

# Computer Aided Design and Prototyping

(ME444 – SPRING 2024)

## Purdue Pete's Adventure Park

### Design Report

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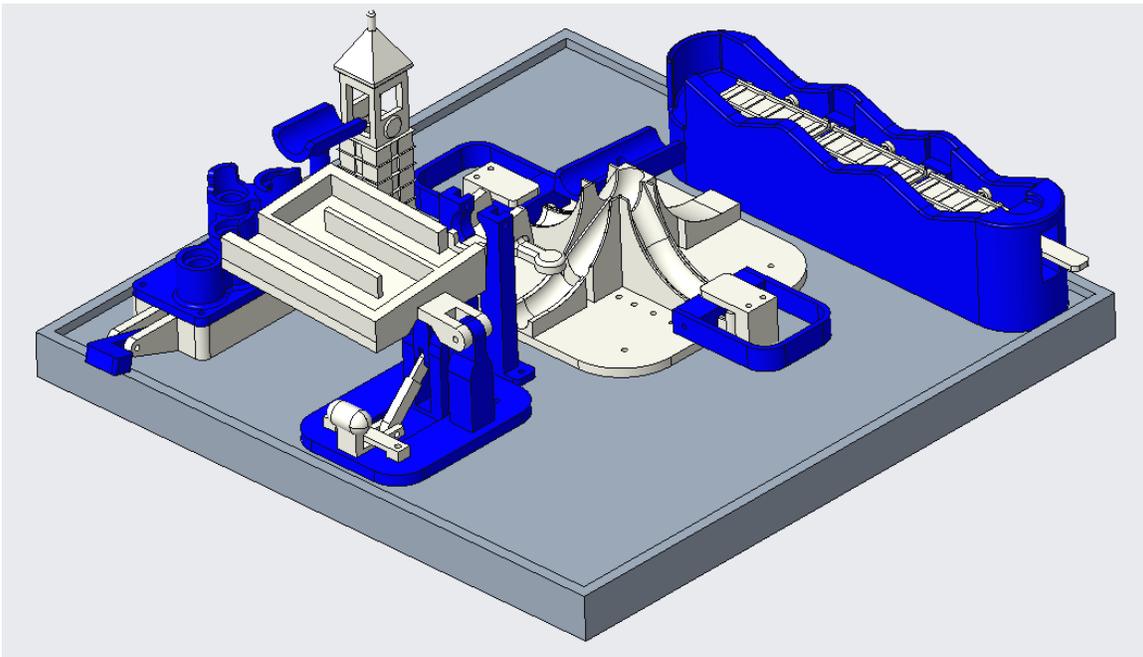
## Revision History

<b>S. No.</b>	<b>Date</b>	<b>Revision ID</b>	<b>Revision Details (Page No., Paragraph, Line No. etc.)</b>	<b>Author</b>
1.	04/28/2024	Revision A	Initial Release, Table of Contents, Executive Summary, Project Background, Boilermaker Special Tracks	Marielle Berin
2.	04/28/2024	Revision B	All CAD figures, Concept Generation & Selection, Design Requirements & Constraints, Engineering Fountain, Miniature Elevator	Jeremy Gilhart
3.	04/28/2024	Revision C	Result and Discussion, Conclusion	Charlie Shifrin
4.	04/29/2024	Revision D	Minor proofreading and formatting edits	Marielle Berin
5.	04/29/2024	Revision E	Steps to Bell Tower, Elevator Transition, Prototyping and Testing	Aed Musa
6.	4/29/2024	Revision F	Maze to Graduation, Bill of Materials	Charlie Shifrin
7.	4/29/2024	Revision G	Final Review for Submission	Marielle Berin

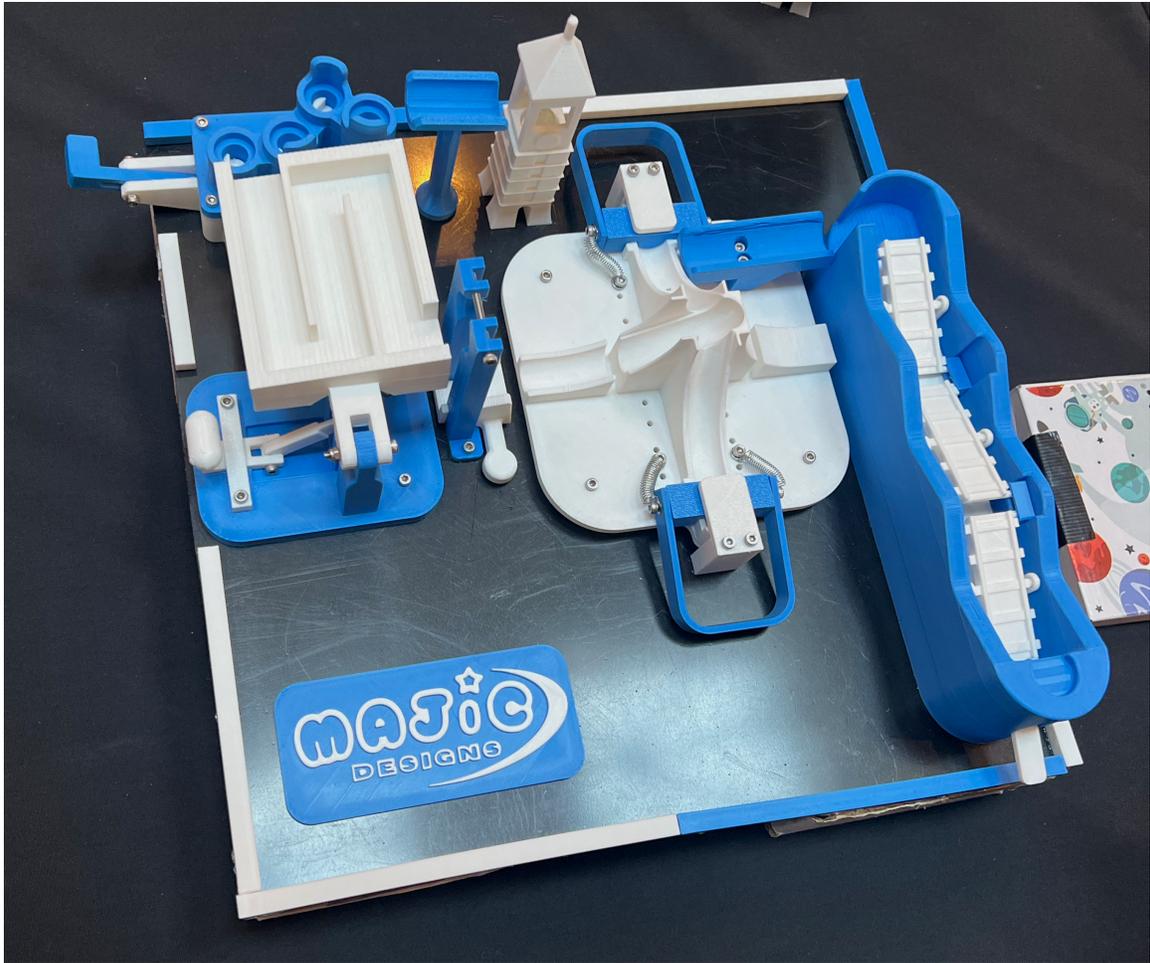
## Executive Summary

Purdue Pete's Adventure Park is a Purdue themed marble course with 4 main mechanical obstacles: the "Boilermaker Special" train tracks, the "Engineering Fountain," a maze to graduation, and the "Next Giant Leaps" to the "Bell Tower." The user begins by placing the ball at the start of the tracks. Using a lever, the user can manipulate the angle of the tracks to roll the ball from the start to the other side. The ball then rolls into one of the sides of the fountain. The user must use the pull tabs to fling the ball to the middle track. If you pull too hard, the ball will roll over to the other side where another slider is waiting. Once the ball rolls down the middle track, the user must lift the ball in the miniature elevator to land in the maze. The maze features a slider mechanism that controls the angle of the platform. The user must navigate the ball through this maze and carefully land the ball in the first hole of the "Giant Leaps." By pushing down on the lever, the user must launch the ball across each step of the "Giant Leaps," across the ramp, and into the Bell Tower. The player with the fastest time wins!

**Final CAD assembly: (ME444g31\Action Toy Project\Final CAD\Purdue Pete's Adventure Park\main-assembly.asm.6**



**Figure 1:** Toy Assembly Rendered in Creo



**Figure 2:** Physical Prototype

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# **1. Introduction**

## **1.1 Project Background**

This project is inspired by the game “Screwball Scramble,” a marble obstacle course originally created by TOMY Games. The goal of this board game is to use skill and coordination to maneuver your marble throughout the track. You can challenge yourself to beat the clock or race against your friends to see who is the fastest!

Purdue Pete’s Adventure Park is a unique spin on the original game, specially designed for Purdue fans! Players must rock the marble across the tilting Boilermaker Special tracks, launch it up the Engineering Fountain, navigate through the maze to graduation, and take Giant Leaps to the top of the Bell Tower. This game is designed for Boilermakers ages 5 and up. It can be played alone or with friends, making it perfect for Purdue family game nights, hobbyists hoping to win a world record, or just to pass the time between classes.

## **1.2 Design Requirements & Constraints**

Project Requirements:

1. Function: novel mechanical or mechatronic toy with two non-trivial actions
2. Size limit: 10x10x10 inches
3. Purchase Budget: \$70

For the course to run smoothly, the team had to carefully consider the size of each subassembly in relation to the transitions and the size of the board. The entire toy had to be designed for assembly, so each component required some means to be fastened to the board. Since this toy is fully mechanical, the team had no issue staying within budget. The entire track was 3D printed, save for the acrylic board and marbles.

## **2. Concept Generation and Selection**

During the concept generation phase, the team brainstormed a large variety of Purdue-themed obstacles. Many of the obstacles were inspired by the original game, Screwball Scramble. The long list of ideas included: the Engineering Fountain, the Bell Tower, train tracks, a magnetic crane, parallel bars, a tire-like obstacle that later became steps to leaps, a blind maze, an open maze, a catapult, and a bell.

The selection process was rather simple. Since the team consists of four members, each member chose a concept they felt particularly drawn to which resulted in the four main obstacles seen on the current prototype. Originally, the plan was to have a control panel, similar to the original Screwball Scramble. During the prototyping phase however, the team realized it was far easier to keep the user inputs attached to each obstacle, additionally making the track less confusing for the user.

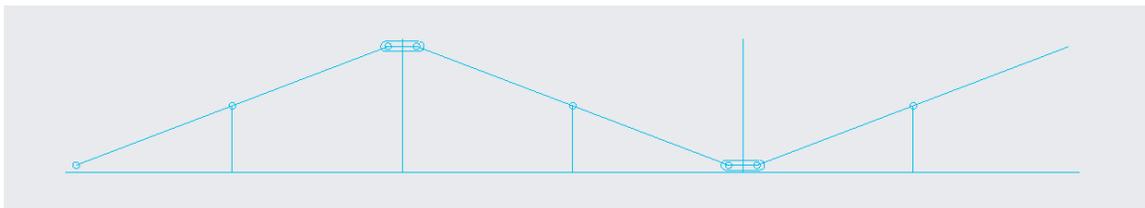
The team later decided to add one final obstacle to help with the transition between the Engineering Fountain and the maze. Since the entrance to the maze is far higher than the exit of the fountain, the elevator obstacle was added. This required the user to pull a slanted platform up

to the height of the maze, at which point the ball would easily roll out and on to the next obstacle.

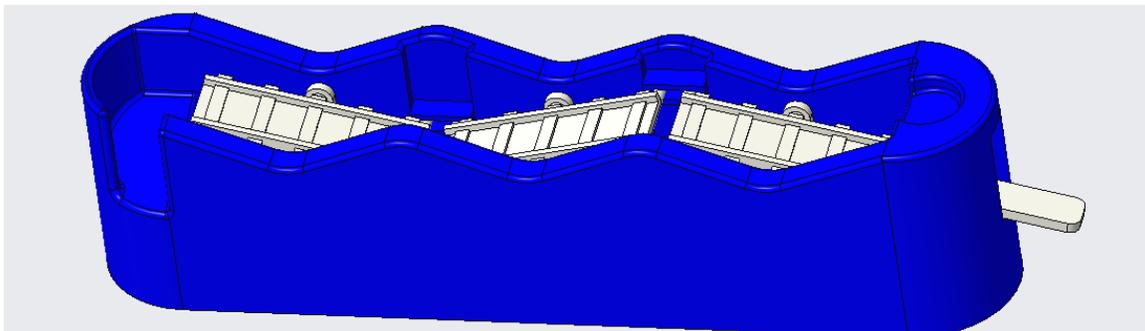
### 3. Detail Design

#### 3.1 Boilermaker Special Tracks

The Boilermaker Special tracks are comprised of three train tracks that each rotate about their central axis. The ends of each track are constrained to a slot in one of the two sliders. When the first track tilts, it pushes the sliders up and down, tilting the other two tracks. The motion skeleton for this component is shown in Figure 3.1.1 below.



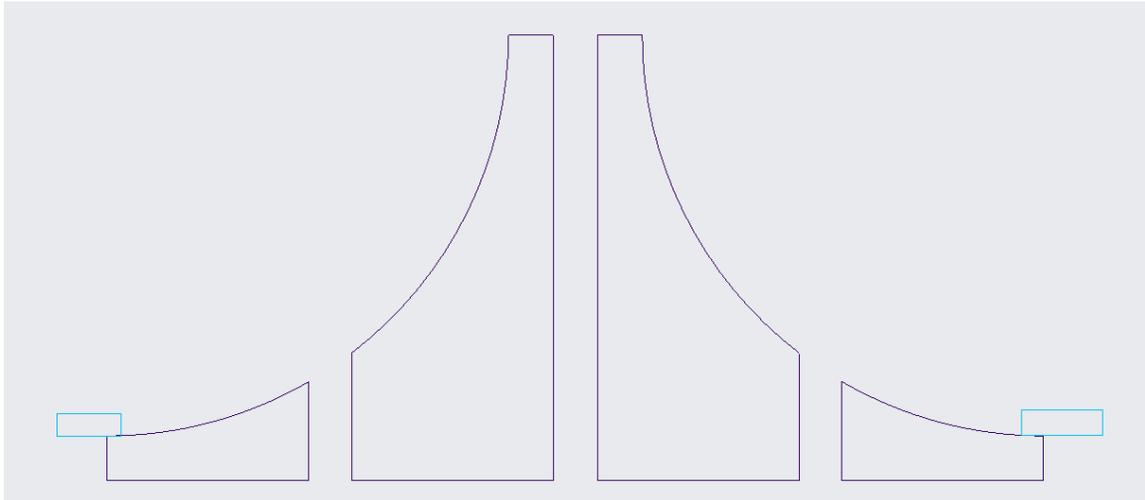
**Figure 3.1.1:** Boilermaker Special Tracks – Motion Skeleton



**Figure 3.1.2:** Boilermaker Special Tracks – Assembly

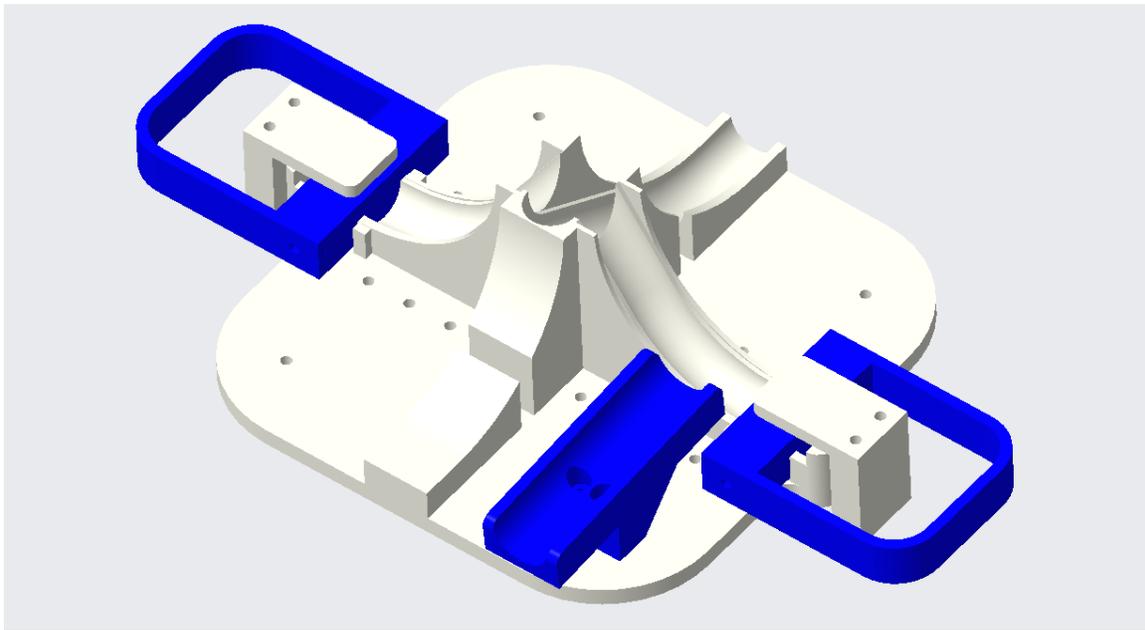
The final subassembly, shown in Figure 3.1.2 above, consists of three tracks, two sliders, a track base, and a large border. The end of the first track extends past the borders, creating a lever for the user to control the motion of the tracks. The borders prevent the marble from rolling off the tracks and constrain the sliders to translate vertically. The end of the border has a 10° slope and the height was adjusted to align with the ramp to the next obstacle.

## 3.2 Engineering Fountain



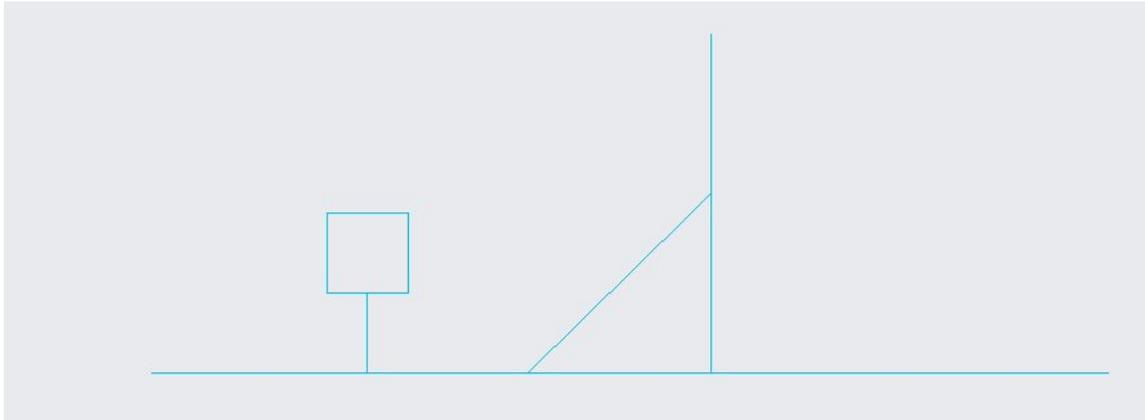
**Figure 3.2.1:** Engineering Fountain – Motion Skeleton

The final assembly for the Engineering Fountain is shown in figure 3.2.2 below. The primary component is the Engineering Fountain shaped base. This contains three marble tracks and one flat leg. The launcher components are each comprised of two separate parts. One slider part was originally designed and printed. Then, a handle was attached to make the pulling motion easier so that it does not interfere with the springs. Next, a cover was added above each slider so that the slider is not pulled upward, but instead is slid backward as desired. Finally, a ramp was added to the base so that the marble could roll easily from the end of the Train Tracks onto the start of the Engineering Fountain obstacle.



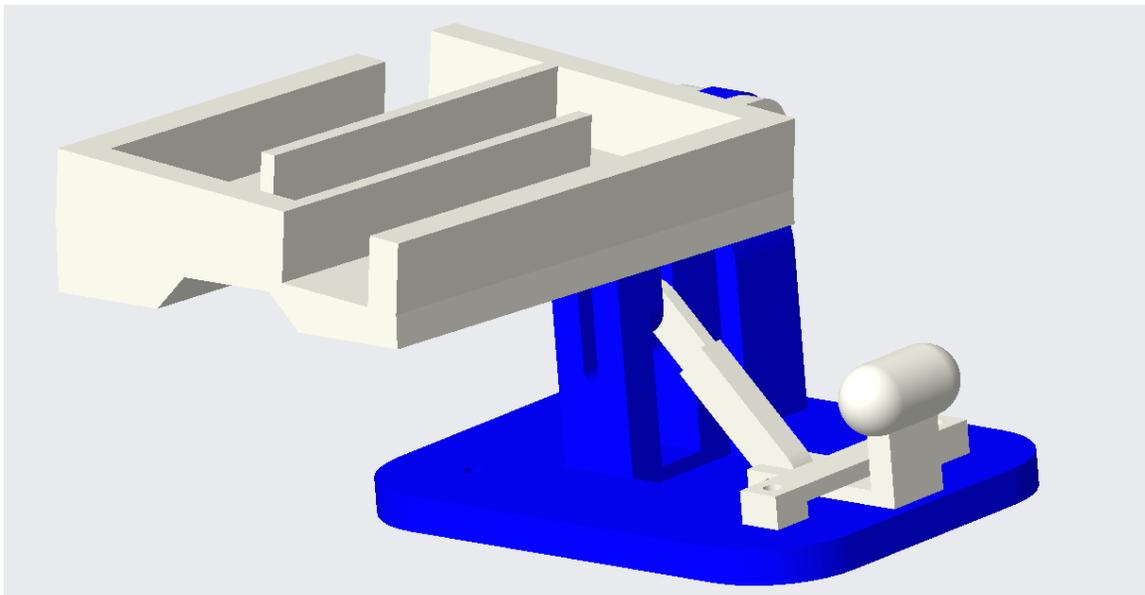
**Figure 3.2.2:** Engineering Fountain – Assembly

### 3.3 Maze to Graduation



**Figure 3.3.1:** Maze to Graduation – Motion Skeleton

The final assembly for the Maze to Graduation obstacle can be seen below in Figure 3.3.2. This consists of a maze on an upper plate supported in two points by a base plate. One of these points is a hinge while the other is the arm of the actuation mechanism. This mechanism consists of a slider and two arms constrained to slots. This allows the user to push and pull the knob to tilt the maze, guiding the marble. The motion skeleton for this mechanism can be seen above in Figure 3.3.1. The first iteration of this design did not have the proper spacing on the arms to allow the maze to fully actuate. In subsequent designs this was changed but the maze was still hard to control. To fix this, the slot was shortened to keep the arms in a more feasible range of motion, and a slot was added to the bottom of the maze plate to allow for the full range of motion. The entrances and exits to the maze were also changed to align with the obstacles before and after this component.



**Figure 3.3.2:** Maze to Graduation – Assembly

### 3.4 Steps to Bell Tower

The Steps to Bell Tower obstacle, shown in Figure 3.4.1, moves the marble into the Bell Tower by launching it across four platforms that increase in elevation. This obstacle can be split into 3 parts: the launcher, the ramp, and the Bell Tower. First, the marble arrives onto the launcher platform after rolling from the previous obstacle, the maze to graduation. The user then skips the ball along the four platforms and onto the ramp by pressing a lever. The ramp then guides the marble into the Bell Tower completing the game.

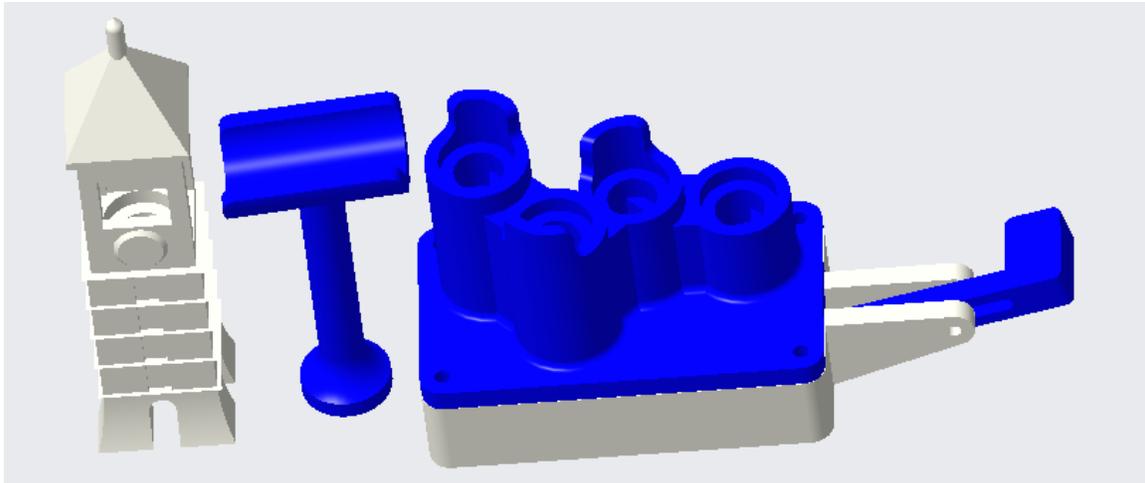


Figure 3.4.1: Steps to Bell Tower – Assembly

The launcher mechanism launches the marble when the user presses the lever. The mechanics of the launcher can be seen in motion skeleton shown in Figure 3.4.2 below. As the lever is pressed downward the launching spikes move upward which launches the ball onto the next platform.

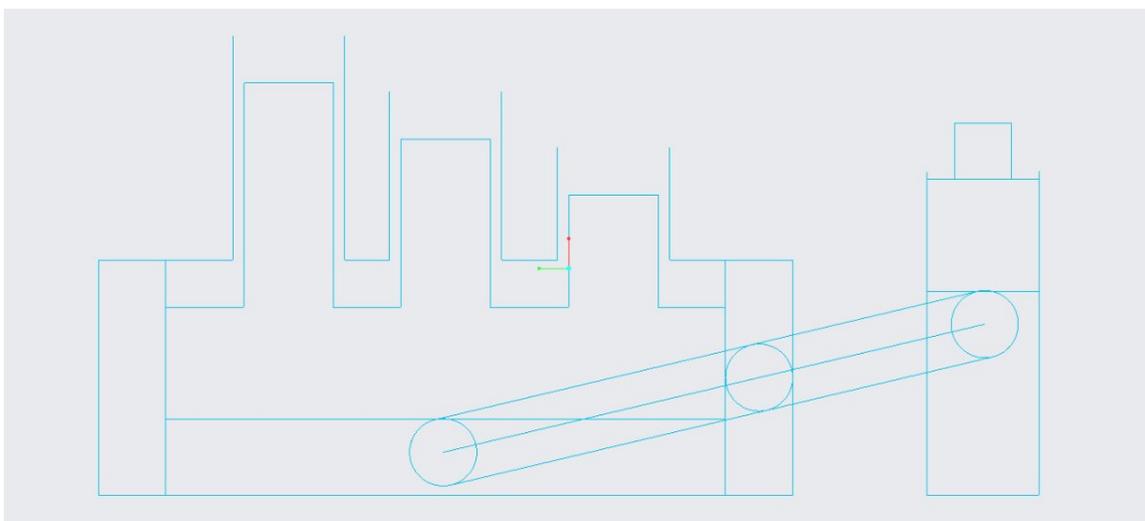
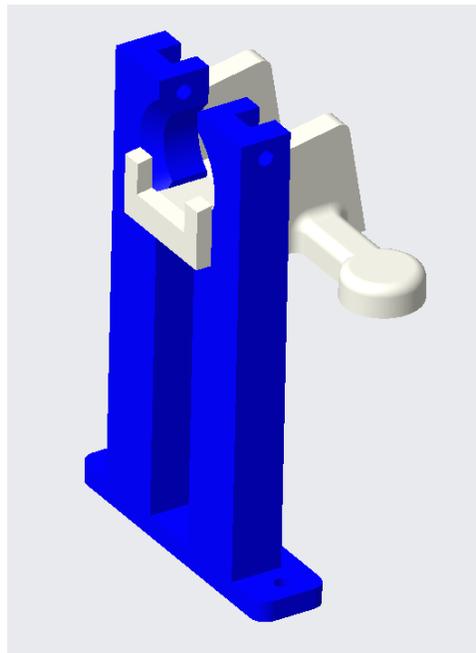


Figure 3.4.2: Steps to Bell Tower – Motion Skeleton

### 3.5 System Integration

The system integration of the entire assembly used a bottom-up design. Each obstacle was designed and prototyped in isolation and then combined into an assembly. The key focus of system integration was determining the order of the obstacles and how the marble would transition from one obstacle to another. It was determined that the obstacle order would be: Boilermaker Train Tracks, Engineering Fountain, Maze, and Steps to Bell Tower. Since the first obstacle (Boilermaker Train Tracks) was at a higher elevation point than the second obstacle (Engineering fountain), a simple ramp was used to connect those obstacles. The second obstacle (Engineering Fountain) was at a lower elevation point than the third obstacle (Maze to Graduation). To get the marble from obstacle two to obstacle three, an elevator mechanism was designed. The miniature elevator, shown in Figure 3.5.1, consists of the elevator platform and an upright slider. After completing the Engineering Fountain obstacle, the marble rolls onto the elevator platform allowing the user to lift the marble to the Maze to Graduation obstacle. The third obstacle (Maze to Graduation) is at a higher elevation point than the fourth obstacle (Steps to Bell Tower) so the marble can roll off the maze and go directly onto the first launching platform of the Steps to Bell Tower obstacle. System integration required strategically placing the obstacles near each other to allow the marble to easily transition.



**Figure 3.5.1:** Elevator – Assembly

## 4. Prototyping and Testing

Since a bottom-up design was used, each obstacle was prototyped in isolation. The prototyping process was done by 3D printing parts, analyzing what changes need to be made to ensure functionality, revising the part design, and reprinting the part. This was done until each obstacle worked properly. Early prototyping consisted of determining the best tolerances for tight and loose fits. It was found that the best offset for loose fits was 0.2mm (about 0.01 in) and the best offset for tight fits was  $< 0.2\text{mm}$ . Later prototyping consisted of obstacle optimization, DFM, and DFA. Minor changes were made to optimize the operation of the obstacles. For example, a cover was added to the sliders on the Engineering fountain to prevent them from being lifted out of the track. Changes like this were made to all the obstacles to enhance the users ease of operation and to prevent obstacle failure. DFM was implemented by designing parts in a way that minimized the need for supports, print time, and filament consumption. This required some redesigning for certain parts to be flat on the bottom. Unused volume from parts were also eliminated. DFA was implemented by adding M3 mounting holes to each obstacle so they could be screwed onto the base of the toy.

All parts were 3D printed in either blue or white PLA at 15% infill with a grid infill pattern. These settings ensured fast print times for prototyping. Since these parts were not subject to any kind of loading, low infill did not increase the probability of part failure.

After printing and assembling each part, the entire board was put together. The build process consisted of mapping out the position of each obstacle by temporarily placing it on the board, marking the position of each obstacle, drilling holes into the board, and then permanently mounting the obstacles to the board with M3 screws and M3 lock nuts. Four cardboard boxes were also glued to the bottom of the board to act as a stand.

The main difficulty with prototyping was determining scale. The marble was the only real reference for how large each obstacle should be. This issue was solved with multiple rounds of prototyping. By seeing each obstacle in physical form, it became easier to determine how big it should be. Another issue encountered was obstacle functionality. Some obstacles did not work as expected. Functionality issues were solved by changing the design of the mechanism entirely. This often involved simplifying the mechanism to be more easily assembled and operated. For example, the original user input for the Boilermaker Special Tracks obstacle was supposed to be a button that the user pressed. This design proved to be too complex when the parts were printed. The design of the mechanism was then revised to be a simple lever. This change made assembly easier, functionality better, and user control more intuitive.

Prototyping for this project required little to no expense. Most parts were 3D printed and the screws and springs were supplied from the lab. The only purchased parts were the HDPE board from Menards and the marbles from Amazon. A more in depth BOM is attached in the Appendix below.

## **5. Results and Discussion**

Overall, the team was able to create a fully functional physical prototype with very few minor issues that affected user experience. The prototype allowed the user to fully play the game as intended. The boilermaker special tracks functioned. However, they often got stuck and required user intervention to resume functionality. This was likely due to a tolerancing issue between two components that could have been resolved with one more prototyping iteration. The Engineering Fountain functioned completely as expected without any issues. A potential future improvement would be to cover or hide the springs in the design. However, the visibility of the springs did not affect the component's performance. The maze also worked as expected with very few issues. Occasionally, the ball would get stuck in one corner, requiring user interference to push the ball forward. This could be improved by slightly increasing the slope of the maze plate. The Steps to Bell Tower challenge also operated as expected with no issues and requires no improvements.

Our team would have liked to include more prototype iterations. There were many issues encountered throughout the prototyping process that were not foreseen in the CAD models. The team believes that many of the issues listed above could have easily been resolved with only one or two more iterations. In the end, the team learned a significant amount about designing parts for assembly, creating moving components in CAD, and prototyping using 3D printing as part of a long-term design process.

## **6. Conclusion**

The team achieved their goal of creating a Purdue-themed version of the popular board game, Screwball Scramble. The final prototype was fully functional throughout the entirety of the toy fair with few minor issues. One more prototype iteration would likely have solved many of these issues. Many stemmed from slight errors in tolerancing 3D printed parts. If the team were to continue working on this project, creating a fully marketable toy, they would resolve these issues, clean up the aesthetics of the toy, and adjust the difficulty level for a wider range of audiences.

## References

*Screwball Scramble*. (n.d.). TOMY. Retrieved April 28, 2024, from <https://us.tomy.com/screwball-scramble/>

# Appendix

## Bill of Materials

<b>Item</b>	<b>Price</b>	<b>Number Used</b>	<b>Purpose</b>
<b>HDPE Sheet</b>	\$17	1	Base Plate
<b>Marbles</b>	\$4.99	10	Component In Game