MECH 3200: Mechanical Pachinko Challenge

Team 91 “We Da Best” Pachinko

By

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CHAPTER 1
INTRODUCTION – PROBLEM STATEMENT

The Mechanical Pachinko Challenge given to us this semester tasked teams to design and build a self-contained tabletop Pachinko machine that infinitely cycles and maintains 20 steel bearing balls (3/16" diameter) between games. The objective of this project is to create an engaging, fully mechanical pachinko machine that emphasizes precise engineering, user safety, and fun gameplay without the aid of electronics.

The operating environment is a standard tabletop with a maximum footprint of 1 ft x 1.5 ft and height of 2 ft, ensuring the device is compact, portable, and stable for consumer use. Along with gameplay our key points of interest include our focus on ergonomics (e.g., launcher optimization), integration of experimental data for design metrics, and overcoming challenges in mechanical design such as tolerances, material selection, and dynamics under gravity. We also were given a tight budget of $100 to emphasize the importance of a compact and portable build as well as making sure we have proper resource allocation to fit the budget. The reason for these constraints is to ensure that we deliver a product that includes launching, aiming, obstacle interaction, scoring, jackpot payout, and ball resetting, while practicing the full engineering design process.

The intended audience for this game is customers who seek a nostalgic experience, and judges who are looking for a durable mechanical device that overcomes strict constraints and was made using the engineering design cycle. The overall goal is to deliver a fully functional device that meets the criteria and reflects our idea process as well as our progression from prototype to final product.

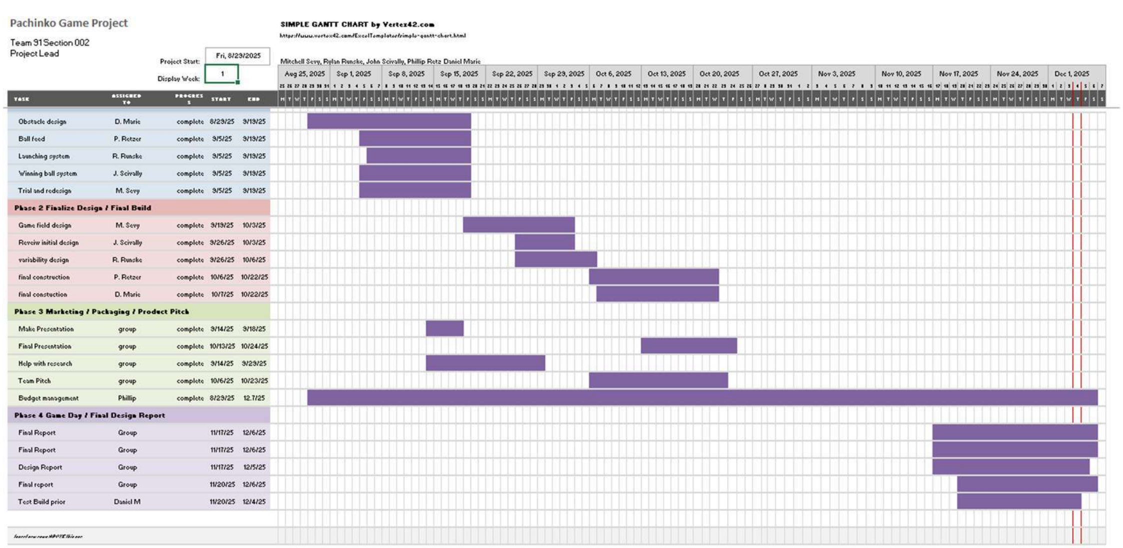
CHAPTER 2
STRATEGY – CHOSEN APPROACH

To successfully complete the Mechanical Pachinko Challenge, our team assigned our members to the parts of the project that they were most accustomed to. We found that keeping everyone working on what they were best at made our progress much smoother. That being said, our team never hesitated to ask for assistance or raise concerns about part of the design. This often resulted in our design being improved through trial and error on multiple portions of the machine. This process resulted in building a trusting team environment where everyone did their part. Of course, toward the end of the engineering phase when we started building, we all started collaborating more and this improved our efficiency.

Our group understood from the beginning that the main goal was to create both a functioning and enjoyable device that fits all the constraints and operates without the use of electronics. To accomplish this, our group focused mainly on our individual strengths. If one member was adept at CAD, they would do a majority of the model's development. If another member was good with their hands, they would do the machining. Another member might focus mainly on documentation and analytics.

To make sure that we chose the most efficient design, we often reference our team design concepts as well as our decision matrix to help eliminate options that we thought wouldn't mix well, or that would reduce repeatability or efficiency.

To make sure that we worked in a timely manner, we used the Gantt chart which showed a base outline of due dates, and when we planned to start and stop working on specific deliverables. This helped us create weekly checkpoints to ensure that we stayed on track with the deadline and that we started fabrication on time. This also helped us since our design process took longer than we expected. Our group was able to look at our schedule and move things around to make sure we met deadlines. (Gantt Chart Below)



CHAPTER 3
MARKET RESEARCH

The Pachinko Machine originated in Japan during the 1930's. The game was developed based off games from France. The early Pachinko games are very similar to the game described by the parameters of the pachinko challenge. Early machines were small wooden boxes with most internal pieces made of metal, and then plastic pieces once plastic became a viable material. The 1970's machines are the most like our desired machine design. The wood frame of the machine has a door on the back to access the internal mechanical parts of the game. The 70's machines also have no electrical pieces for scoring, like our machine. The Launching is all mechanical and operates via a handle or knob being acted on. The balls are stored near the bottom of the machine and are dosed into a launcher which shoots the ball up and into the playfield.

The playfield design of pachinko machines has become flashier with lights and lots of colors or designs. The older the machine, the simpler the playfield design. Early machines had very little to no playfield design. New Pachinko games are usually arcade game like with large design and lights surrounding the game and in the playfield.

The popularity of machines that can be transported easily seemed to be the highest in the 1950's to the late 1970's. Newer machines are usually larger and placed in pachinko arcades. Looking at withdrawn patents, one can see that the early machine design we had is like older portable games. One of the specific patents we studied has multiple jackpot functions. We are including this feature in our machine design. Another feature crucial to the game flow and scoring is a designated structure to hold prize winning or jackpot balls. We needed this feature to be visible to the player for the player to track their score. This is needed because we cannot have an electronic scoring mechanism.

Scoring features are not the only aspects that were inspired by older portable machines. The play field design is most similar to machines of the 1970's. We want to include a plinko obstacle for our level 1 (stationary) obstacle. The dynamic obstacle we are looking at is a dynamic level drop. This obstacle is not seen on the older machines in this exact form, but similar lever type obstacles are included.

Overall machine design is heavily based on the smaller machines. Many aspects of our design resemble machines of the 1970's or small machines of the 2000's. A lot of inspiration came from the older machines because of the restriction on electrical components. Playfield design is very similar to the 1970's designs. The bigger the machine the more complex the functions become. Looking at the smaller machines, they give us viable options for design of mechanical components. Our final design most similarly resembles the 70's style machines with a more complex playfield because of the dynamic obstacles.

CHAPTER 4
DESIGN SPECIFICATIONS

The device was designed to operate within a 1ft x 1.5ft x 2ft footprint. All aspects of the machine had to fit in this footprint, no exception. The game was placed on a table in the footprint and had to meet all the requirements, meaning all the balls, tools, and controls had to stay in place, and the game had to be repeatable. Additionally, the pachinko machine had to have a secure acrylic cover to ensure ball containment and safety.

The pachinko machine had to meet specific requirements that decided how our team would approach this project.

- 5 minutes from the machine being placed to being playable by a customer
- One static and one dynamic obstacle was required in the build
- No adhesives or bands/ strings of any kind
- Must weigh a certain amount and be robust and portable
- No electronics allowed in the build
- Must operate at a range of powers and offer variable aiming to ensure skilled gameplay
- Must be a score reset that is all or nothing
- Must be a jackpot function that offers a "payout"
- Minimum of 5 fabrication methods must be used
- The machine must continuously cycle 20 steel balls
- Total cost limit of $100

Any requirements not met would result in a heavy loss of points or even disqualification. Due to these hefty consequences these restraints majorly influenced the way the group went about the different stages of the design process.

The group made an extensive list of Engineering Requirement Metrics (ERMs) outlining the achievable goals for the project. These goals include spring rigidity, ball circulation, and restart duration. A chart of the groups ERMs and Engineering Requirement Limits (ERLs) are shown below.

Requirements	ERM	ERL	Notes
Machine Dimensions	Complete device measurements	>0.5 ft x 1ft x 1.5 <1ft x 1.5ft x 2ft	Aligns with challenge limit
Steel Ball quantity and circulation	A number of 3/16" steel balls in constant use	20	Mandated by project rules
Spring Rigidity	Spring stiffness	299N/m	Obtained from lab experiments
Spring Stretch	Maximum compression	1.35 inch	Ensures proper launch
Ball Weight	Mass per Ball	3.36E-4 lbs	For dynamic calculations
Launch Apex	Ball height post-launch	15 inches	Endures ball reaches obstacles without overshooting
Reset Time	Time to complete a full score and ball reset	≤5 minutes	Must be a single mechanical input
Weight	Total assembled device weight	≤20lbs	Improves portability and affects scoring

These ERMs and ERLs were chosen using the design rules and through our testing of the machine, and they determined the process we chose to test and finalize our game.

Through our design process, our team focused on many different aspects to ensure that our device meets all expectations. One of the main things we focused on was the ease of playing. We didn't want our game to be confusing to run; we wanted anyone to be able to step up and play with little to no explanation. To ensure that this was possible we thought it crucial to make our device as consistent as possible from the start to finish of each playthrough. This meant refining our game so that there were no jams and making sure that our obstacles were reliable.

One of the ways we made sure to keep track of was our Product Design Specifications (PDS) document that shows all the goals and requirements our device must meet. Throughout the whole process, the sheet was a reminder of what we must accomplish and how we must do so to ensure the final product meets the constraints. (PDS attached below)

TEAM #: _91________ *MECH 3200*

PRODUCT DESIGN SPECIFICATIONS

USER NEEDS & ATTRIBUTES	
• Win the Game • Device to Launch the Ball • resetting game field obstacles • ball management and storage • player feedback system • scoring • visual score report	• Defined End to the Game • Score Reset • User Input Variability • Minimum Two Actions • Minimum Two Obstacles • Easy Part Instal • Cost Effective

NECESSARY FUNTIONS
Launch Balls, Hit Obsacles, Have Scoring System, Have Rewards, Have a Win Function, Have a Lose Function, Have a Ball Return Function

CONSTRAINTS

Description	Metrics	Notes
• Continuously 20 Balls • Aiming and Launching • Reseting Game Field] • Managing the Cycle • Minimum 2 Actions • One Jackpot • Need Static and Dynamic Obstacles • Acrylic Cover •	Size Boxing	> 0.5ft x 1ft x 1.5ft and < 1ft x 1.5ft x 2ft
	Prep Time	5 Minutes
	Budget	$100
	Electronics	No Electronics Allowed
	Time	5 Minutes to prepare
	Device Mobility	transportable, Robust, Stable, Handle to Carry
	Building Constraints	No Adhesives, Bands, Rubber, Threading

CHAPTER 5
GAME DESIGN

Our device is a mechanical Pachinko machine that uses steel balls through a series of static and dynamic obstacles, including a jackpot. Our design approach was to make the machine repeatable, straightforward, and visually appealing, featuring a wooden framework, acrylic viewing window, 3d printed internals, with systems for propelling the balls, tallying points, jackpot distribution, and resetting.

When beginning a play session, the operator possesses 20 steel spheres in the repository. Every sphere is propelled individually via a mechanical spring-driven piston. The user has the option of two launch “tracks” to steer it across the play area barriers and potentially into the jackpot zone. The aim is to trigger the jackpot to keep playing the game longer. The tally of balls used is shown through a clear acrylic viewing window. A sphere counts as "played" after descending through the play area.

The session ends once every sphere has been deployed. Then, the participant may reinitialize the activity by pulling a handle and activating a recirculation system. This system drops all spheres—regardless of whether they earned points or were merely utilized—back to the loading zone. After the spheres are reset, the game is prepared for another cycle of engagement. This reset setup guarantees that engagement cannot resume until a complete reinitialization occurs, meeting the rule set in place that all balls must be reset at the same time (no cheaters).

The play area was designed to have a diverse set of obstacles to encounter via a mix of strategically located obstacles. The static component consists of fixed pegs. Arranged below the split of paths, these pegs have the ability to redirect the balls right before reaching either jackpot or losing zones. Each sphere starts through the launcher, aimed through a separate track, to either jackpot storage, jackpot trigger, or losing zones.

An additional primary aspect involves active levers, which adjust the sphere's speed on impact. This modification adds a dynamic encounter and satisfies the assignment's rule for speed/course modifiers. Following interaction with the levers, the sphere is directed along routes that guide the jackpot distribution. The jackpot directs the sphere in a pathway, causing it to distribute additional points or spheres.

The directing system is situated at the top of the launching track and functions as the participant's primary control method. Its arrangement enables the participants to target the jackpot. Directing not only diversifies engagement but also incorporates a reliability factor, offering the player the chance to influence results via launcher alignment and launcher strength. The launcher features a spring, allowing the player to determine the force the ball is launched with.

Collectively, these components form a complex play area where the participant must trigger the jackpot before they run out of balls. The blend of mechanical systems allows the user to completely reset the system after each use and control the direction/speed of each ball to hit the jackpot. Our focus on reliability and robustness makes our machine repeatable and seamless to be played again.

CHAPTER 6
PROBLEM CLARIFICATION AND IDEATION

In order for our group to work together effectively, we broke down the project into many different parts. This decomposition of the overall project helped us to pinpoint the essential functions the machine must carry out and helped us set an order of importance for the overall building process. With the project being simplified into its smaller tasks, it helped us brainstorm potential ideas and later helped us decide on the most optimal design.

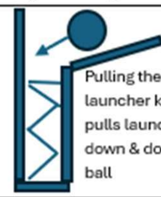
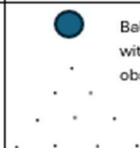
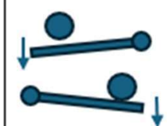
Functional Decomposition-

1. Dose Ball – Feed the ball into the launching chamber to begin the game
2. Aim Ball – Chose which path the ball will follow before launching
3. Launch Ball – Mechanically propel the ball into the playfield
4. Guide Ball – Ensure the ball interacts with the obstacles
5. Score/ Capture Ball – Capture balls and make sure scoring is accurate
6. Reset Game – Return balls to beginning and reset score and playfield
7. Store Ball – Make sure the balls are stored between games

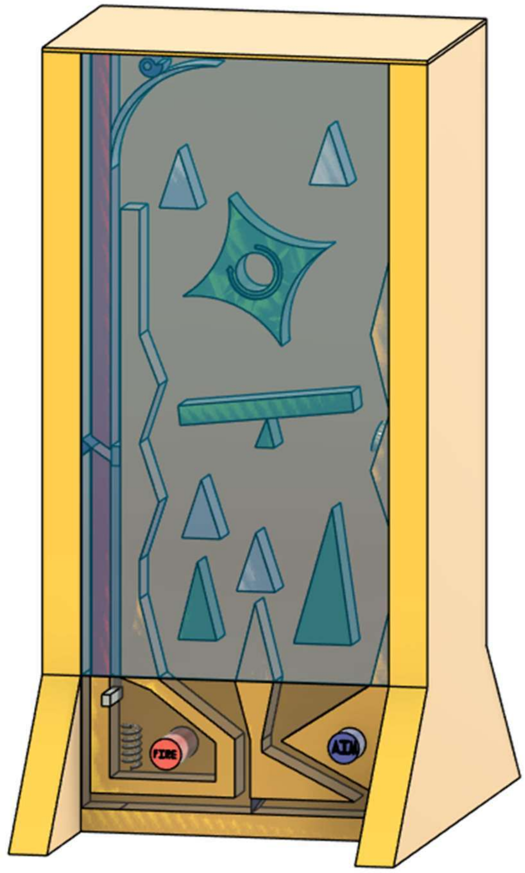
Ideation -

After laying out the task into more manageable sub sections, we began the ideation phase. As a group, we used functional decomposition to brainstorm multiple ideas for each section. To help we developed a Morphological Matrix that displayed the decision-making process we went through to land on our final design. We then decided as a group which options would work best with each other to create a quality machine and supply fun gameplay.

Morphological Matrix

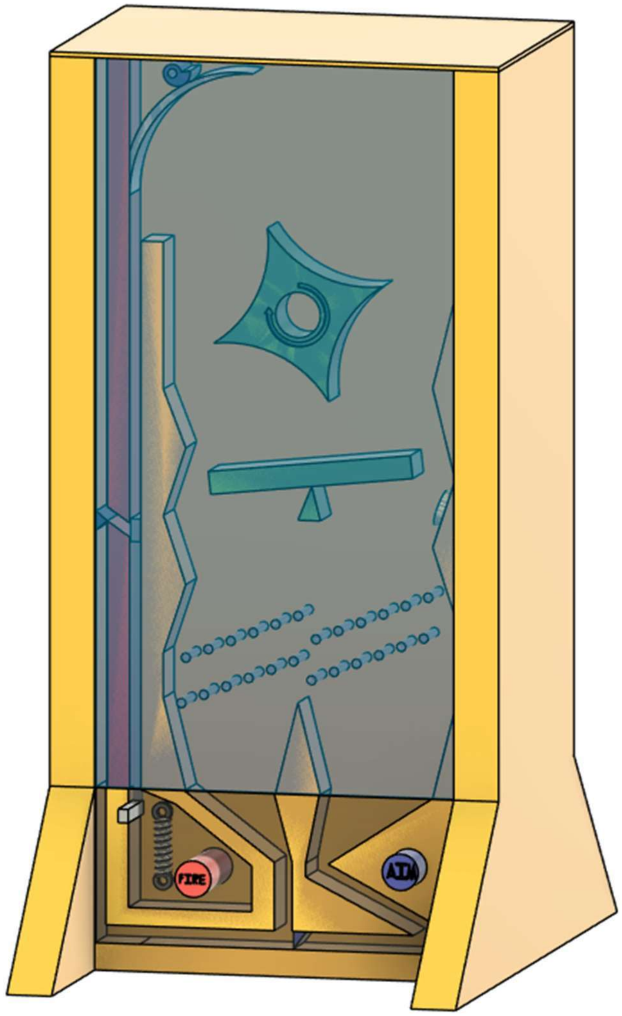
Dose Ball:	 Pulling the launcher knob pulls launcher down & doses ball	
Launch Ball:	 Releasing the launcher knob launches the ball via releasing the spring	
Interact with obstacles:	 Ball interacts with the plinko obstacle	 Ball weight operates the dynamic level drop arms
Update Score:	 Winning balls are stored in a visible area and are counted for score	
Capture Balls:	 Losing balls are stored separate from winning balls and are hidden from view	 Winning balls are stored in a visible area and are counted for score
Reset:	 When reset button is pressed the bottom opens on the storage area and releases the balls into the dosing channel	 When the reset is pushed the bottom drops out of the winning ball storage and releases balls to the dosing channel

CHAPTER 7
DESIGN CONCEPTS



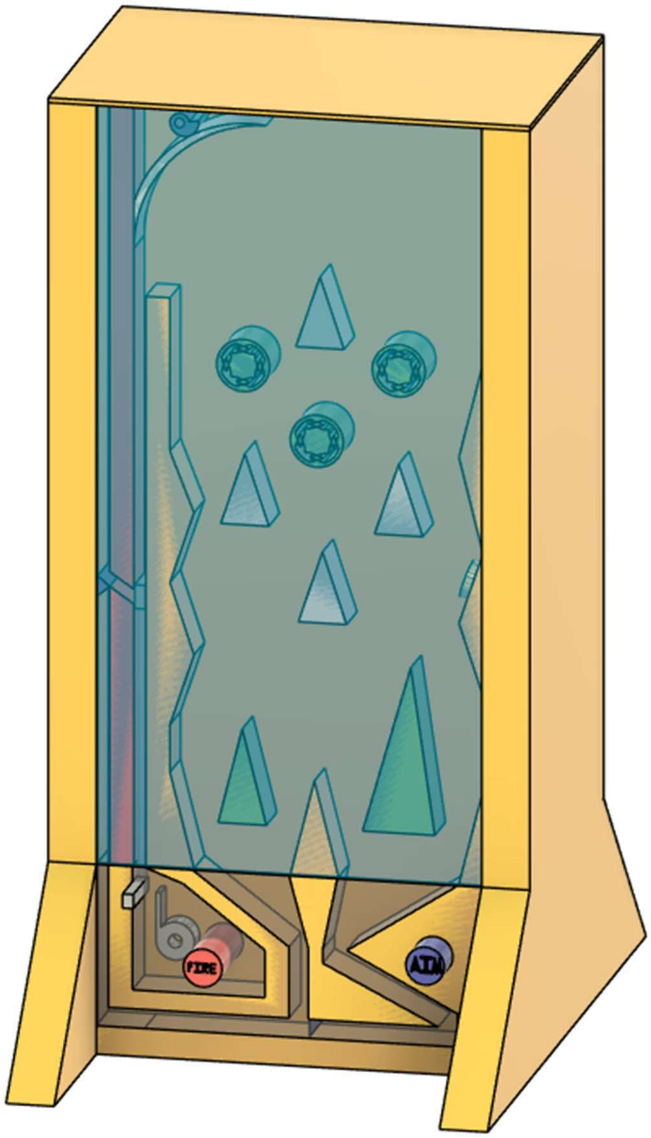
MCGUIRE DESIGN 1

- Unique Features: Playfield with a high population of splitter style obstacles
- Benefits: Manipulation of splitter size can change the randomness of the game flow
- Drawbacks: Splitters could not give enough randomization
- Duty cycle
    - Dose Ball
    - Launch ball
    - Interact with splitter
    - Interact with seesaw
    - Secure ball or jackpot function
    - Score update
    - Reset
- Metric analysis: All constraints met, allows accessible gameplay
- Needs analysis: More random game flow, Need for higher skill requirement



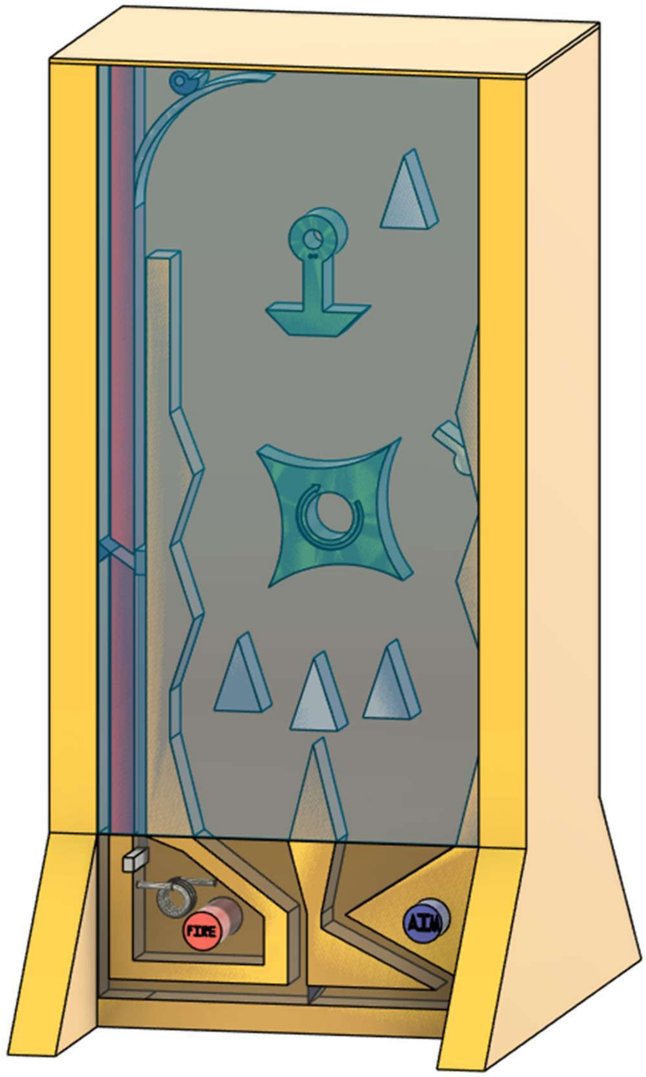
MCGUIRE DESIGN 2

- Unique Features: Playfield with a high population of peg style obstacles
- Benefits: Pin impacts cause randomness of the game flow, simple manufacturing
- Drawbacks: Only one dynamic feature
- Duty cycle
    - Dose Ball
    - Launch ball
    - Interact with spinner
    - Interact with seesaw
    - Interact with pegs
    - Secure ball or jackpot function
    - Score update
    - Reset
- Metric analysis: All constraints met, allows accessible gameplay
- Needs analysis: More dynamic features, Need more user interaction



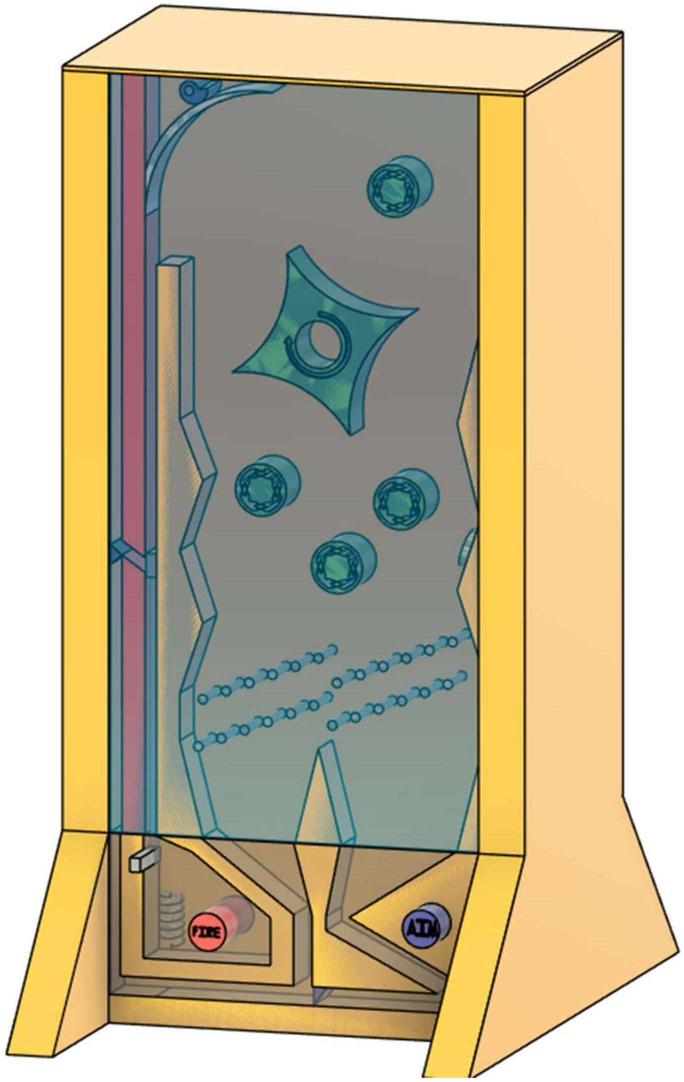
RYLAN DESIGN 1

- Unique Features: Playfield with roller and splitter style obstacles
- Benefits: Rollers slow down the ball speed, longer play time
- Drawbacks: Splitters could not give enough randomization
- Duty cycle
    - Dose Ball
    - Launch ball
    - Interact with splitter
    - Interact with rollers
    - Secure ball or jackpot function
    - Score update
    - Reset
- Metric analysis: All constraints met, allows accessible gameplay
- Needs analysis: More randomness and chaos, Need more small features



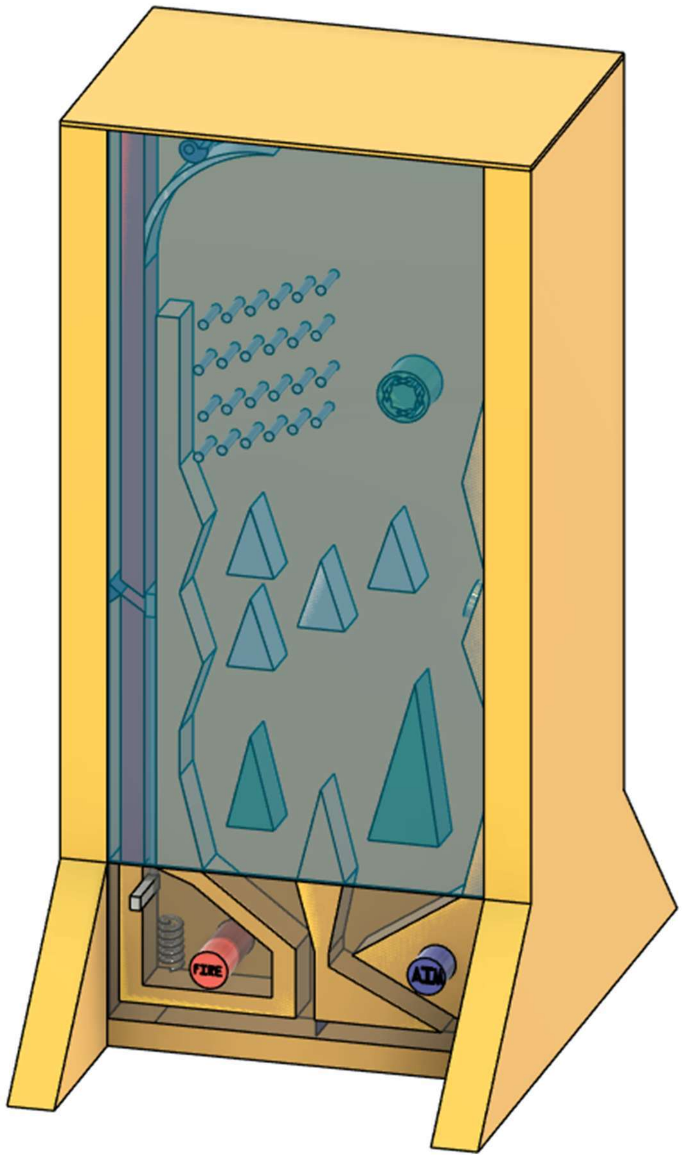
RYLAN DESIGN 2

- Unique Features: Playfield with a dynamic seesaw
- Benefits: Balls guaranteed to interact with dynamic obstacles
- Drawbacks: Easy to reach jackpot, no obstacles in the way
- Duty cycle
  - Dose Ball
  - Launch ball
  - Interact with seesaw
  - Interact with splitters
  - Secure ball or jackpot function
  - Score update
  - Reset
- Metric analysis: All constraints met, allows accessible gameplay
- Needs analysis: Lots of empty space, could be filled with other things



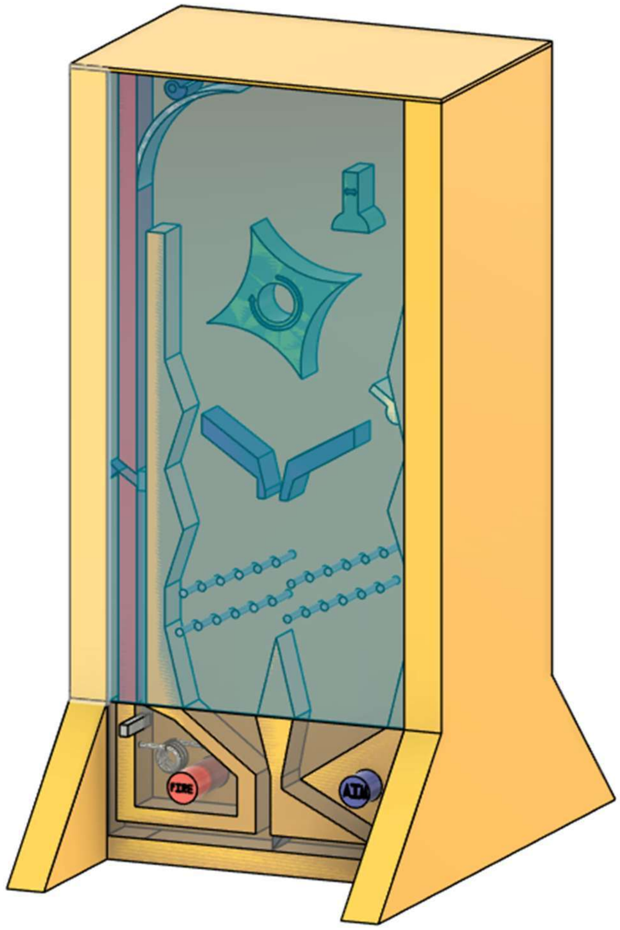
MITCHELL DESIGN 1

- Unique Features: Playfield with pegs and rollers, new jackpot button system
- Benefits: Jackpot button is accessible, pegs make chaos
- Drawbacks: Rollers allow for ball to slow down, reducing speed to hit pegs
- Duty cycle
    - Dose Ball
    - Launch ball
    - Interact with roller
    - Interact with pegs
    - Secure ball or jackpot function
    - Score update
    - Reset
- Metric analysis: All constraints met, allows accessible gameplay
- Needs analysis: Ball speed should be high before hitting pegs



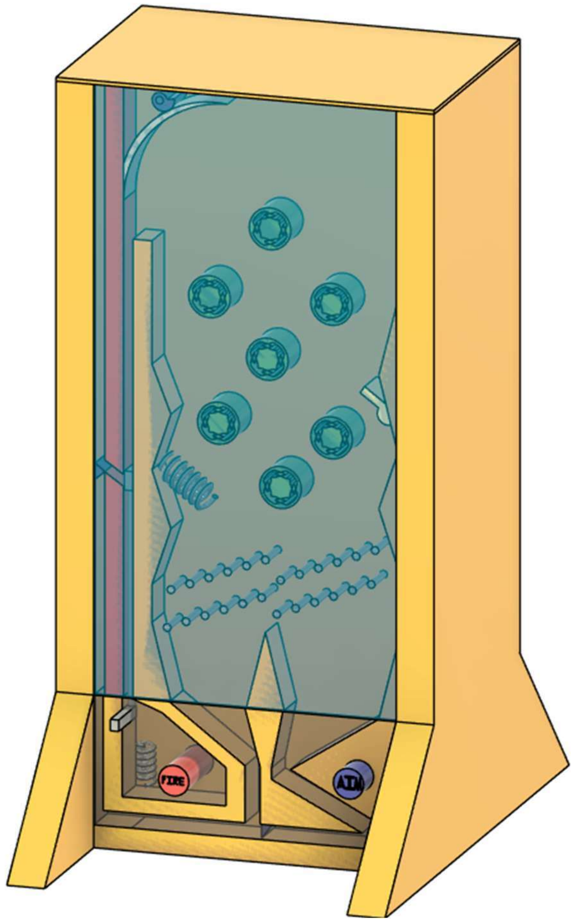
MITCHELL DESIGN 2

- Unique Features: Playfield with group of pegs and roller
- Benefits: Different paths for ball, random impacts
- Drawbacks: Splitters could create too many winning balls
- Duty cycle
    - Dose Ball
    - Launch ball
    - Interact with pegs
    - Interact with splitters
    - Secure ball or jackpot function
    - Score update
    - Reset
- Metric analysis: All constraints met, allows accessible gameplay
- Needs analysis: More random game flow, predictable paths



DANIEL DESIGN 1

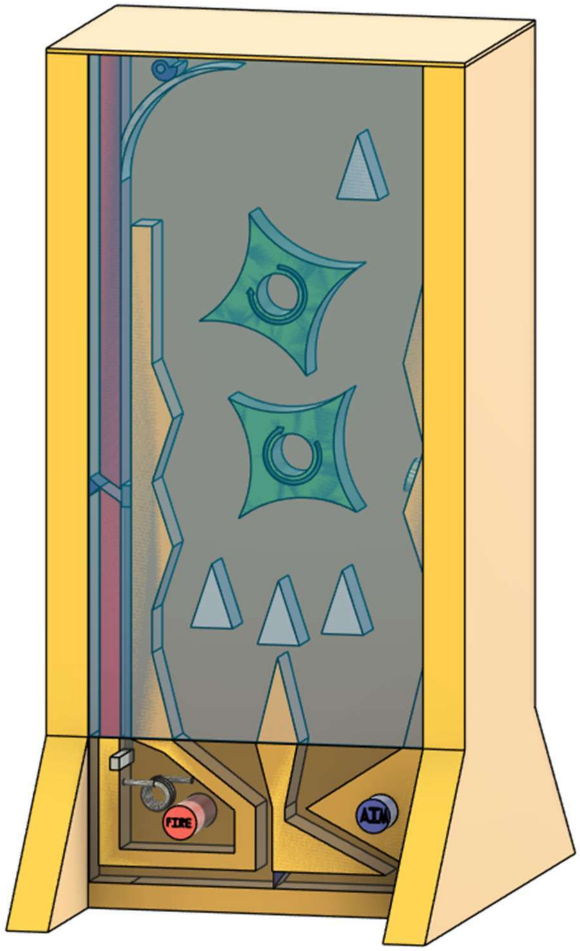
- Unique Features: Playfield with a funneling system
- Benefits: funnel allows for very rare jackpot hits
- Drawbacks: Pegs being below funnel reduce randomness
- Duty cycle
    - Dose Ball
    - Launch ball
    - Interact with funnel
    - Interact with pegs
    - Secure ball or jackpot function
    - Score update
    - Reset
- Metric analysis: All constraints met, allows accessible gameplay
- Needs analysis: Funnel below pegs instead of above



DANIEL DESIGN 2

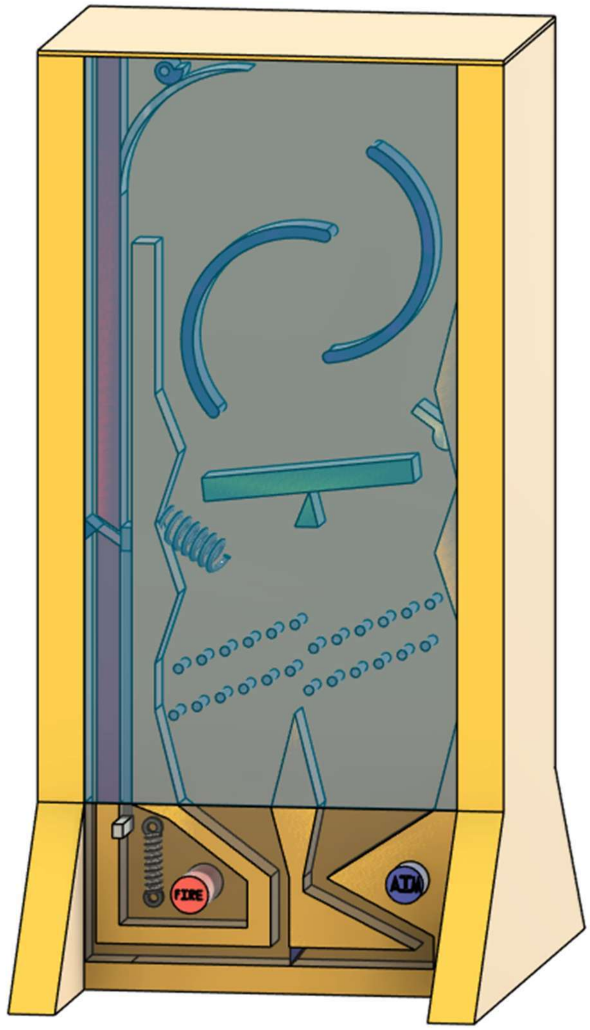
- Unique Features: Playfield with a high population of rollers and pegs
- Benefits: Manipulation of
- Drawbacks: Splitters could not give enough randomization

- Unique Features: Playfield with a spinner and splitter obstacles
- Benefits: Manipulation of splitter size can change the randomness of the game flow
- Drawbacks: Spinners could be hard to move with only the weight of the ball affecting them
- Duty cycle
    - Dose Ball
    - Launch ball
    - Interact with splitter
    - Interact with seesaw
    - Secure ball or jackpot function
    - Score update
    - Reset
- Metric analysis: All constraints met, allows accessible gameplay
- Needs analysis: More random game flow, Need for higher skill requirement
- Needs analysis: More consistent game flow



PHILLIP DESIGN 1

- Unique Features: Playfield with a spinner and splitter obstacles
- Benefits: Manipulation of splitter size can change the randomness of the game flow
- Drawbacks: Spinners could be hard to move with only the weight of the ball affecting them
- Duty cycle
    - Dose Ball
    - Launch ball
    - Interact with splitter
    - Interact with spinner
    - Secure ball or jackpot function
    - Score update
    - Reset
- Metric analysis: All constraints met, allows accessible gameplay
- Needs analysis: More consistent game flow



PHILIP DESIGN 2

- Unique Features: Playfield with a half circles and plinko
- Benefits: Manipulation of radius can change the randomness of the game flow and number of plinko can have the same effect
- Drawbacks: half circles are not very random with how it would affect the ball
- Duty cycle
  - Dose Ball
  - Launch ball
  - Interact with half circle
  - Interact with plinko
  - Interact with seesaw
  - Secure ball or jackpot function
  - Score update
  - Reset
- Metric analysis: All constraints met, allows accessible gameplay
- Needs analysis: More random game flow, Need for higher skill requirement

CHAPTER 8
SELECTION OF DESIGN

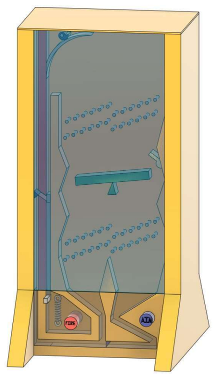
TEAM # 91
TEAM MEMBER NAMES
Mitchell Sevy
Rylan Runske
McGuire Scivally
Daniel Marie
Phillip Retzer

DECISION CRITERIA
Not too complex, compatable with all parts, difficult enough to hold attention, all parts are doable/ realizable.

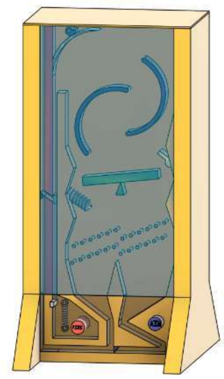
SELECTION CRITERIA
- A: Compatibility assured
- B: Fulfils demands of requirement list
- C: Realisable in principle
- D: Within permissible costs
- E: Incorporates direct safety measures
- F: Maximizes criteria fulfillment
- G:

Design Concept Name	A	B	C	D	E	F	G	Remarks (Reasoning)	Decision
Daniel 1	+	+	–	+	+	+		Button Jackpot is too complex	NO
Mitchell 1	–	+	-	+	+	+		button Jackpot is complicated	NO
Rylan 1	+	+	+	+	+	+		Very realistic	Backup
Phillip 1	+	+	–	+	+	+		Button Jackpot not realistic	NO
McGuire 1	+	+	+	+	+	+		Well designed, could work	Backup
Daniel 2	+	+	–	+	+	+		Jackpot button isn't great	NO
Mitchell 2	+	+	+	+	+	+		Our go to design	YES
Rylan 2	–	+	+	+	+	–		Wheel dynamic is too complex	NO
Phillip 2	-	+	-	+	+	-		Cant do Torsional for laucher	NO
McGuire 2	-	+	-	+	+	-		Torsional launcher is realizable	NO

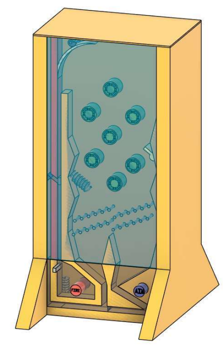
The selection chart is a thought organizing tool to aid in the final decision of a design. We listed possible designs which had a multitude of different design aspects created by team members. We wanted to ensure that our machine was robust and easy to operate, able to be manufactured, conformed to restraints, and was enjoyable to play. We have more specific criteria listed in the chart. The + or – denotes whether the design meets our selection criteria. Ultimately, the decision came down to small aspects of playfield design and the construction of the design. Our backup designs had aspects of the playfield which we thought would be harder to construct given the criteria we had to meet for the overall project. The backup options still got a '+' in the realizable in principle, but the favorite design choice has what we think is the easiest design to build. Being easier to build also means we



Mitchell 2



McGuire 1



Rylan 1

Decision Matrix

Requirements	Weight	Mitchell 2	McGuire 1	Rylan 1
Launcher	0.3	10	9	10
Static Obstacle	0.2	10	8	10
Dynamic Obstacle	0.2	9	9	8
Jackpot	0.1	8	8	8
Scoring	0.2	8	8	8
	Net Work = 1	9.2	8.4	9

The decision matrix takes our favorite designs and ranks them by importance of function and how well the design can carry out that function. Our prototype with the highest average score is the design we chose. The weight of the launcher is the highest because that is where every game starts. For the machine to be playable, the launcher has to function. Static obstacles will be the most populated in the playfield and affect gameplay a lot, thus we gave it a weight of 2/10. The same principle applies to dynamic obstacles only if it does not take up as much space on the playfield. The jackpot and then scoring revolve around the same idea, so we game the two similar weights. The scoring was emphasized to the team in the design criteria, so it gained slightly more focus in weighting. Scores in each category reflect our confidence in the function of each design. The first design listed scored the best because of confidence in launcher design and playfield game flow.

Launcher Rating was determined based on spring type. Compression springs are the type of spring we decided was the best suited to our launcher application. Strictly plinko pins for the static obstacle choices are the best for the gameplay and the randomization we need in the game. Jackpot and scoring operate similar for all designs and warrant the same score.

CHAPTER 9
DESIGN DESCRIPTION

Once our team selected the gravity-fed pachinko concept and had selected obstacles for the final design, we began developing each level focusing on reliability, predictable ball behavior, and player feedback. Our machine operates through a consistent mechanical cycle: ball loading, release, descent through obstacles, scoring, and resetting. This duty cycle established the functional framework used to design each subsystem and ensure smooth transitions from one stage of gameplay to the next.

To regulate ball entry and prevent accidental double-feeds, the ball reservoir and release gate were modeled as a passive gravity system with a manually actuated trigger. Reducing the angle of the ball feeding to 10 degrees helped to reduce static friction and ensured only one ball dispensed at a time.

One issue we ran into was balls being shot up and not making it out of the launcher track, resulting in two balls trying to be launched at the same time. To fix this, we lowered the ball feeding tube, so the launcher must be pulled down for a ball to get into the position to be launched. Fixing this issue helped ensure continuous play without clogging.

The division from the jackpot side/ losing side was the primary randomization subsystem. Balls would either go left or right at a split, the left being the jackpot side, either landing in the jackpot storage or the trigger, which is a "win". If balls went past the jackpot side, they are on the "collection" side. After dropping through the dynamic drop level, the balls encounter a field of pegs. Peg spacing, diameter, and material were iteratively adjusted to balance chaotic movement with predictable scoring probabilities. Balls that dropped down the collection side had the chance to be randomly bounced over to the jackpot side and vice versa.

Player interaction in pachinko is minimal but still important, particularly in the launching lever. Our first-generation lever design produced excessive resistance due to a set pullback distance. To evaluate ergonomics and repeatability, the set distance was removed, and the launcher is now completely driven by the user.

The next issue we encountered was the dynamic drop levels not functioning properly. On version 1, we hollowed out the side opposite where the balls would drop, with the idea being that gravity would return the flippers to flat, but encountered that the balls were not heavy enough, and the infill of the 3d printed parts was affecting the center of gravity. For version 2 we printed the parts with 100% infill and cut slots in the acrylic that stopped the motion of the levers at 15 degrees, which was enough for the ball to drop through the level. These ended up working as desired and gave a satisfying drop to the balls.

The ball's motion through the peg field was approximated using simplified projectile segments between peg impacts. Spacing each peg to be 2-3 ball diameters apart gave us the desired chaotic motion that we were targeting.

The scoring tray geometry was developed to maximize catch reliability across varying entry angles. Splitting winners/losers was simple, dividing the playfield to winning and losing side, with more losers to counteract the bonus from the jackpot.

The jackpot proved difficult, since it must be manually reset by the user due to the “mechanical only” constraint in place for us. After many designs we came to a system in which the jackpot is split into collection and then the final winner. Both the collection and winning balls can be manually reset between uses to ensure that someone does not go to play and not have access to all 20 balls.

Each mechanical subsystem — the ball release, peg field, lever interface, jackpot, and scoring tray — was designed using fundamental mechanical principles to ensure reliable, safe operation. Our design objectives for ball flow and user interaction were largely met, and the repeatability was as desired.

CHAPTER 10
FMEA / LIGHTWEIGHTING/ STREAMLINING

The failure modes and effects analysis is a systematic method used to correct potential failure points in a product. The pachinko machine has many small parts that must function without failure. In the case of a failure regarding a small part, the game could lose important functions such as launching the ball into the playfield. Specific parts to look at in the analysis are springs, gears, fasteners, and small printed parts. Severity of failures, frequency of occurrence, and ability to detect failures are all considered.

Spring wear in the launcher was our largest concern in the design process. If spring fails or fatigues, then the game is not playable. The ball would not be able to enter the playfield in this case. To combat this, we designed our launcher so that when it is unloaded, there is no compression force in the spring. This design ensures that the spring will not be fatigued from being compressed or extended while the launcher is not in use. The compression spring also sets in a track that keeps the spring from compressing in a manner that could damage it. The spring cannot bow because it is restricted to vertical compression. These precautions in the design limit severity and greatly decrease occurrence. If there is a spring failure in any manner, the launcher will not be able to get the ball into the playfield consistently. Our design minimizes all risks of spring failure. The risk priority of a spring failure is the highest compared to other failure modes we studied.

A launcher jam is another high priority failure mode. If two balls are being doses into the launcher at once it could cause a jam. The feed channel is only slightly bigger than one ball to decrease the chance of this happening. A jam is an easy failure to fix if it happens. If the launcher happens to launch two balls into the playfield, this will not affect the functional health of the machine. This failure is not as severe, but the frequency of which it happens is higher than the spring failure. It is easy to detect this failure. The player can see the feed channel through the acrylic to monitor the launcher.

The highest priority structural failure possibility is bolt shearing. The hardware is relatively small to keep the exterior of the machine smooth. If any of the bolts break, it could cause instability in the structure of the machine. To add more stability in this case, the machine has pairs of bolts at fastening locations. If one bolt breaks, there is another bolt which retains most of the stability. We imagine that the only time a bolt would be shearing/breaking is during transport. If the machine were to be dropped from a great enough height, the failure of a bolt could take place. This failure is detectable and simple to fix with spare parts. We used a standard size bolt in all locations where one is used. The failure of a bolt should not happen often. Only in an extreme case of force exerted on the machine should a bolt shear. Also, a structural failure could occur due to excessiveness being applied. The Body of the machine is the main structure. 3D printed blocks are placed at corners to add to the rigidity. A drop or similar force applied to the machine could harm the structure. The added structure adds enough strength that normal actions and transportation of the machine. The structure failure has a low-risk priority number due to the low rate of occurrence and medium severity rating.

Gear shearing is the failure mode that has the most severe effect on the machine. If a gear in the launcher fails, then the launcher loses all function. As severe as this failure may be, it will not occur often. We selected the direction of the print to reduce the chance of forces causing a failure. The gear teeth are relatively large. The same applies to the teeth on the rack. Because of the printing method, the risk priority is low.

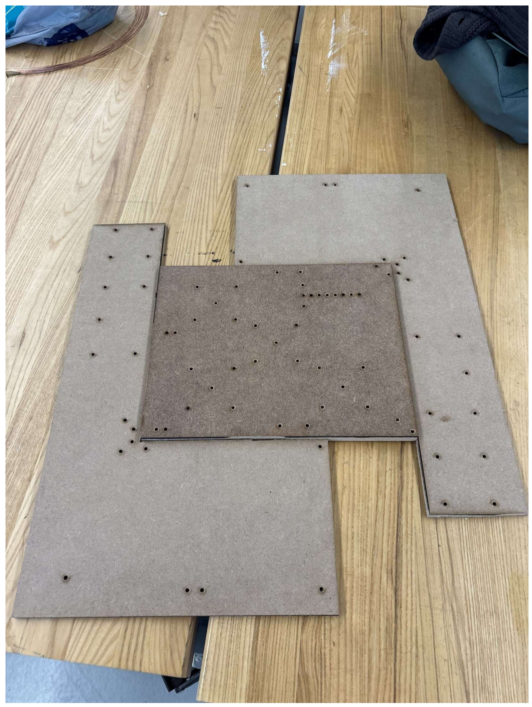
	Severity (S)		Occurrence (O)		Detection (D)			
Failure mode	Effects	S Rating	Causes	O Rating	Controls	D Rating	RPN	Recommended Action
Spring wear	The launcher loses consistency	6	spring fatigue due to being extended for longer periods of time	2	If a spring does not have the stength to launch the ball into the playflied	9	1.33	Design launcher so that spring is never being held extended for long periods of time
Launcher Jam	Two balls are launched or the balls get stuck in the launcher	3	two balls feed at one time	4	Test launcher prior after manufacturing and ensure tolerances during manufacturing	9	1.33	Tighter tolerances for the ball feed to ensure only one ball feeds
Bolt Shearing	Could cause instability in certains structural aspects	6	Too much force applied to bolt	1	Check threading and structual state of bolts.	7	0.857	Use more bolts in areas of high stress to spread out the forces applied
Gear shearing	loss of launcher function	8	Excess stress on gear teeth	1	Check teeth for defects. Check launcher function	10	0.8	Ensure proper material of construction for gear
Structural failure	Machine becomes unstable or structurally compromised	5	A drop or large force is applied to the structure	1	Handling of the machine will indicate the state of the structure	8	0.625	Add structural features inside the game housing

In regard to lightweighting, our thoughts shifted to what kind of materials were going to be used in the construction. 3D printing is a large part of our construction process, because of the variety of plastics that can be used we can base a choice of the weight and function that needs to be provided. All plastics are light when compared to other materials and are relatively strong when printed correctly. For the one metal part we designed aluminum was used. Aluminum is a lightweight metal, but more weight was needed at the back of the machine, so we used metal instead of plastics. The structure of the machine is MDF; it is lightweight but provides enough structure to support machine function. To aid in structure, we used 3d printed blocks to increase rigidity at seams in the MDF.

Design aesthetics are enhanced by the color options in plastics. 3D printing provides a wide range of choices for all plastic options. The acrylic at the front of the machine also has multiple color options, and we are using the options to add a more attractive visual aspect to the game. Bolts were countersunk to give the exterior of the machine a clean and smooth look, further adding the aesthetics.

CHAPTER 11
PROTOTYPING / FABRICATION

When fabricating the piece, we used the water jet to manufacture our metal parts. The water jet was the best choice because it would cut through metal and produce a precise piece. For our wood-based material, we first used the laser cutter to outline the cuts, as some of the holes that needed to be drilled were in locations difficult to measure precisely. Then, we utilized the vertical band saw for the long cuts. Due to our boards not needing to be cut all the way, we used the band saw instead of the table saw. As for the holes, we used the drill press to ensure accuracy. We used two methods on the drill press. One was traditional drilling techniques. The other was countersinking holes for smoother exterior.

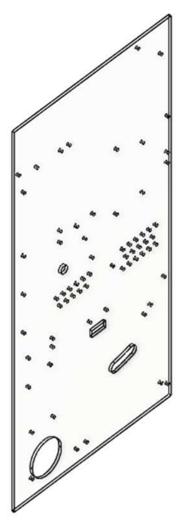


Additionally, we used hand tools such as a hacksaw to cut material smaller than what machinery can safely cut. We also used sandpaper and deburring tools to refine the 3D-printed, metal, and wood parts.

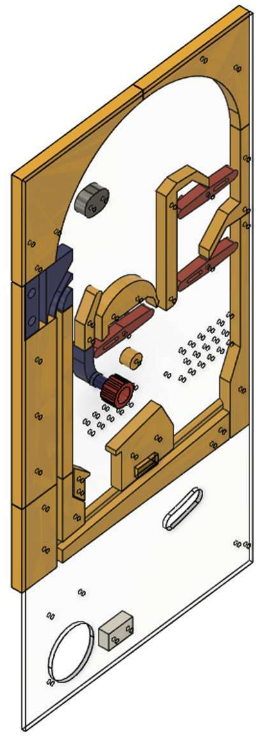
Most of the machine's parts were made from PLA, due to its light weight, affordability, versatility, and precision. PLA has a few drawbacks, being that it is fairly brittle, and that it is prone to heat warping, neither of which would have been an issue for the machine, as the machine operates at room temperature, and there is no source of friction powerful enough to heat PLA to its melting point. Brittleness is a factor in the durability of the overall machine, however it cannot produce enough force on its own to break any internal parts, and a user would have to be deliberate to break any part on the machine. MDF was chosen mainly for its price point, as the machine needed a few large parts to make up the majority of its frame. MDF is also lighter and more structurally consistent throughout, so countersinking holes was much more feasible compared to alternatives. Acrylic, while comparatively expensive to PLA and MDF, offered transparency, which is required to see and affect the gameplay itself, and ease of manufacturing. Acrylic cuts nicely on the laser cutter, allowing for extremely precise parts, along with requiring nearly zero post processing work, which cannot be said for PLA and MDF. The machine's aluminum part was originally part of the prototype machine for a part that was supposed to have minimum flexibility, but was repurposed in the new design to act as a counterweight to help offset how front heavy the design is. While aluminum is the most expensive material per unit, the part is relatively small, which is itself a strength of aluminum that a part can be small and durable.

All fasteners in the machine are M3 hardware, with bolts ranging from 25mm (roughly 1 inch) to 50mm (roughly 2 inches). Since our machine requires compact parts, the small diameter of M3 hardware lets us put fasteners into thin parts that would otherwise break if ¼ inch hardware was used. Additionally, we needed bolts that are long enough to secure multiple layers of parts, so M3 also fits the bill, as they fit both requirements needed while also being durable enough to support the machine's frame.

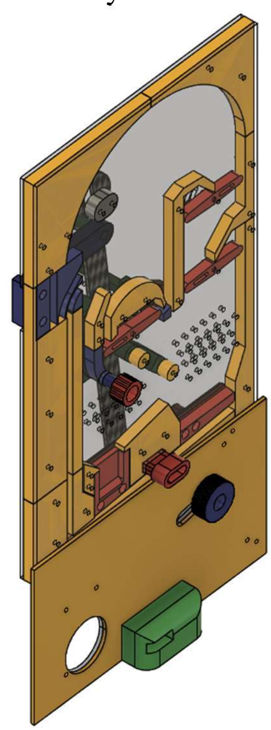
Construction:
Since the machine has a layered design, the machine needs to be assembled layer by layer, starting with the pieces of acrylic at the front of the design.



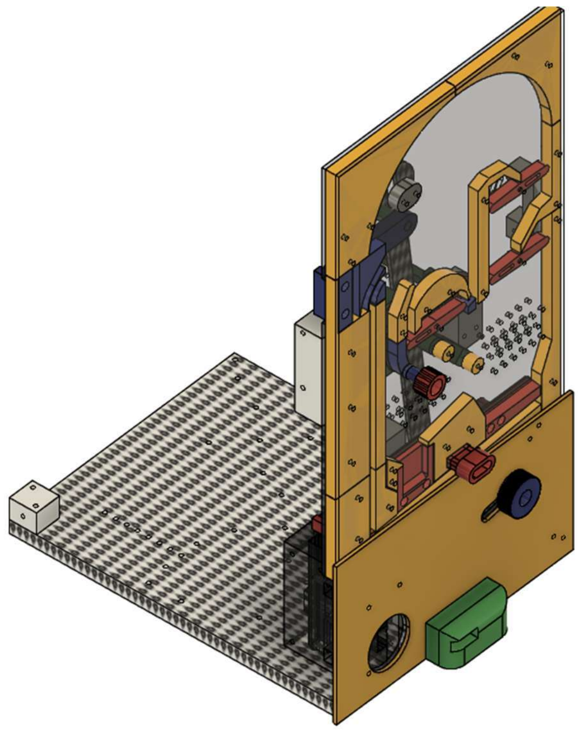
Afterwards, all of the parts that make up the sealed part of the system must be put into place.



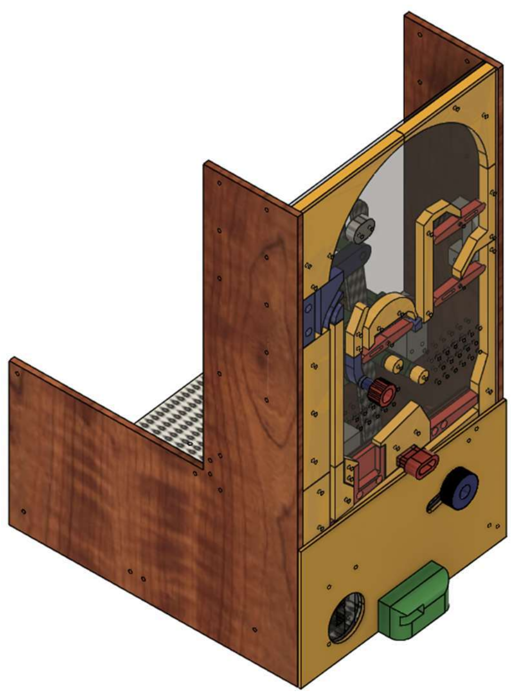
At this point, all of the fasteners must be inserted into each hole but not bolted down. Then, the rear piece of acrylic must be put into place. Additional parts that are behind the acrylic also need to be put into place, as well as a few in the very front.



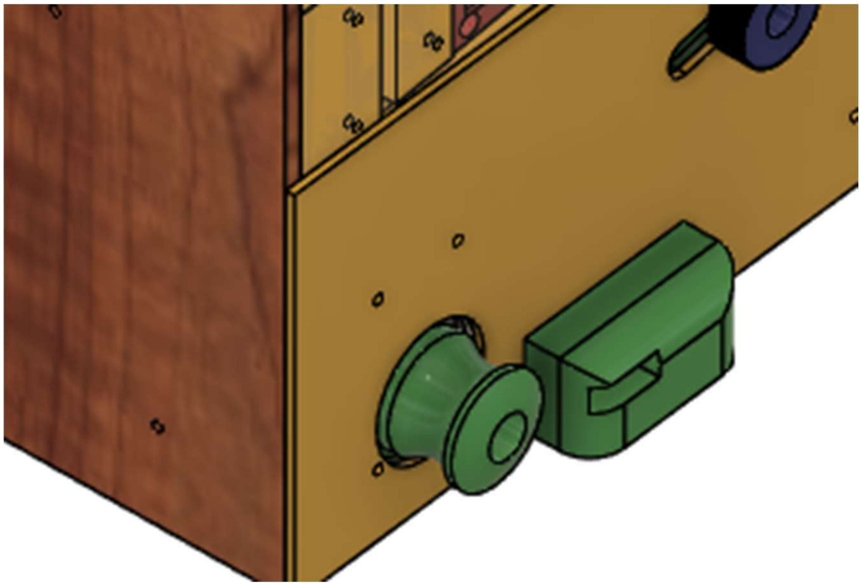
Then, this part must be attached to the base of the machine.



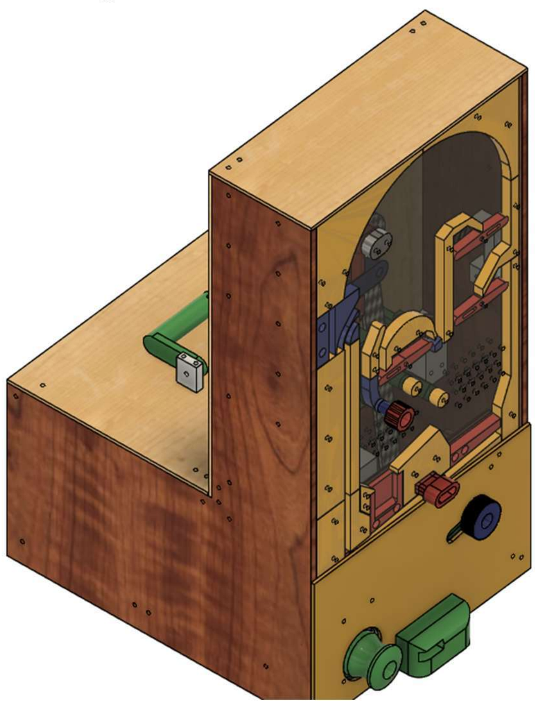
After this, the walls of the frame must be attached.



Then, the launcher must be put into place. A spring needs to be placed underneath the hole in the bottom of the launcher, as well as an additional spring attached to the rear of the launcher, held in place by a bolt.



Lastly, the remaining wooden panels must be installed on the rear, along with the handle.



CHAPTER 12
OPERATIONAL READINESS

The operational readiness of the pachinko device was evaluated through multiple stages of testing, including early prototype assessments and a final proving trial. These sessions were designed to measure mechanical performance, ball-flow reliability, and compliance with the design requirements established for the Pachinko Challenge. Early prototype testing allowed the team to identify mechanical inconsistencies and change subsystem interactions, while the final proving trial validated system functionality under realistic gameplay.

Across all testing phases, the device demonstrated the ability to perform essential gameplay functions, including ball loading, release actuation, controlled descent through the play field, obstacle interaction, scoring, and automatic recirculation. Several Engineering Requirement Metrics (ERMs) were successfully met, such as continuous cycling of steel balls, single-motion release control, and intuitive user interaction. The cheat-proof scoring tray functioned consistently, clearly separating scored and unscored balls to prevent cheating and ensure accurate scoring and evaluation of outcomes.

Testing also exposed a number of areas requiring refinement. During both prototype and proving trials, the ball release lever exhibited intermittent sticking due to overcomplicated launching systems. This issue was traced to tight tolerances around the shaft and some errors during the printing process. Additionally, several early tests revealed uneven interaction between the ball and the dynamic drop levers, that required modification of the “flippers”.

A more significant issue was identified within the ball collection and recirculation channel. The first version of the collection process went against the defined rules, since balls could be released one at a time between games and had to be completely reworked to meet constraints.

Despite these challenges, many aspects of the machine are performed effectively. The peg array produced the desired balance of randomness and variation, giving balls a last chance to switch positions. The scoring system, consisting of individually sized pockets and a funneling return mechanism, operated reliably across repeated trials. The ball dosing system successfully delivered one ball per lever actuation and prevented accidental double-feeding, even during rapid gameplay. Additional strengths included the clear acrylic faceplate, which provided excellent visibility, and allowed the user to easily keep track of scoring.

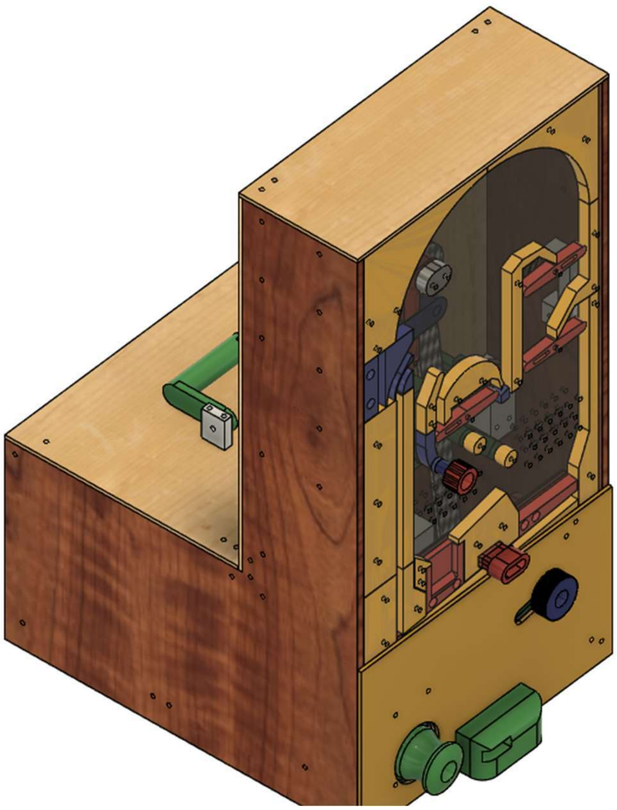
Several design improvements are recommended in response to testing outcomes. 100% infill of dynamic levels, removal of set level pull length, jackpot rework, 3d print tolerance fixes, post print work of the parts, and the addition of a counterbalance block to prevent from the user having to hold the machine in place while playing.

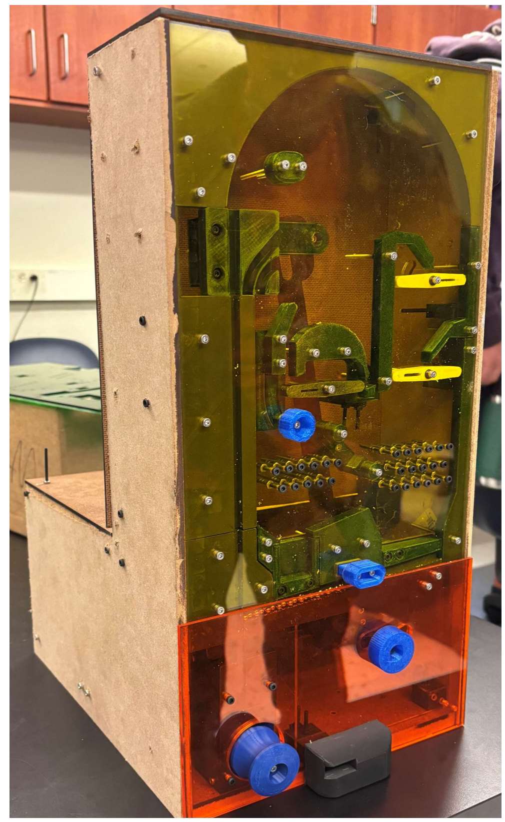
Notably, prototype testing confirmed the success of several core design features. The large-format playfield allowed for long, cinematic ball movements, while the staggered peg geometry ensured chaotic and random varied trajectories. The manually actuated release lever offered a satisfying degree of player control once friction was minimized. The scoring tray and ball return system worked cooperatively to maintain uninterrupted gameplay cycles. The multiple acrylic pieces allow for more simple construction, along with separating between clear-colored acrylic.

In conclusion, the testing process verified the core functionality of the pachinko machine while highlighting opportunities for refinement. The prototype met the mechanical, functional, and user-interaction goals of the challenge, demonstrating operational readiness. With minor adjustments to friction, material thickness and tolerances, and alignment, the design could be further optimized for reliability, durability, and overall player experience.

CHAPTER 13
FINALIZED DEVICE AND QUALITY ASSURANCE

Overall, our performance during the proving trial went extremely well. We had a few minor issues that did not affect the performance of the machine itself. The design was effective for our trial. The issues were mostly user-based. For example, a ball launched would occasionally not clear the lane. This could be due to the user misjudging the distance/intensity the launcher required. Especially if it is their first few times using the machine. Due to the target demographic using this machine varies extremely, the launcher data collected would be inconsistent.





This machine features many unique aspects to set itself apart from the competition. The high quality launch system provides many possible ways to aim and power the user's launch, and the high difficulty of scoring points of this game makes sure the user explores many ways of playing the game. Many of the machine's buttons and sliders have satisfying actions, such as the smoothness of the launch and the click of the reset mechanism. The playfield is sure to keep every user glued to the viewing window, as the plinko feature turns what seems like a lost point into a score, and a score into a lost point. Last but not least, there is a rotating handle for ease of transport, with the machine featuring a weight of less than 10 pounds.

The overall cost to produce this machine would be $88.10 (See Appendix B for more details).

The instructions to operate the machine are as follows:

1. Ensure that the machine is properly reset and there are no balls in the playfield. To do this, actuate each of the reset mechanisms.
2. Pull back the launch handle and release it to fire a ball. Make sure your hands are clear of the rear of the handle to avoid pinching any fingers.
3. Repeat until you cannot fire any more balls. Balls should be fired one at a time for the best user experience.
4. Count your score, and reset the game. Whenever you are ready to play again, repeat from the first step.