Fall 2018

Group O - Lacrosse Ball Passer

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Executive Summary

The goal of our design group was to make a lacrosse ball passer that could be used in a team practice or individual setting. Wayne Jaekle, WashU's head lacrosse coach defined major customer needs as producing a consistent pass speed and angle, an interactive interface allowing an automatic time interval between passes, and being easy to load. These needs lead to our main design goals: 1. A ball capacity of 30, 2. A minimum pass speed of 30 mph, and 3. A 5 second time interval between passes. Mock ups and brainstorming exercises led to our team's selection of a concept to move forward with, a horizontal, two-wheeled design with a conveyor system used to feed balls between the wheels to launch the ball. Different engineering equations were used to determine the theoretical speed we could shoot a ball based on the diameter of our wheels, which helped guide us in the selection of motors and wheels. Once these parts were specified, they were mounted on a sheet of plywood at a ten degree angle, and the feeding mechanism was built off of this. We set a five gallon bucket above the motors with spiraled HVAC tube inside to hold the balls. The ball would drop from this bucket into a jai-Alai stick, which rolled the ball into a modified PVC pipe and into the wheels, launching the ball. This design met the goals of holding 30 balls and producing a 30 mph pass. Due to cost considerations and lack of time, a conveyor feeding system was not used, nor was a time interval for passes developed. After completing this project, our team learned the importance of sticking to a formulated design process and have become more inspired to attempt new designs.

MEMS 411: MECHANICAL ENGINEERING DESIGN PROJECT
FALL 2018

Lacrosse Ball Passer

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1 INTRODUCTION

The project that we have chosen for Mechanical Engineering Senior Design is the lacrosse ball passer. Lacrosse is a very fast paced sport and all players benefit from shooting drills that focus on catching a shooting with a 'quick release'. However, in order to practice this skill currently it requires multiple people and high levels of passing ability by the feeders, so it cannot be done alone. A machine that would launch a lacrosse ball at a realistic passing speed, and be able to do so with repeatable accuracy would have a very high demand in the lacrosse community from coaches and players alike. From our extensive discussion with WashU's Head Lacrosse Coach, Wayne Jaekle, there are certain features that our machine will need to have to accomplish the goal effectively, and to be the prefered machine compared to current market competitors. These features include: consistent pass speed/location/angle, locational mobility, wireless power, adjustable time between passes, and easy to load. Each of these features will have associated problems to overcome during design and will addressed and overcome by prototyping.

Figure 1: WashU Logo

Figure 2: Lacrosse Logo

2 PROBLEM UNDERSTANDING

2.1 BACKGROUND INFORMATION STUDY

Similar Existing Devices:

2.1.1 Jugs 18-Ball Baseball Feeder

Figure 3: Jugs Pitching Machine

Link: https://jugssports.com/ball-feeders/18-ball-baseball-feeders/

Description: The Jugs 18-Ball Baseball Feeder is a device used to throw multiple baseballs one after another. Two wheels driven by an electric motor are used to throw a baseball every six seconds at a prescribed speed and direction. The motor and wheels sit on a collapsible tripod base, and a storage track attaches to the motor and is additionally supported with a bipod base. The storage track is set at a downward angle towards the wheels to gravity feed up to eighteen baseballs before having to manually reload again. A timed rolling mechanism allows one ball to drop into the wheels every six seconds.

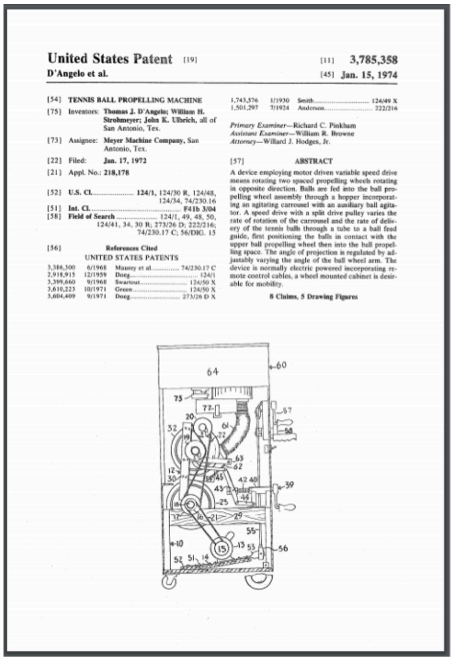
2.1.2 The Gun

Figure 4: The Gun Basketball Returner

Link: http://sportcourtsfitness.com/gun/

Description: The Gun is an automatic basketball rebounding and passing device. It includes a collection net that catches made or missed shots and funnels the basketball down into the base of the device. The base can accommodate two basketballs so one can be shot by the player and another can be passed out of the body to the player shortly after. An adjustable timing mechanism is used to regulate how quickly another ball will be passed after each shot. The collection net is supported by 4 aluminum poles that collapse down for storage, while the base rests on four wheels for portability.

2.1.3 Tennis Ball Feeder Patent



United States Patent [19] [11] **3,785,358**
D'Angelo et al. [45] **Jan. 15, 1974**

[54] **TENNIS BALL PROPELLING MACHINE**
[75] Inventors: **Thomas J. D'Angelo; William H. Strohmeyer; John K. Ulbrich,** all of San Antonio, Tex.
[73] Assignee: **Meyer Machine Company,** San Antonio, Tex.
[22] Filed: **Jan. 17, 1972**
[21] Appl. No.: **218,178**

[52] **U.S. Cl.** .... **124/1,** 124/30 R, 124/48, 124/34, 74/230.16
[51] **Int. Cl.** **F41b 3/04**
[58] **Field of Search** .... 124/1, 49, 48, 50, 124/41, 34, 30 R; 273/26 D; 222/216; 74/230.17 C; 56/DIG. 15

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Primary Examiner—Richard C. Pinkham
Assistant Examiner—William R. Browne
Attorney—Willard J. Hodges, Jr.

[57] **ABSTRACT**

A device employing motor driven variable speed drive means rotating two spaced propelling wheels rotating in opposite direction. Balls are fed into the ball propelling wheel assembly through a hopper incorporating an agitating carrousel with an auxiliary ball agitator. A speed drive with a split drive pulley varies the rate of rotation of the carrousel and the rate of delivery of the tennis balls through a tube to a ball feed guide, first positioning the balls in contact with the upper ball propelling wheel then into the ball propelling space. The angle of projection is regulated by adjustably varying the angle of the ball wheel arm. The device is normally electric powered incorporating remote control cables, a wheel mounted cabinet is desirable for mobility.

8 Claims, 5 Drawing Figures

Figure 5: Patent for Tennis Ball Propelling Machine

Patent Number: US3785358A

Description: This is a patent for an automatic tennis ball feeder. The key features in the patent are that it can deliver a tennis ball with substantial topspin that replicates how an elite level player would hit the tennis ball. It also mentions the claim to a flexible tube feeding system with a large hopper to store multiple balls and a housing with exterior wheels for portability.

2.2 USER NEEDS

Table 1 - Customer Needs Interview

Product: Lacrosse Ball Thrower **Customer: Wayne Jaekle, WashU Club Men's Lacrosse Head Coach**			
Question	Customer Statement	Interpreted Need	Imp.
Current issues to address	An apparatus to periodically pass a lacrosse ball	Machine produces **consistent pass speed/angle**	5
Self-reloading a need?	Cleaning up balls takes a while, would help but isn't totally necessary. More important to have easy reload	**Easy to load** with balls	3
Need the apparatus to be mobile?	Would be helpful to give different angles for passes, but can be stationary if need be	Apparatus Mobility	4
Cycle time?	Might be useful to change for full team practices as opposed to a solo session	Interactive Interface/**variable time interval** b/w passes	5
Electric or Battery Powered	Pulling out a long cord might be difficult, would be easier if battery-powered	Wireless Power	4
Appearance a factor?	Doesn't need to look sleek, just needs to get the job done	Apparatus Appearance	2

2.3 DESIGN METRICS

Table 2: Interpreted Customer Needs

Need Number	Need	Importance
1	Machine produces consistent pass speed/angle	5
2	Easy to load with balls	3
3	Apparatus Mobility	4
4	Interactive Interface	5
5	Wireless Power	4
6	Apparatus Appearance	2

Table 3: Target Specifications

Metric Number	Associated Needs	Metric	Units	Acceptable	Ideal
1	2	Ball Capacity	# of balls	30	50
2	3	Total Weight	lb	100	50
3	1, 4	Fastest pass rate (Δt between throws)	seconds	5	3
4	1	Accuracy of Pass	in^2	18	12
5	1	Speed of pass	mph	30-50	20-70
6	5	Battery Life	minutes	60	120+

3 CONCEPT GENERATION

3.1 MOCKUP PROTOTYPE

Figures 6-8: Different Angled Views of Mockup Lacrosse Ball Passer

Description: The mockup we created in studio uses two horizontal spinning wheels to propel lacrosse balls. A conveyor belt is used to transfer and load each lacrosse ball using extrusions to secure each ball on the belt. The conveyor belts upper shaft is resting on two supports that allow it to rotate freely. The lower shaft is connected to the housing and is powered by a battery located within the housing. The ball storage mechanism is a slanted vessel that uses gravity to deliver the balls to the conveyor belt. The whole thing is housed in a light shell that has a dolly attachment, which allows for transport.

3.2 FUNCTIONAL DECOMPOSITION

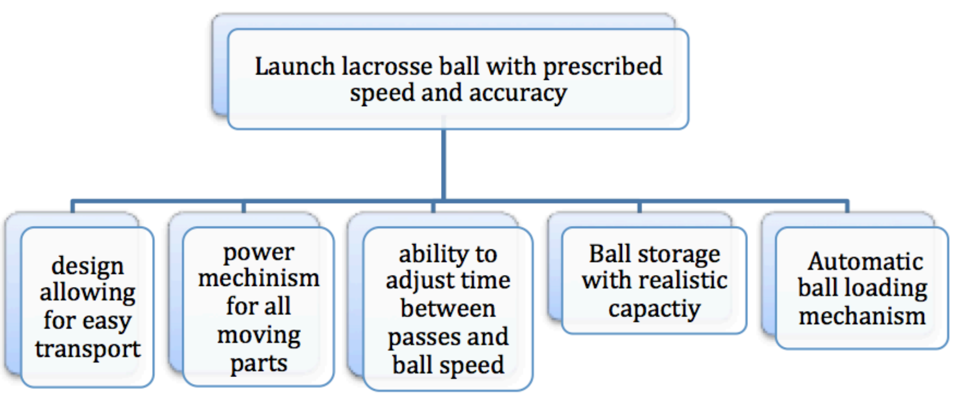


Figure 9: Function Tree of Lacrosse Ball Passer

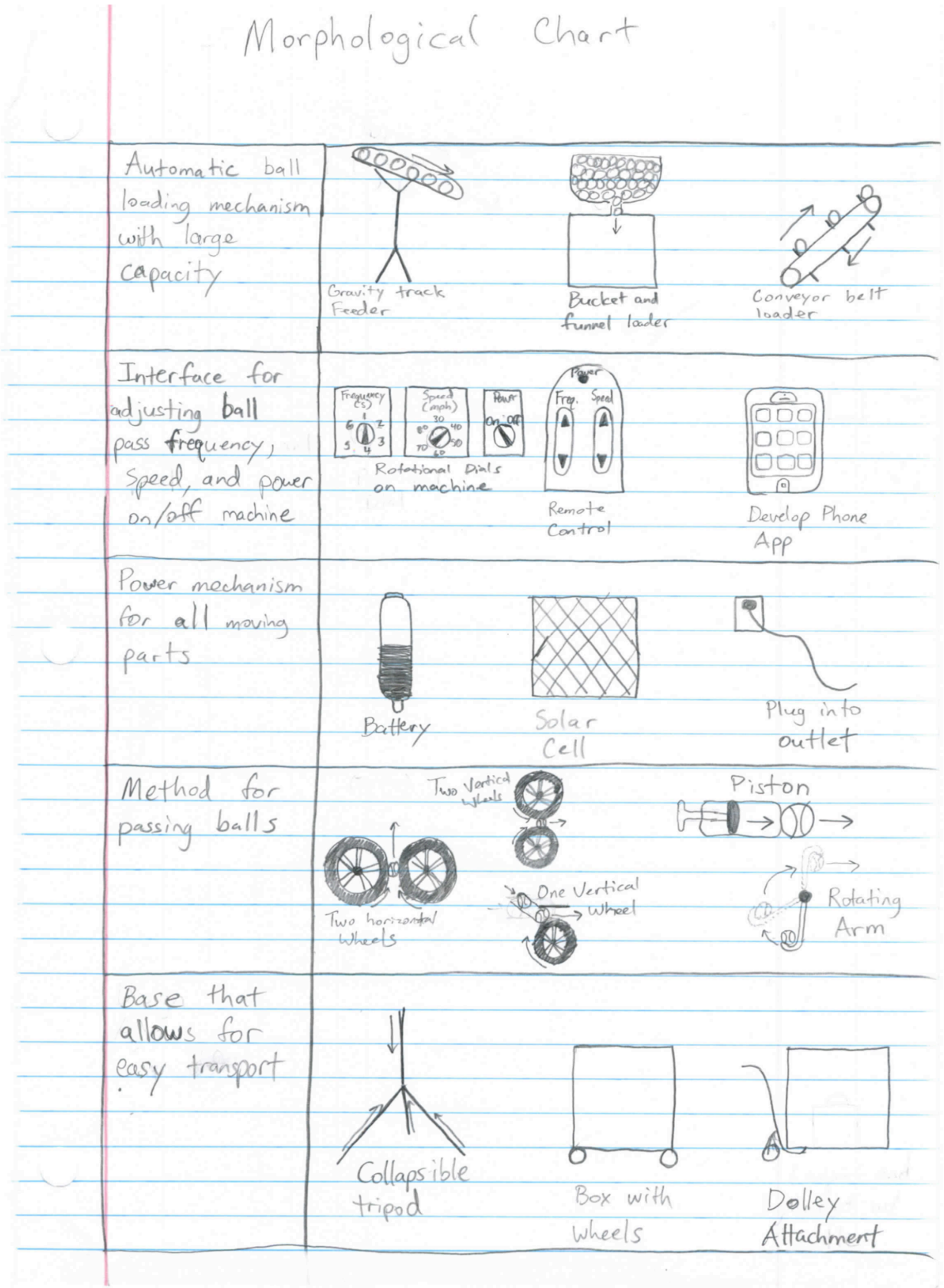


Figure 10: Morphological Chart for Lacrosse Ball Passer

3.3 ALTERNATIVE DESIGN CONCEPTS

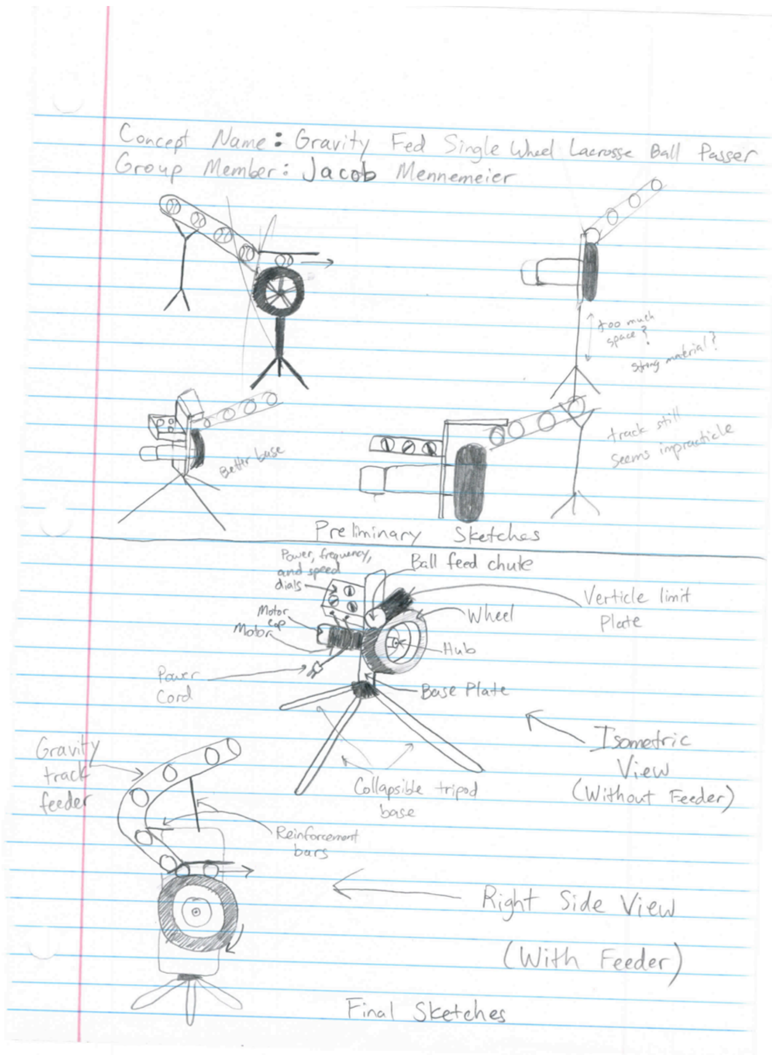


Figure 11: Preliminary and Final Sketches of Gravity Fed Single Wheel Passer

Description: The Gravity Fed, Single Wheel Lacrosse Ball Passer is powered by an electric motor that spins a wheel to propel a lacrosse ball forward. A curved tube allows gravity to feed the balls into the wheel, and dials are used to manually adjust speed and frequency of passes as well as turning the machine on and off.

Solutions used:

1. Gravity feeder
2. Rotational dials
3. Plug into outlet
4. One vertical wheel
5. Collapsible tripod

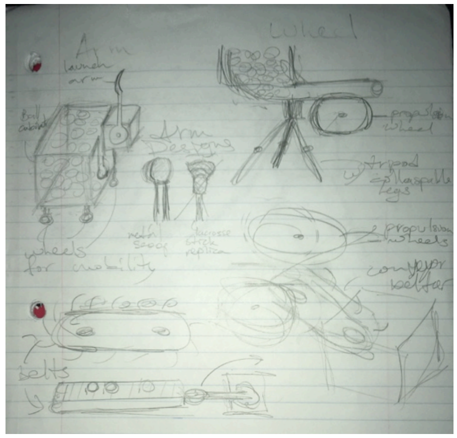


Figure 12: Preliminary Sketches of Lacrosse Ball Passer

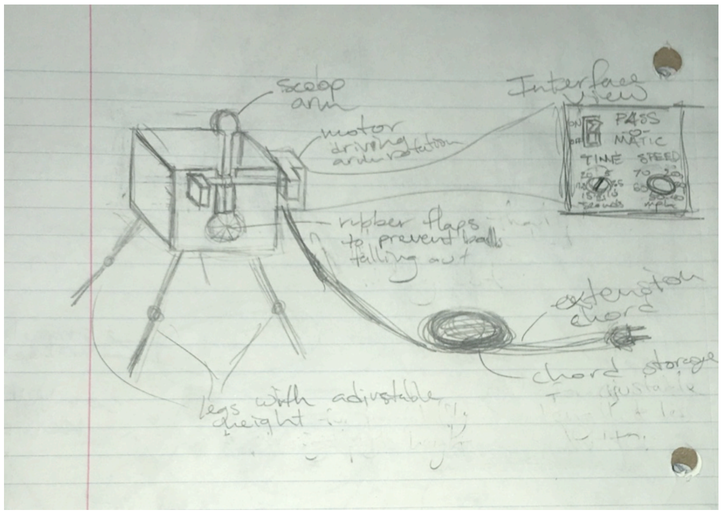


Figure 13: Final Sketch of Rotating Arm Passer

Description: The Rotating Arm Lacrosse Ball Passer is powered using an extension chord, which was chosen for reduced size and weight for increased mobility, and uses a rotating arm to fire lacrosse balls at desired speeds and time intervals. It functions primarily by a motor powered rotating shaft which drives the scoop arm around in circles to collect and then launch lacrosse balls. The cabinet, which opens upwards and holds up to 50 lacrosse balls, has rubber flaps that allow the arm to rotate into the ball cabinet and keeps balls from falling out. It is supported by 4 retractable legs that can be retracted for storage and for obtaining different launch heights. On the side of the box housing the motor is a switch and dial interface used for turning the machine off/on and changing the speed and time between pass.

Solutions:

1. Bucket and gravity ball loader
2. Rotating Dials
3. Four Collapsible legs
4. Plug into wall w/ adjustable extension chord
5. Rotating Arm

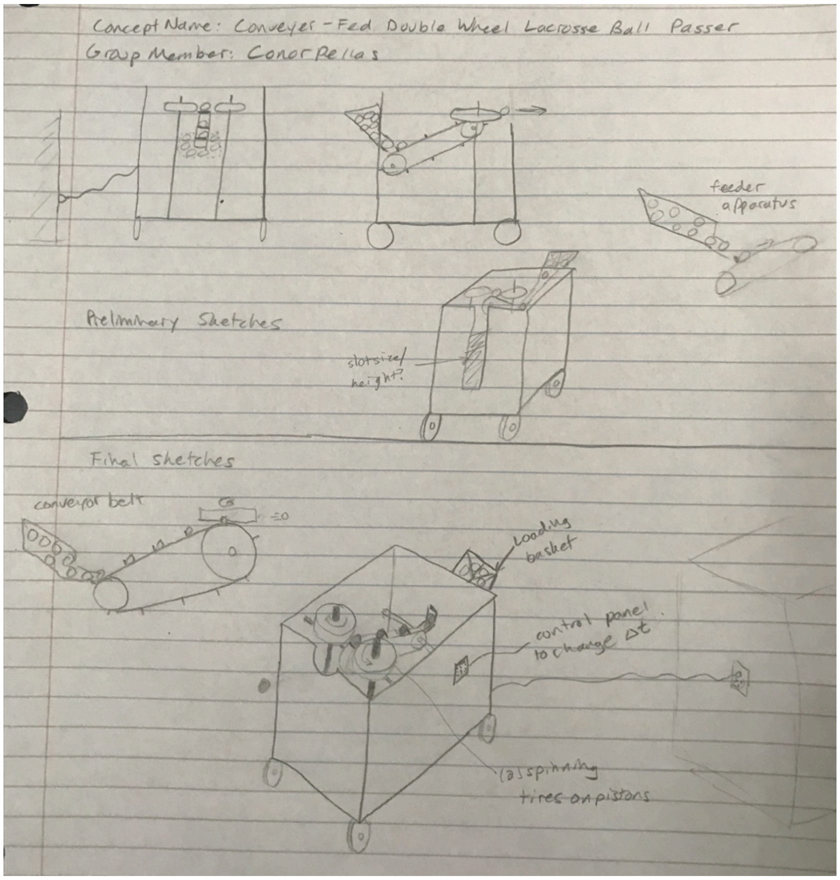


Figure 14: Preliminary and Final Sketches of Conveyor-Fed Double Wheel Lacrosse Ball Thrower

Description: The Conveyor-Fed Double Wheel Lacrosse Ball Thrower is electrically powered via chord and operates using a conveyor system with teeth equally spaced apart, fed by gravity from behind the apparatus in a loading basket. The interface on the side has options for changing the conveyor belt speed, and also the tire speed that catches the ball via friction and accelerates the ball. The system launches the ball at a specified speed at a fixed angle of release.

Solutions:

1. Plug Into Outlet
2. Keypad Interface Control Panel
3. Gravity-Fed Loading Basket
4. Two Vertical Wheels
5. Box With Wheels
6. Conveyor Belt Loader

4 CONCEPT SELECTION

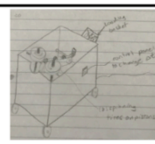
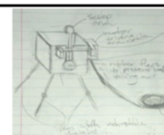
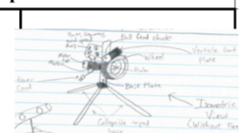
4.1 SELECTION CRITERIA

Table 4: AHP

	Produces consistent pass speed and angle	Has a large ball capacity	Apparatus is mobile	Easy to use, interactive interface	Looks attractive	Consistent ball loading apparatus	Row Total	Weight Value	Weight (%)
Produces consistent pass speed and angle	1.00	5.00	5.00	3.00	9.00	3.00	26.00	0.31	30.57%
Has a large ball capacity	0.20	1.00	3.00	0.20	7.00	0.33	11.73	0.14	13.80%
Apparatus is mobile	0.20	0.33	1.00	0.20	5.00	0.20	6.93	0.08	8.15%
Easy to use, interactive interface	0.33	5.00	5.00	1.00	7.00	1.00	19.33	0.23	22.73%
Looks attractive	0.11	0.14	0.20	0.14	1.00	0.11	1.71	0.02	2.01%
Consistent ball loading apparatus	0.33	3.00	5.00	1.00	9.00	1.00	19.33	0.23	22.73%
						Column Total:	**85.04**	**1.00**	**100%**

4.2 CONCEPT EVALUATION

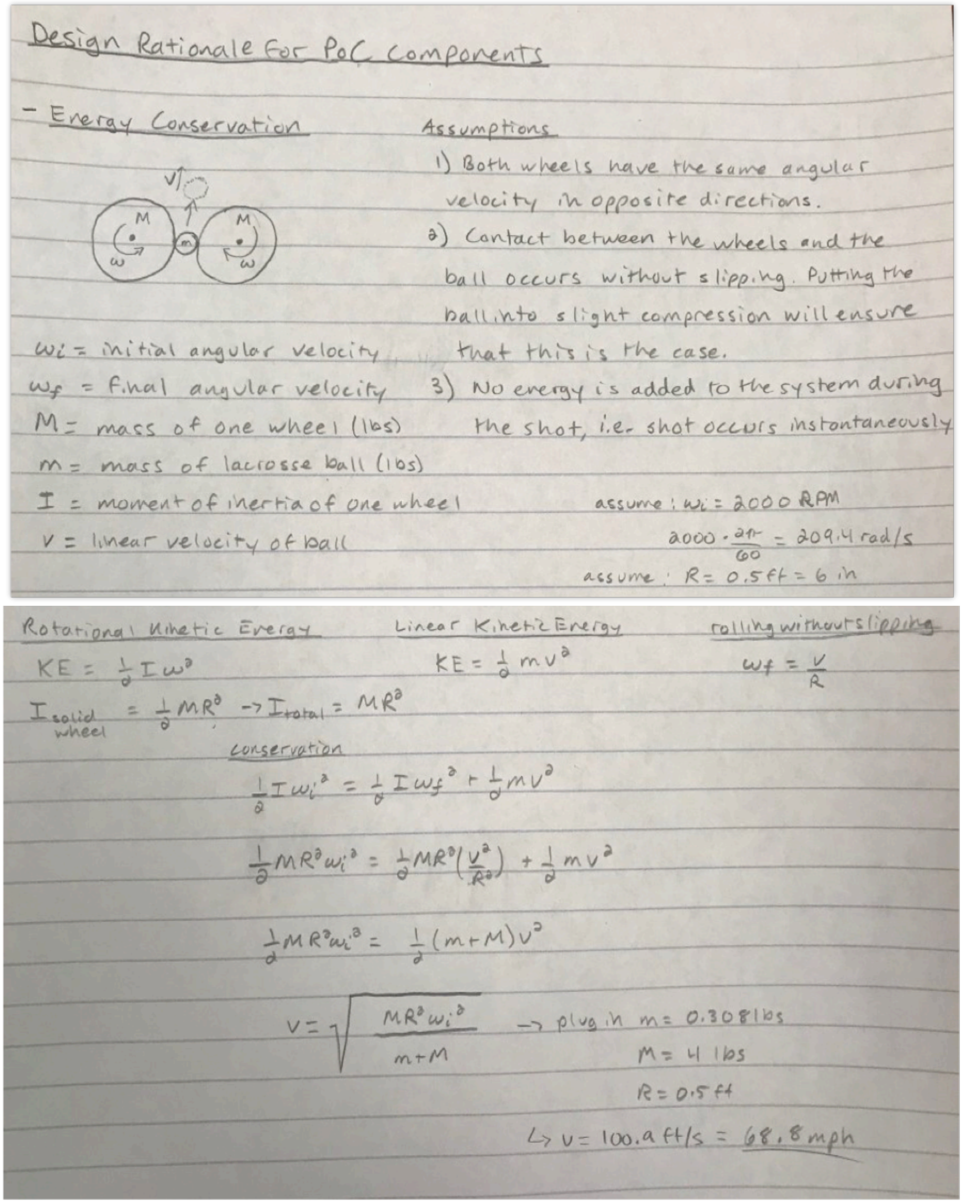
Table 5: Weighted Scoring Matrix

		Alternative Design Concepts					
							
Selection Criterion	**Weight (%)**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**
Produces Consistent Pass Speed and Angle	30.57	5	1.53	4	1.22	5	1.53
Has a Large Ball Capacity	13.8	4	0.55	5	0.69	3	0.41
Apparatus is Mobile	8.15	3	0.24	4	0.33	3	0.24
Easy to Use, Interactive Interface	22.73	4	0.91	5	1.14	4	0.91
Looks Attractive	2.01	2	0.04	2	0.04	2	0.04
Consistent Ball Loading Apparatus	22.73	4	0.91	2	0.45	3	0.68
	Total score	**4.184**		**3.870**		**3.818**	
	Rank	**1**		**2**		**3**	

4.3 EVALUATION RESULTS

Looking at the results, it was clear that there was much importance placed on the absolutely necessary functions of the lacrosse thrower apparatus. In the case of each design succeeding in a consistent angle and speed of pass, the only one that might show some randomness is the armature, yet it is still unclear how accurate any design will be. In addition, the consistent ball loading apparatus criterion has a lot of weight to it in order to try to mitigate the variability in passes, which is important to machines that want to be consistently functional with respect to the customer's needs and wants. The designs all vary in support systems, the winning design with wheels while the other designs focus on a triangular pattern for easy portability. However, since the need for full mobility wasn't as dire, the effects of the scoring weren't realized as much in the end. Ball capacity was more on the important side as well, as the client expressed they would rather not have to reload the machine very often if possible. Each design scored high in their own respect, however the design with 2 wheels won in the end.

4.4 ENGINEERING MODELS/RELATIONSHIPS



Design Rationale for PoC Components

- Energy Conservation

Assumptions
1) Both wheels have the same angular velocity in opposite directions.
2) Contact between the wheels and the ball occurs without slipping. Putting the ball into slight compression will ensure that this is the case.
3) No energy is added to the system during the shot, i.e. shot occurs instantaneously

ω_i = initial angular velocity
ω_f = final angular velocity
M = mass of one wheel (lbs)
m = mass of lacrosse ball (lbs)
I = moment of inertia of one wheel
v = linear velocity of ball

assume: $\omega_i = 2000$ RPM

$2000 \cdot \frac{2\pi}{60} = 209.4$ rad/s

assume: $R = 0.5$ ft $= 6$ in

Rotational Kinetic Energy

$KE = \frac{1}{2} I \omega^2$

$I_{\text{solid wheel}} = \frac{1}{2} M R^2 \rightarrow I_{total} = M R^2$

Linear Kinetic Energy

$KE = \frac{1}{2} m v^2$

rolling without slipping

$\omega_f = \frac{v}{R}$

conservation

$$\frac{1}{2} I \omega_i^2 = \frac{1}{2} I \omega_f^2 + \frac{1}{2} m v^2$$

$$\frac{1}{2} M R^2 \omega_i^2 = \frac{1}{2} M R^2 \left(\frac{v^2}{R^2}\right) + \frac{1}{2} m v^2$$

$$\frac{1}{2} M R^2 \omega_i^2 = \frac{1}{2}(m+M) v^2$$

$$v = \sqrt{\frac{M R^2 \omega_i^2}{m+M}}$$

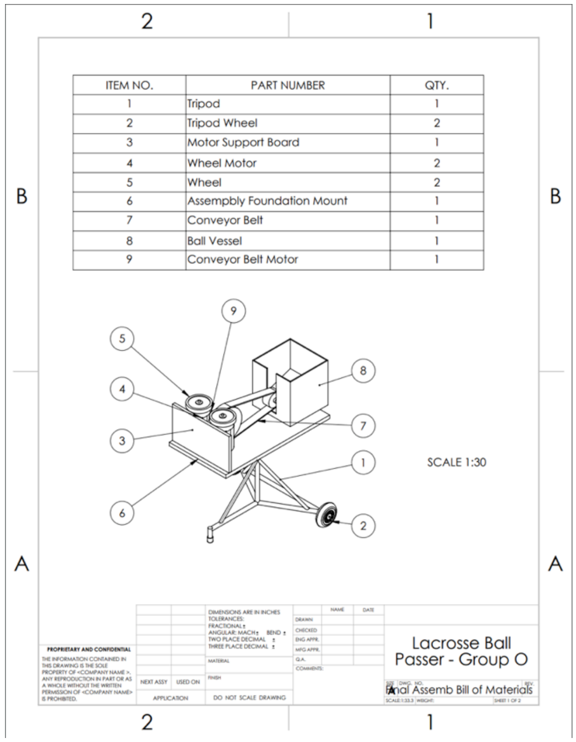
→ plug in $m = 0.308$ lbs, $M = 4$ lbs, $R = 0.5$ ft

↳ $v = 100.9$ ft/s $= 68.8$ mph

Figure 15-16: Engineering Model for Motor Energy Analysis

5 CONCEPT EMBODIMENT

5.1 INITIAL EMBODIMENT



ITEM NO.	PART NUMBER	QTY.
1	Tripod	1
2	Tripod Wheel	2
3	Motor Support Board	1
4	Wheel Motor	2
5	Wheel	2
6	Assemply Foundation Mount	1
7	Conveyor Belt	1
8	Ball Vessel	1
9	Conveyor Belt Motor	1

Figure 17: CAD Drawing of Initial Embodiment

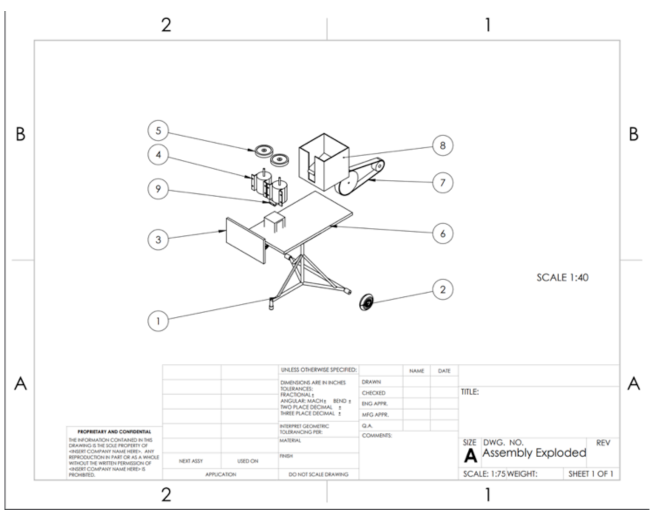


Figure 18: Exploded CAD Drawing of Initial Embodiment

5.2 PROOF-OF-CONCEPT

Performance Goals:

- Pass ball at 30 mph
    - Preferably want to get to a higher speed, but this is a good benchmark for us.
- Pass ball at time minimum interval of 5 seconds
- Ball capacity of 30 (i.e machine can run autonomously for a 30-ball cycle without failure)

CAD Embodiment

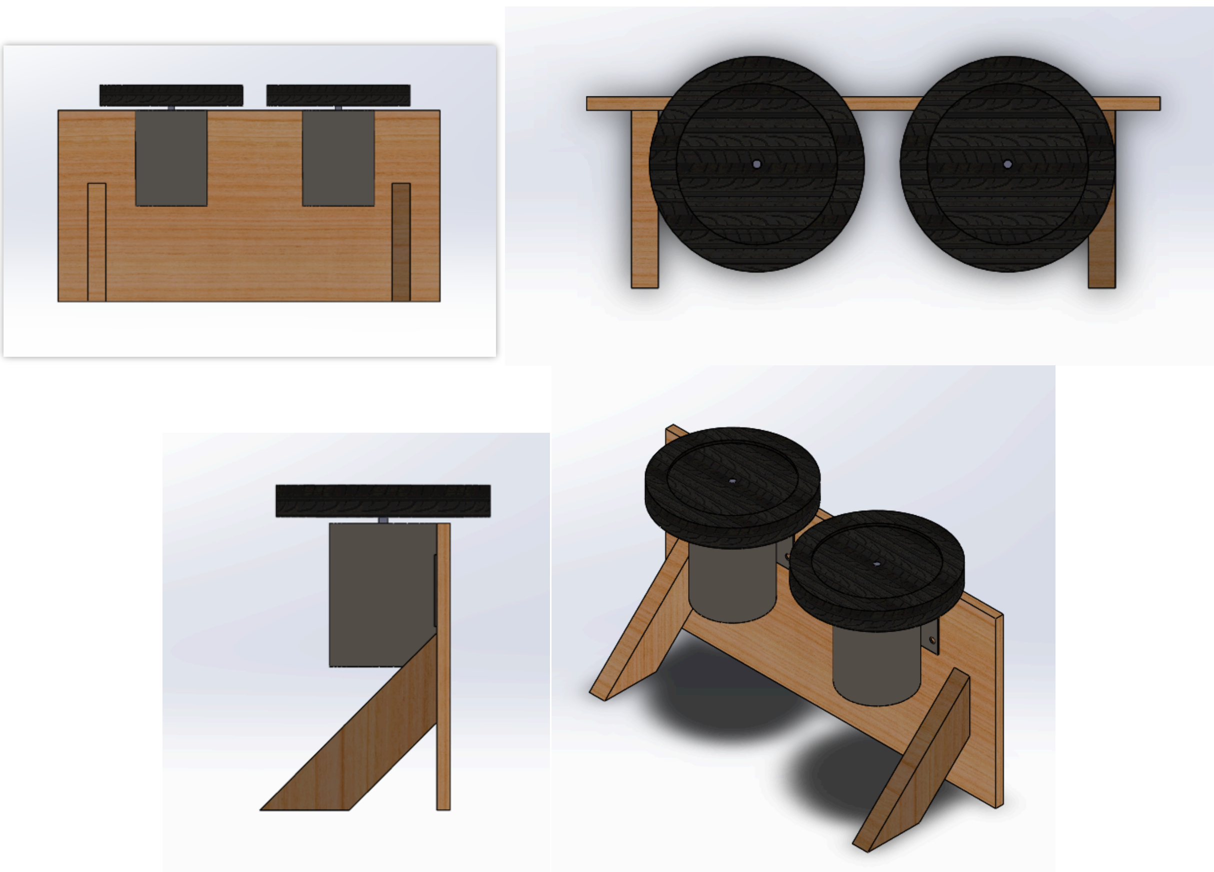


Figure 19-22: CAD Model of Working PoC Prototype

PoC Prototype

Figure 23-26: Images of PoC Prototype

6 WORKING PROTOTYPE

6.1 OVERVIEW

In the transition from our PoC prototype to our working prototype, we made the following changes/additions: secured an identical backboard onto the existing backboard to increase thickness and strength, secured the entire apparatus to a bottom wood board, crafted a ball track using PVC and a repurposed Jai-Alai stick, repurposed a bucket along with an aluminum chute to make the ball-loading apparatus, and crafted supports for the bucket/track and secured them to the bottom board.

6.2 DEMONSTRATION DOCUMENTATION

Figure 27-30: Images of Working Prototype

6.3 EXPERIMENTAL RESULTS

The first performance goal was to be able to launch a ball at 30 mph, and one of our demonstrations showed a speed of around 28 mph. We are confident our prototype could get to a higher pace, however the electrical limitations associated with our motors kept us from testing at much higher speeds. We also realized that as the speed of the wheels reached levels higher than 30 mph, the vibration levels increased dramatically, which put the other components of our working prototype at risk of not functioning properly. As it currently stands, an individual must plug the machine into a wall for only 3-4 seconds before unplugging, to ensure safety.

Our next performance goal we met was having at least a 30-ball capacity within the prototype. The goal here was to make it realistic enough so that a large team could go through a set of launches without having to reload balls too often. We ended up exceeding our goal, with our apparatus holding 34 balls at its maximum. The most difficult parts of housing the balls was minimizing the space that it would occupy and also the nature of how they needed to be arranged so that none of the balls would get stuck. In the end, our solution proved to solve both these issues.

The one performance goal we weren't able to meet was the time-delay between launches. We understood from the onset that this aspect of our design would be the most difficult to research and master, and when it came to the final stages of our prototype construction, it became too tall of a task for our group to accomplish. We were much more focused on ensuring the ball would consistently launch in a good fashion, and with more time, we believe we could have taken the next step to solve the time-delay issue.

7 DESIGN REFINEMENT

7.1 DESIGN FOR SAFETY

Wheel Attachment

Risk Name: Wheel Attachment

Description: Due to cost considerations, the wheels used to attach to the motors on our device had to have an independently spinning bearing epoxied so it wouldn't turn and this bearing was also epoxied to the motor shafts. These areas are being put under a large force each time the motors turn, and if the epoxy doesn't hold, a wheel could potentially fly off the motor.

Impact: 3. While the wheel will be spinning at a very high rate, the motor shaft would most likely cause the wheel to shoot straight up, making it difficult to hit anyone standing in a likely position upwards of 5 feet away. However, if the wheel grips the ground well, it could shoot off the ground and hit somebody's feet or shins.

Likelihood: 2. The 2 part epoxy we chose is rated to withstand 4250 psi. Theoretically, the factor of safety of this happening is .

7.3.2 - Pinch Hazard

Risk Name: Pinch Hazard

Description: The wheels that are used to shoot the lacrosse ball are spaced approximately 2 1/8" apart and if a hand were placed in this space while operating the device, it could get pulled through similarly to a ball. This risk would be especially present if a ball were stuck in the device and someone tried to dislodge it with their hand.

Impact: 5. Under the correct circumstances, it isn't hard to imagine someone breaking their hand due to this risk.

Likelihood: 3. It seems reasonable that a ball would eventually get stuck in the device. If the device wasn't powered down when removing the ball, someone could definitely hurt their hand. Also, while our group continues making a feeding device, our hands have to be somewhat close to the wheels to test the device, so we are at a higher risk during earlier stages of the project.

7.3.3 - Ball Striking

Risk Name: Ball Striking

Description: The device is intended to launch a projectile in the direction of a human. Appropriate equipment and protective gear is advised during use, however, a ball could strike a person in flight. Failures that could result in being struck by a ball could be vibration of the motors, lean in the wheels, or a worn down ball, all of which could cause a ball to travel away from its intended mark.

Impact: 5. Whether it be the person who is intentionally using the device or a random passerby, a failure in the device could cause a ball to strike somebody in the head, causing a concussion or other brain damage.

Likelihood: 5. If the device is used enough times, it will almost assuredly hit somebody at some point.

7.3.4 - Electrical Shock

Risk Name: Electrical Shock

Description: The device is wired through the back of the motors and through a power cord that is plugged into a standard 120 volt wall outlet. If a wire were to come loose and needed to be worked on and the device was not unplugged, there would be a risk of electrical shock.

Impact: 2. Since the device is used with standard wall outlets, the risk of the shock isn't too severe. However, someone with a pre-existing heart condition could see a significant impact from this risk.

Likelihood: 1. The wiring is very tightly secured and most likely will not come apart.

7.3.5 - Heat/Fire

Risk Name: Heat/Fire

Description: The motors do not have internal capacitors to keep them from burning up during use. So, if running at max rpm, the motors could get very hot to the touch as well as possibly start a fire.

Impact: 3. While a fire is always a dangerous event, the area could be fairly easily contained due to the size and power of the motors being relatively small at only ¼ hp.

Likelihood: 2. A controller will be added to the device so the power can be regulated to prevent this issue. However, when testing the devices full capabilities, it could be worked at close to max rpm.

7.3.6 - Heat Map and Risk Prioritization

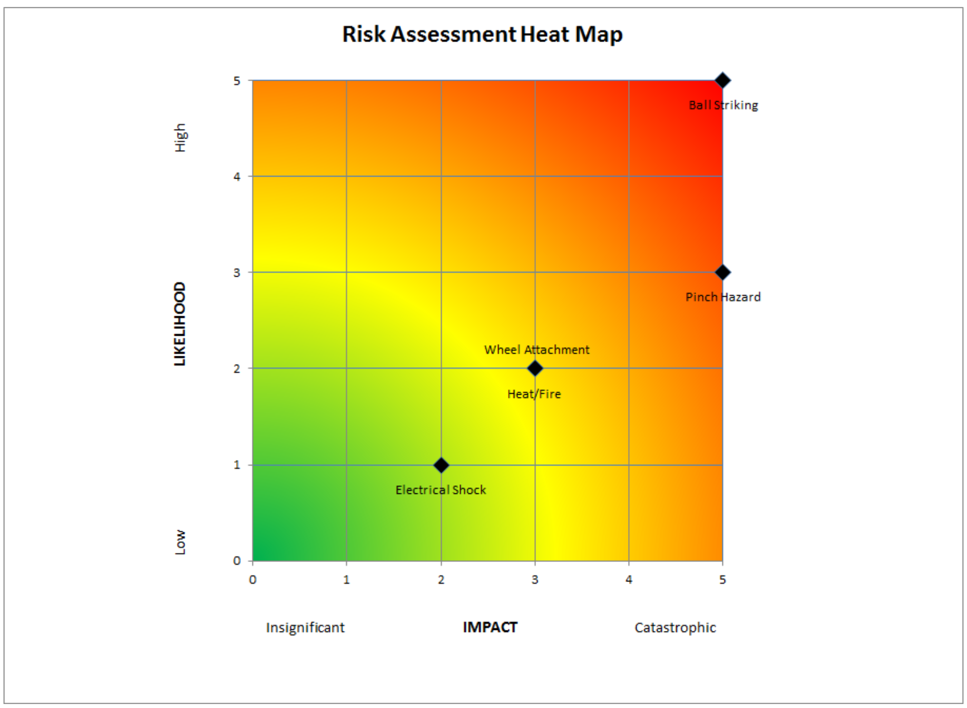


Fig. 33: *Risk Assessment Heat Map*

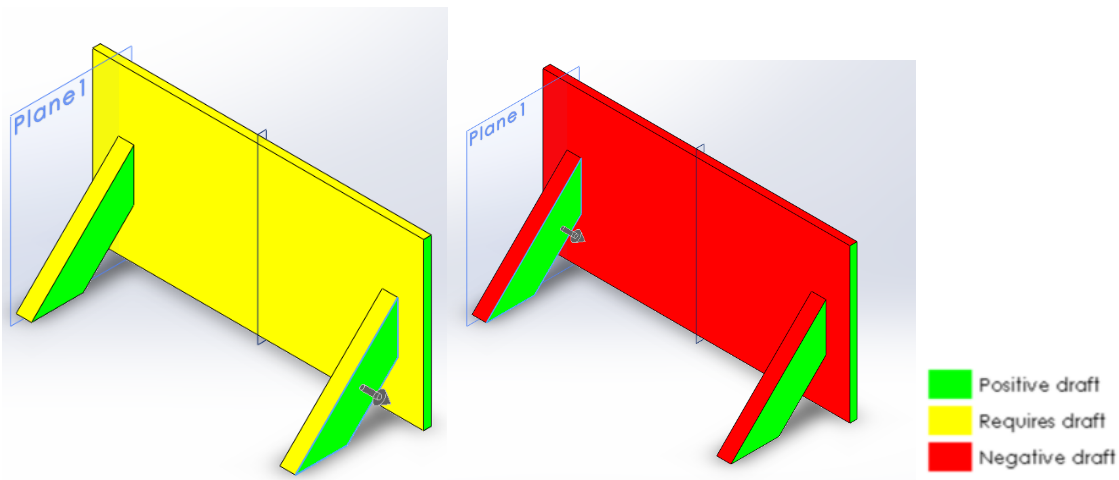
As shown by the heat map, the risk priorities are ordered from highest priority to lowest in the following order:

1. Ball Striking
2. Pinch Hazard
3. Heat/Fire
4. Wheel Attachment
5. Electrical Shock

Ball striking is easily the highest priority risk because it has the most opportunity to happen and can lead to severe injury. Pinch hazard is next highest because while the impact can be quite high (a broken hand), there just aren't many situations where the opportunity would take place. The only reason the likelihood is a 3 is due to multiple adjustments that need to be made during testing. Next, heat/fire and wheel attachment each had the same risk score, but we placed heat/fire as a higher priority. This was because the epoxy work is already finished and largely being relied on no matter what because it cannot be undone. Our future choice of how to control our motors' power will be prioritized to prevent overheating or a fire. Lastly, electrical shock was the least prioritized risk. This was due to the fact that the likelihood of electrical work needing to be done is minimal along with the potential impact of the failure

7.2 DESIGN FOR MANUFACTURING

7.4.1 - Draft Analysis



Before **After**

Fig. 34: *Before and after images of a Solidworks part using "Draft Analysis"*

To create either positive or negative drafts, we changed the surfaces from being exactly 90 degree angles to having an angle suitable for a molded or cast part. From the back of the part to the front, the base plate was given an extra 3 degree draft angle which made the part suitable to pass the draft analysis for only positive and negative drafts.

7.4.2 - DFM Analysis

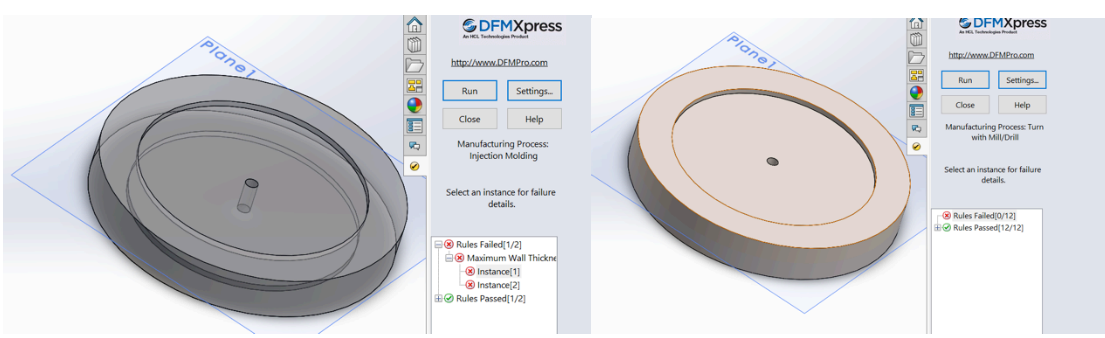


Fig. 35: *DFM analysis on wheel Solidworks part with injection molding and turn with mill/drill manufacturing processes.*

The first Design for Manufacturing analysis contained a failure for maximum wall thickness. This was to be expected because of wheel of this geometry would not be a part that is typically injection molded. The second Design for Manufacturing analysis contained no errors because this geometry could be milled if desired.

7.3 DESIGN FOR USABILITY

Vision Impairment

- For people with a vision impairment such as colorblindness or another related disorder, this could possibly affect the usability of our device if, for example, one of the wires connected to the motor were to be disconnected during operation. The wiring scheme is largely dependent on the colors of each connection, so a person with colorblindness may have issues reconnecting the wires. Similarly, if a person were to have presbyopia, they may struggle to read some of the essential lettering and numbering of the parts, which could cause considerable confusion.

Hearing Impairment

- For people affected by presbycutia, this may prove to be dangerous because of the power of our machine. Our wheels can get up to a pretty high speed if the proper controls aren't used, and when the wheels reach and high RPM, the vibrations involved could become severe, and possibly cause injury to the person using the machine if they can't hear the machine's vibrations. In a similar fashion, if the machine is loaded with lacrosse balls and is in operation at a high speed, the person might be in danger of getting hit by a ball if they can't hear the balls being launched.

Physical Impairment

- For people with varying physical impairments, one source of danger involving our prototype might come from having to unplug the machine if something fails within the apparatus. If the person involved can't readily get over to where the machine would be plugged in (which is likely simply due to the machine's intended location related to the nearest power outlet) then somebody might get hurt. Arthritis may also introduce some struggles, seeing that the wiring is largely dependent on small wires connected to even smaller ports.

Language Impairment

- Assuming that our future instructions for our prototype aren't written in another language other than English, this definitely would cause some difficulties. Beyond that, the machine is intended to work simply by plugging it in, and in our final design, the controller used to vary the wheel speed will only take numerical inputs, so we don't see many other issues arising with a language barrier.

Control Impairment

- Related to the physical impairment section, distraction could lead to a very dangerous outcome while using our machine. Our machine is very high powered, involving lacrosse balls which are innately dense and can cause serious injury when struck at a high speed. If the person using the machine is fatigued, say for someone using the machine to practice alone, one may eventually get tired before all of the balls have been launched and could get seriously hurt from the impact of another launched ball while the person is unaware.

8 DISCUSSION

8.1 PROJECT DEVELOPMENT AND EVOLUTION

8.1.1 Does the final project result align with its initial project description?

In our initial project description, we specified that we wanted our final prototype to achieve the following: a consistent pass speed/location/angle, locational mobility, wireless power, adjustable time between passes, and easy to load. Along the way, we began to understand the difficulty of achieving each of these goals, and made the necessary changes to our design plan based on practicality of time and budgetary restrictions. Based on the numerous obstacles we encountered, we then narrowed the scope down to our original project statement, which stated our goal was to "Make a machine that passes a lacrosse ball at a specified speed and accuracy to players in a practice setting." When comparing our current prototype to this more abbreviated goal statement, we believe our prototype accomplished our goals. Our current prototype isn't able to shoot at a user-specified velocity, which stems from the obstacle we ran into with modulating our motor voltages. However, if operated closely by a user, a speed of about 30 mph can be reached. With respect to the accuracy of the ball launch, we've experienced little to no variance in final position of the ball after launch, however it isn't 100% consistent.

8.1.2 Was the project more or less difficult than expected?

Our group believes that the project was much more difficult than we originally expected. In the beginning it was tough to see the finish line, understanding that there was a lot of work between then and the final prototype. We found out in the first month or so that the amount of preparation and planning required before construction was immense, however it proved to be very beneficial as we progressed. When it came to constructing our prototype, we ran into fewer issues than we thought we would, however this was partly because we took a more patient approach before we made any physical changes to the apparatus.

8.1.3 On which part(s) of the design process should your group have spent more time? Which parts required less time?

Our group should have spent much more time on designing our timed-release system. Through the majority of the construction phase, we were more concerned with getting the ball to the correct position between the wheels rather than the mechanism that periodically releases said ball at a specified time interval from the previous launch. We knew this mechanism would involve an Arduino-powered rotary piece, with a lacrosse ball-sized hole on one section of the piece, but a lack of time in the end did not allow us to construct this aspect. We also presumed that the wiring of the motors would take a majority of our time, however after doing our research, we were able to make the motors functional on the first attempt.

8.1.4 Was there a component of the prototype that was significantly easier or harder to make/assemble than expected?

Securing the wheels onto our two motors might have been the toughest design challenge we faced. We found that the D-shape of our motor shafts made it difficult to mate with the inner shaft of our wheels, even though they were the same nominal diameter. There was a small gap left between the shaft and wheel, and ultimately, we decided to fill in the gap with a high-strength steel epoxy that can withstand very high pressures. This clearly led to some faulty meshing between the shaft and the wheel, which resulted in heavy vibrations in our apparatus at high speeds.

8.1.5 In hindsight, was there another design concept that might have been more successful than the chosen concept?

In the end, we feel that our chosen design concept was the most viable option in order to succeed. For the majority of the time, we researched countless ways to store and load balls before an intended launch, most of which were too complex to craft from scratch and/or were too expensive to purchase. So, there may have been a more successful ball-loading design out there, but we did the best we could in the end using leftover materials from other sources. With respect to the motor-wheel combination, it was determined almost from the project's inception where the two motor-wheel components needed to be placed, because no other viable option could be found.

8.2 DESIGN RESOURCES

8.2.1 How did your group decide which codes and standards were most relevant? Did they influence your design concepts?

It was tough for us to find more than one or two codes or standards that were relevant to our project. We came up short besides a general safety standard for portable sports machinery, which explained the safety specifications required for operation. Looking back, the codes and standards that we chose had little to no influence on our design concepts. The crux of what we gained from our research of codes/standards was newfound awareness of the general safety of our prototype, because operating machinery that has as much power as ours requires that the machine be safe enough to operate.

8.2.2 Was your group missing any critical information when it generated and evaluated concepts?

With respect to the wiring required for motor operation, we were at a loss for direction. Each of the two motors we bought came with little to no explanation regarding the supplementary components needed, so extensive research and consulting was necessary. Once all of the materials were purchased, even more time was spent assembling them and connecting to the motors in the right fashion. In addition, we needed to do research on how to modulate the voltage supplied to each motor in order to modulate the speed of each launch, however this venture was unsuccessful.

8.2.3 Were there additional engineering analyses that could have helped guide your design?

One engineering analysis that might have helped better guide our design would have been an electrical diagram of our motor system with all of the components clearly labeled with nominal values. This most likely would've given us a better insight into what system could be utilized to vary the total voltage going to each motor. Although mechanical engineers rarely focus solely on the electrical components of a system, they generally must be aware of its components, and be able to explain it well enough to somebody with more of an electrical expertise.

8.2.4 If you were able to redo the course, what would you have done differently the second time around?

If we could redo this course, our group would have to be way more proactive when it comes to ordering parts (along with logging those orders) and completing assignments, while leaving ample time for revision. The process we underwent this semester was to build, encounter an aspect of our prototype that required new materials, then go purchase the necessary materials from a department store. If we could do it again, we would first brainstorm for more time before we went and crafted our components, so that we could save time and be more efficient.

8.2.5 Given more time and money, what upgrades could be made to the working prototype?

If we were given more time, we believe we would be able to craft a fully-functional ball-release mechanism so that our time-delay issue could be fixed. Not one member of our group has the knowledge regarding Arduino set-up and coding, however with more time to study how these units operate, we're confident that we could develop a solution. If we had more money as well, we would have originally purchased stronger materials than wood to help to better anchor our motors and wheels. We also would have been able to find a suitable platform upon which our prototype could rest so that our launches could reach their intended height, and we may have been able to find the proper fittings that would ensure a clean fit between our motor shaft and wheels.

8.3 TEAM ORGANIZTION

8.3.1 Were team members' skills complementary? Are there additional skills that would have benefitted this project?

In the end, we found that our team worked *very* well together. Originally, we weren't sure of our specific individual strengths. It wasn't until our assignments came around that we realized that Mackenzie is better at working with his hands, Jacob is adept at the prototype computer-analysis and keeping the group on track, and Conor was stronger with conceptualizing the prototype components. In terms of additional skills that could have benefitted us, besides more knowledge regarding electrical wiring of motors, we believe a greater sense of urgency would have helped alleviate some of the issues we ran into.

8.3.2 Does this design experience inspire your group to attempt other design projects? If so, what type of projects?

This project, after going through it from start to finish, definitely helped pique our interest in similar projects regarding sports machinery. However, when looking at the projects that involve extensive electrical knowledge and coding expertise, we realize that we would tend to stay away from those. We have become more interested in projects of a higher scale physically, rather than smaller prototypes. Other than that, we weren't overly inspired to further our prototype-design in a substantial way.

APPENDIX A – COST ACCOUNTING WORKSHEET

	Part	Source Link	Supplier Part Number	Color, TPI, other part IDs	Unit price	Quantity	Total price
1	Wheels	RAINGER-APPROV	1NXB0	12" d., 1 3/4" w.	$17.70	2	$35.40
2	Motors	ct/DAYTON-1-4-H	6XH64	1/4hp, 1750 rpm, 1 7/8" shaft length	$82.25	2	$164.50
3	Jai-alai Stick	https://www.chewy.com/nerf-dog-jai-alai-	82326	Blue, 4.5 x 4.25 x 18.8 inches	$11.99	1	$11.99
4	2 Part Epoxy	https://www.amazon.com/Gor	N/A	4250 psi, 10 min set time, 0.5fl oz	$5.87	1	$5.87
5	Plywood Sheet	https://www.homedepot.com/p	1502108	3/4" x 2 ft x 4 ft	$15.89	1	$15.89
Total:							$233.65

APPENDIX B – FINAL DESIGN DOCUMENTATION

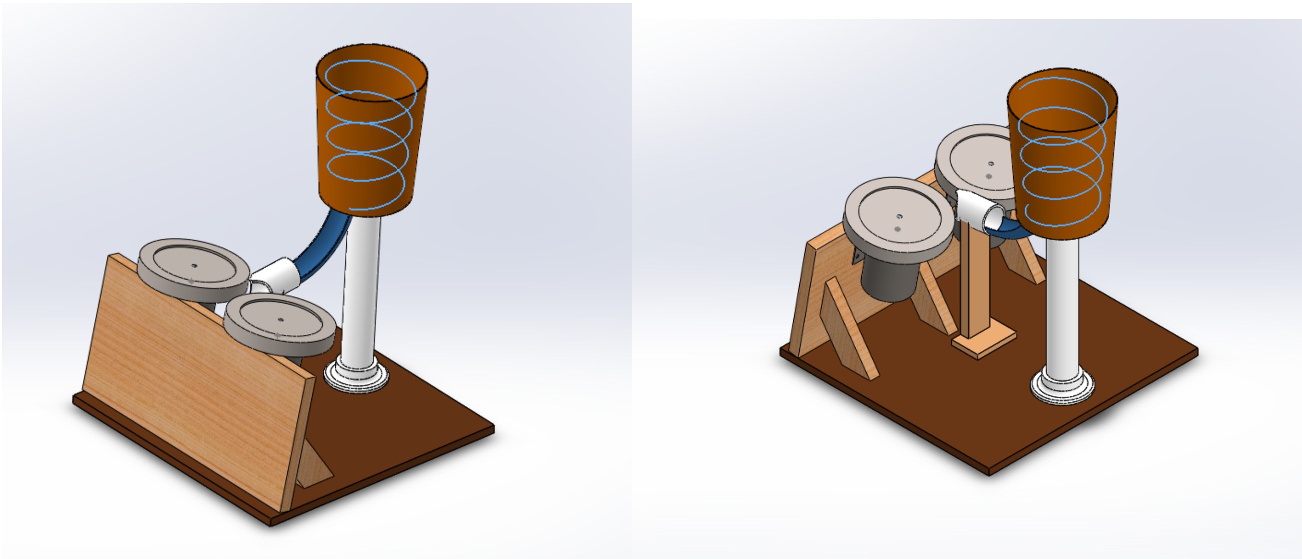


Figure 36-37: Prototype CAD Model

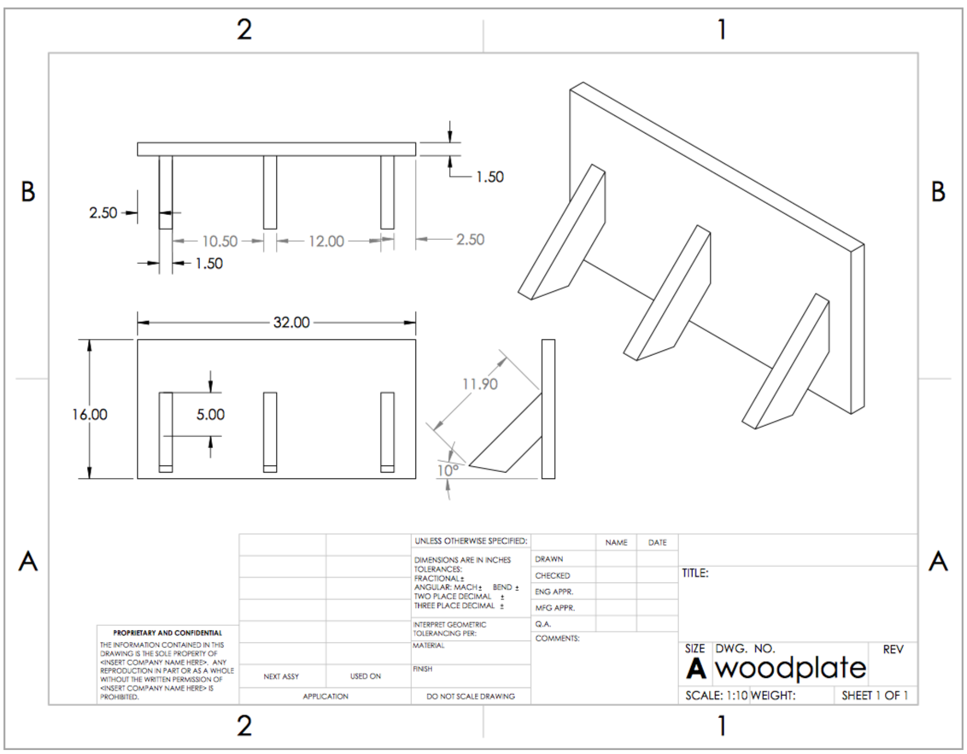


Figure 38: CAD Drawing of Wood Plate

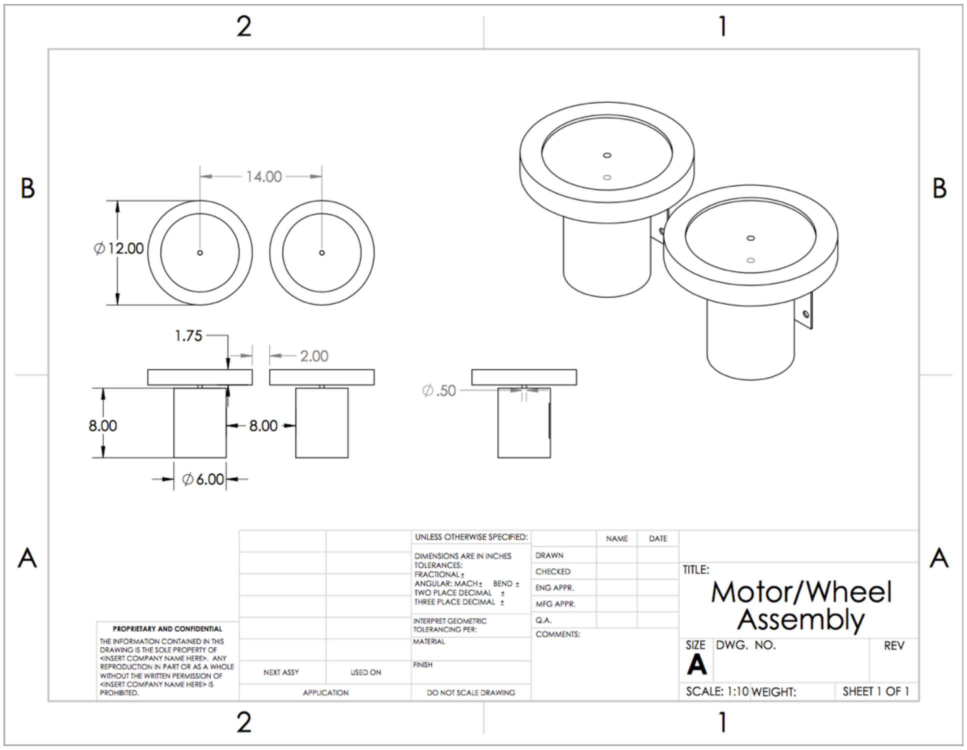


Figure 39: CAD Drawing of Motor/Wheel Assembly

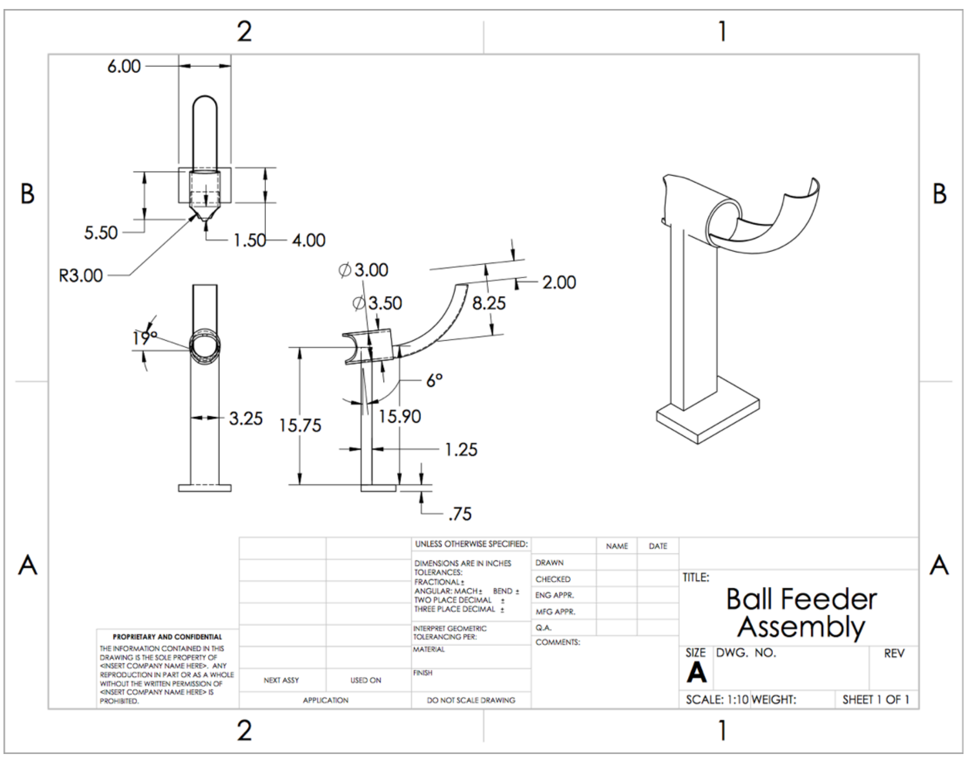


Figure 40: CAD Drawing of Ball Feeder Assembly

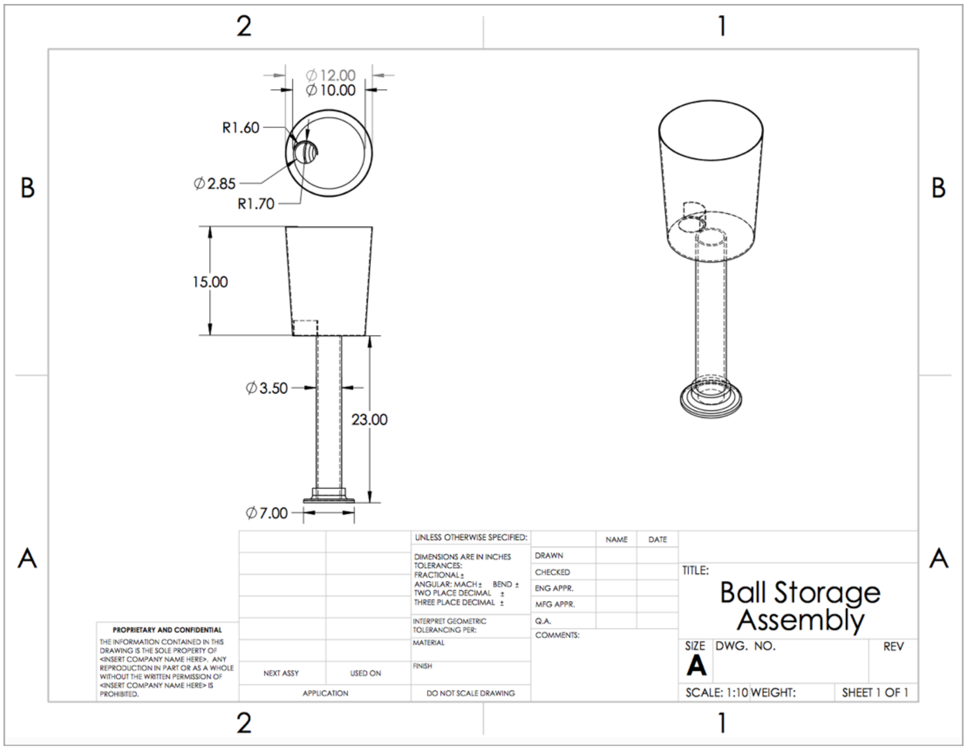


Figure 41: CAD Drawing of Ball Storage Assembly

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[3] “JUGS Machine.” *Is It Time to Get Rid of the Designated Hitter...or Expand It to the National League?* , jugssports.com/ball-feeders/18-ball-baseball-feeders/.