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Toy Train Group 1

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MEMS 411

Toy Train 1

Toy Train 1

Peter Szostak, Chris Levin, Chris
Haeberle

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1 Introduction

1.1 **Project** problem statement

Toy Train - Design a toy train that carries and lays its own track as it travels. Load the train with an assortment of straight and curved track and have it select and install the pieces in sequence while moving forward over the track as it laid. This is a simple toy and should not involve computers or programming.

1.2 List of team members

- Peter Szostak
- Chris Levin
- Chris Haeberle

2 Background Information Study

2.1 A short design brief description that defines and describes the design problem

2.2 Summary of relevant background information (such as similar existing devices or patents, patent numbers, URL's, et cetera)

https://www.google.com/patents/US3300826?dq=conveyor+belt&hl=en&sa=X&ei=5WR_VLecD8GgyASCtoKQDw&sqi=2&pf=1&ved=0CCQQ6AEwAQ

https://www.google.com/patents/US1974330?dq=toy+train&hl=en&sa=X&ei=FmV_VMvvBY-RyATqhoLwDQ&ved=0CCsQ6AEwAg

https://www.google.com/patents/US1534303?dq=toy+train+track&hl=en&sa=X&ei=TGV_VP-ADoT5yASOiIGABQ&ved=0CDIQ6AEwAw

3 Concept Design and Specification

3.1 User needs, metrics, and quantified needs equations. This will include three main parts:

3.1.1 User Needs Interview

Table 1: User Needs Interview

Customer Data: Toy Train			
Customer: Prof. Jakiela		Interviewers: Peter Szostak, Chris Levin, Chris Haeberle	
Address: 1 Brookings Drive		Date: 9/8/2014	
Question	Customer Statement	Interpreted Need	Importance
Should train be able to make turns?	Train should be able to go straight right or left.	Train can make turns.	5
Does the track have to be in pieces or can it be one continuous track?	Track pieces must be separated and the fit together.	Track is in separate pieces.	5
How fast should train be able to go?	Train should be able to go at least 1/10 the speed of put down track	Train goes at least 1/10 the speed of original train.	3
How large of a circuit should train be able to make?	Closed loop track should be at least three ft. in diameter.	Track is at least 3 ft. diameter loop.	4
	No bigger than ten ft. in diameter	Track is smaller than 10 ft. diameter loop.	4
How is train powered? Or how much power should it use?	Doesn't matter how it's powered. It should use no more than three times original power input.	Train uses less than 3 times original power.	3
How much should the train weigh?	A few pounds tops.	Train weighs less than 5 lbs.	4
Does train have to complete full loop or can it start picking up pieces halfway through?	Train must complete full loop	Train has carries enough track pieces to complete a full loop.	5
Does the train have a predetermined route or can you pick which way you want it to go?	It would be cool if you could tell train which way to go as it operates.	Train can change direction as it goes based on user input	1
Does the train only have to go left, right, or straight?	It would be cool if it could go up, down, or intersection pieces.	Train can lay other pieces in addition to straight, right or left.	1
Does train need to pick up pieces after they are laid?	It would be cool if train could also pick up pieces	Train can pick up track pieces in addition to laying them down.	3

3.1.2 List of identified metrics

Table 2: Identified Metrics

Need Number	Need:	Importance
1	Train can make turns	5
2	Track is in separate pieces	5
3	Train is at least 10% of original speed	3
4	Track loop is at least 3 ft. in diameter	4
5	Track loop is smaller than 10 ft. in diameter	4
6	Train uses less than 300% of original power	3
7	Train weighs less than 5 lbs	4
8	Train carries full library of pieces to complete loop	5
9	Train changes direction based on user input	1
10	Train can lay other pieces besides straight, right, or left	1
11	Train can pick up track pieces	3

3.1.3 Table/list of quantified needs equations

Table 3: Design Metrics

Design Metrics: Toy Train					
Metric Number	Associated Needs	Metric	Units	Min Value	Max Value
1	1	Can make turns	binary	0	1
2	2	Track in separate pieces	binary	0	1
3	3	Speed	percentage	10	100
4	4,5	Diameter	ft.	3	10
5	6	Power	percentage	100	300
6	7	Weight	lbs.	0	5
7	8	Carries full library of pieces	binary	0	1
8	9	Allows user input	binary	0	1
9	10	Can lay "other" pieces	binary	0	1
10	11	Can pick up pieces	binary	0	1

Figure 1: Quantified Needs Equations

Need #	Need	Metric										Need Happiness	Importance Weight	Happiness Value	
		Can make turns	Track in separate pieces	Speed	Diameter	Power	Weight	Carries full library of pieces	Allows user input	Can lay "other" Pieces	Can pick up pieces				
1	Train can make turns	1												0.132	
2	Track is in separate pieces		1											0.132	
3	Train is at least 10% original speed			1										0.079	
4	Track loop is at least 3 ft. in diameter				1									0.105	
5	Track loop is smaller than 10 ft. in diameter				1									0.105	
6	Train uses less than 300% of original power					1								0.079	
7	Train weighs less than 5 lbs.						1							0.105	
8	Train carries full library of pieces to complete loop							1						0.132	
9	Train changes direction based on user input								1					0.026	
10	Train can lay other pieces besides straight, right, left									1				0.026	
11	Train can pick up pieces										1			0.079	
	UNITS	binary	binary	percent	ft.	percent	lbs.	binary	binary	binary	binary		TOTAL HAPPINESS:		
	Best Value	1	1	100	3	100	0	1	1	1	1				
	Worst Value	0	0	10	10	300	5	0	0	0	0				
	Actual Value														
	Metric Happiness														

3.2 Four (4) concept drawings

Figure 2: Concept Design 1

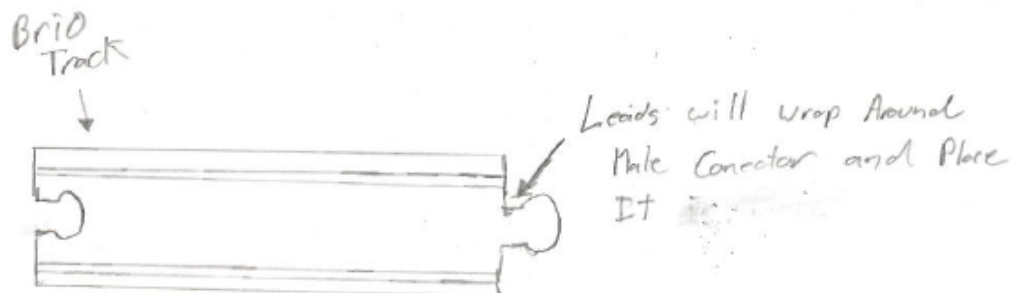
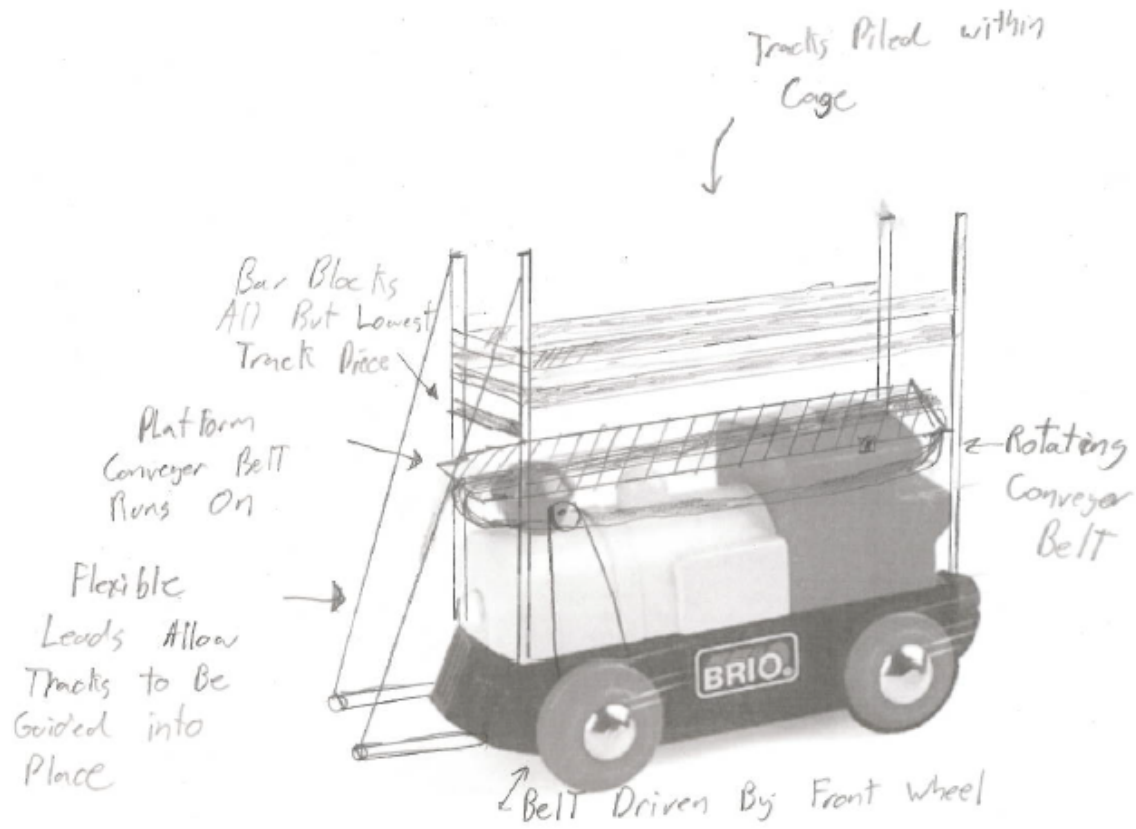


Figure 3: Concept Design 2

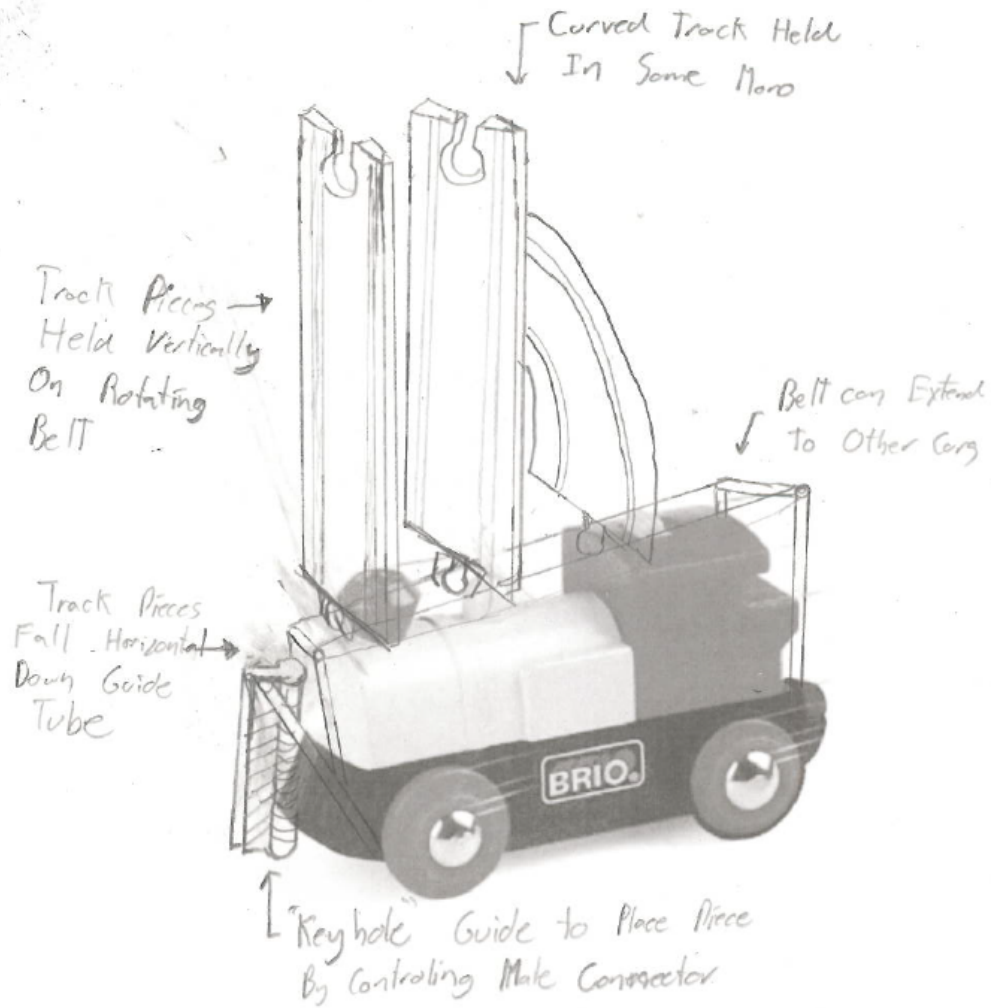
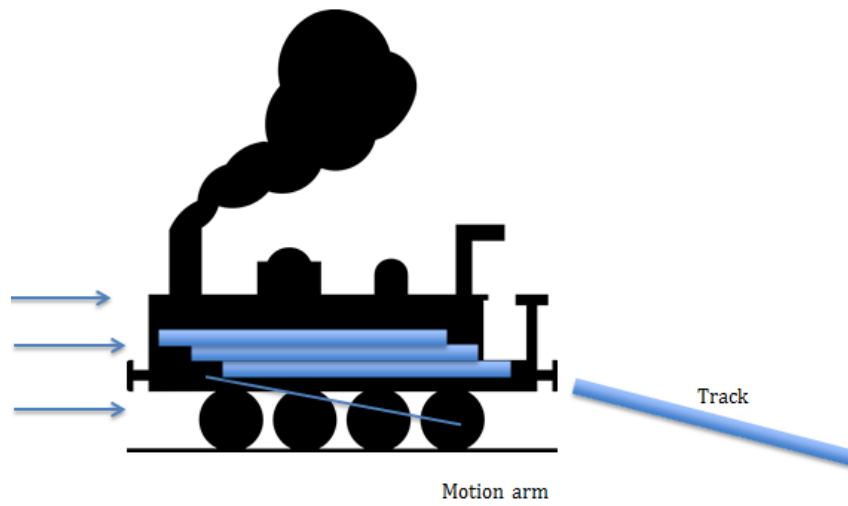


Figure 4: Concept Design 3



Close up Connection

Wooden track

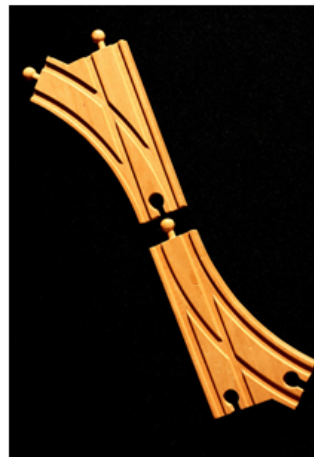
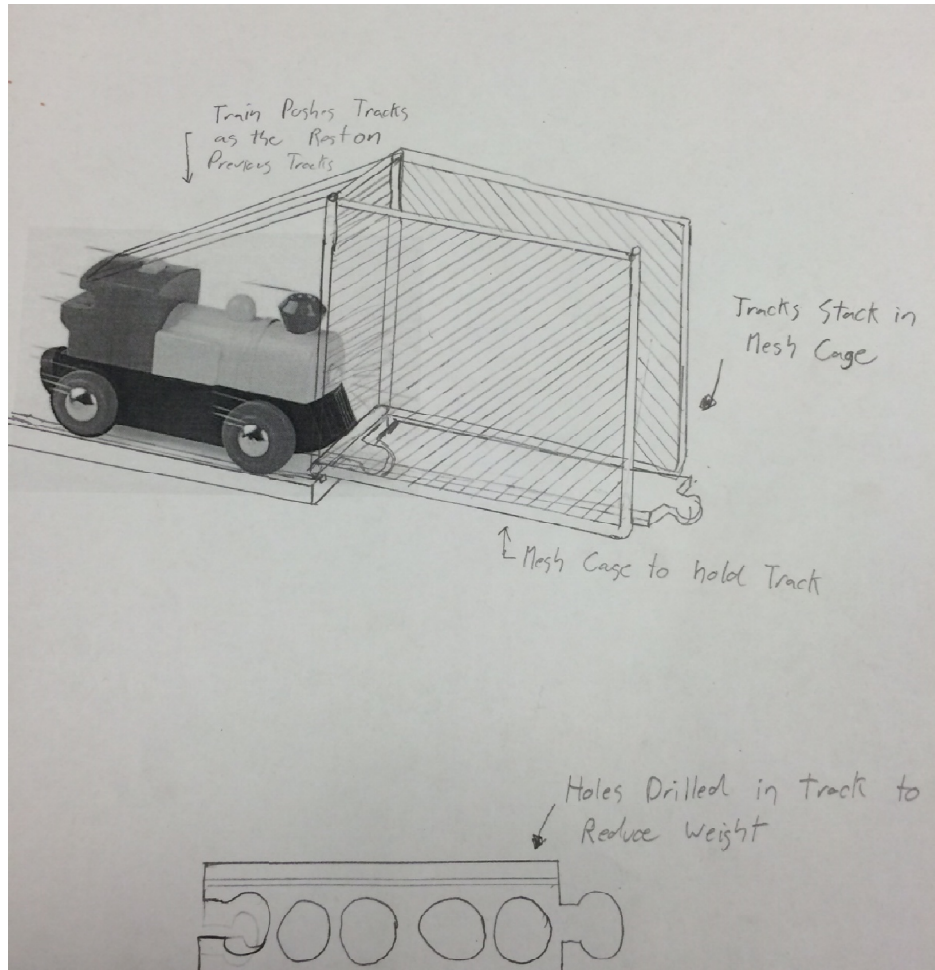


Figure 5: Concept Design 4



3.3 A concept selection process.

3.3.1 Concept scoring (not screening)

Figure 6: Concept Scoring

Need #	Need	Metric										Need Happiness Option 1	Need Happiness Option 2	Need Happiness Option 3	Need Happiness Option 4	Importance Weight	Happiness Value Option 1	Happiness Value Option 2	Happiness Value Option 3	Happiness Value Option 4
		Can make turns	Track in separate pieces	Speed	Diameter	Power	Weight	Carries full library of pieces	Allows user input	Can lay "other" pieces	Can pick up pieces									
1	Train can make turns	1										0	1	0	1	0.132	0	0.13	0	0.13
2	Track is in separate pieces		1									1	1	1	1	0.132	0.13	0.13	0.13	0.13
3	Train is at least 10% original speed			1								0.5	0.6	0.8	0.4	0.073	0.04	0.05	0.06	0.03
4	Track loop is at least 3 ft. in diameter				1							0.1	0.7	0.1	0.85	0.105	0.01	0.07	0.01	0.09
5	Track loop is smaller than 10 ft. in diameter				1							0.1	0.7	0.1	0.85	0.105	0.01	0.07	0.01	0.09
6	Train uses less than 300% of original power					1						0.5	0.5	0.25	0.5	0.073	0.04	0.04	0.02	0.04
7	Train weighs less than 5 lbs.						1					0.6	0.6	0.4	0.4	0.105	0.06	0.06	0.04	0.04
8	Train carries full library of pieces to complete loop						1					0	1	0	1	0.132	0	0.13	0	0.13
9	Train changes direction based on user input							1				0	0	0	0	0.026	0	0	0	0
10	Train can lay other pieces besides straight, right, left								1			0	0	0	1	0.026	0	0	0	0.03
11	Train can pick up pieces									1		0	0	0	0	0.073	0	0	0	0
UNITS		binary	binary	percent	ft.	percent	lbs.	binary	binary	binary	binary	TOTAL HAPPINESS:								
	Best Value	1	1	100	3	100	0	1	1	1	1	0.29	0.69	0.28	0.71					
	Worst Value	0	0	0	10	300	5	0	0	0	0									
	Actual Value Option 1	0	1	50	10	200	2	0	0	0	0									
	Metric Happiness Option 1	0	1	0.5	0.1	0.5	0.6	0	0	0	0									
	Actual Value Option 2	1	1	60	5	200	2	1	0	0	0									
	Metric Happiness Option 2	1	1	0.6	0.7	0.5	0.6	1	0	0	0									
	Actual Value Option 3	0	1	80	10	250	3	0	0	0	0									
	Metric Happiness Option 3	0	1	0.8	0.1	0.25	0.4	0	0	0	0									
	Actual Value Option 4	1	1	40	4	200	3	1	0	1	0									
	Metric Happiness Option 4	1	1	0.4	0.85	0.5	0.4	1	0	1	0									

3.3.2 Preliminary analysis of each concept's physical feasibility

Concept 1:

This concept is built over a commercially available Brio battery powered electric train. At its heart a conveyor belt is run by the forward left wheel of the Brio train. This belt is geared so that it will dispel a track at precise intervals to allow the track to fit perfectly into place. Precise timing is extremely important to this design, any slip. A few assumptions are required for this design. Firstly it is assumed that the friction coefficient between the stacked tracks is relatively small. This would allow the lowest track on the conveyor belt to slide unimpeded into place. This design is simple but might be limited by the amount of tracks that can be stacked upon a single train. Also this design would have to be modified extensively to accommodate curved pieces. Manufacturing of this design would be relatively simple as all materials are relatively accessible.

Concept 2:

Also built around a battery powered brio train, this concept holds the tracks vertically by the male connector. This would allow tracks to be stored across multiple cars. The tracks would be slotted into place by a "guiding tube" which is shaped like the female connector of the wooden tracks. The "guiding tube" would allow for precise lying of track and it would also allow for a little variability in the timing. Precise timing would still be required for this design but variability due to slipping and friction would not apply. Curved pieces could also fit perfectly into the system with no extra tuning. This would allow for a turning track or circular track to be placed with no trouble. Manufacturing of this design would be relatively simple as all materials are relatively accessible

Concept 3:

Is a visually appealing design. The tracks are contained inside of the train, where they are stacked. A small slit, the size of a cross section of the track, located in the front of the train, just above the wheels, is where the pieces are ejected. The rotational motion of the wheels drives a mechanical “rake” that pushes the lowest piece of the stack through the ejection site. The next piece is help up by the rake until the rake makes a complete rotation. Once the rotation is complete, the next piece will fall into place and the rake will continue to operate. From here, the main difficulties of the design will be incorporating turn pieces.

Concept 4:

The toy train will have a “cage” containing the track pieces stacked on top of each other. The train will need to start off on a piece of track. The bottom piece in the cage will be resting partially on the first piece of track. From there, once the train is turned on it will move forward, decreasing the amount of contact between the old and the new piece of track. Once the train moves entirely over the first piece of track, the next piece in line will fall straight down and make a connection. From here this process repeats itself until a full loop has been executed. Since the cage will be in adherently heavy, there will need to be a counterbalance located towards the back of the train. This design will be reliable in the fact that the only acting force to lay the tracks is gravity. This design can take turn

3.3.3 Final summary

WINNER: CONCEPT DESIGN 4

Design 4 is our winner. Unanimous decision. One of the biggest obstacles in our project design is incorporating the turn pieces. Design three would not be able to easily lay a turn piece followed by a straight piece without an additional guidance system added to the design. Design 1 and 2 are able to carry turn pieces via conveyor belts. In the first design, the turn pieces are sitting on the conveyer, which may make for clumsy transitions between pieces laid. Design 2 will be able to guide the pieces into place using a small guidance piece that the connector piece of the track fits into. Design 4 is very simple, in a good way. The reliability of using the train forward motion to carry and drop the track is unparalleled in the toy train world as we know it. The cage in design 4 can be built to accommodate the straight and turn pieces. In this way, the track laying system is oriented normal to the train, and the train turning will not affect the way the pieces can be laid, since the system is oriented with the train and not the floor.

3.4 Proposed performance measures for the design

1. Train can make turns and complete a full loop
2. Loop is greater than 3' in diameter and less than 10'
3. Train weighs less than 5 lbs
4. Train travels atleast 10% original speed
5. Trains uses less than 300% of original power
6. Train carries full library of pieces

4 Embodiment and fabrication plan

4.1 Embodiment drawing

Figure 7: Embodiment Front View

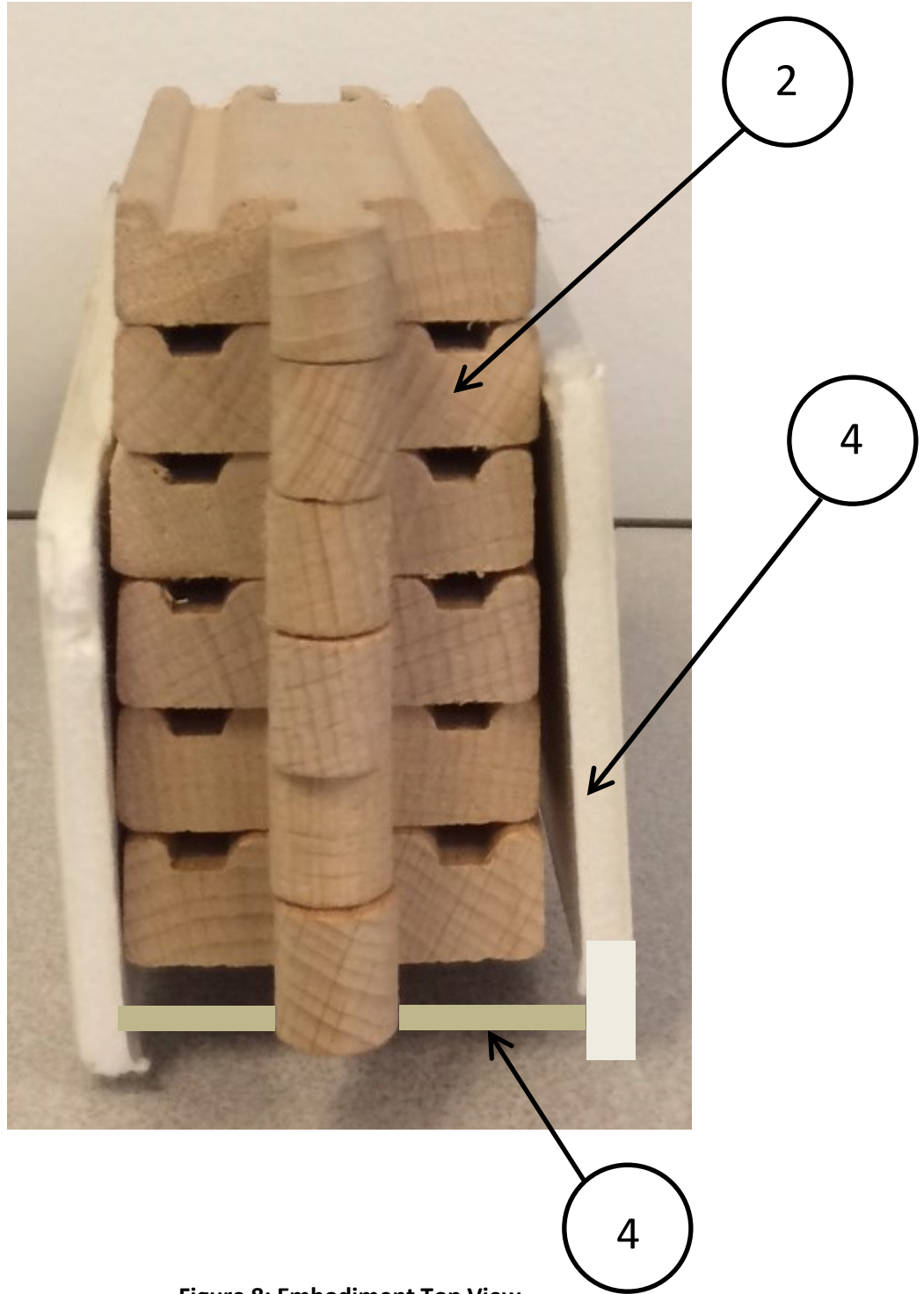


Figure 8: Embodiment Top View

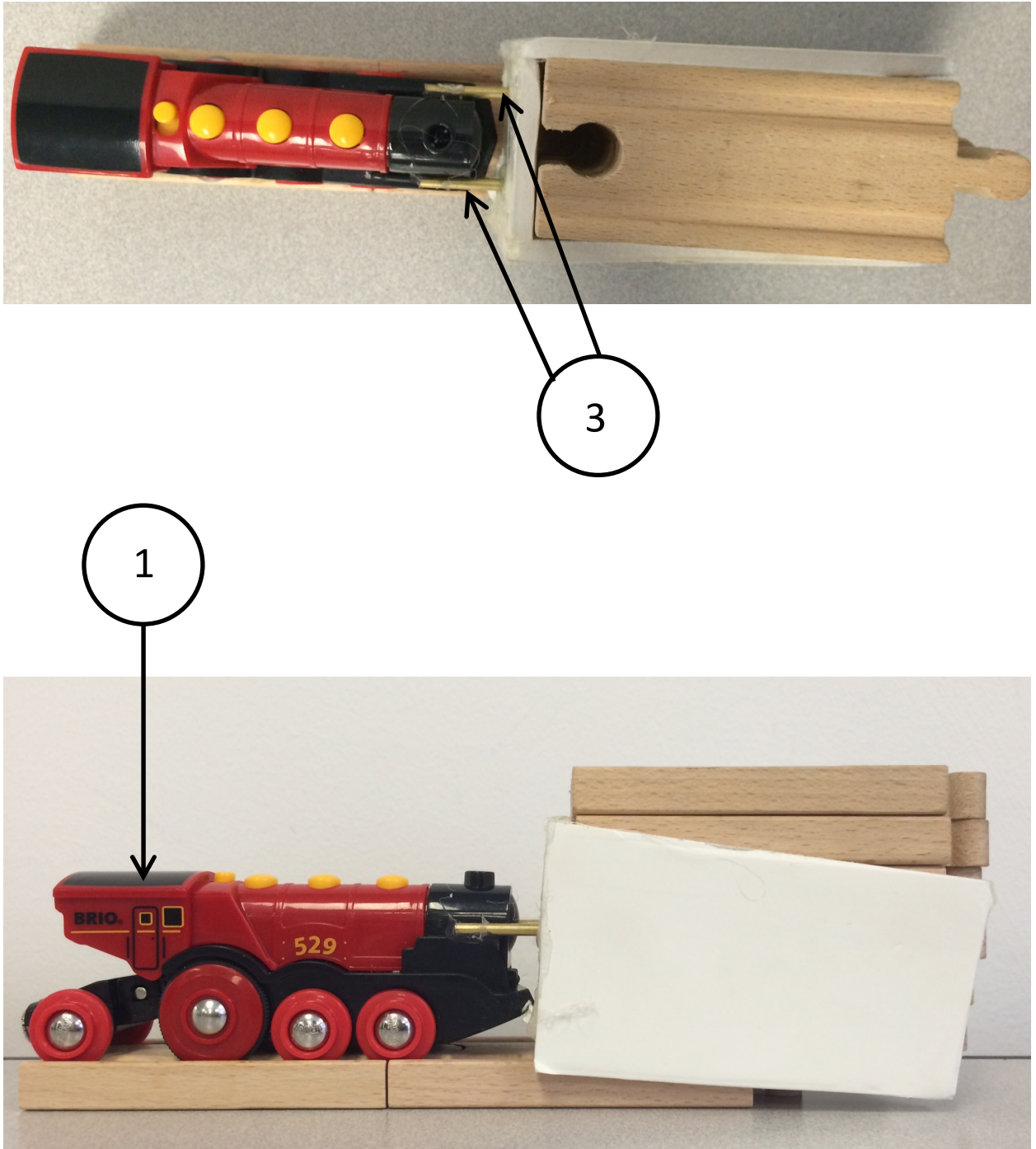


Figure 9: Embodiment Side View

4.2 Parts List

Table 4: Embodiment Parts List

Part No.	Part
1	Train
2	Track
3	Back Support Rods
4	Front Support Rod
5	Foam Cage

Table 5: Embodiment Materials List

Part	Use	Supplier	Part No.	Price
BRIO Mighty Red Locomotive	Train/Base	Brio	BRI-33592	\$24.95
Conductor Carl Wooden Track Set				
-24 Long Curved Tracks				
-25 Long Straight Tracks				
-25 Short Curved Tracks				
-25 Short Straight Tracks	Train Tracks	Conductor Carl	B005FLUH3E	\$44.99
1/8 in. x 48 in. Plain Steel Cold Rolled Round Rod	Support rods Front/Back	Home Depot/Crown Bolt	#48840	\$2.97
1/2in x 4ft x 8ft Polyiso Rigid Foam Board	Cage walls/back	Home Depot	#754404	\$11.24
				Total = \$84.15

4.3 Draft detail drawings for each manufactured part

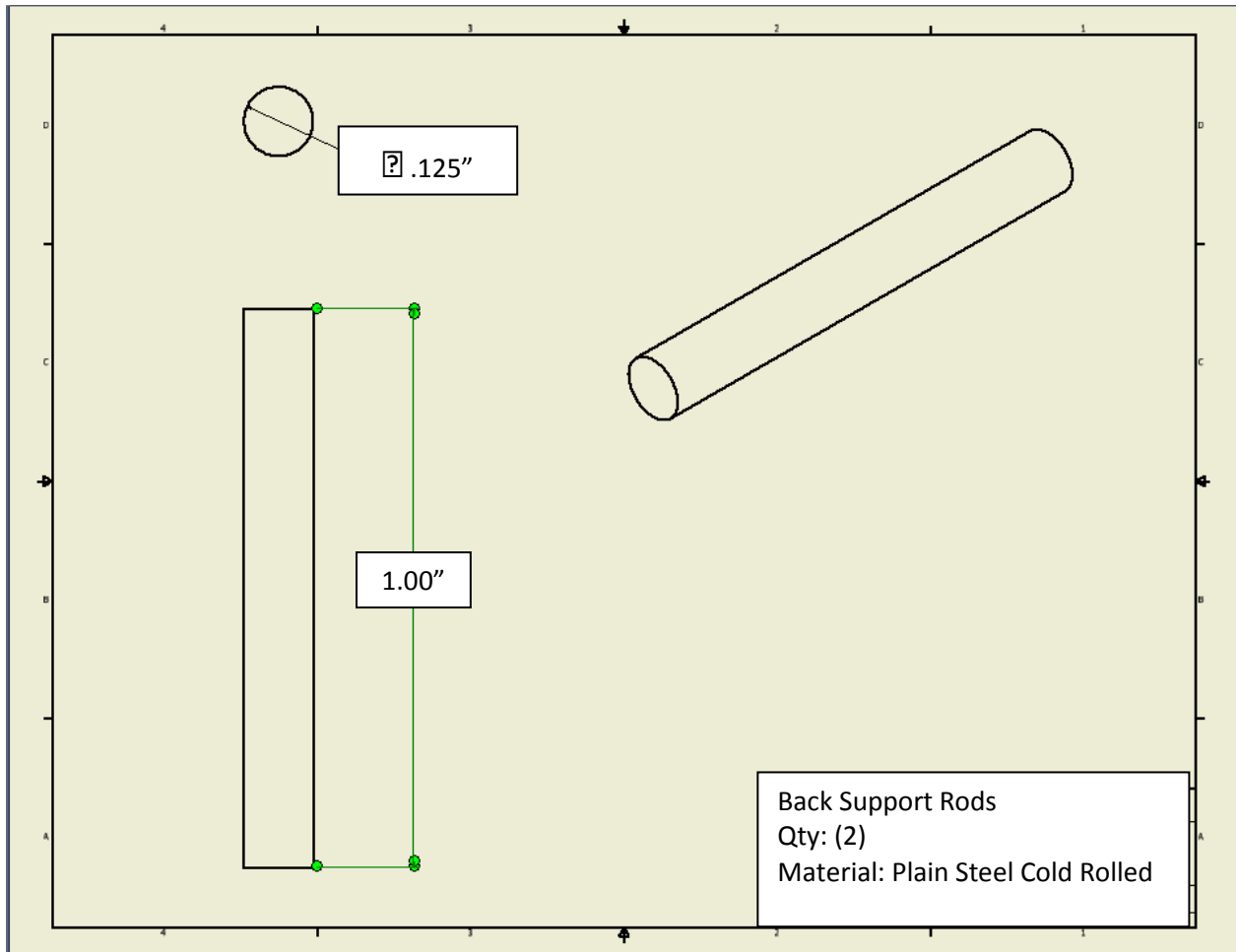


Figure 10: Embodiment Back Support Rods

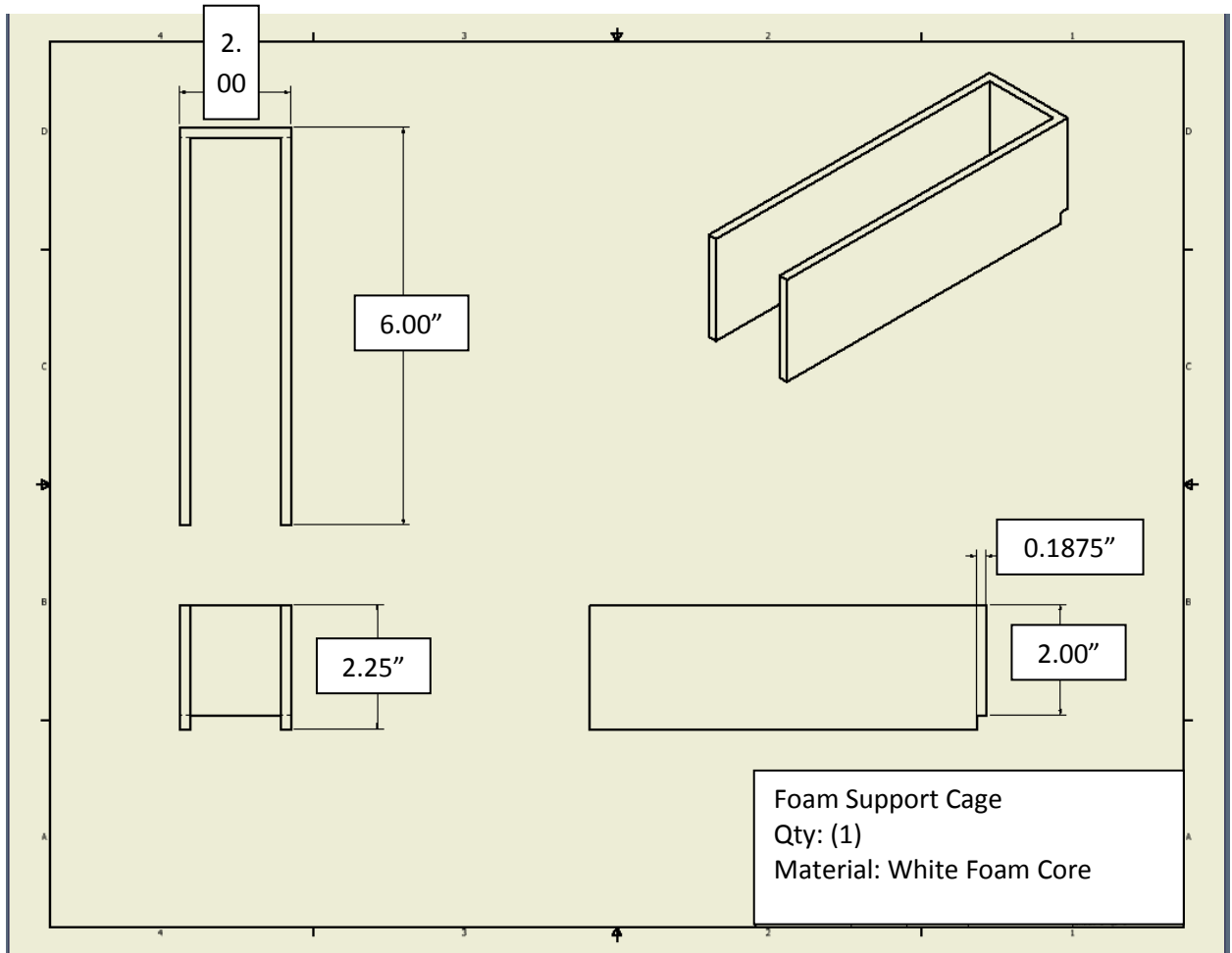


Figure 11: Embodiment Support Cage

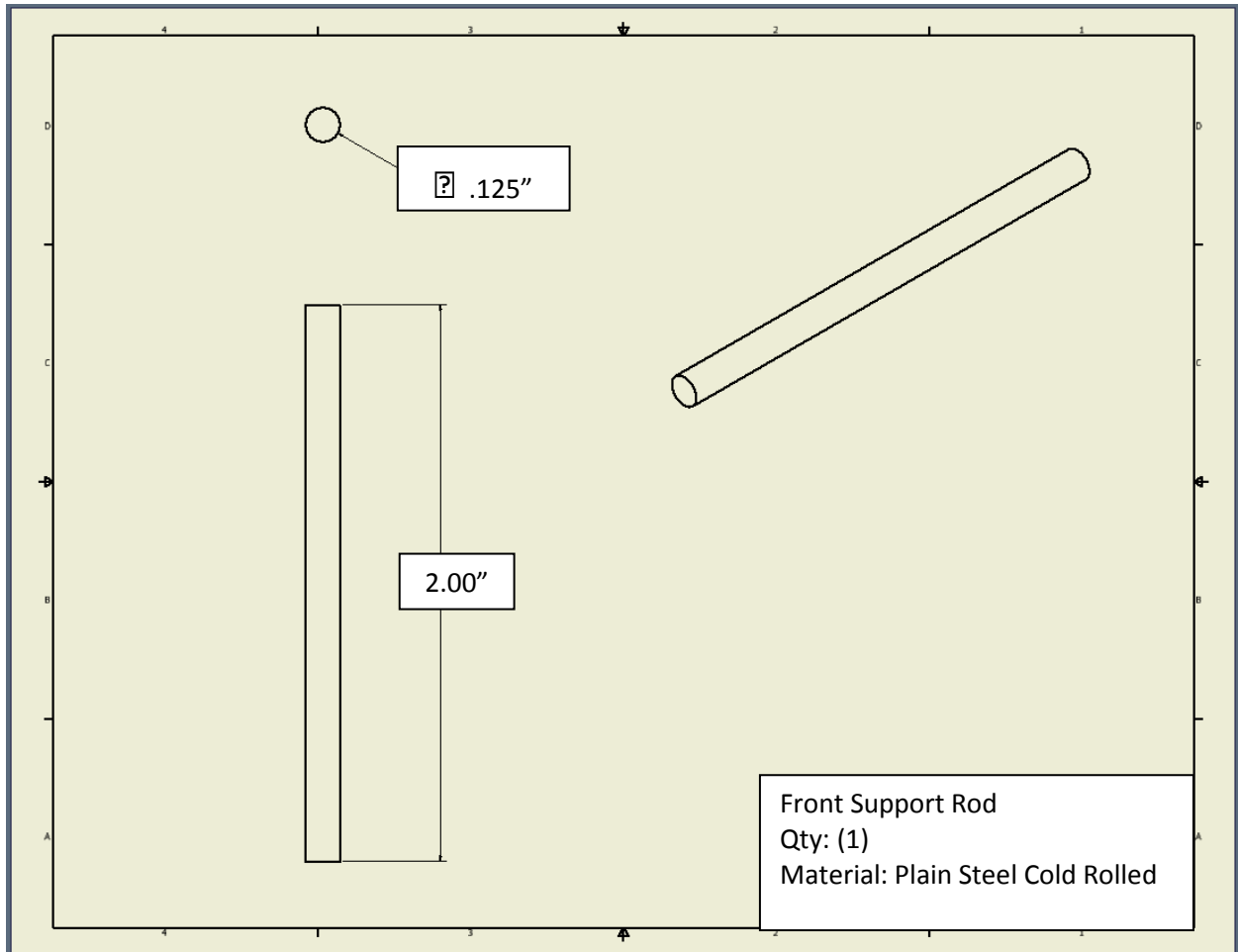


Figure 12: Embodiment Front Support Rod

4.4 Description of the design rationale for the choice/size/shape of each part

Part 1- Train:

We chose the Mighty Red Locomotive from brio for its universality, price and power. Brio trains are the most popular on the market, and can be found amongst most toddlers toys. As the design specifications stated this project was conceived by witnessing toy trains. Of all the commonly available trains that run on the standard wooden track. The mighty Red Locomotive is the only one that utilizes two AAA batteries, most use simply one. It is marketed by its producers as the most powerful train they develop. This locomotive is also larger than most of the standard brio trains which gives us a larger surface on which to attach leads and/or anchors from the track lying device.

Part 2 – Tracks:

The Conductor Carl wooden track set was chosen specifically because it is the cheapest available version of the classic Thomas the tank engine wooden track. This type of track was chosen not only because it is the most universal, but also because it has simple male female track connection. These track connections are the most simple on the market and allow for easy slotting into each other. The tolerance on these connections is $\pm 1/32$ of an inch. This connection might be modified to give us more tolerance as needed. However the prototype functioned with little to no track alterations. The track is also made out of a lightweight wood. The long wooden piece has a mass of 44.5 grams. Please see power analysis and track connection tolerance below for more detail

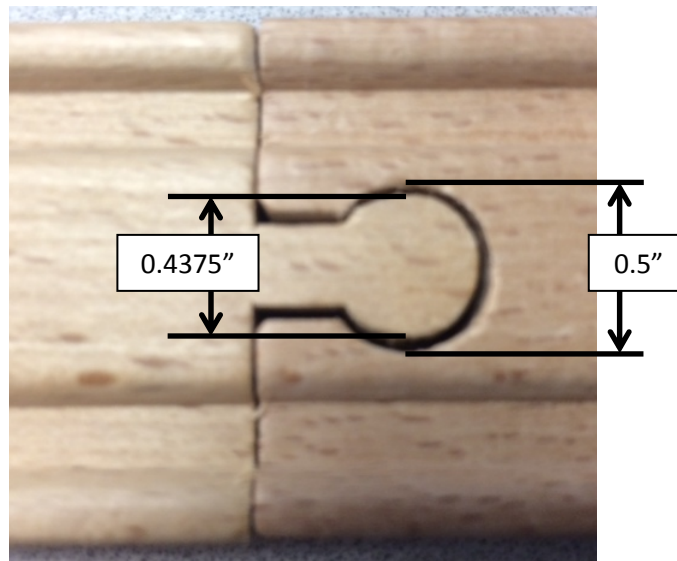


Figure 13: Track Connection Tolerance

Power Analysis:

It was experimentally determined that our train has the power capability to push approximately seven (7) of the 6" track pieces. We determined that in order to complete a 3 ft. loop we will need approximately 16 pieces. Please see picture below:

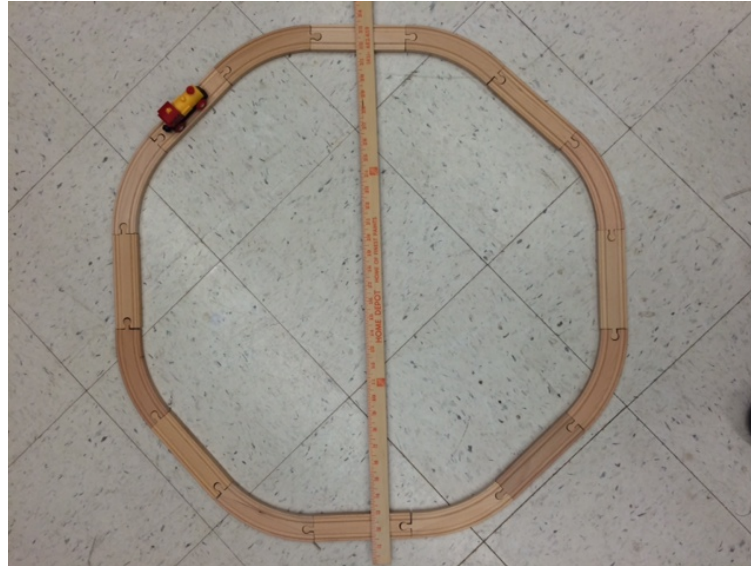


Figure 14: Track Radius

We also weighed one of the 6" pieces and determined that it weighed approximately 44.5 g or 0.0981 lbs. Therefore the total pushing force of our train is approximately 0.6867 lbs. In order to push the weight of all 16 pieces necessary to complete the loop we will need to cut down the weight of each piece by approximately 60%. We will accomplish this by cutting each track in half along the z-axis, cutting the thickness in half. Also we will hollow out some of the inner portion of the track to further reduce weight. After all this if we still do not have enough power we can just add another engine.

Part 3 – Metal Rods:

The purpose of the metal rods is to act as a frame for and a connector to the foam cage which holds the tracks. This rod was selected as it is the perfect match of weight and strength. Most importantly however, as weight and strength ratios of comparable metal rods might be even more suitable, the steel metal rod is cheap and easily attainable. It also works well with hot glue to create solid joints.

Part 4 – Foam Board:

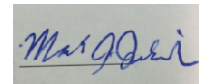
The foam board is chosen mostly for its lightweight and cost effectiveness. It is also very simple to cut shape and adhere to other parts of the design. The sides of the foam board are also very slick which allow the track pieces to slide easily into place.

5 Engineering analysis

5.1 Engineering analysis proposal

5.1.1 A form, signed by your section instructor (insert your form here)

ANALYSIS TASKS AGREEMENT



PROJECT: Toy Train 1 NAMES: Peter Szostak INSTRUCTOR:

Chris Levin

Chris Haeberle

The following engineering analysis tasks will be performed:

- Build Prototype of Design 4 that can lay at least 2 straight track pieces (all group members)
- Peter - Analyze prototype to make sure it meets speed design goals (1/10 original speed)
- Levin - Analyze prototype to make sure it has enough power to carry track pieces
- Haeberle - Analyze prototype to make sure it will meet weight and track diameter requirements (weight < 5 lbs, track diameter > 3 ft.)

Diameter Requirements = 3ft

Each piece is about 6 inches

Should need about 18 pieces

Once we receive pieces we will build prototype with two pieces and measure the towing force. We can then scale up the design to 18 pieces and calculate the power necessary using:

$$P=F*V$$

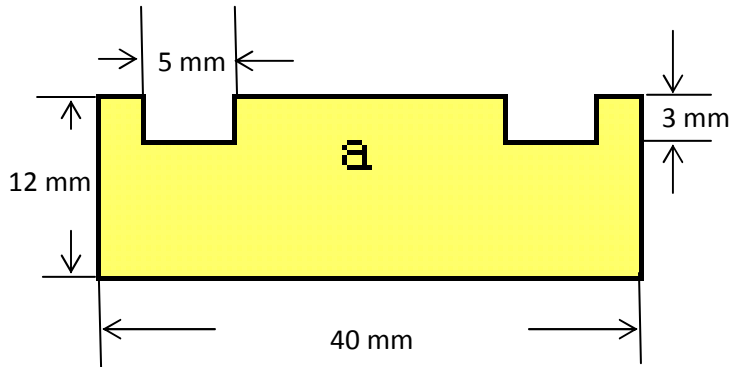


Figure 15: Track Cross-Section Dimensions

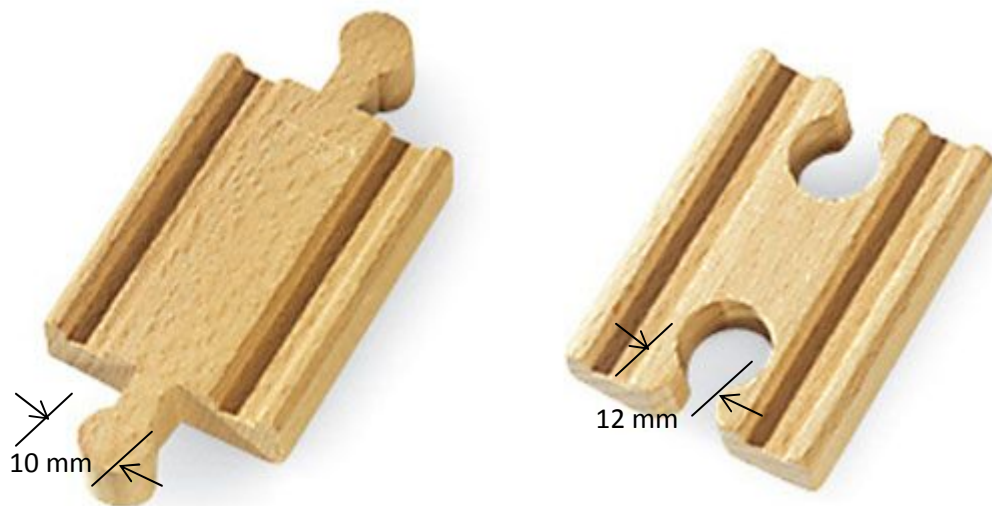


Figure 16: Track Top-View Dimensions

We may need to modify the track connection in order to make the tolerance looser and have more leeway.

5.2 Engineering analysis results

5.2.1 Motivation.

In building our preliminary prototypes and in playing around with the track system and train that we purchased, we realized that there were going to be two major issues to resolve to get our train to work, and lay its own tracks. The first issue was the weight of the track and the limit on how much our train could push. Through some analysis that I will outline later, we

discovered that in order to push the weight required to make a full loop we would either need to significantly cut down the weight of the tracks or get a more powerful train. The second issue that was necessary to resolve in order to get our project to work was the issue of orientating the track pieces such that they would lay in two one another correctly. It was easy to lay a bunch of straight pieces in a row but to make turns was a different story. We tried a lot of different techniques before finally figuring out the best way to make a turn. I will discuss that process in more detail later.

5.2.2 Summary statement of analysis done.

1. Calculating the maximum weight that the train could push:

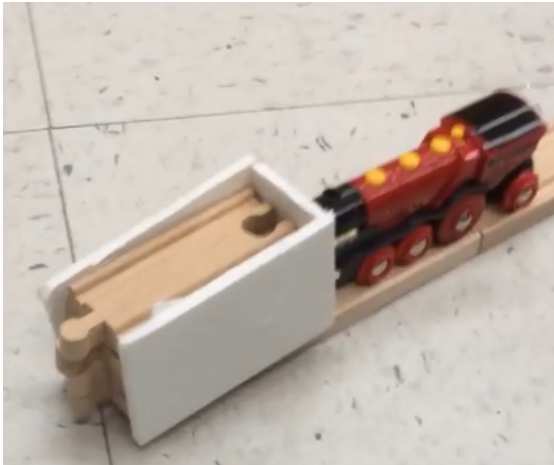


Figure: 17 Train Weight Test

Several Tests we performed to figure out the maximum load the train could push and how we could increase that load or reduce weight of tracks.

2. Getting the pieces to lay into one another:



Modifications were made to track to make it easier for train to lay track.



Figure 18: Track

Modifications

5.2.3 Methodology.

To figure out the weight that the train could push we first used a scale to find the mass of each of the track pieces. We then constructed a test rig to place pieces in and ran several trials with the train pushing tracks of increasing weight. We observed how the train slowed down with increase weight and eventually how at a certain point there was too much weight to overcome the static friction between the tracks.

To get the tracks to align we experiments with many different methods. The most difficult problem was getting a straight piece to align after coming around a turn because the train was position at an angle as it came around the turn. We initially tried to do a lot of trigonometry to figure out the angle at which the train had to lay the track. But this proved to be too difficult because the margin for error was so small. So we ended experimenting with creating different grooves in the track and combining different pieces to overcome this problem.

5.2.4 Results.

Below are the results from our trials in figuring out the maximum weight our train could push. A lot of times the train had trouble overcoming static friction. To combat this we implementing a support train to run behind the main train to give it a bump when it became stuck. This allows the train to push a lot more weight.

Table 6: Track Masses

Type of piece	mass (g)
Big Straight	47
Big Curved	50
Small Straight	26
Small Curved	26

Table 7: Track Mass vs. Train Speed

Mass of track	Speed of train (ft/s)	Speed of train (m/s)
0	0.37	0.112776
52	0.335	0.102108
76	0.311	0.094793
150	0.2728	0.083149
300	0.2126	0.0648
350	0.208	0.063398

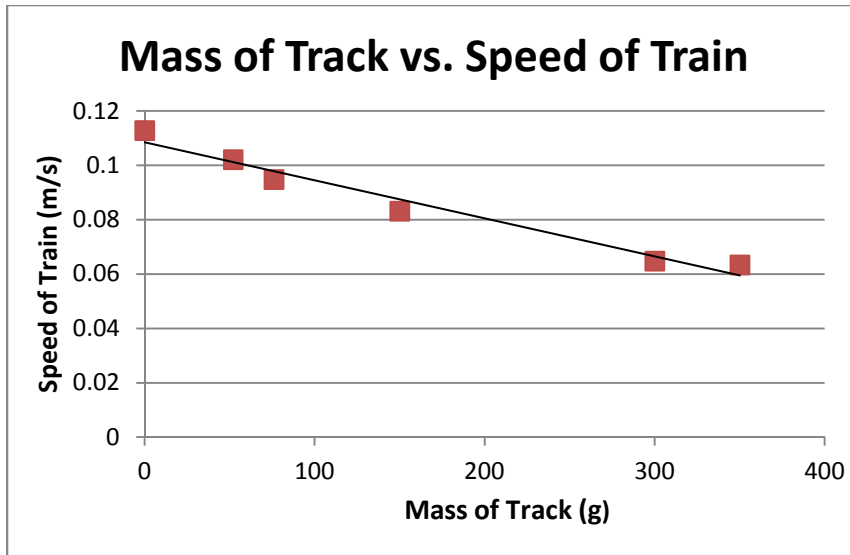


Figure 19: Graph of Mass of Track vs. Train Speed

To overcome the problem of laying track around turns we created a new turn piece by connecting a small curved piece followed by a straight piece, so that the train had time to straighten out before laying the next piece. This is shown in the image below:



Figure 20: Image of Modified Turn Piece

5.2.5 Significance.

Through all our analysis we have discovered some main issues. The biggest thing we realized that our current train doesn't have the power to complete a full loop. We have shown that it can lay straight pieces and a curved piece but doesn't have the power to lay enough tracks to complete the loop. Therefore we have been looking at getting a new, more powerful train. You can see the progression of our prototypes below:

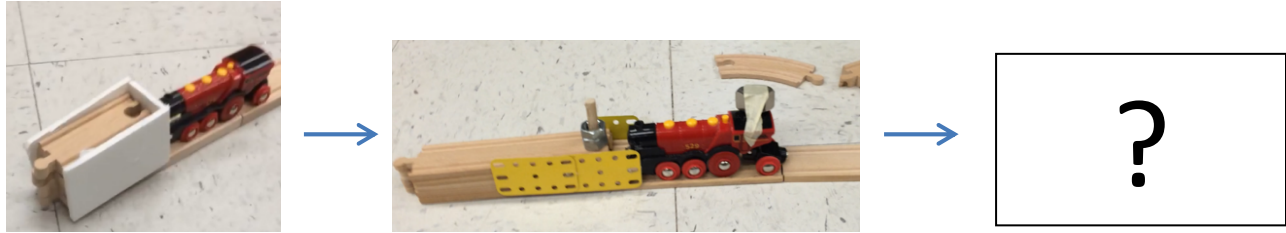


Figure 21: Prototype Design Progression

Another major issue is the consistency of our grooves. Cutting a good groove in the underside of the pieces has been the key to getting pieces to lay straight and to make turning possible. We will need to work with the machine shop to make this process more standard and perfected.

Lastly, working with the distribution of weight has been difficult. As you can see above in the photos we have had to add weights to various areas of the train to ensure the drive wheel stays on the track and that the train goes straight. Perfecting this weight distribution will also be essential for the final prototype.

5.2.6 Summary of code and standards

We realized early on that the best way to solve the issues we had been experiencing was to start prototyping in lab and problem solve as we went along. Our initial design has changed so much and the reason we have been successful so far has been because we started prototyping early enough to see the problems we were having. If we had spent too much time on initially designing we would not have had as much time to problem solve once we started building.

We really tried to follow the standard engineering design process in our project. After our initial research, we developed some designs, and since then we have been working on successive iterations of prototypes. Like I already stated it has been these prototypes that have been the most useful problem solving tools.

6 Working prototype

6.1 A preliminary demonstration of the working prototype (this section may be left blank).

6.2 A final demonstration of the working prototype (this section may be left blank).

6.3 At least two digital photographs showing the prototype



Figure 22: Working Prototype (unloaded)

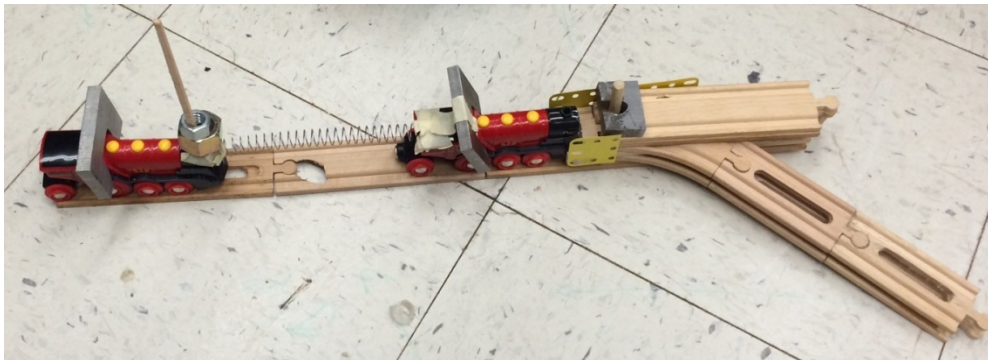


Figure 23: Working Prototype (Loaded)

The train is made up of three distinct sections. The track cage in front is designed to hold both straight and curved pieces. The front train is the primary source of power and pushes the track cage. It has been extensively modified to run at an optimal speed for laying the tracks, and it has been properly counterbalanced to offset the weight of the tracks in the track cage. The final part of the system is the secondary train which acts as backup force, should the primary train have difficulty rounding corners

or transitioning between tracks due to its load. The secondary train is attached to the primary train via a spring. This spring compresses when the primary train gets stuck. The release of this compression creates a gentle bump that allows the primary train to continue without being derailed.

6.4 A short videoclip that shows the final prototype performing



MOV1.mov

Please see attached video of our train performing. We had the following performance specs.

1	Train can make turns – This spec has been accomplished.
2	Track is in separate pieces - This spec has been accomplished.
3	Train is at least 10% original speed - This spec has been accomplished.
4	Track loop is at least 3 ft. in diameter – We have not been able to complete a full loop yet but when we do it will be greater than 3 ft. in diameter and smaller than 10 ft. in diameter.
5	Track loop is smaller than 10 ft. in diameter - We have not been able to complete a full loop yet but when we do it will be greater than 3 ft. in diameter and smaller than 10 ft. in diameter.
6	Train uses less than 300% of original power - This spec has been accomplished.
7	Train weighs less than 5 lbs. - This spec has been accomplished.
8	Train carries full library of pieces to complete loop – We have not been able to carry this many piece yet but we hope it will soon.
9	Train changes direction based on user input –This spec was more of an added bonus and we most likely will not be able to accomplish.
10	Train can lay other pieces besides straight, right, left – This spec was more of an added bonus and we most likely will not be able to accomplish.
11	Train can pick up pieces –T his spec was more of an added bonus and we most likely will not be able to accomplish.

Table 8: Performance Spec. Results

6.5 At least four (4) additional digital photographs and their explanations



Figure 24: Track Cage Detail

This picture shows the pieces in the track cage. As you can see there is a steel block on top of the track pieces. This steel piece was machined to a specific size and shape to act as a counterweight for the track pieces as they wait to be laid. As each piece is laid the steel block falls down in the track cage applying a continuous force such that the pieces lay correctly. Through our engineering analysis we were able to figure out where weight was needed and then machine this piece to help with both the distribution of weight and also track alignment.



Figure 25: Drive Wheel Counterweight

This picture shows one of the two counterweights that we machined to fit on the back end of each train to make sure that the drive wheel at all times stayed on track. With all the weight in the front of the train with the pieces of track it was essential to weight the back of the train. The train only has one drive wheel in the back so without being weighed down, the drive wheels would not make contact with the track and the train would not move. Distribution of weight was a problem we encountered with our engineering analysis and the use of counterweights helped eliminate that issue.



Figure 26: Modified Straight Track

This picture illustrates what one of the straight piece look like. This is a view of the underside of the track. As you can see the front end of the track has been milled out. This is to reduce the weight of the front of train such that the track does not lean forward when it is sitting in the track cage. Also, you can see that a groove has been milled into the back end of the track. This help guide the track into place before falling as it slides along the previous track. Aligning the track to fall into place was one of our biggest engineering analysis problems and was solved using a groove system.



Figure 27: Modified Curved Track

This picture is of a curved piece. Once again, you can see the front end of the track is milled out. This is to keep the weight of the track in the back since when the curved pieces sit in the track cage they are a long cantilever beam and it is essential for the weight distribution to be in the back so that the track does not tip over. Also, you can see the curved piece has been modified and is really a short turn piece with a straight piece attached to it. This is because it was extremely difficult to lay a track while coming around a turn. The train was coming at an angle so the next track piece would have to be offset at an opposing angle. With a track system that has a lot of variability, this was essentially impossible. By adding straight track to the end of the curve, it then allows for the train to straighten out and the next piece to be laid. This was the single biggest engineering analysis, issue we ended up having to overcome and was the key in the alignment of our track pieces.

7 Design documentation

7.1 Final Drawings and Documentation

7.1.1 A set of engineering drawings that includes all CAD model files and all drawings derived from CAD models. See Appendix C for the CAD models.

See Appendices for CAD Drawings, Parts List, and Bill of Materials

Figure 28: Final Drawing Side View

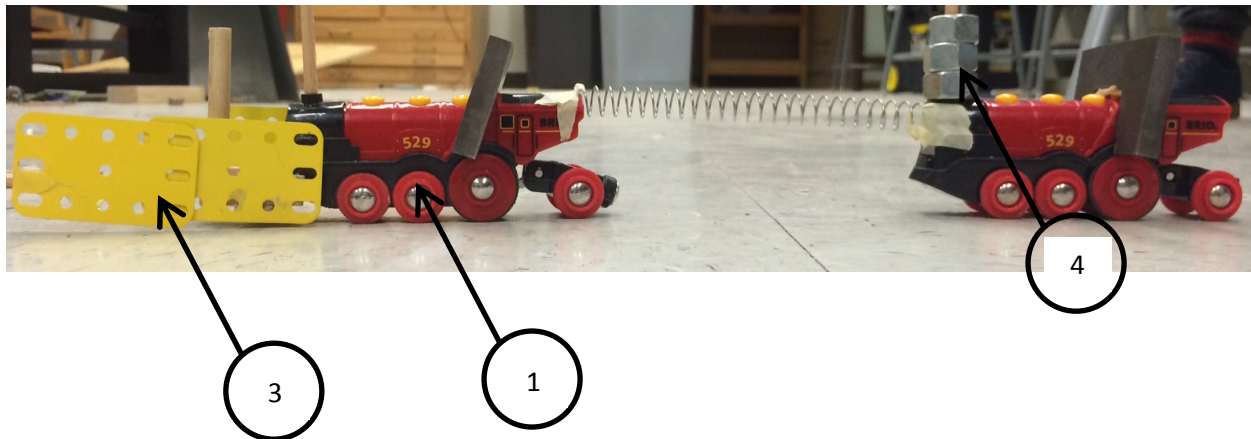


Figure 29: Final Drawing Top View

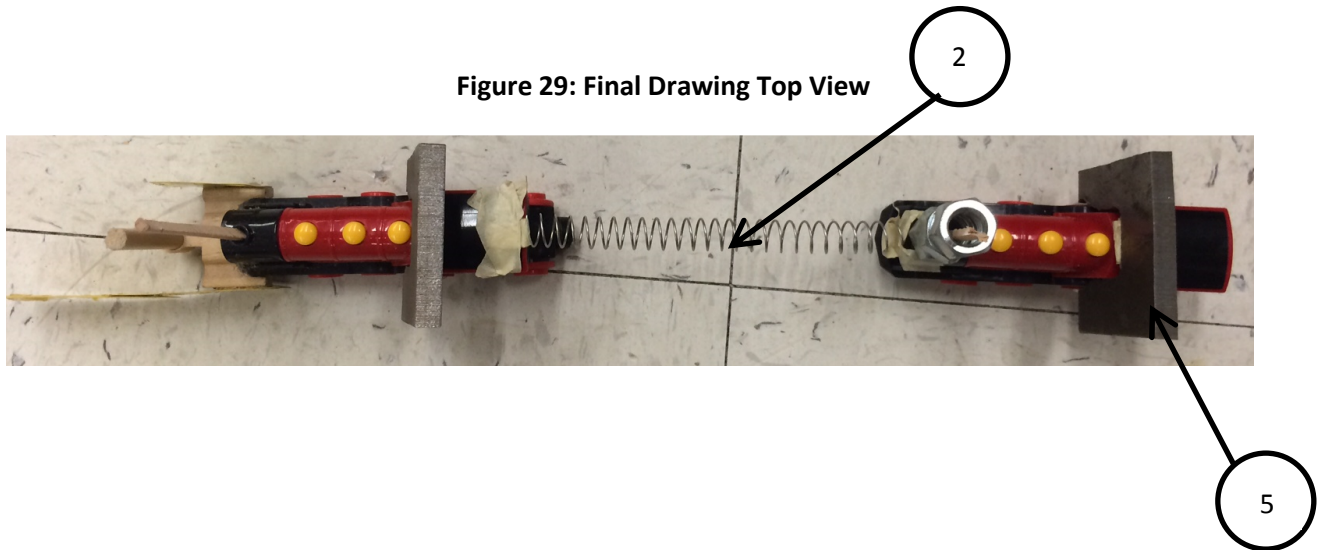


Figure 30: Final Drawing Front View

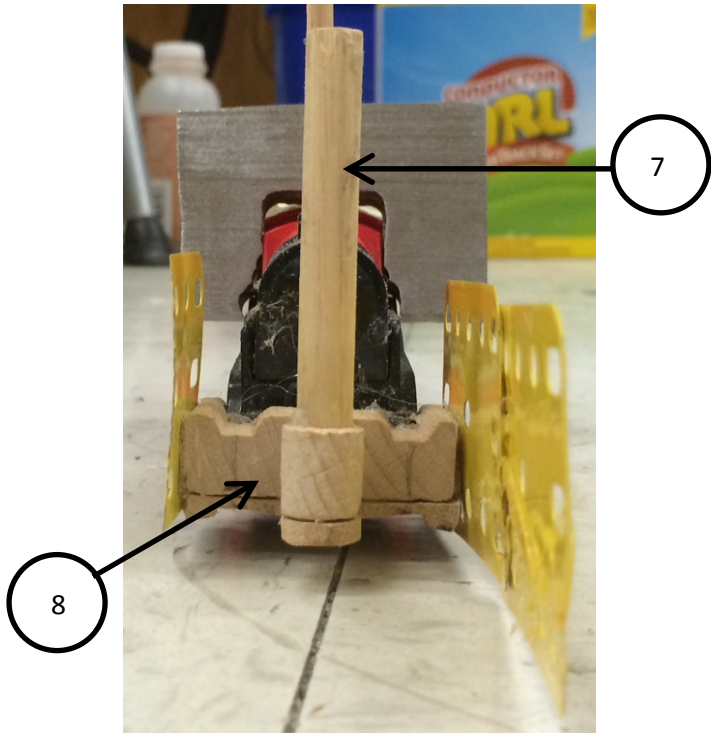
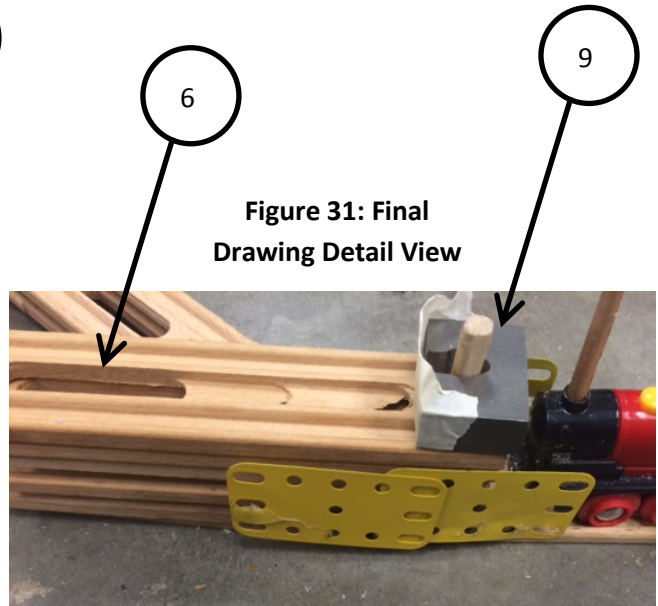


Figure 31: Final Drawing Detail View



7.1.2 Sourcing instructions

7.2 Final Presentation

7.2.1 A live presentation in front of the entire class and the instructors (this section may be left blank)

7.2.2 A link to a video clip version of 1

Final Prototype: <http://youtu.be/iuljTbaiPXA>

Final Presentation: <https://www.youtube.com/watch?v=jqK16CfHKEU>

7.3 Teardown

TEARDOWN TASKS AGREEMENT

PROJECT: Toy Train 1 NAMES: Peter Szostak INSTRUCTOR: _____
Chris Levin
Chris Haerberle

The following teardown/cleanup tasks will be performed:

- Clean out Basement of all our Train Materials.
- Tidy up basement lab, in particular corner where our stuff was.

Mary Malhot
12/8/14

8 Discussion

8.1 Using the final prototype produced to obtain values for metrics, evaluate the quantified needs equations for the design. How well were the needs met? Discuss the result.

We had three primary needs. The train had to be able to lay turn and straight pieces. The train and track pieces to be laid had to run on the tracks. And the train had to complete a 3 foot loop. The first two metrics were completed. The train could lay curves and straight pieces in any order. The train also ran completely on the tracks. In other words it was completely capable of laying new tracks for any other train. Unfortunately the train was unable to lay a complete loop. This was due to the fact that the train did not have the required power to carry enough tracks. This was a completely novel creation and it is the first one of its kind that we were able to find.

8.2 Discuss any significant parts sourcing issues? Did it make sense to scrounge parts? Did any vendor have an unreasonably long part delivery time? What would be your recommendations for future projects?

We had very few issues part sourcing. Most of our parts were scrounged. This was due to the fact that we had no plan to follow on what would work. We had to run things on an almost entirely trial and error system. Ideas came and went and parts to make those ideas work were jerry rigged from scroungable materials. For future projects, now that we have created a road map of what works and what doesn't, we would more accurately create parts. 3D printing of many of our parts would create a more reliable product.

8.3 Discuss the overall experience:

8.3.1 Was the project more or less difficult than you had expected?

This project was an exciting challenge. At first, we were very confident with our designs. We thought that everything would go smoothly, exactly as planned. It turned out that implementing our designs brought forth unforeseen challenges with our train. For instance, adding an extra engine car did not simply double the power of the train; it changed the entire dynamics of our system. Overall this project was a difficult, yet enjoyable challenge.

8.3.2 Does your final project result align with the project description?

Our project description was to build a train that lays its own tracks. From there we had different metrics; the train had to lay turns and straight pieces and complete a loop. It also had to carry all of the pieces used. We completed the tasks of laying turn and straight pieces. We did not have enough

space (nor the correct weight ratio) for the train to hold all the pieces necessary to complete a loop. With that being said, we met the project description by producing a train that could lay its own tracks, turns and straight pieces.

8.3.3 Did your team function well as a group?

Our group chemistry was instrumental in our success of this project. Because we were friends before this semester, we were not afraid to be open and honest. This allowed us to quickly roll over problems and disagreements. We also understood the importance of being available. Especially towards the end of the semester, we needed to meet more often. Nobody missed a single group work session.

8.3.4 Were your team member's skills complementary?

Our team was made up of three very different minds. This meant the clashing of ideas, but also the creation of new thoughts. We would argue that our group member's skills are complementary.

8.3.5 Did your team share the workload equally?

Yes, physically, we were all present and active for any building of our project. Peter Szostak was instrumental about keeping the group work organized and up to date on deadlines.

8.3.6 Was any needed skill missing from the group?

I do not think we lacked any essential skill. We all had experience working in the shop. We all are very creative and were able to see through our designs. As mentioned before we were loyal to the group's work. We had all the skills necessary in successful groupwork.

8.3.7 Did you have to consult with your customer during the process, or did you work to the original design brief?

We did not work with a customer.

8.3.8 Did the design brief (as provided by the customer) seem to change during the process?

We did not work with a customer.

8.3.9 Has the project enhanced your design skills?

It is always good to get back into the machine shop. It is easy to forget exactly how all the machines operate, and how to set them all up correctly. So physically it was good practice to work with real materials in the machine shop. Schematically, it was very interesting to design something and then

actually make that design come to life. When designing something, it is important to see through the design to the machining processes used. Some designs are just not physically possible with the machines available to us.

8.3.10 Would you now feel more comfortable accepting a design project assignment at a job?

Yes.

8.3.11 Are there projects that you would attempt now that you would not attempt before?

Yes.

9 Appendix A - Parts List

Table 9: Final Parts List

Part No.	Part	Quantity
1	Train	2
2	Spring	1
3	Metal Support Cages	3
4	Nuts	3
5	Drive Wheel Counterweights	2
6	Tracks	Many
7	Support rod	2
8	Track Placer	1
9	Track Counter Weight	1

10 Appendix B - Bill of Materials

Table 10: Final Bill of Materials

Part	Use	Supplier	Part No.	Price
(2x) BRIO Mighty Red Locomotive	Train/Base	Brio	BRI-33592	\$49.90 (29.95 each)
(1x) Steel Spring	Train Connector	Found in Shop	N/A	N/A
(3x) 1" x 2" x 1/16" Yellow Sheet Metal Pieces	Support for Track Pieces	Found in Shop	N/A	N/A
(3x) 1/2" Nuts	Counterweight	Found in Shop	N/A	N/A
(2x) 2.5"x1.5" 1/2" Steel Stock	Counterweight	Found in Shop	N/A	N/A
Conductor Carl Wooden Track Set	Train Tracks	Conductor Carl	B005FLUH3E	\$44.99

-24 Long Curved Tracks -25 Long Straight Tracks -25 Short Curved Tracks -25 Short Straight Tracks				
(2x) ¼" Diameter x 3" Wooden Rod	Supporting track/ nuts	Found in Shop	N/A	N/A
(1x) Wooden Track Placer (cut from original track)	Laying Track	Conductor Carl	B005FLUH3E	See Above price for Track
(1x) 1" x ¾" x ½" Steel Stock	Counterweight	Found in Shop	N/A	N/A
				Total = \$84.15

11 Appendix C - CAD Models

Figure 32: Drive Wheel Counterweights

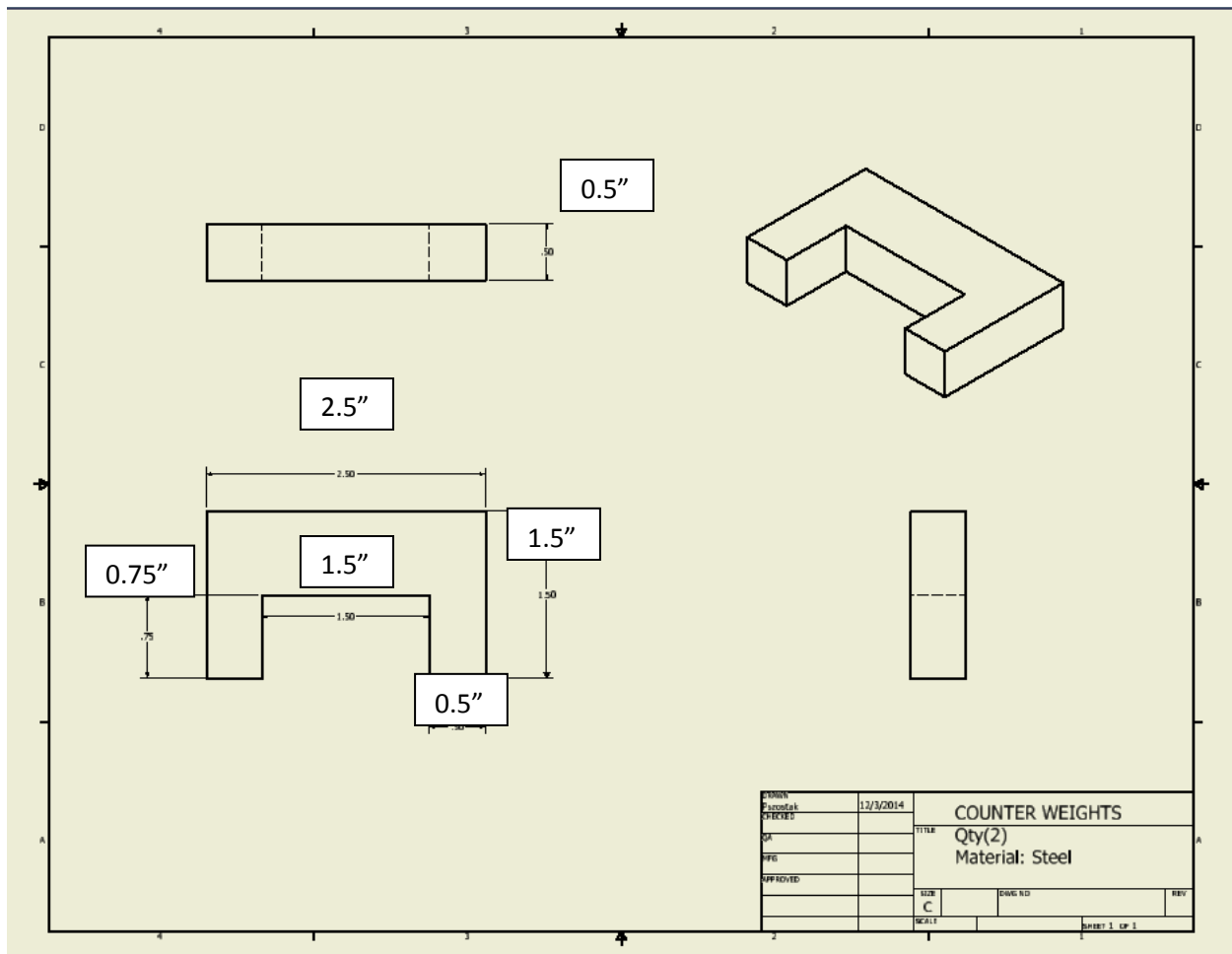


Figure 33: Support Rod

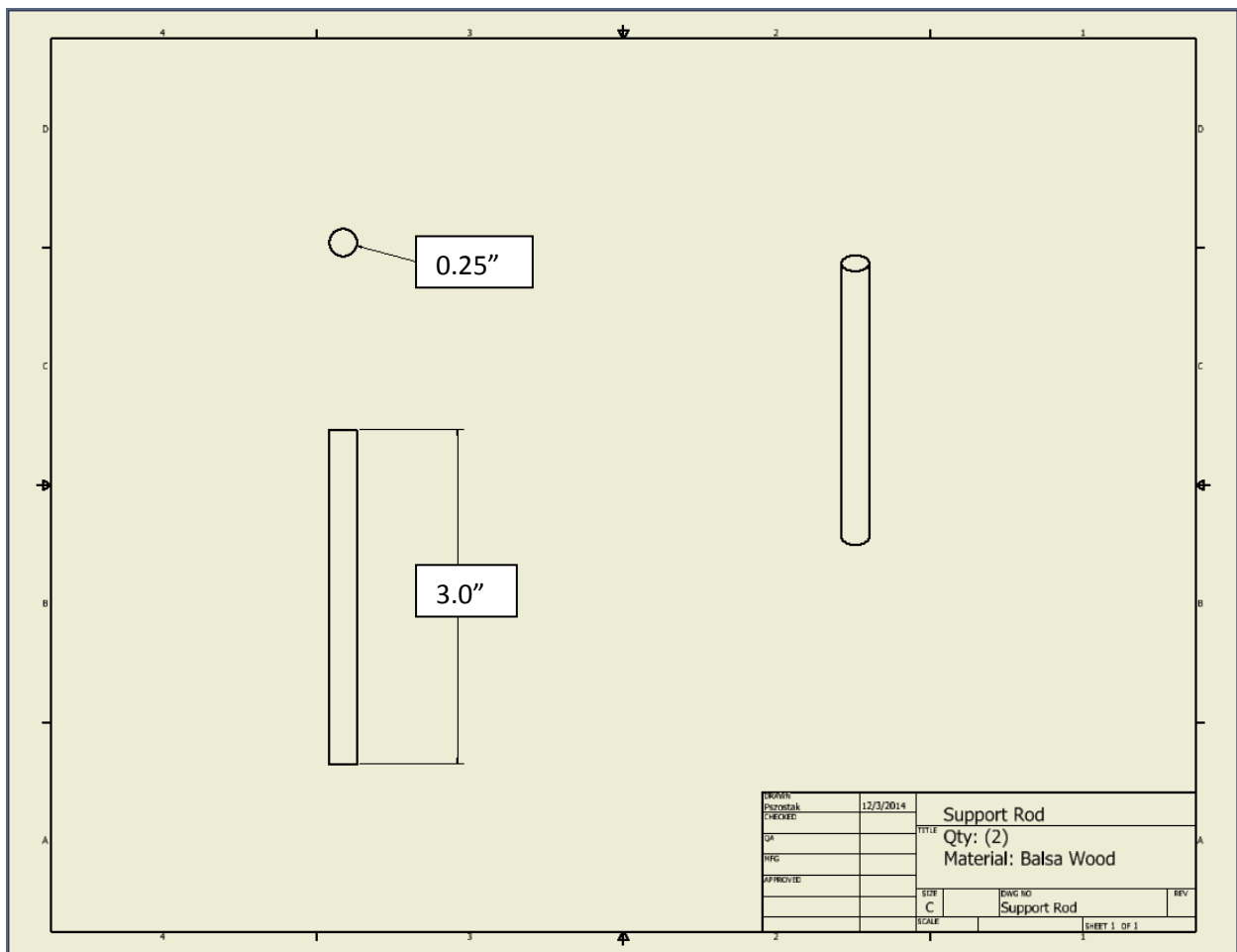


Figure 34: Track Placer

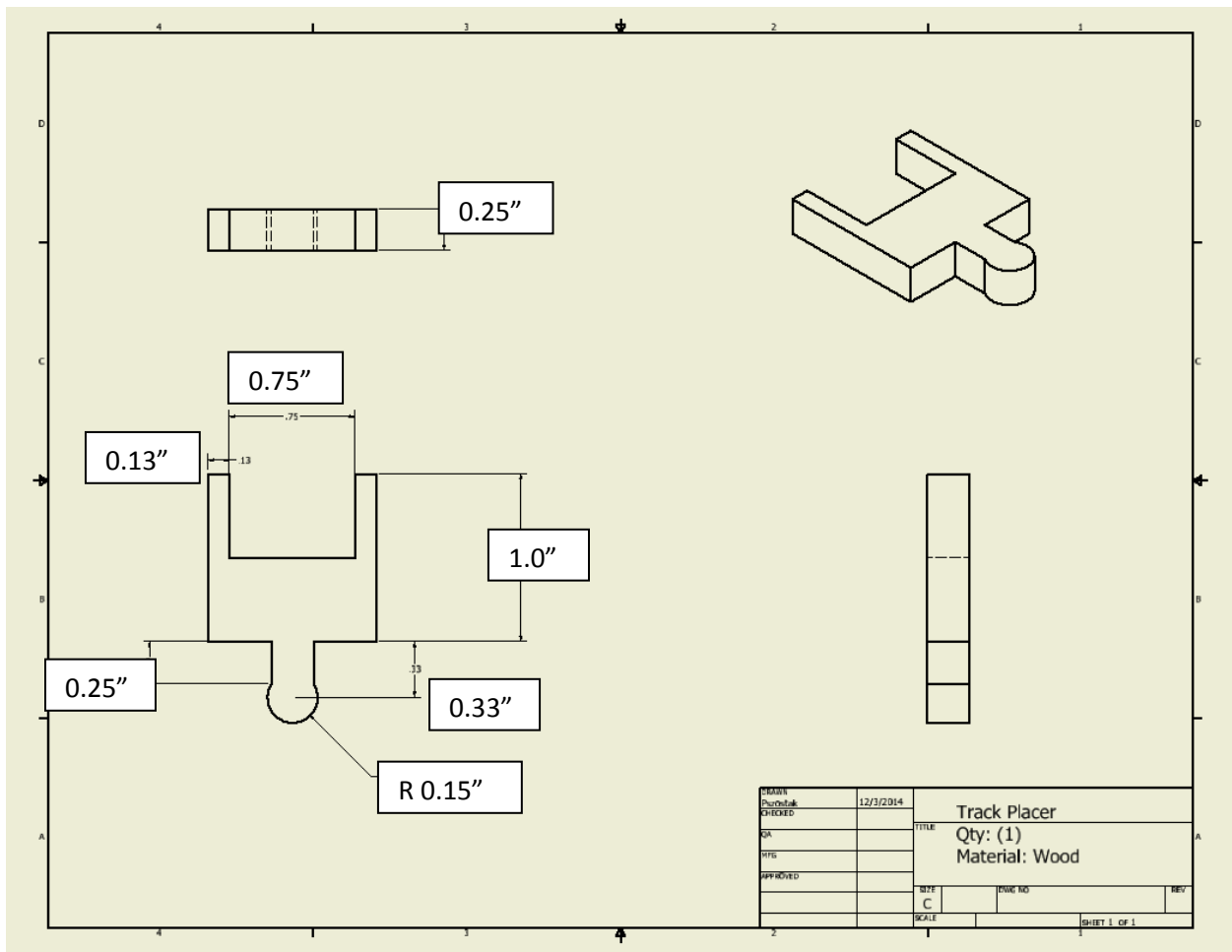
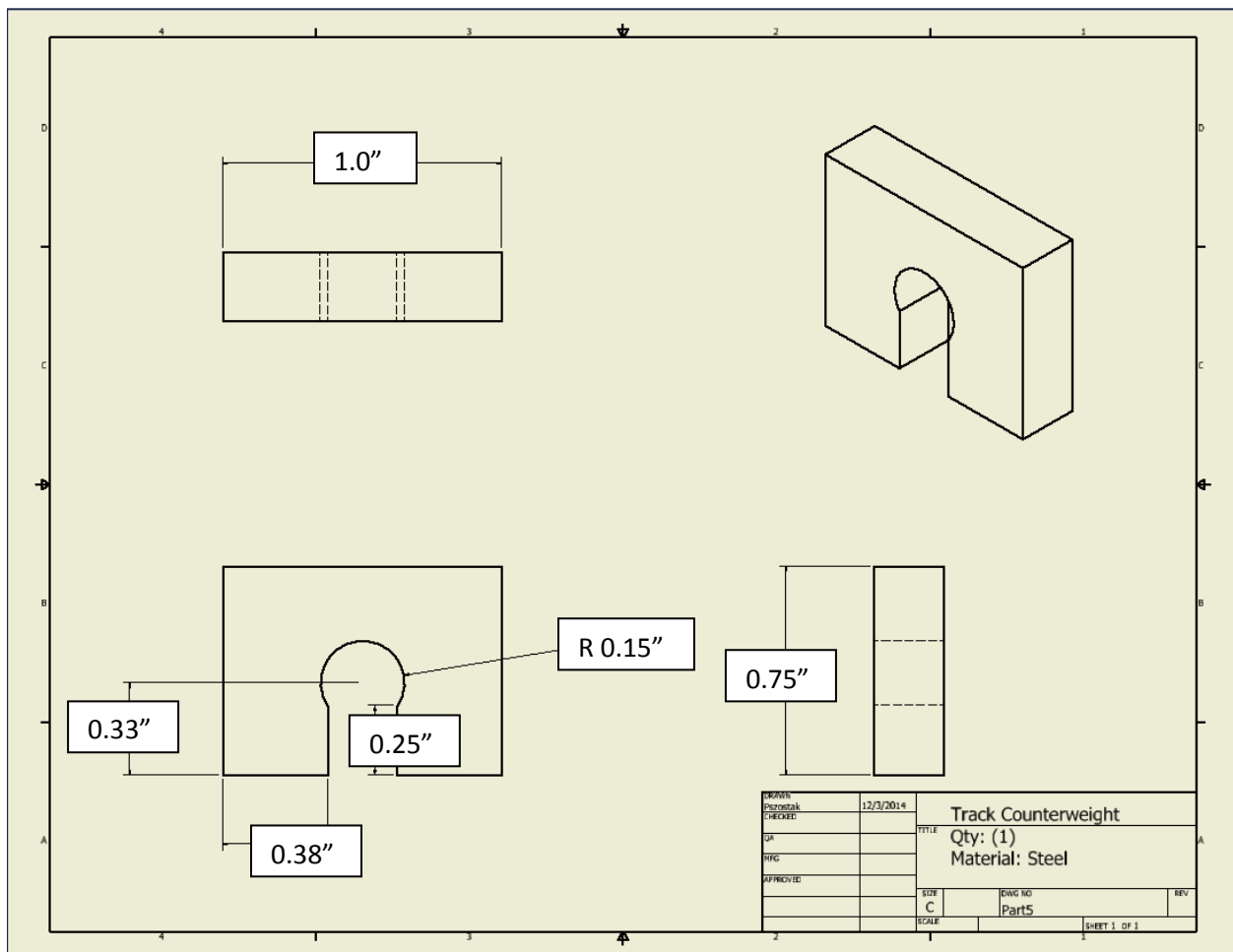


Figure 35: Track Counterweight



12 Annotated Bibliography (limited to 150 words per entry)

Cowen, Joshua L. "Patent US1534303 - Toy Train Track." *Google Books*. Lionel Corp, 21 Mar. 1925. Web. 23 Sept. 2014.

This Source provided good background on a toy track system that is on the market. It ultimately ended up being quite complicated and led us in the direction of a simpler track system.

Groff, Emory L. "Patent US1974330 - Toy Train." *Google Books*. American Flyer Mfg Company, 14 Apr. 1994. Web. 19 Sept. 2014.

This Patent is for a toy train that help give us some insight into how a basic toy train operates. With this patent we refined our search to the type of train that we wanted to modify for our project.

Irvin, Reed T. "Patent US3300826 - Conveyor Belt and Method of Jointing Same." *Google Books*. Russell Mfg Co, 17 Aug. 1976. Web. 18 Sept. 2014.

Originally we toyed with the idea of implementing some sort of conveyor belt system in our train in order to bring pieces to the front and lay down the tracks. Ultimately we did not use a conveyor belt, but this source was helpful in learning about how a basic conveyor belt works.