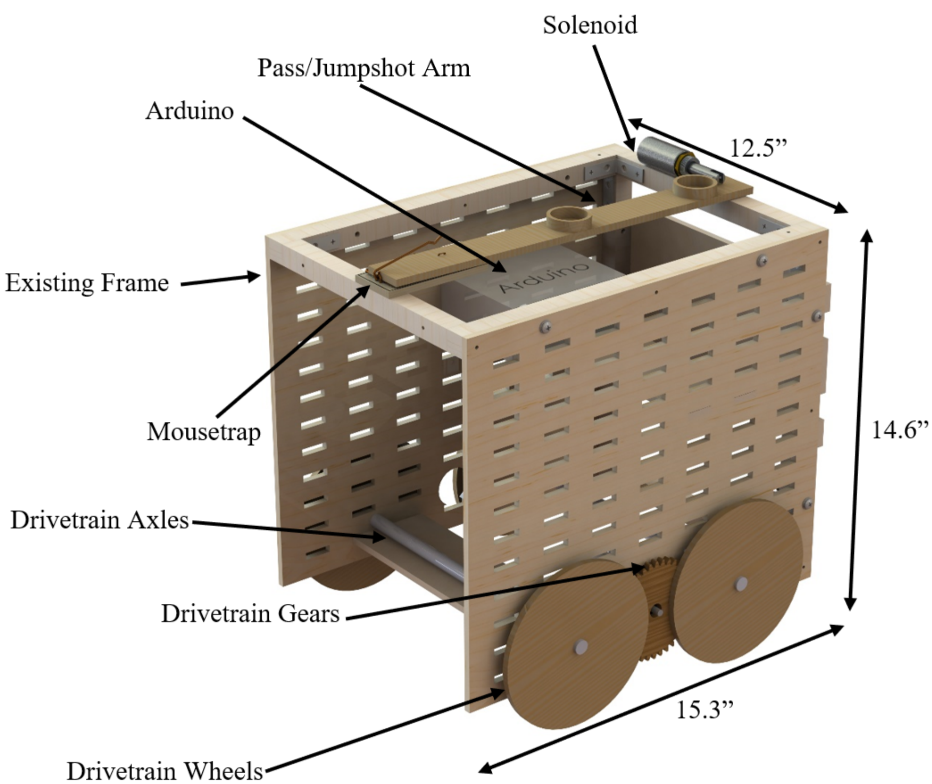


Figure 16: Driving Design Starting Setup

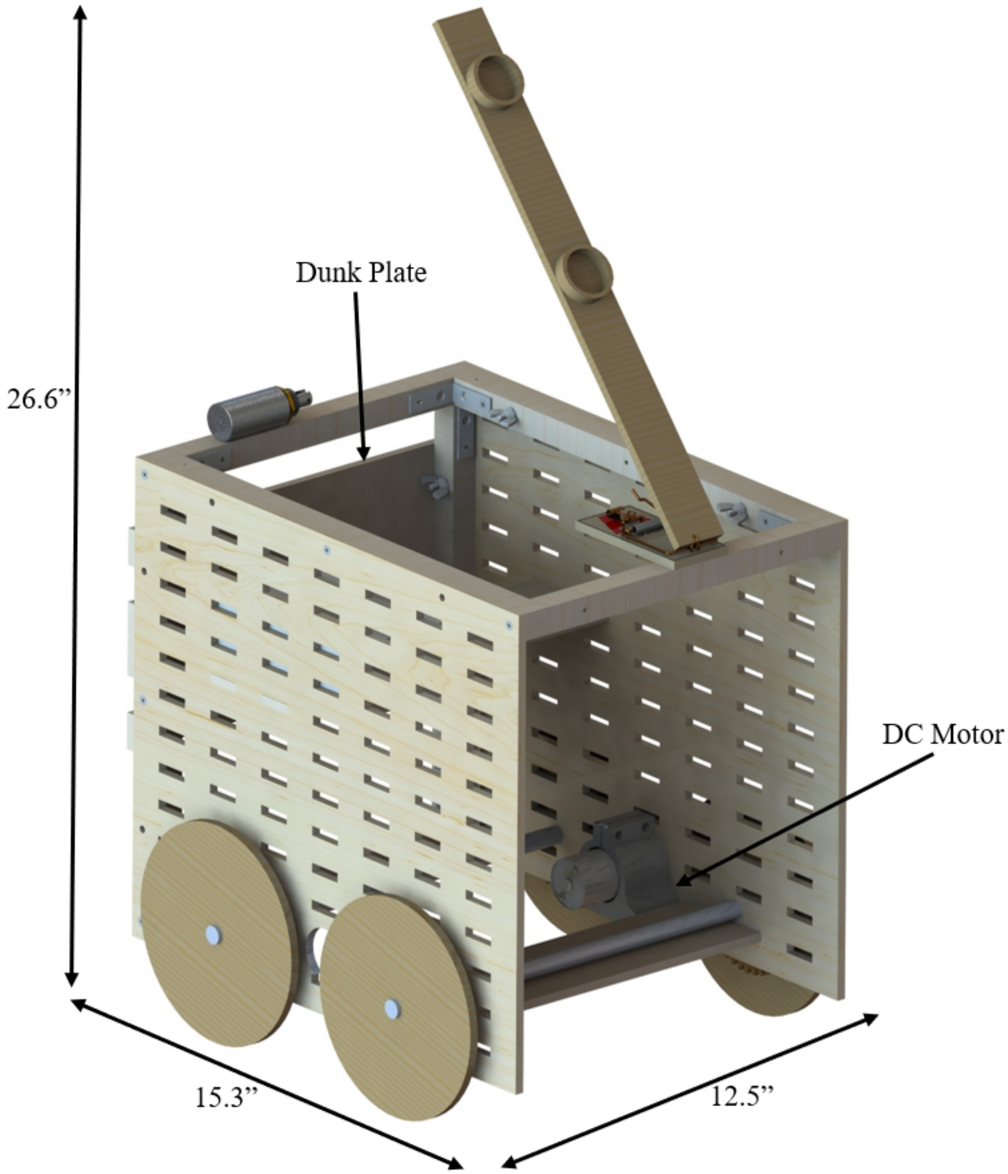


Figure 17: Driving Design Operating Setup

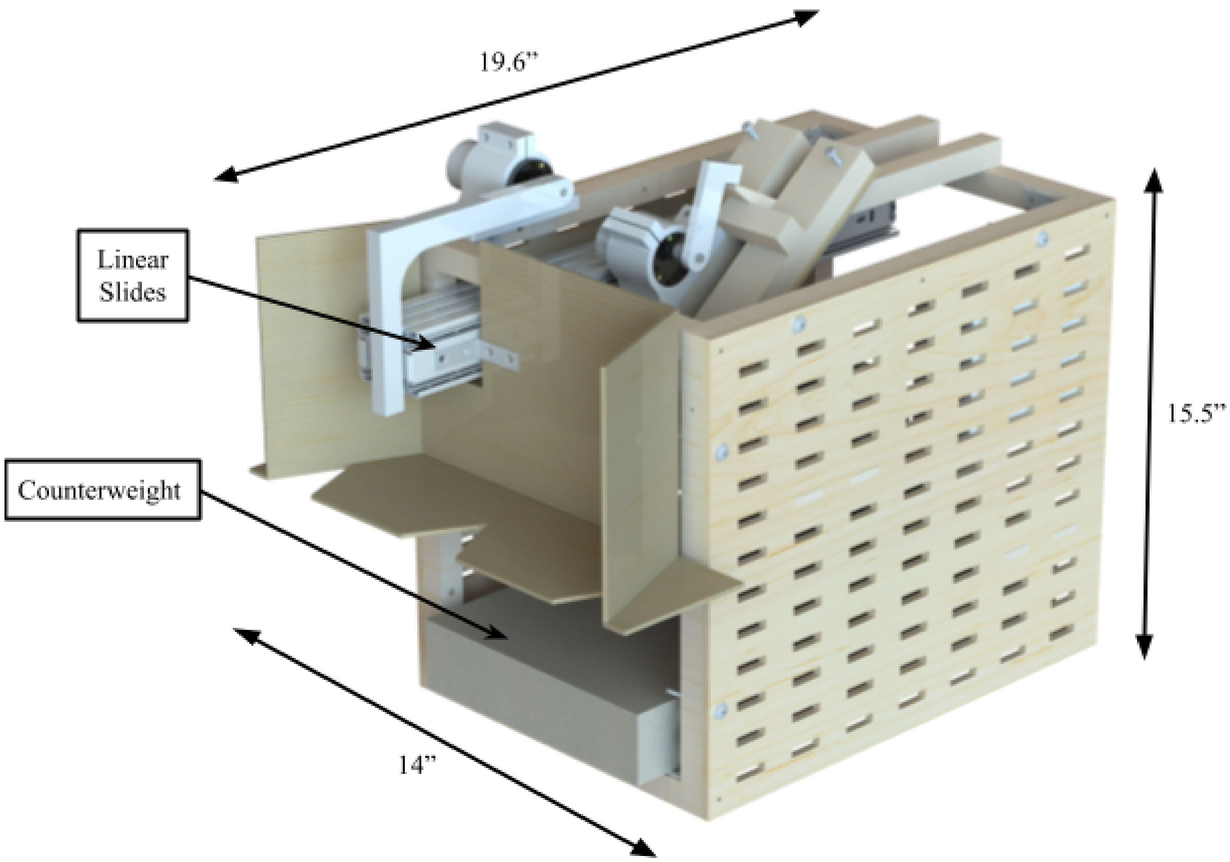


Figure 18: Pitchfork Design Starting Setup

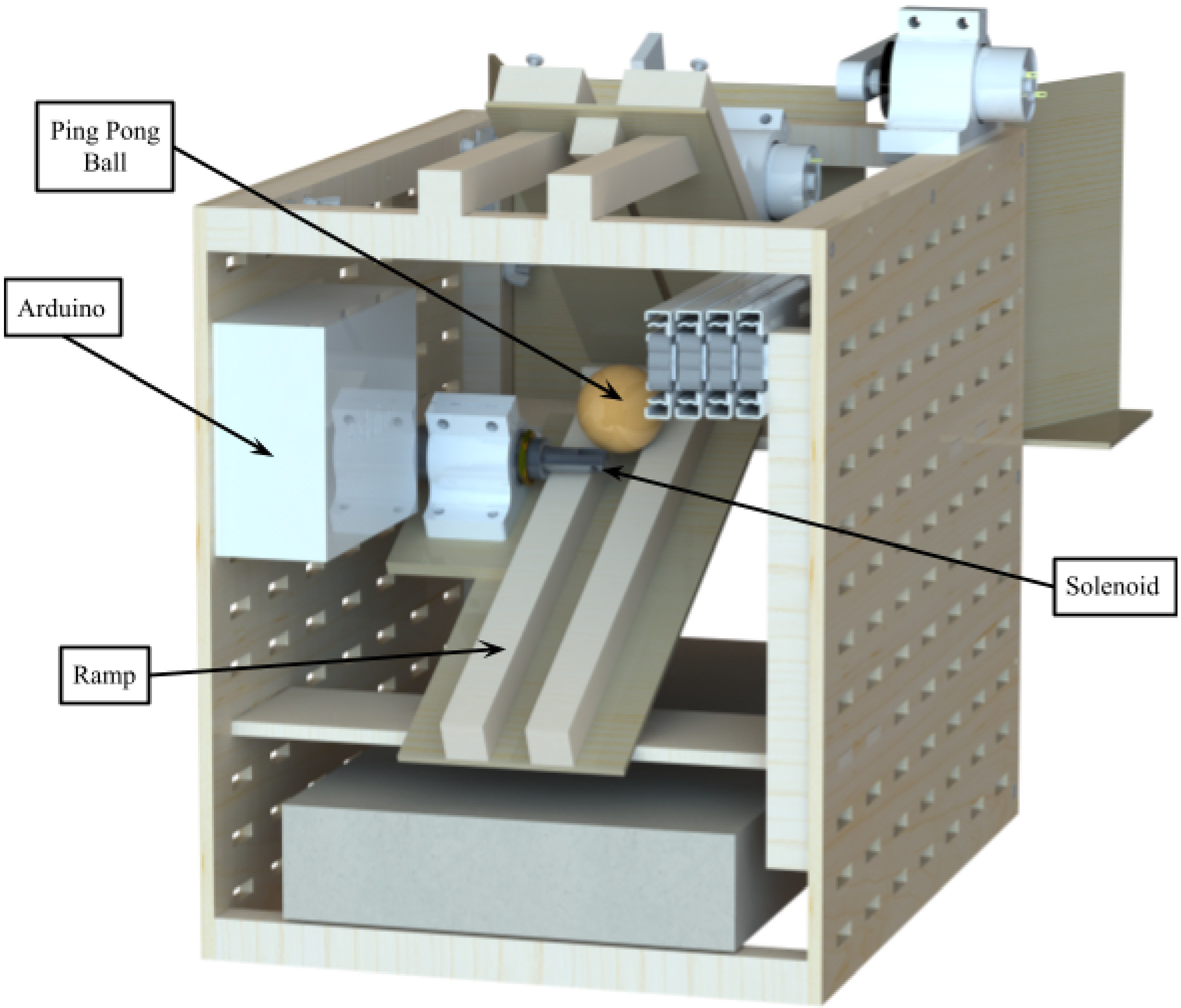


Figure 19: Pitchfork Design Pass Mechanism

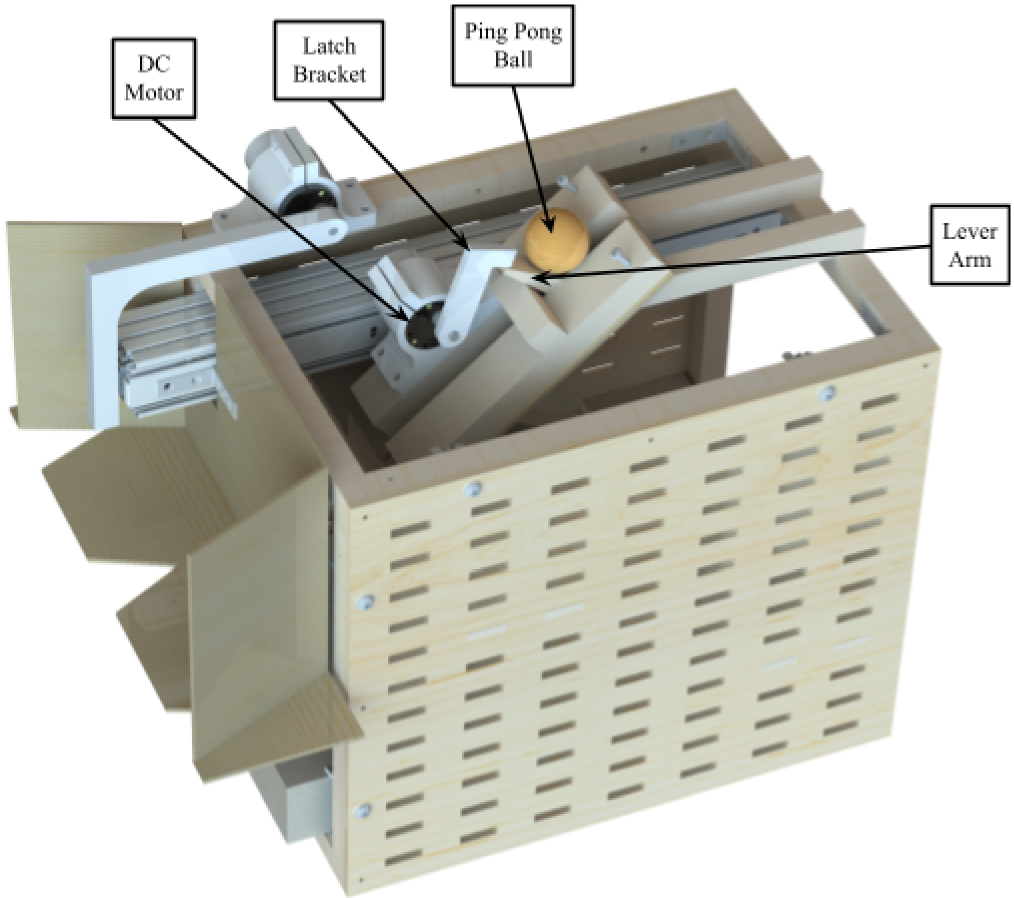


Figure 20: Pitchfork Design Jumpshot Mechanism

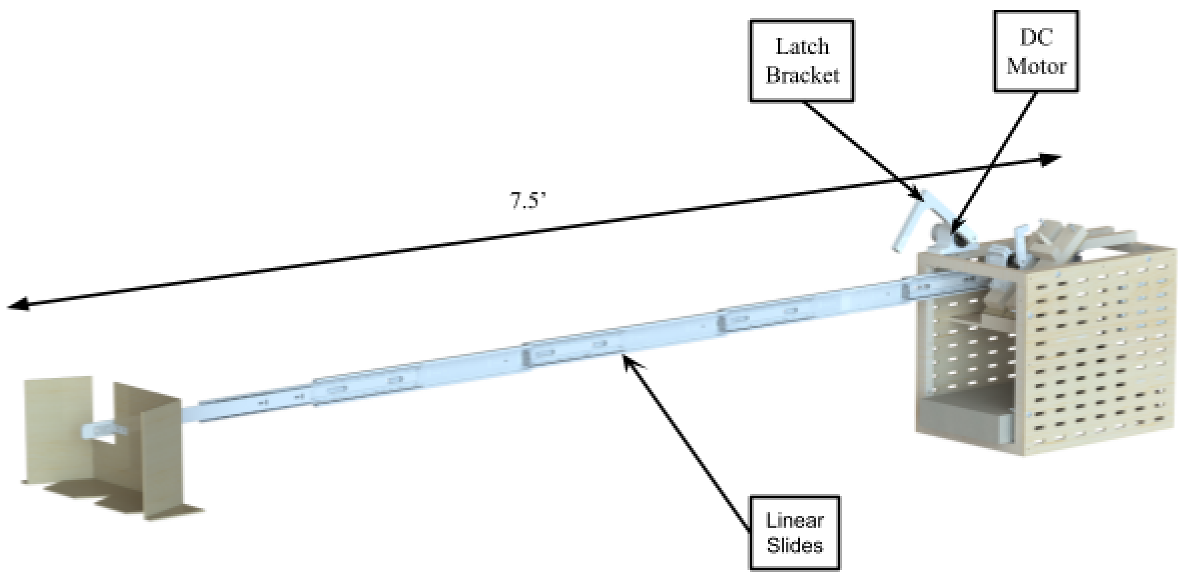
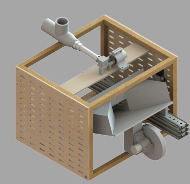
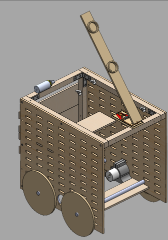
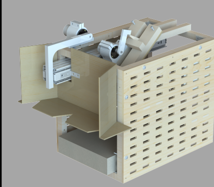
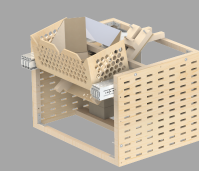


Figure 21: Pitchfork Design Deployed State

Table 22: First Level Evaluation Matrix

Criteria	Cannon Design	Driving Design	Pitchfork Design	Final Design
Complete Launch Task	Datum	S	S	S
Complete Pass Task		-	+	+
Complete Jumpshot Task		S	+	+
Complete Dunk Task		-	+	+
Meet Sizing Requirements		+	+	+
Operate Autonomously		S	S	S
Don't Move Before Start & After End		S	S	S
Affordable		S	S	S
Safe to Operate		S	S	S
Consistently Perform Tasks		-	+	+
Portable		+	+	-
Easy to Set Up		-	-	+
Aesthetically Pleasing		S	-	+
sum +	0	2	6	7
sum S	13	8	5	5
sum -	0	4	2	1
Total	0	-2	4	6
Rank	3	4	2	1

Table 23: Third Level Evaluation Matrix

Criteria	Importance	Cannon Design		Driving Design		Pitchfork Design		Final Design	
									
		Rating	Weighted Total	Rating	Weighted Total	Rating	Weighted Total	Rating	Weighted Total
Complete Launch Task	9	4	36	4	36	4	36	4	36
Complete Pass Task	6	3	18	2	12	3	18	3	18
Complete Jumpshot Task	7	3	21	3	21	4	28	4	28
Complete Dunk Task	8	2	16	0	0	1	8	3	24
Meet Sizing Requirements	10	1	10	4	40	4	40	4	40
Operate Autonomously	10	4	40	4	40	4	40	4	40
Don't Move Before Start & After End	10	4	40	4	40	4	40	4	40
Affordable	10	3	30	4	40	3	30	2	20
Safe to Operate	7	4	28	4	28	4	28	4	28
Consistently Perform Tasks	5	2	10	1	5	3	15	4	20
Portable	4	1	4	3	12	1	4	1	4
Easy to Set Up	6	3	18	3	18	2	12	3	18
Aesthetically Pleasing	1	2	2	2	2	2	2	3	3
Total		36	273	38	294	39	301	43	319
Relative Total		0.73		0.79		0.81		0.86	
Rank		4		3		2		1	

<u>Scale:</u> 4 = very good, 3 = good, 2 = adequate, 1 = just tolerable, 0 = unsatisfactory

Table 24: Competition Scores

Sprint 1							
Run #	Launch	Pass	Jumpshot	Dunk Ball Score	Money Ball 1 Score	Money Ball 2 Score	Total Score
1	1	3	8	1	1	1	15
2	1	1	8	1	1	6	18
3	1	3	8	1	6	6	20
						Average Score:	17.7
Sprint 2							
Run #	Launch	Pass	Jumpshot	Dunk Ball Score	Money Ball 1 Score	Money Ball 2 Score	Total Score
1	1	3	8	3	8	6	29
2	1	3	8	3	8	6	29
3	1	3	8	3	6	8	27
						Average Score:	28.3
Final Competition							
Run #	Launch	Pass	Jumpshot	Dunk Ball Score	Money Ball 1 Score	Money Ball 2 Score	Total Score
1	1	3	8	0	0	0	12
2	1	3	8	1	8	8	29
3	1	3	8	1	8	8	29
						Average Score:	23.3

Table 25: Results from Testing

Testing Results							
Run #	Launch	Pass	Jumpshot	MB 1 Score	MB 2 Score	Dunk Score	Total Score
1	1	3	8	8	1	1	22
2	1	3	8	8	8	1	29
3	1	3	8	8	10	1	31
4	1	3	8	8	8	1	29
5	1	3	8	8	8	1	29
6	1	3	8	8	8	1	29
7	1	1	8	8	8	1	27
8	1	3	8	6	8	1	27
9	1	1	8	6	8	1	25
10	1	3	8	8	1	1	22
						Average Score:	27

References

[1] "indianaconstructors.org," Indiana Constructors, Inc., 17 October 2018. [Online]. Available: https://indianaconstructors.org/pinch-shear-wrap-and-crush-points/. [Accessed 19 February 2021].

[2] T. Galassi, "osha.gov," United States Department of Labor, 5 April 2015. [Online]. Available: https://www.osha.gov/laws-regs/standardinterpretations/2013-06-04-0. [Accessed 19 February 2021].

Contributions Statement

1. Cole Sosnowski - Contributed toward the generation of CAD, creation of figures, writing the alternate design section, creating the bill of materials, as well as final editing.
2. Neel Maity - Contributed toward the creation of figures and writing the problem understanding and design overview section, as well as final editing
3. Josh Zeisloft - Contributed toward the generation of figures, writing the abstract, introduction and discussion sections, as well as final editing.
4. Hunter Schaufel - Contributed toward the generation figures, writing the problem understating section and conclusion, as well as final editing.