Fall 12-9-2014

Toy Train Group II, Track Laying Train

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MEMS 411 Senior Design Final Report

Toy Train II

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1 INTRODUCTION

1.1 Project Problem statement

The purpose of this project is to design a track-laying machine which lays discrete tracks in sequence as it moves, holds straight and curved tracks, and involves minimal programming. The product may cost in the range of $200-500 dollars, should be suitable for children (including safe choice of materials), and responsive to user input. It is preferable if the "train" is battery powered, able to close a loop, runs on household surfaces such as floors and tables, and is compatible with standard remote control train sets. Extra features could include the ability to pick up track once laid. The design should be thought of as having two purposes; primarily, as a toy suitable for children through adults; and secondarily, as a proof of concept for a military application in which the device lays tracks later used by other trains as supply lines.

1.2 Team members

The team members are: William Andersen, Chiamaka Asinugo, and Jordan Zwetchkenbaum.

2 BACKGROUND INFORMATION STUDY

2.1 Design brief

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 programing.

2.2 Summary of relevant background information

Harsco Rail's P811 track renewal system

One of the closer parallels to our design prompt was a train that is design to repair and renew tracks. The device is toted by a train and able to both remove tracks, including targeting specifically crossties or spikes. By contrast, our project dealt with tracks as discrete unit segments.

Fisher-Price Disney Mickey's Magic ChooChoo

This toy for children ages 3 and up represented the closest parallel to our design objective among products already existing. The device lays its own tracks by feeding them through a cycle of laying and collecting. By contrast, our objective was specifically to lay tracks continuously. We also targeted an older age group.

Patent US 2998196 A

A combined track and panel hinge for folding toy railroad train boards. This represented a potential method of folding and storing track which was not realized.

Patent US 20030136857 A1

This common toy train track design was considered by our group but ultimately rejected in favor of Lego's flexible track segments.

3 CONCEPT DESIGN AND SPECIFICATION

3.1 User needs, metrics, and quantified needs equations

In order to move from the design brief to a full understanding of the project problem, a three-step process must be undergone. In the first step, the user is interviewed about his or her needs and desires for the finished product. In the second step, the interview statements are correlated to measurable traits of the product which can gauge success. In the third step, these "metrics" are formalized into a weighted, normalized equation which can predict the satisfaction of the consumer based on the traits of the product.

3.1.1 Record of the user needs interview

Two tables are included here. In Table 1, interview questions and customer statements are drawn together to identify user needs. In Table, user needs are numbered and redundant ones eliminated.

Project/Product Name: Toy Train II			
Customer: Prof. Mark Jakiela		**Interviewers: Jordan Zwetchkenbaum, Will Andersen, Chiamaka Asinugo**	
Address: Washington University			
Willing to do follow up? Yes		**Date: 10th September, 2014**	
Type of user: Devoted father		**Currently uses: Regular toy train**	
Question	**Customer Statements**	**Interpreted Need**	**Importance**
Why do you want a toy train that lays track?	Able to reach undeveloped areas	Model lays its own track	5
What do you like about existing toy trains and tracks?	Wood toy trains have standard track couplings	Model is based on standard track system	3
	Tracks are interchangeable and reversible	Model is based on standard track system	3
	They can be very engaging as toys	Model has user input	4
What do you dislike about them?	Wooden tracks lack definite joining at unions	Tracks remain in place during use	5
	Wooden tracks lack stability	Train remains perpendicular to tracks	4
Is there any specific train model you're interested in?	I would recommend an existing track system like Thomas the Tank Engine	Model is based on standard track system	3
How fast should it go? How fast should it lay track?	It should take less than three times the duration for me to lay them myself	The model takes less than three times the duration for a user to lay them	4

Who is using it? Age range?	It could target 4 -12 old if it does enough cool stuff	Model is safe for children	5
What kind of power input would you like?	I would prefer batteries to power it up	Model is battery powered	4
How much time in use?	Should be able to complete track circuit in one run	Model completes track path without recharging	5
Should it reload the tracks it has laid? What do you want to happen once the track is laid?	It would be ideal if it could pick up the track circuit	Model reloads laid track circuit	2
How big/long a track should it have? And storage space?	Track should be variable.	Track path is variable	2
	Direction can be controlled by remote control	Track path is variable	2
Do you want a standard/variable design for the track?	Any type of toy train track can be used	Model is based on standard track system	3
	Tracks must be put down in discrete segments	Discrete tracks are used in path	5
	Track should make a closed loop	Track path is closed	3
Do you want to move back and forth?	It might be useful but its not necessary	Model lays track in reverse direction	1
Should it avoid obstacles?	Can use a remote control to make it turn left and right	Train direction can be controlled electronically	3
Where do you want to use it? What kind of surface/environment?	A typical toy train table (30"x50")	Model can make turns in an enclosed space	4
	It runs on a floor or typical toy train surface	Model runs on a flat surface	3
Are non-computing electronics allowed?	Can use remote controls to interact	Model has minimal programming	4
How much assembly time for user?	A few minutes	Model requires minutes to assemble	3
How much are you willing to spend on it?	Up to $500 if it meets standards	Model cost is competitive with other toy trains	3

Table 3.1.1: User needs interview

	Interpreted Need	Importance
1	Discrete tracks are used in path	5
2	Model can make turns in an enclosed space	4
3	Model completes track path without recharging	5
4	Model cost is competitive with other toy trains	3
5	Model has minimal programming	4
6	Model has user input	4
7	Model is based on standard track system	3
8	Model is battery powered	4
9	Model is safe for children	5
10	Model lays its own track	5
11	Model lays track in reverse direction	1
12	Model reloads laid track circuit	2
13	Model requires minutes to assemble	3
14	Model runs on a flat surface	3
15	The model takes less than three times the duration for a user to lay them	4
16	Track path is closed	3
17	Track path is variable	2
18	Tracks remain in place during use	5
19	Train direction can be controlled electronically	3
20	Train remains perpendicular to tracks	4

Table 3.1.2: User Needs and Importance

3.1.2 List of identified metrics

Metrics #	Associated Needs	Metric	Units	Best Value	Worst Value
1	1	Length of stored track	cm	400	0
2	2	Radius of curvature	cm	50	75
3	3	Distance traveled without charging	cm	400	0
4	4	Total price	dollars	500	1000
5	5	Number of programmed features	integer	0	5
6	6	Number of user controlled actions	integer	3	0
7	6,19	Remote controlled	binary	1	0

8	7	Number of track brands it runs on	integer	2	0
9	8	Maximum distance at which the model can be controlled	cm	200	0
10	9	Number of hazardous parts	integer	1	5
11	10,14	Total length of track laid	cm	400	0
12	11	Number of track laying directions	integer	6	0
13	12	Percentage of pieces gathered	percent	100	0
14	13	User assembly time	minutes	1	5
15	15	Laying rate	track/min	30	10
16	16	Percent of trials successfully closing loops	percent	100	0
17	17	Types of closed track shape	integer	3	0
18	18	Distance tracks move during use	cm	0	0.5
19	20	Number of times train falls from track	integer	0	2

Table 3.1.3: Metrics and Associated Needs

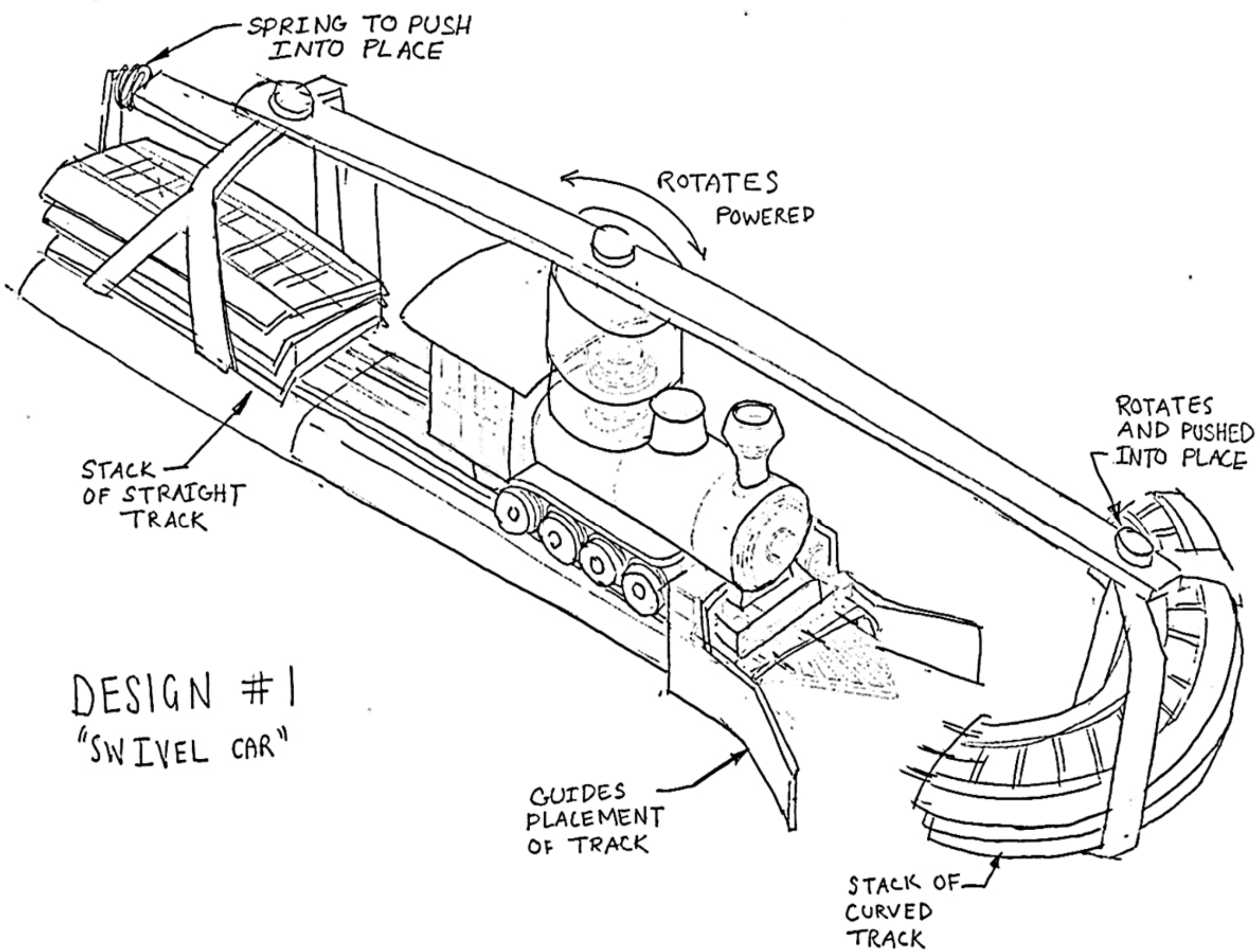
3.1.3 Quantified needs equations

The ultimate goal is to meet the user needs as fully as possible, and to that end, the metrics were plotted against the user needs in a table for the sake of measuring how well each design meets the user's desires. Scores on metrics are inputted and then weighted according to the importance of the need they measure. The results are normalized into a score between 0 and 1 predicting the satisfaction of the user with the design.

The quantified needs equations are summarized below in a table that happens to evaluate our final prototype. Refer to section 3.3 for tables organized according the MEMS 311 convention.

	Units	Best Value	Worst Value	Actual Value	Normalized Metric Happiness
Length of stored track	cm	400	0	140	0.35
Radius of curvature	cm	50	75	75	0.00
Distance traveled without charging	cm	400	0	400	1.00
Total price	$	500	1000	275	1.45
Number of programmed features	int	0	5	0	1.00
Number of user controlled actions	int	3	0	2	0.67
Remote controlled	bin	1	0	1	1.00
Number of track brands it runs on	int	2	0	1	0.50
Maximum distance at which the model can be controlled	cm	200	0	200	1.00
Number of hazardous parts	int	1	5	1	1.00
Total length of track laid	cm	400	0	140	0.35
Number of track laying directions	int	6	0	3	0.50
Percentage of pieces gathered	percent	100	0	0	0.00
User assembly time	min	1	5	2.5	0.63
Laying rate	track/min	30	10	10	0.00
Percent of trials successfully closing loops	percent	100	0	0	0.00
Types of closed track shape	int	3	0	0	0.00
Distance tracks move during use	cm	0	0.5	0.5	0.00
Number of times train falls from track	int	0	2	0	1.00

Figure 3.1: Quantified needs equations



3.2 Concept drawings

Figure 3.2.1: Concept #1 – The swivel Car

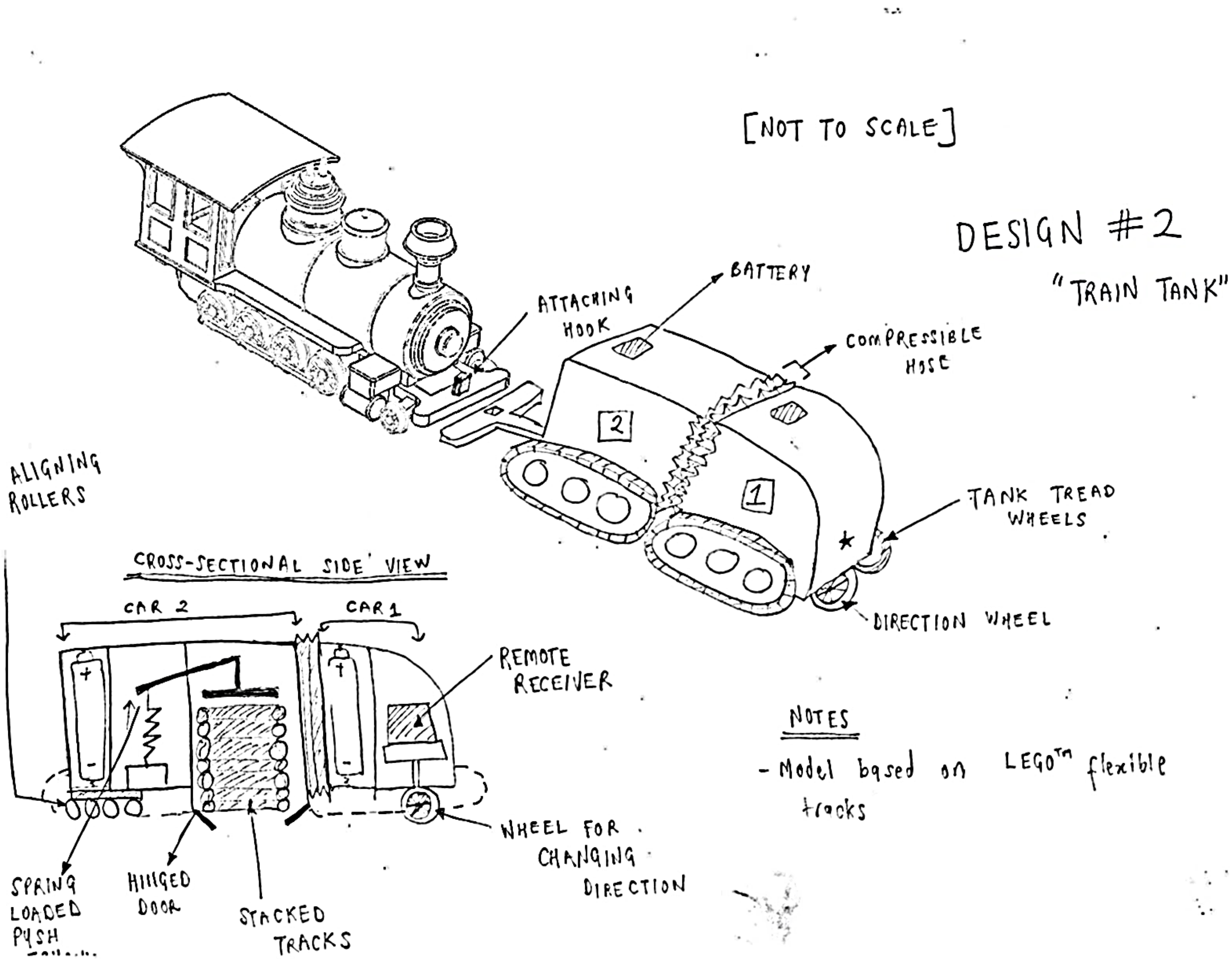


Figure 3.2.2: Concept #2 –Train Tank

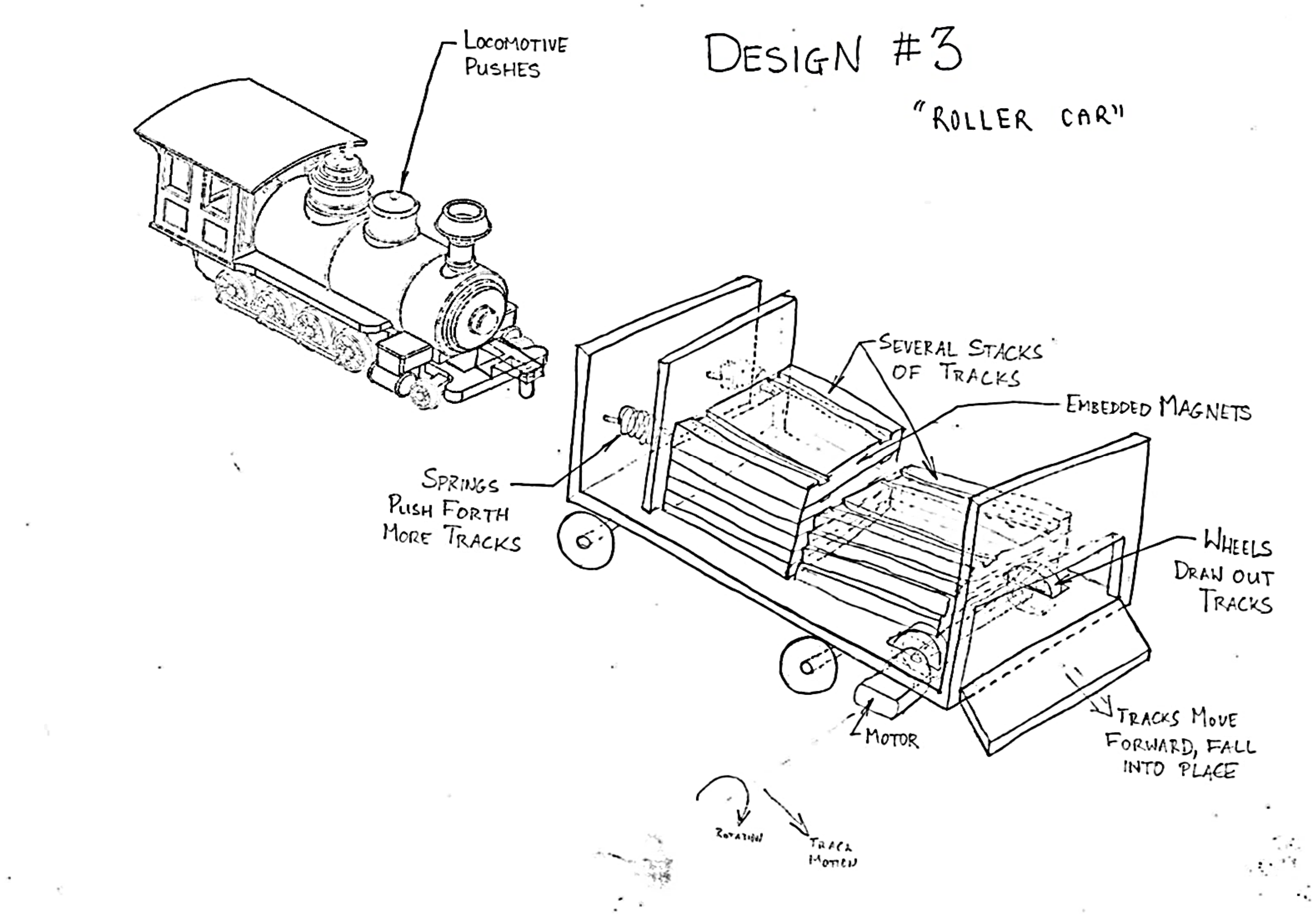


Figure 3.2.3: Concept #3 – Roller Car

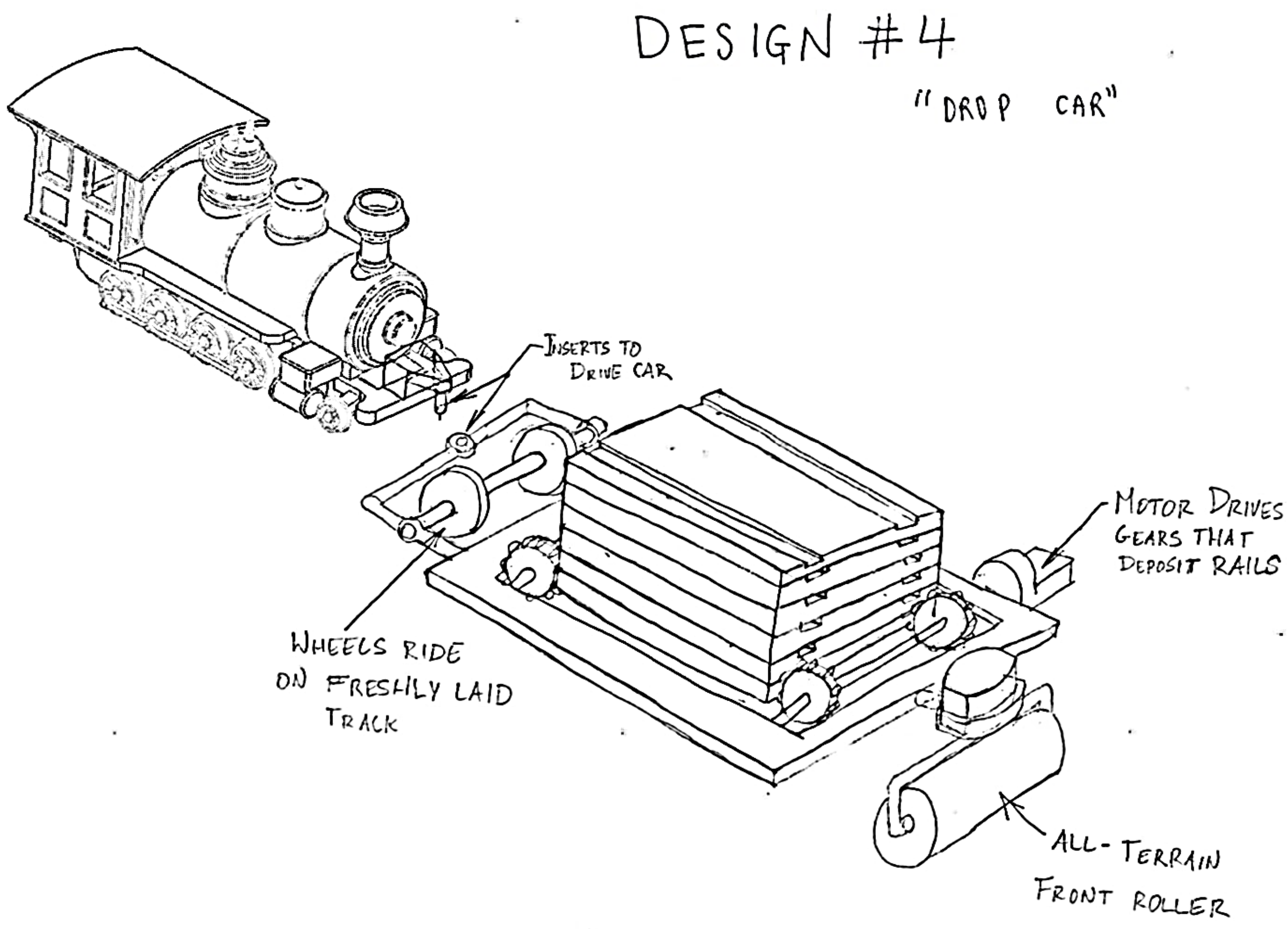


Figure 3.2.4: Concept #4 – Drop Car

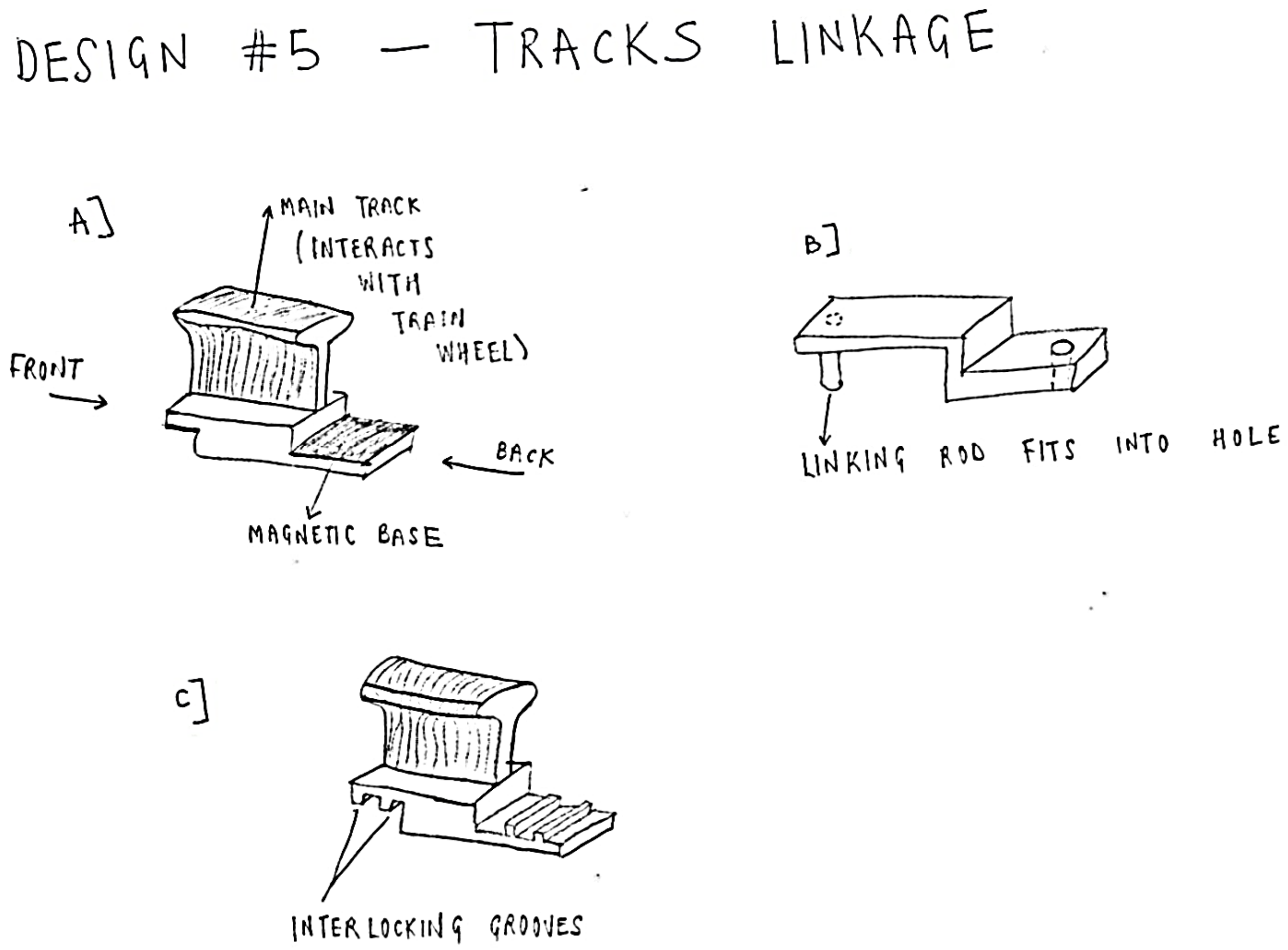


Figure 3.2.5: Track Concepts

3.3 Concept selection process

3.3.1 Concept scoring

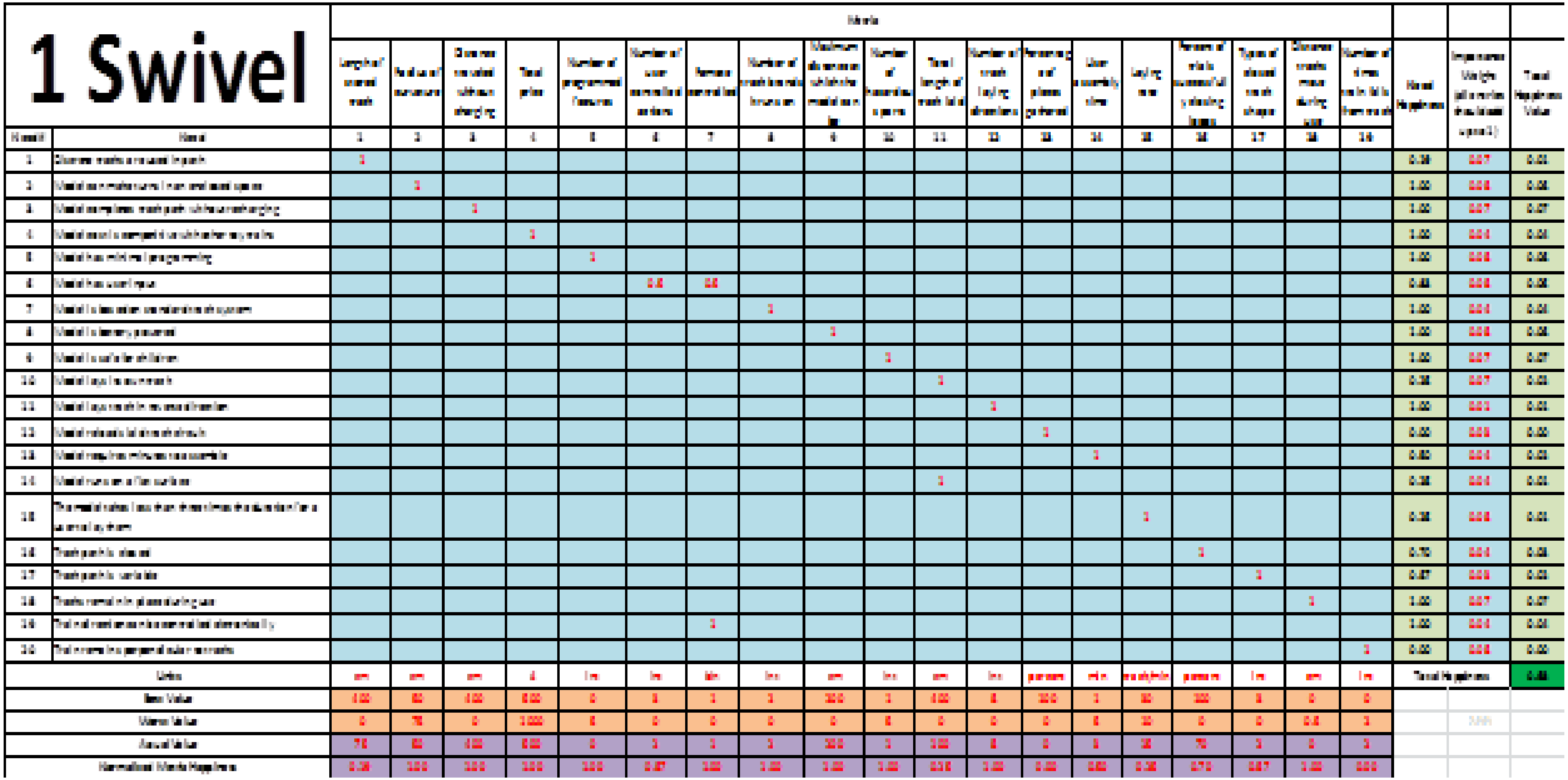


Figure 3.3.1: Concept Scoring – Swivel Car

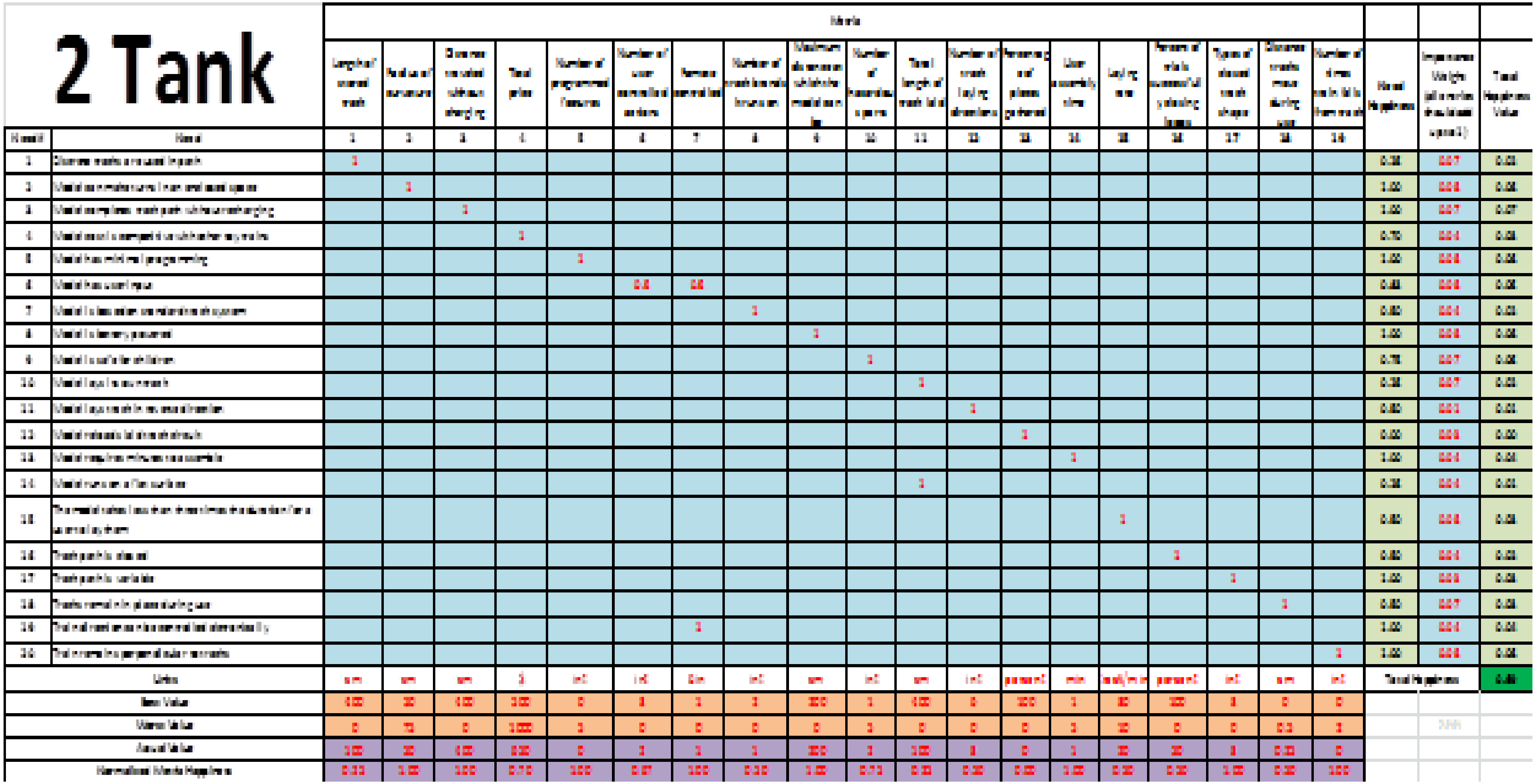


Figure 3.3.2: Concept Scoring – Train tank

3 Roller		Metric																					
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Need #	Need	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19			
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Normalized Metric Happiness		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Figure 3.3.3: Concept Scoring –Roller Car

4 Dropout		Metric																				
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Figure 3.3.4: Concept Scoring –Drop Car

3.3.2 Preliminary analysis of each concept's physical feasibility

DESIGN #: 1 Swivel Car

The Swivel Car rotates one stack of straight track and one stack of curved track into position. It could be designed for a standard track as long as the curved track has the same connection on both sides. However, it would not need to be double-sided track. The design is likely to have large moments and problems with balance.

DESIGN #2: Train Tank

The Train Tank allows for a more engaging user input using remote controllers. The spring loaded mechanism periodically 'stamps' out individual track pieces from the stacking compartment and the aligning rollers work to shift the tracks into the designated direction. Though theoretically feasible, this timed sequence is crucial in the design process and could potentially cause problems. The design is aimed to be mostly compatible to different train models however it has an invariable laying speed which may cause performance problems.

DESIGN #3: Roller Car

The Roller Car is pushed in front of a powered train. Rollers push a track segment out of a slot while a wall keeps the others in. Springs push the stacks of tracks up to the rollers. The design uses jointed Lego track to create curves as it moves. The car dispenses the track before it rolls over it. The car can hold a significant amount of track. It would place track less accurately than other designs, so it is less likely to close a loop of track.

DESIGN #4: Drop Car

The Drop Car leads a train and uses gears to release the bottom segment in a stack of tracks while still gripping the ones above it. The gears do not accommodate different shaped tracks, so the design can only lay straight tracks unless a mechanism for moving different stacks over the drop area could be added.

3.3.3 Final summary

Most of the competitors were strong, but two models came definitively ahead of the others in the scoring process. These were designs 1 and 2, Swivel Car and Train Tank. Design 1 (Swivel Car) scored second at 68 points, with high marks in several areas, including: its ability to lay down sharp turns, its compatibility with standard track brands, its ability to respond to many kinds of user input (including the option to lay tracks in reverse), and the stability of the paths it establishes. Its shortcomings included a short supply of track to be laid and instability on account of its gigantic swiveling lever arm.

Design 2 (Train Tank) ranked barely first at 69 points. It lacked in rail storage but made up for this with robustness in many areas, including turn radius, number of routes achievable, safety, assembly time, and stability. Its disadvantages included higher cost (not a high priority) and number of compatible track brands (also not critical).

Design 3 (Roller Car) was a close third with 64 happiness points. Its track storage dwarfed competing models but its turn radius and stability were less robust than Train Tank's. Assembly time also lagged slightly behind as well. Thus, although more train like than Train Tank, Roller Car lagged slightly behind. Similarly, Design 4 (Drop Car) lagged far behind all other with 47 happiness points. Unable to find a way to accommodate anything other than straight tracks, it failed to meet many of the necessary criteria.

Ultimately, the choice came down to Swivel car or Train Tank. The team felt that Swivel Car's enormous lever arm likely presented more of a disadvantage than the metrics calculated for, as it was likely to topple frequently, and this could be very frustrating to the user. Thus it was eliminated from the running. Train Tank, the first place contender, was selected as the first model to be tested, with Roller Car (a fairly close third) being available as the second option should Train Tank fail.

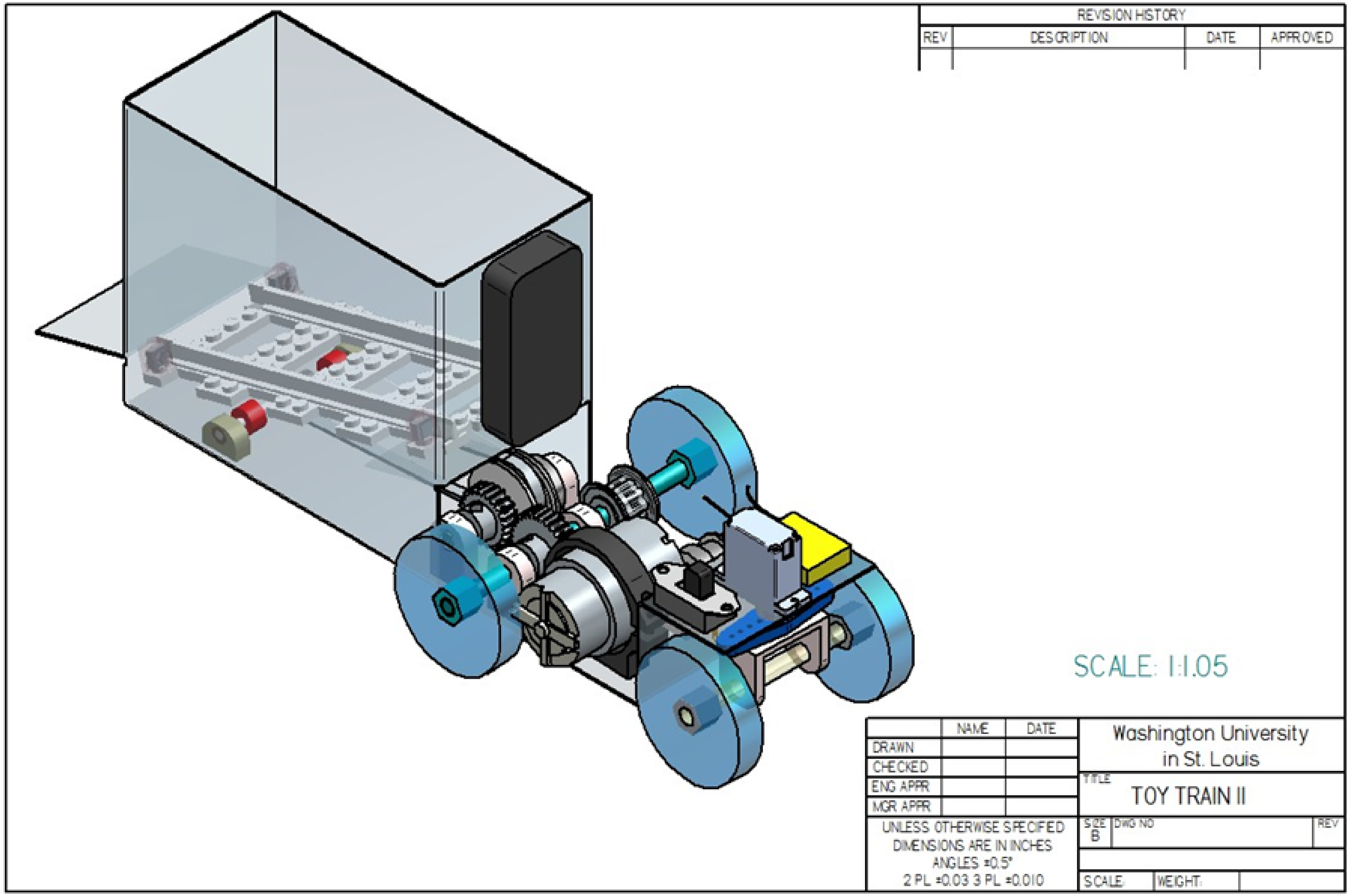
3.4 Proposed performance measures for the design

1. Length of stored track is more than 150cm
2. Radius of curvature is less than 50cm
3. User assembly time is less than 3min
4. Laying rate is at least 15 tracks/min

4 EMBODIMENT AND FABRICATION PLAN

4.1 Embodiment drawing

See following pages.



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in St. Louis
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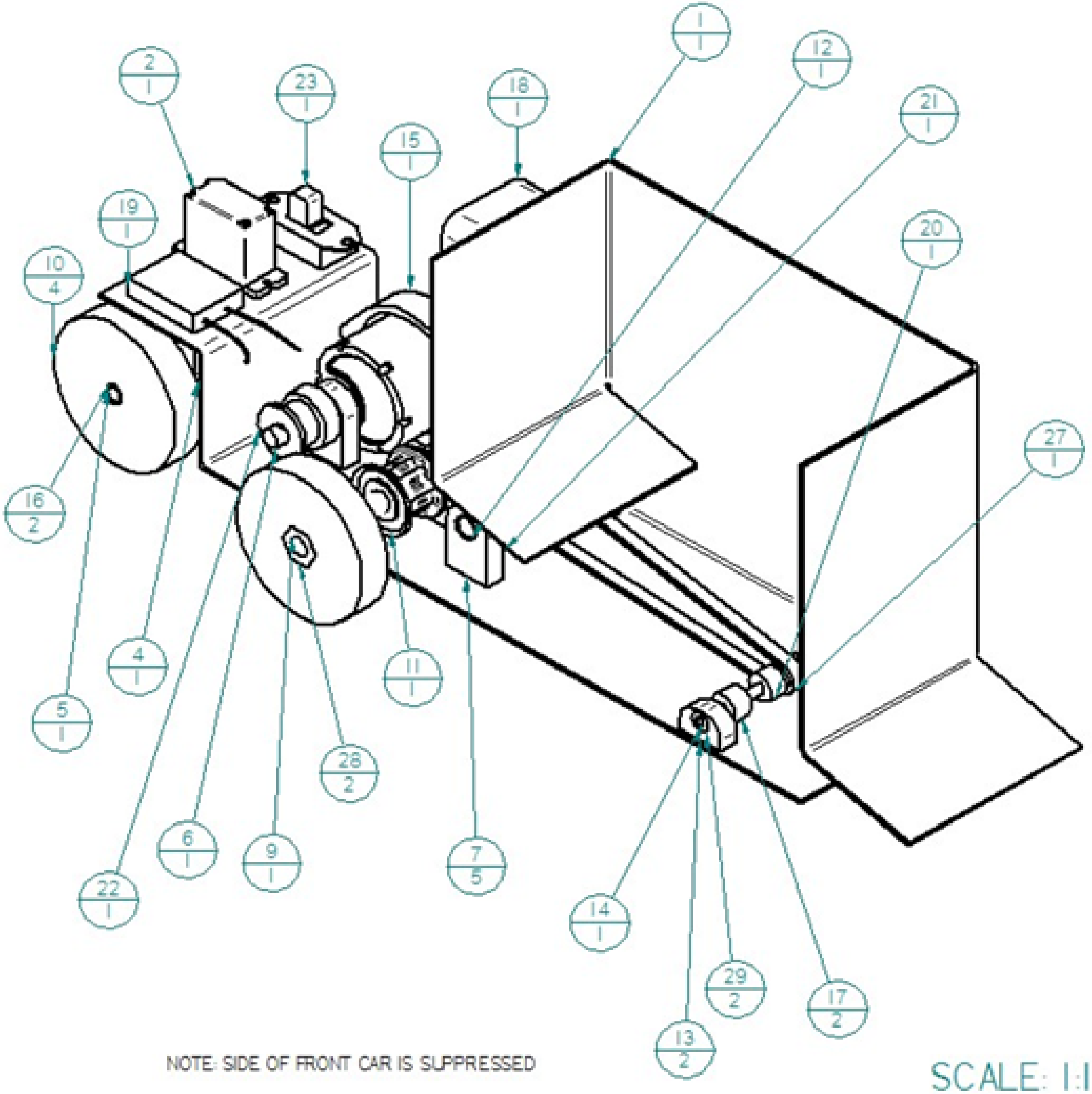

NOTE: SIDE OF FRONT CAR IS SUPPRESSED

SCALE: 1:1.25

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

Part #	Part	Quantity
1	Front Car Body	1
2	Turnigy TGY-180D Servo	1
3*	Turnigy Servo Arm Full Arm	1
4	Wheel Mount	1
5	Servo Wheel Shaft	1
6	Standard Gearmotor - 51 RPM	1
7	Shaft Mount	5
8*	SAE 841 Bronze Sleeve Bearing, 1-4 Shaft	3
9	Front Wheel Shaft	1
10	BaneBots Wheel, 1-78 x 0.4in, 12in, Hex Mount, 30A	4
11	Mxl Series Timing-Belt Pulley, 14 Belt Width, .740 OD, 22 Teeth	1
12	Gear Change Shaft	1
13	Roller Mount	2
14	Roller Shaft	1
15	Motor Mount	1
16	BaneBots Hex Hub	2
17	Precision Urethane Drive Roller - Slimline	2
18	E-Flite 800mah Double Cell 2S 7.4V 20C Lipoly Pack, JST	1
19	RC Receiver	1
20	Mxl Series Timing-Belt Pulley, 14 Belt Width, .425 OD, 10 Teeth	1
21	Mxl Series Timing-Belt Pulley, 14 Belt Width, 1.210 OD, 40 Teeth	1
22	Mxl Series Timing-Belt Pulley, 14 Belt Width, .685 OD, 20 Teeth	1
23	Toggle Switch	1
24*	Servo City 32 Pitch Plain Bore Gears, 24T (24 Teeth)	1
25*	Servo City 32 Pitch Plain Bore Gears, 30T (30 Teeth)	1
26*	Mxl Series Timing-Belt (165MXL)	1
27	Mxl Series Timing-Belt (110MXL)	1
28	BaneBots Bushing, 12in, Hex mount	2
29	SAE 841 Bronze Sleeve Bearing, 1-8 Shaft	2

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

TITLE
TOY TRAIN II

SIZE B | DWG NO | REV

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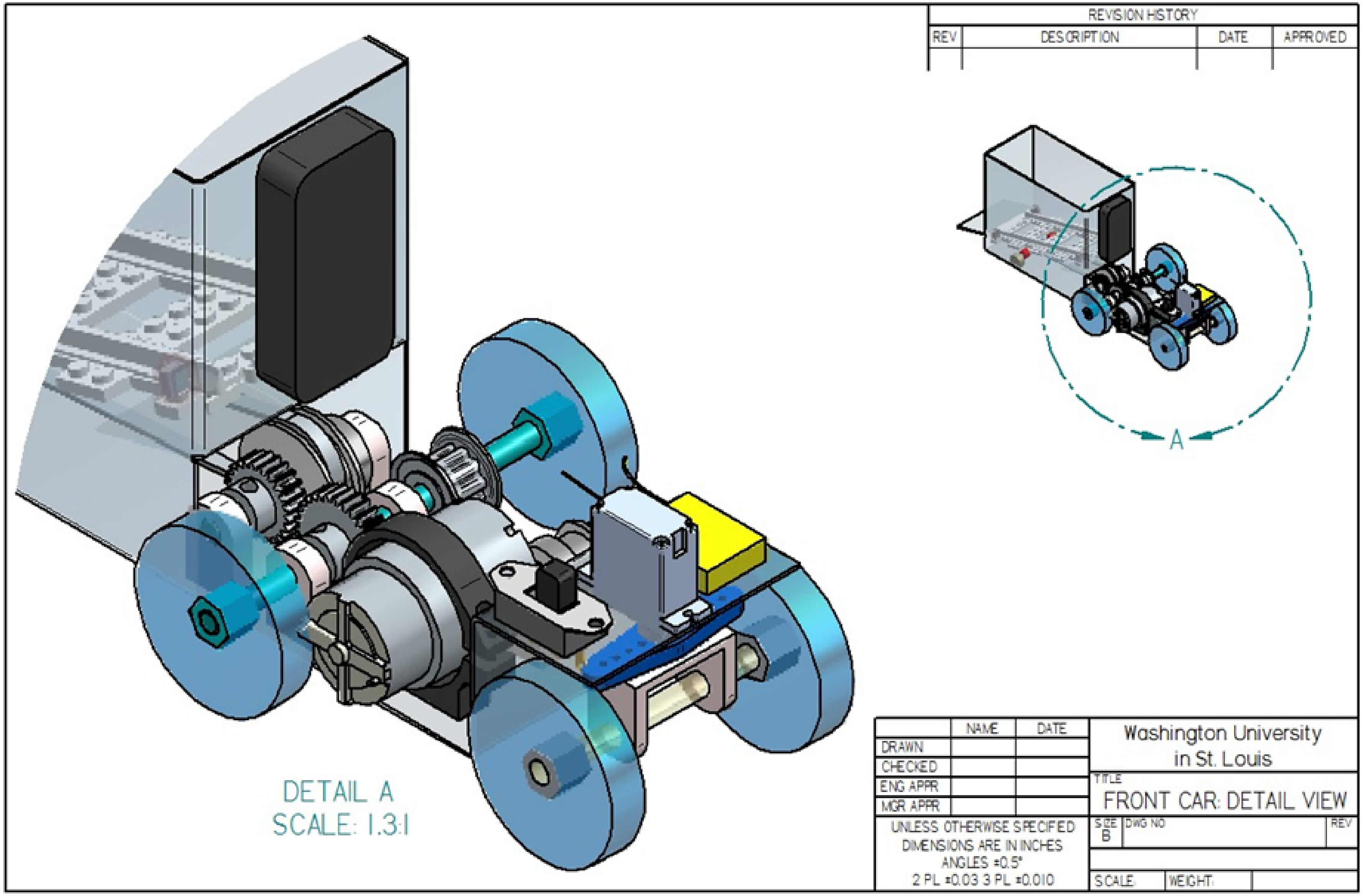
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Washington University
in St. Louis
TITLE
FRONT CAR: DETAIL VIEW
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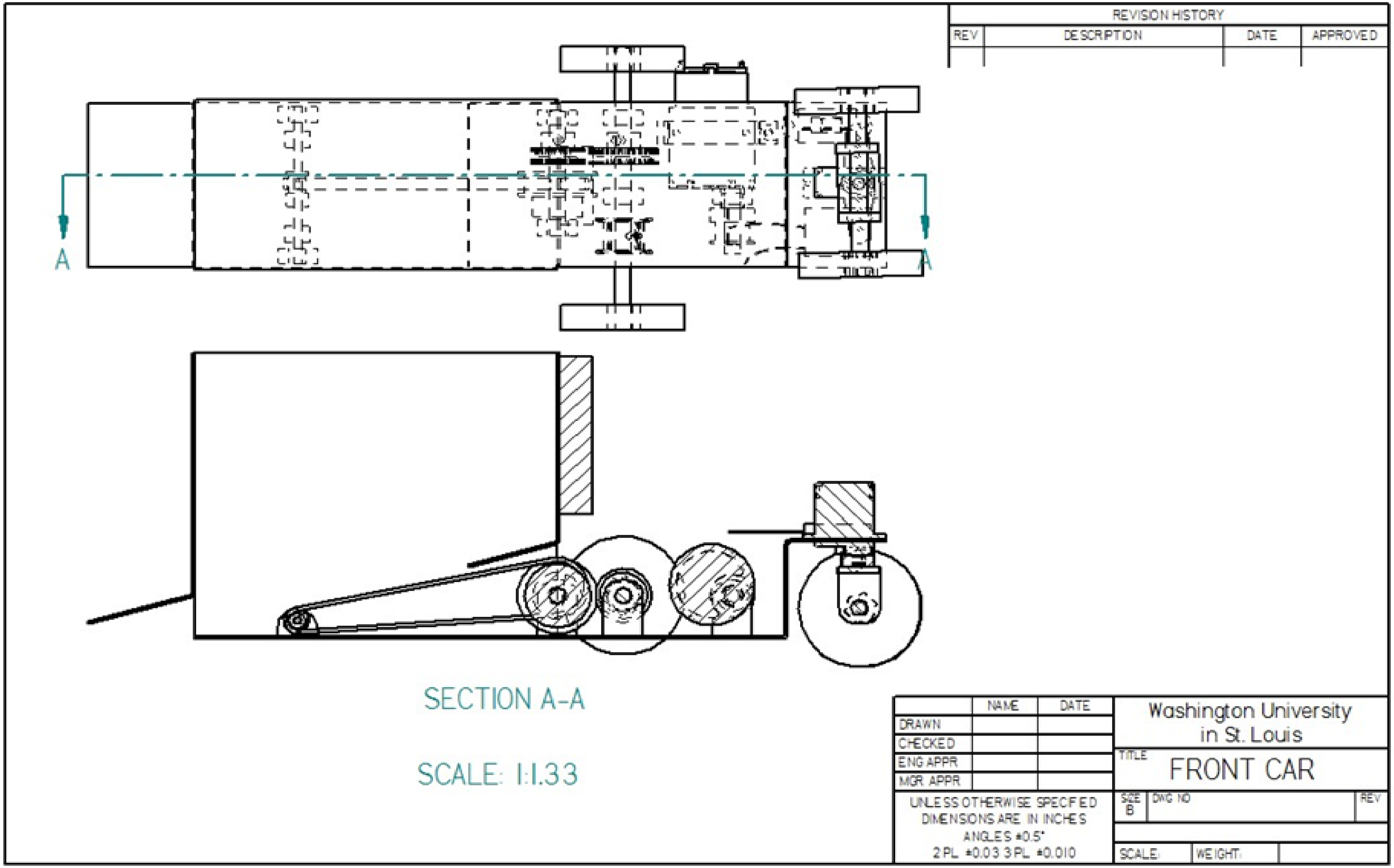
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Washington University
in St. Louis
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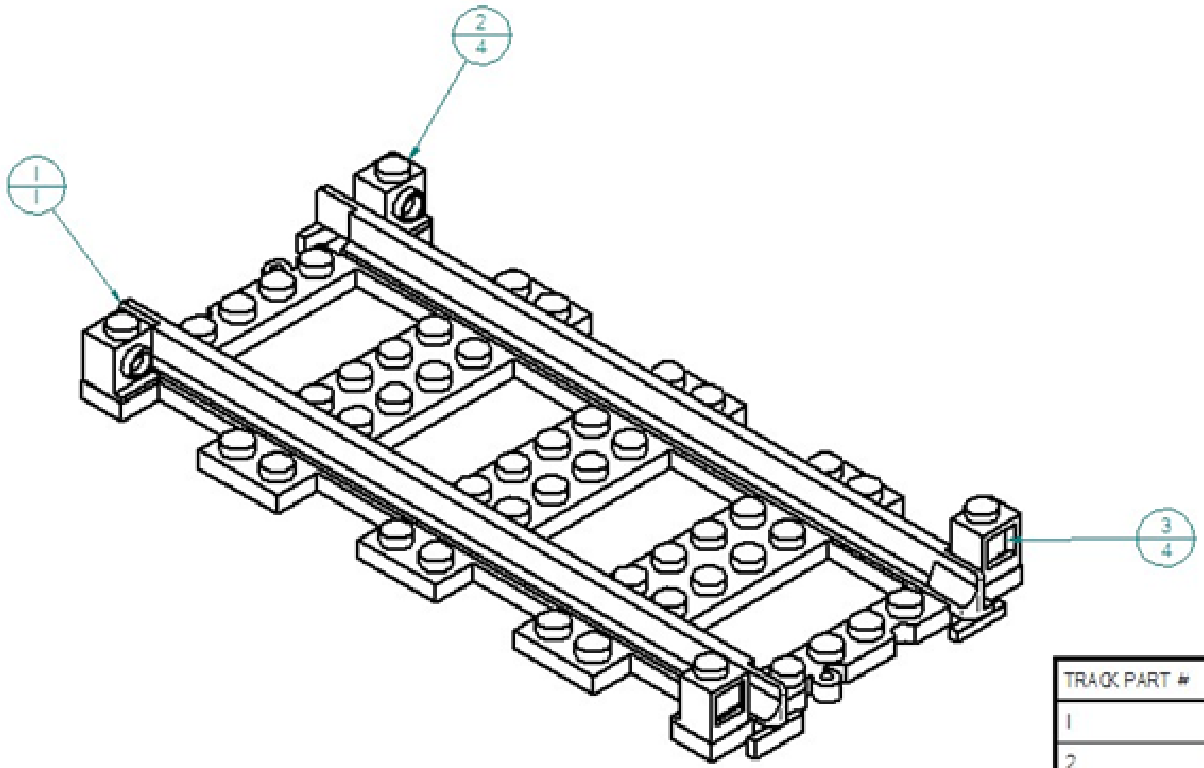

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TRACK PART #	TRACK PART	QUANTITY
1	Lego Track	1
2	Lego Angular Brick 1x1	4
3	Square Magnet	4

	NAME	DATE
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UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±0.5°
2 PL ±0.03 3 PL ±0.010

Washington University
in St. Louis

TITLE
SINGLE TRACK ASSEMBLY

SIZE	DWG NO	REV
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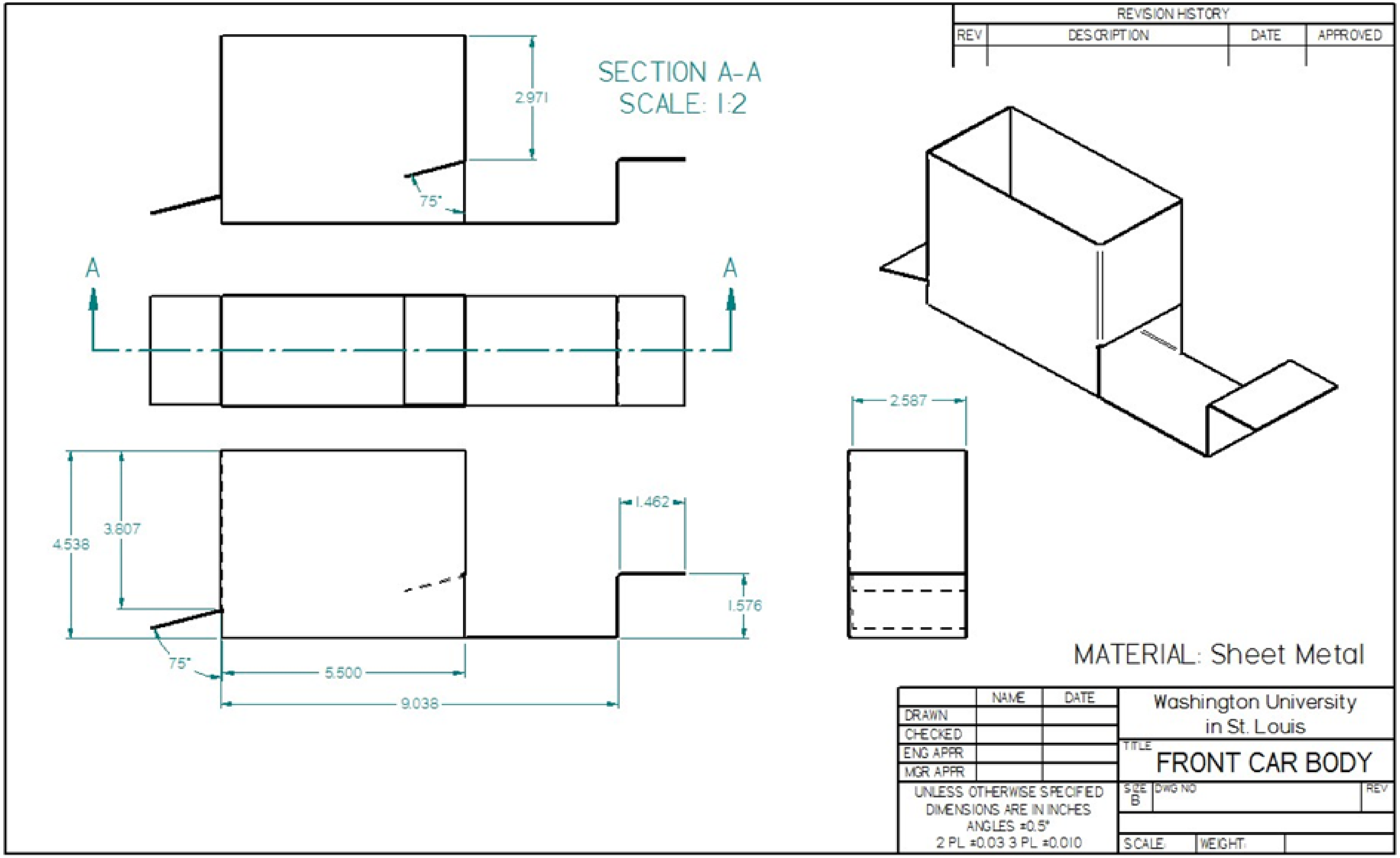
SCALE:	WEIGHT:	

4.2 Parts List

See Appendix A

4.3 Draft detail drawings for each manufactured part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DATE
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Washington University
in St. Louis
TITLE
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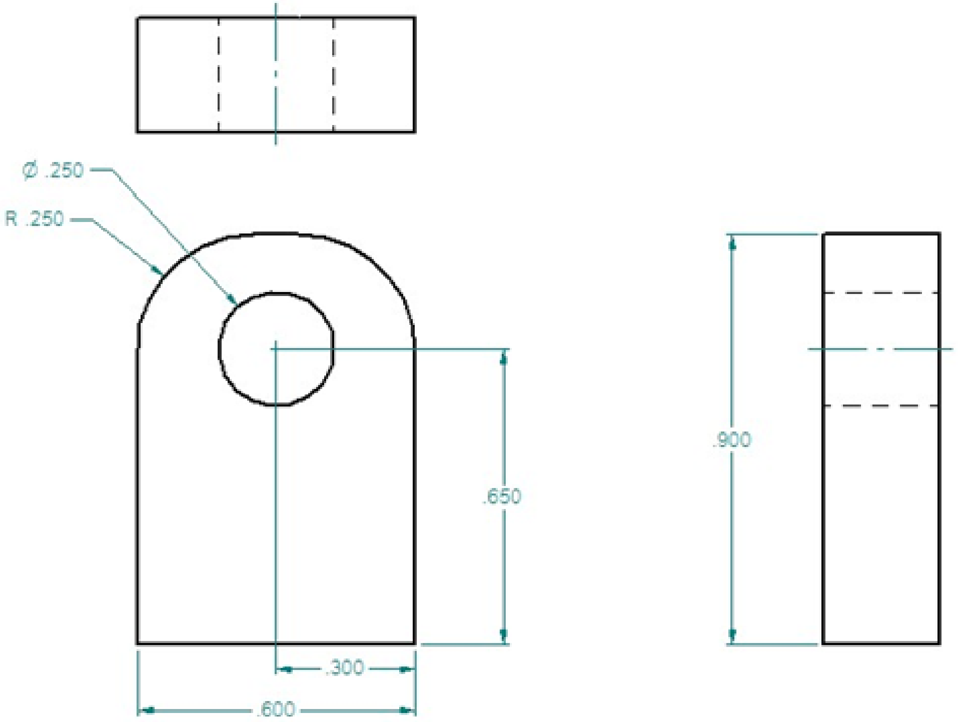

SCALE: 4:1

MATERIAL: Polypropylene from McMaster Carr

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DIMENSIONS ARE IN INCHES
ANGLES ±0.5°
2 PL ±0.03 3 PL ±0.010

Washington University
in St. Louis

TITLE
SHAFT MOUNT

SIZE	DWG NO	REV
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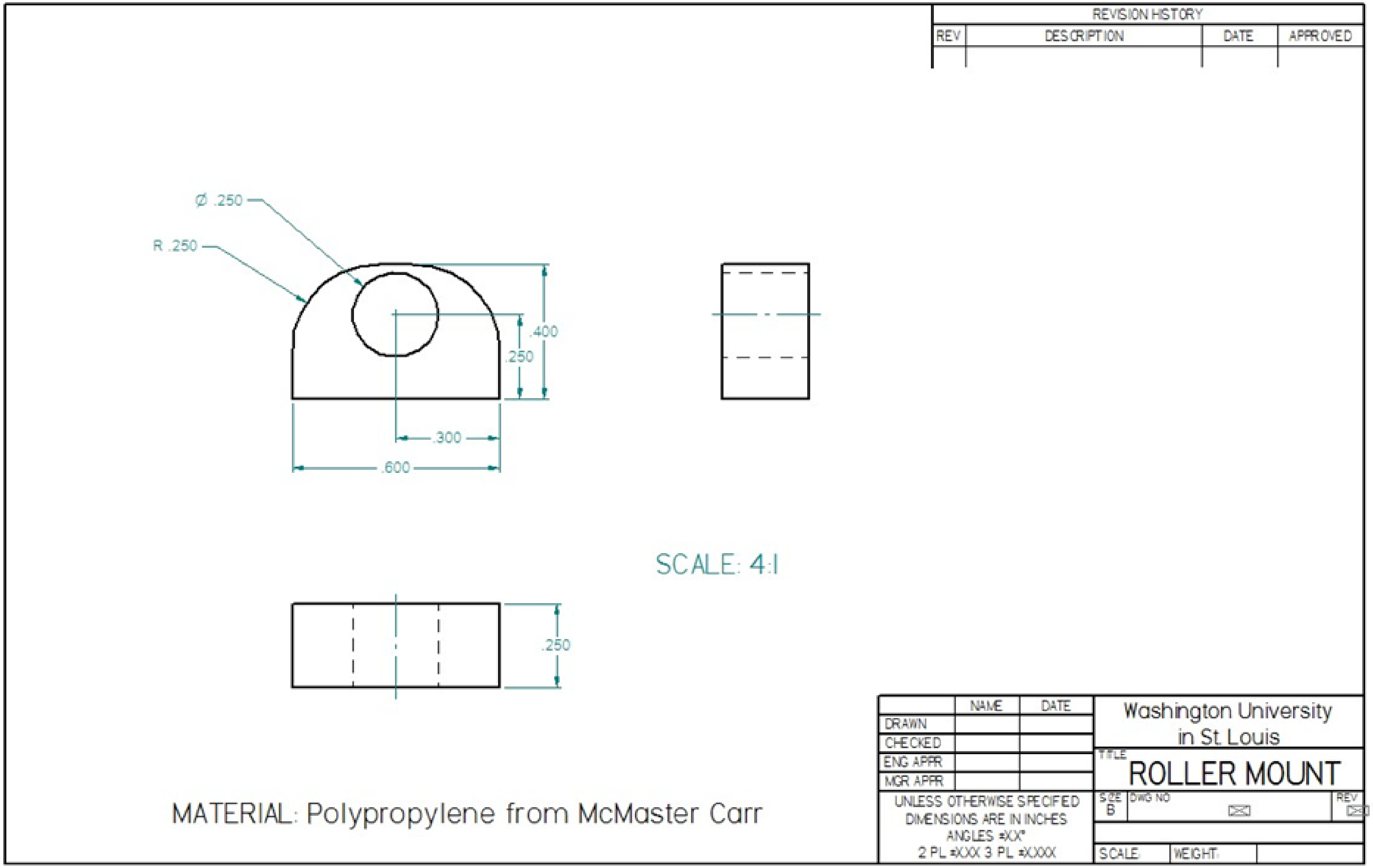
SCALE:	WEIGHT:	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Washington University
in St. Louis
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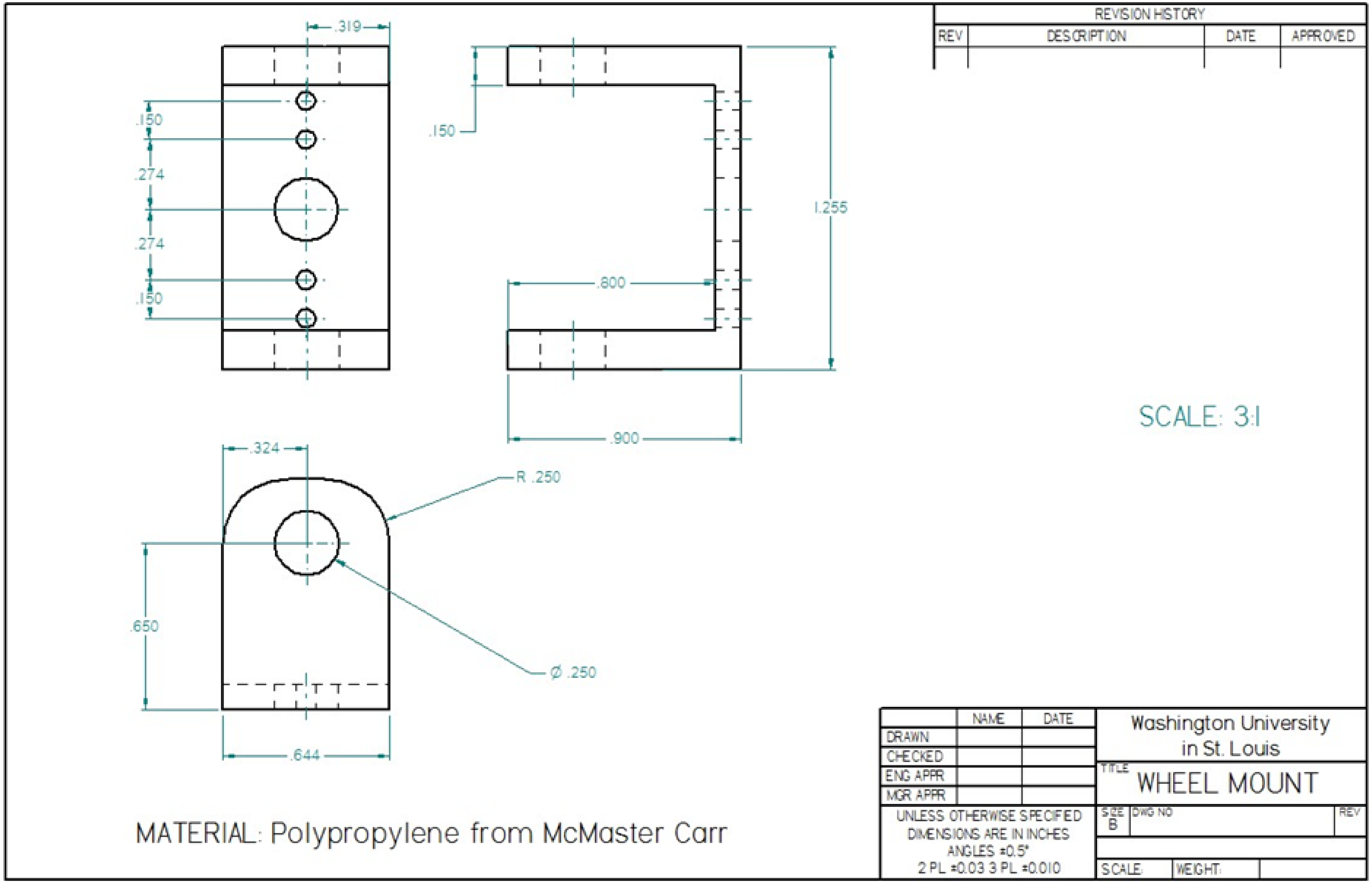
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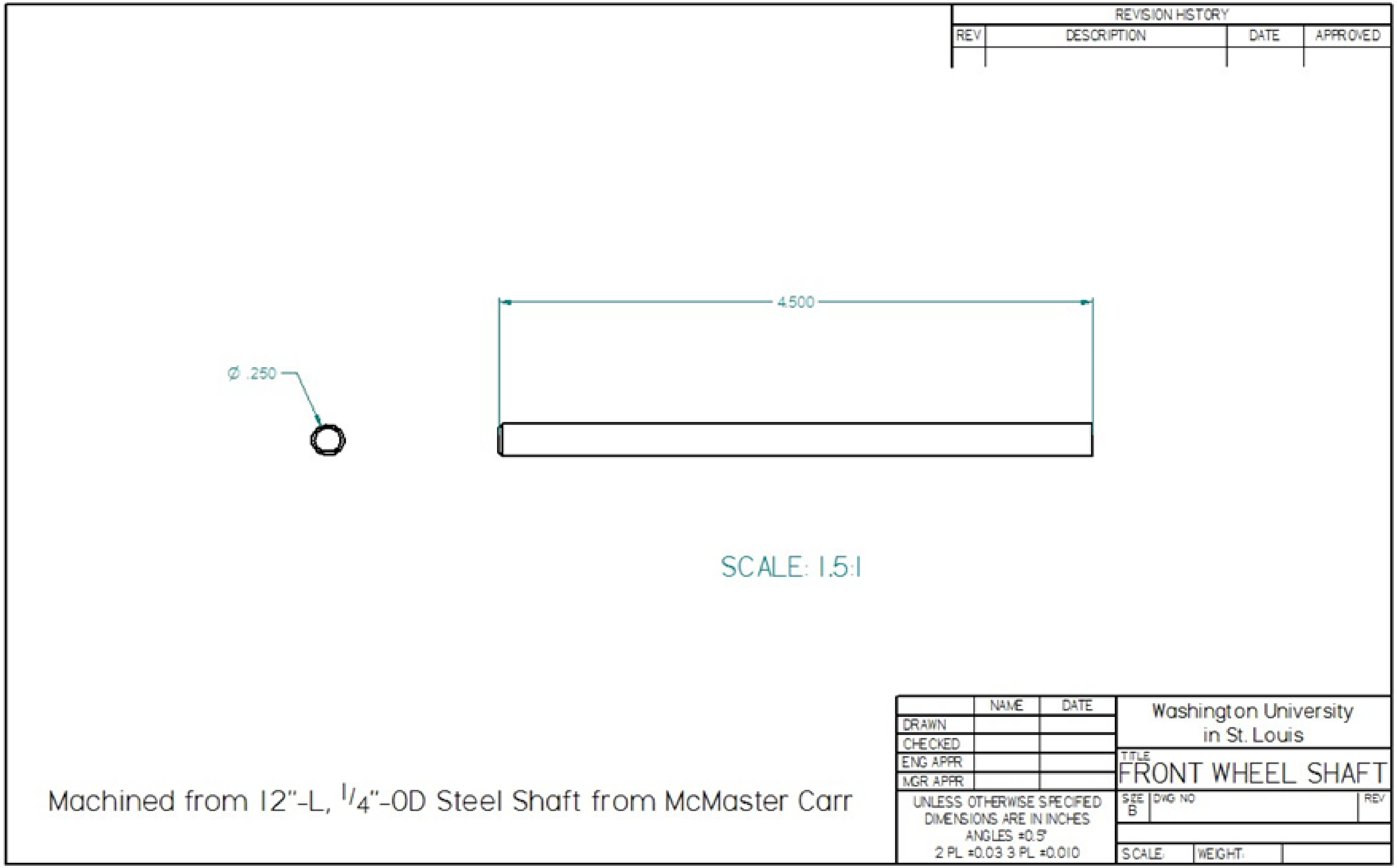
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Washington University
in St. Louis
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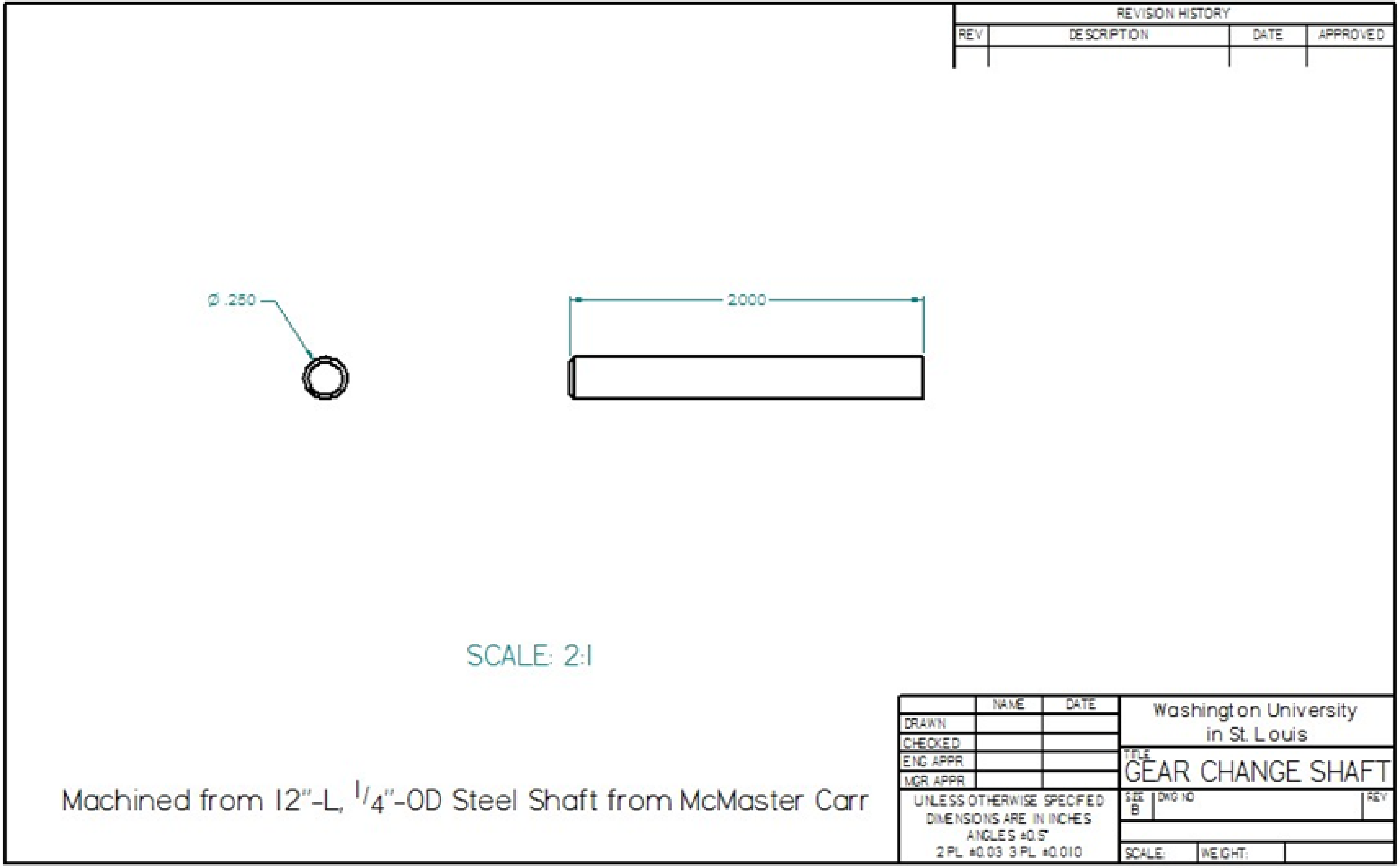
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DIMENSIONS ARE IN INCHES
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Washington University
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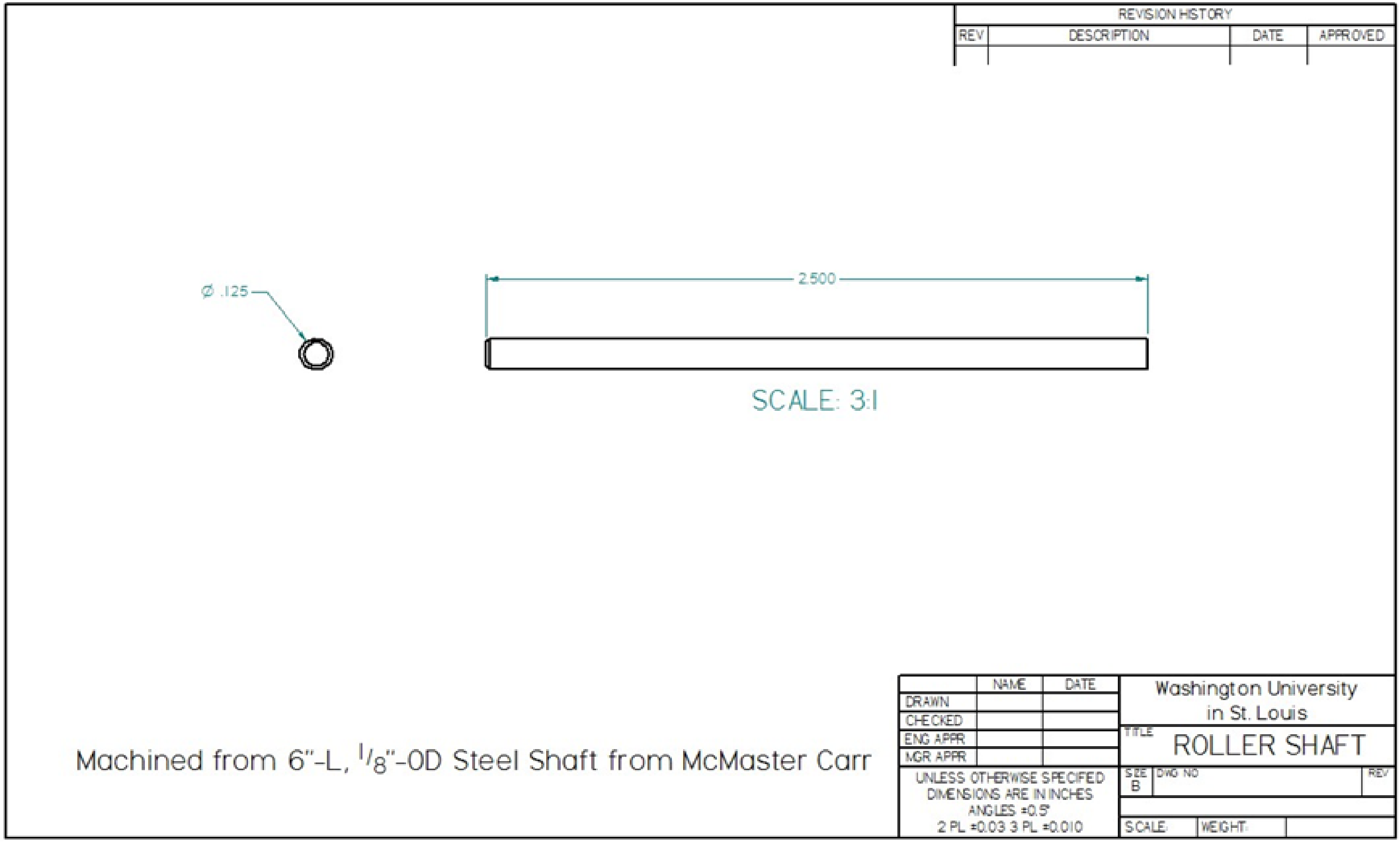
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Washington University
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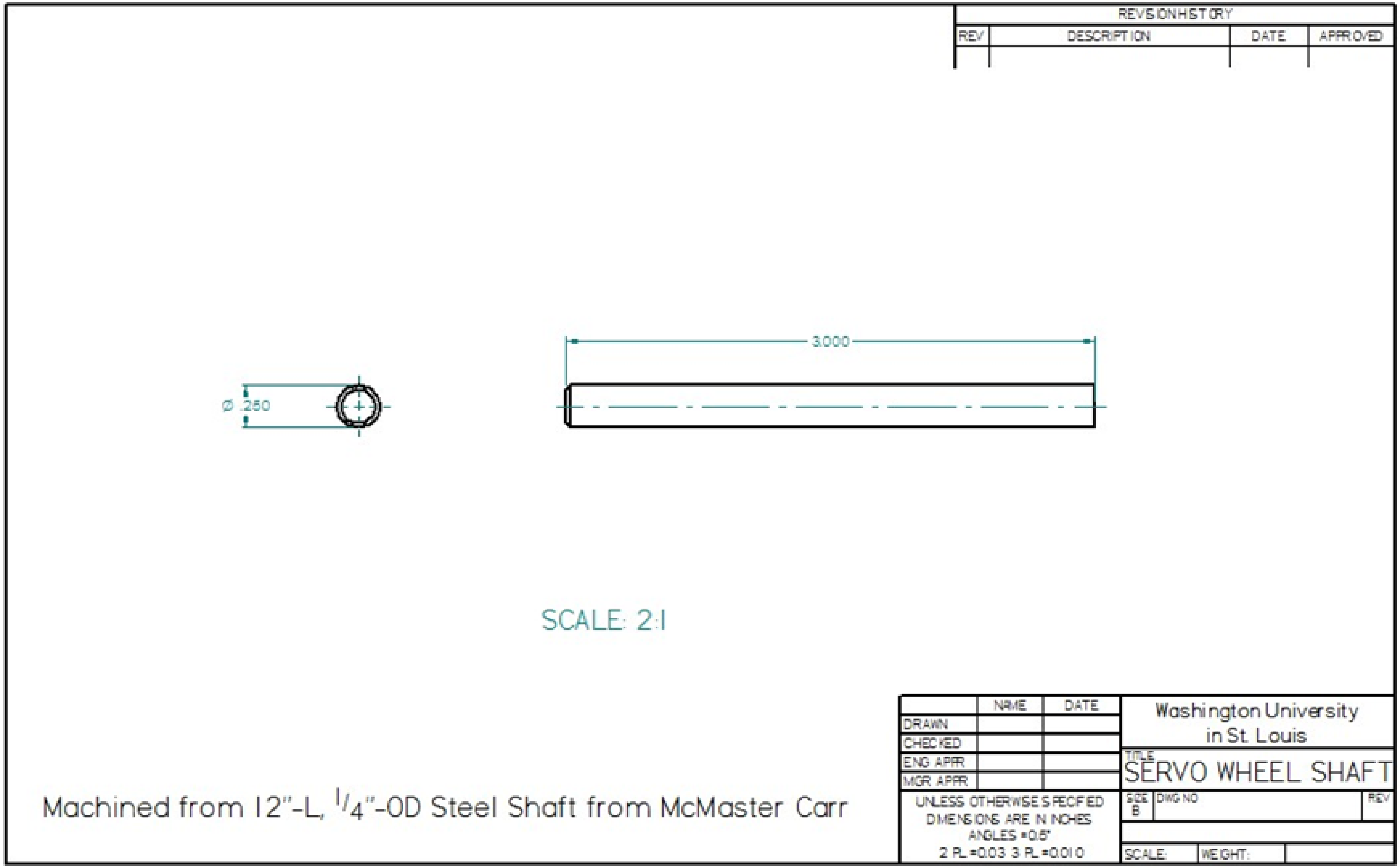
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UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±0.5°
2 PL ±0.03 3 PL ±0.010
Washington University
in St. Louis
TITLE
SERVO WHEEL SHAFT
SIZE
B
DWG NO
REV
SCALE:
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4.4 Description of the design rationale for the choice/size/shape of each part

Critical Dimension: Motion Transformations

A critical analysis on this project was to plan for the track to dispense at exactly the same rate as the train moves forward. To do this, we connected the shafts driving both the wheels and the track dispensing rollers via gears and belt pulleys.

Correcting the Direction Of Motion

All shafts in a belt system rotate in the same direction. Two shafts interlinked by gears rotate in opposite directions. The track must dispense behind the lead car while the car moves forward; that is, the dispenser and drive wheels rotate opposite directions. Therefore, a system of belts is used with one gear between the drive and dispensing ("roller") shaft.

Perfecting the Ratios Of Diameters

The diameter of the track feeding rollers is far smaller than that of the driving wheels. In order to perfectly synchronize the linear feet of distance moved to the linear feet of track laid, the correct conversions must be employed when connecting shafts with pulleys and gears. This is governed by the relation

$$\omega_1 D_1 = \omega_2 D_2$$

stating that linear distance on the left equals linear distance on the right. Take the left hand side to be our dispensing rollers. We have chosen wheels such that D_2 is five times larger than D_1, requiring us to make ω_1 five times larger than ω_2 to maintain equality. This was accomplished using a 5:4 ratio on the gears and then a 4:1 ratio on the pulleys connecting the drive wheels to the track-dispensing rollers.

Design Rationale by Part Number:

#1 - Casing: 1/16" Sheet metal was chosen to create a thin casing to hold the tracks and create the track-dispensing ramps and guides. It is also easily available.

#2 – Servo: Selected for a generous 180 degree range of rotation to work with.

#3 - Servo arm: A 1 ⅝" servo arm was chosen to support the shaft of two opposite wheels across the width of the device.

#4, #13, #14 - Shaft Mounts: Polypropylene mounts will be fabricated with easily machinable material to create mounts that are large enough to allow clearance for the gears and pulleys, but small enough to fit into our designed casing.

#5, #9, #12 - <u>¼" Shaft</u>: ¼" Shaft was chosen for its compatibility with a wide range of gears and pulleys in the appropriate sizes. D-shaft is comparable in price to round shafts and saves labor.

#6 - <u>Motor</u>: The motor does not need to be fast (20 RPM max speed at 7.4 V), which is easily satisfied by this model (begins rotation at 1 V; 51 RPM at 12 V).

#7 - <u>⅛" Shaft</u>: The smaller shaft was chosen to accommodate the boring on the small rollers.

#8, #29 - <u>Sleeve Bearings</u>: ¼" and ⅛" SAE 841 sleeve bearings were chosen based on the size of the ¼" and ⅛" shafts respectively and based the limited space in the casing.

#10 - <u>Wheels</u>: For the drive wheels an even ratio between the diameter of the rollers and the drive wheels is necessary to keep track delivery synced with forward movement. Wheels of 1 ⅞" diameter were chosen for their 5:1 ratio with the rollers, easily accomplished using gears and pulleys. Rubber treads ensures a no-slip condition, critical to syncing. Servo Wheels were chosen to match the drive wheels, since consistency tends to be economical.

#11, #22 - <u>Belt Pulley System for Motor:</u> The Timing Belt Pulley from Motor to Drive Shaft was selected to be slightly smaller than the pulley on the drive shaft, giving a mechanical advantage.

#15 - <u>Motor Mount:</u> The motor mount was chosen based on its inner diameter to match the diameter of the chosen motor.

#16 - <u>Wheel Hub:</u> 6mm Wheel hubs were chosen to axially secure the drive wheels to the ¼" drive shaft. The rotation of the shaft must drive the wheels without slipping.

#17 - <u>Rollers to Dispense Track:</u> The smallest drive rollers available on McMaster Carr were chosen to fit in the small space underneath the track storage, bringing the track as close to the ground as possible for easy delivery. Rubber surface ensures a no-slip condition. Diameter: ⅜"

#18 – Battery**:** The battery must be able to output stall torque of motor (0.5A) for at least 1h. Part rated for 800mAh which provides 1.6 hours of full power usage.

#19 – RC Controls: The receiver requires only one channel. The most basic model on the market has 4. The speed controller is necessary to deliver RC input to the Servo.

#20, #21 - Pulleys for Converter Shaft and Roller Shaft:

A 4:1 ratio from converter to roller shaft assists in the motion transformation necessary to sync track laying with forward movement.

#23 - Switch: Inserting a switch allows the user to preserve battery charge the device and unplugging the battery after each use.

#24, #25 - Gears for Drive Shaft and "Converter" Shaft:

A 5:4 ratio from drive to converter shaft assists in the motion transformation necessary to sync track laying with forward movement.

#26, #27 - Timing Belts: Only MXL series is small enough to fit in the tiny space around the track-dispensing rollers. Broad ¼" MXL belts were chosen over ⅛" or 3/16" to ensure stable power transmission.

#28 - Wheel bushings: Wheel-matching bushings were chosen for the steering wheels mounted on the servo, allowing them to roll freely.

#30 - Tracks: Lego Flexible track was chosen so the train could be laid in straight segments and curved as desired by the motion of the car. Individual pieces connect to form a larger flexible segment that will be modified to connect to other large segments by magnets. It is also a reasonably large scale to contain the necessary parts.

#31 - Angular Lego Brick: The 1x1 Lego angular block was chosen as a magnet base because it fits on the tracks and has hollow space for the magnets. It may also provide some magnetic insulation from other magnet directions.

#32 - Square Magnets: Magnets were chosen to pull and hold the track segment ends together. They were chosen for their ability to fit inside a standard Lego brick, which can be easily affixed to the studs on the tracks.

#33 - Setscrews: Matching setscrews will prevent the pulleys, gears, and rollers from rotating on the shaft.

#34,# 35 - Screws and Nuts: The 1/4" 6-32 Socket head machine screws were chosen because they are small enough to fit in the chosen and fabricated mounts, and nuts were chosen for the screws to hold the servo onto the casing.

#36 - Speed Controller: The suitable speed controller is available from the ASME stock room.

#37, #38 - Retaining Rings: The ¼" Retaining rings were chosen to prevent axial motion along the shaft without varying the shaft diameter. These will be place around the mounts so that the shaft doesn't slide axially and around the gears and pulleys so that they also keep their axial position. The shafts will require machining to create grooves. The ⅛" Retaining rings were chosen similarly to prevent axial motion on the shaft for the rollers.

5 ENGINEERING ANALYSIS

5.1 Engineering analysis proposal

5.1.1 A form, signed by your section instructor

ANALYSIS TASKS AGREEMENT

PROJECT: TOY TRAIN 2

NAMES: Jordan Zwetchkenbaum,

Will Andersen

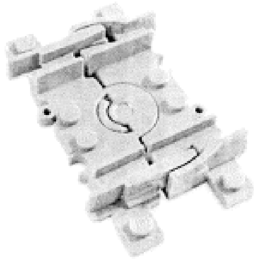
Chiamaka Asinugo

INSTRUCTOR: Mark Jakiela

The following engineering analysis tasks will be performed:

1. **Track laying mechanism:** We will construct a prototype track laying cart which dispenses track as it moves, to demonstrate the capability of the rolling-wheel design to accurately and consistently dispense track.

2. **Track:** Modify existing Lego flexible track to incorporate magnetic linkage and demonstrate track coupling ability of prototype. Experimental analysis may include hook and groove prototype if magnetic prototype is inadequate.



The work will be divided among the group members in the following way:

Zwetchkenbaum & Andersen - Track laying prototype

Asinugo - Track coupling prototypes

Instructor signature: JMJ Print instructor name: T. Bever

5.2 Engineering analysis results

5.2.1 Motivation. Describe why/how the before analysis is the most important thing to study at this time. How does it facilitate carrying the project forward?

Insofar as our goal is to create a toy train that lays its own tracks, there are two critical functions our device must perform to succeed. First, the device must dispense discrete tracks and second these tracks must link together in such a way as to bear the load of a train on them. These two primary challenges are represented by the two analyses we performed for both the track-laying and the track-linking mechanism. Without either of these elements properly functioning, the project is fundamentally unsuccessful. A track-laying mechanism prototype will show that the tracks will dispense close to each other. The track prototype will show that the track will connect as it is laid. This is important to determine if the track linkage design is compatible with the model. This analysis should provide the maximum range that the atomic units of track can be placed in before the attractive magnetic forces cannot construct the track circuit. It also will show whether the magnets are strong enough to keep the track together while the track curves.

5.2.2 Summary statement of analysis done. Summarize, with some type of readable graphic, the engineering analysis done and the relevant engineering equations

Per the recommendation of Dr. Jakiela, our analysis involved testing early prototypes of our models, as hard engineering analysis was not very applicable to this project (i.e., there are no parts in danger of failure due to fatigue, no parts that risk uncontrolled resonance, etc.). For the laying mechanism, we assembled a rudimentary working carriage and pulled it along to demonstrate the synchronization between the turning of the drive wheels and the turning of the track-laying wheels. For the linking mechanism, we manufactured several tracks with a potential linking mechanism based on magnets and demonstrated their ability to firmly hold the tracks together with minimal help

5.2.3 Methodology. How, exactly, did you get the analysis done? Was any experimentation required? Did you have to build any type of test rig? Was computation used?

Laying – The magazine was first assembled according to our initial design. However, alterations were necessary to improve manufacturing such as the shapes of the shaft mounts, the placement of the mounts on the base, and the placement of the roller shaft. We tested the device by first pulling it along and measuring the distance between tracks laid, and then repeated the process with the battery included in the circuit. The dimensions of the tracks (with the added angle bricks) were measured to determine the size of the magazine, and the required sheet metal dimensions. The analysis of our gears and pulleys is based on the computations in our embodiment and fabrication plan.

Linking – We tested different methods of attaching magnets to the track, ultimately choosing hot glue over a filled surface, and then tested the rigidity with which adjacent tracks will secure. Magnets were glued onto the assembled unit track to test their ability to grip firmly and secure a viable connection between tracks. We tested the maximum distance between the tracks and the range of angled-displacement which the magnetic linkage would work. The tracks were slid over each other in an approximation of their position in the magazine.

5.2.4 Results. What are the results of your analysis study? Do the results make sense?

Laying – We tested dispensing magnet-free tracks. The configuration of the screws and the inclined flange initially prevented the track from dispensing freely. (We fixed this by advancing the rollers to the edge of the magazine.) Pushing the track clear of the flange is often necessary and will be addressed by moving the flange outside the magazine on the final prototype. The track falls within 1' – 2' from the end of the previously laid track, when it does not catch. We expect the magnetic tracks to help reduce this distance. The center of gravity is farther back which makes the back of the car drag.

Linking - The magnets are able to link tracks placed up to 1' apart but they also interact with the prototype's body. Because the magnets stick to the poorly selected steel magazine, the track-laying mechanism cannot be tested with the constructed track assembly. In the final prototype, an aluminum frame will be used. We also tested the linking strength of the magnetic tracks outside of the magazine and found it to be very robust. The magnets need to be carefully glued onto the tracks to prevent blocking the groove that lets the tracks slide together.

5.2.5 Significance. How will the results influence the final prototype? What dimensions and material choices will be affected? This should be shown with some type of revised embodiment drawing.

Track Linking

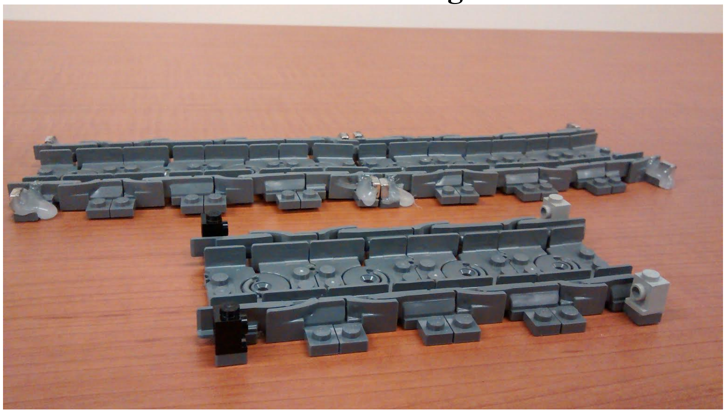


Figure 5.2.1: Foreground – original design for magnet holders
Background –prototypes of hot-glued magnets as track connectors.

Track Laying

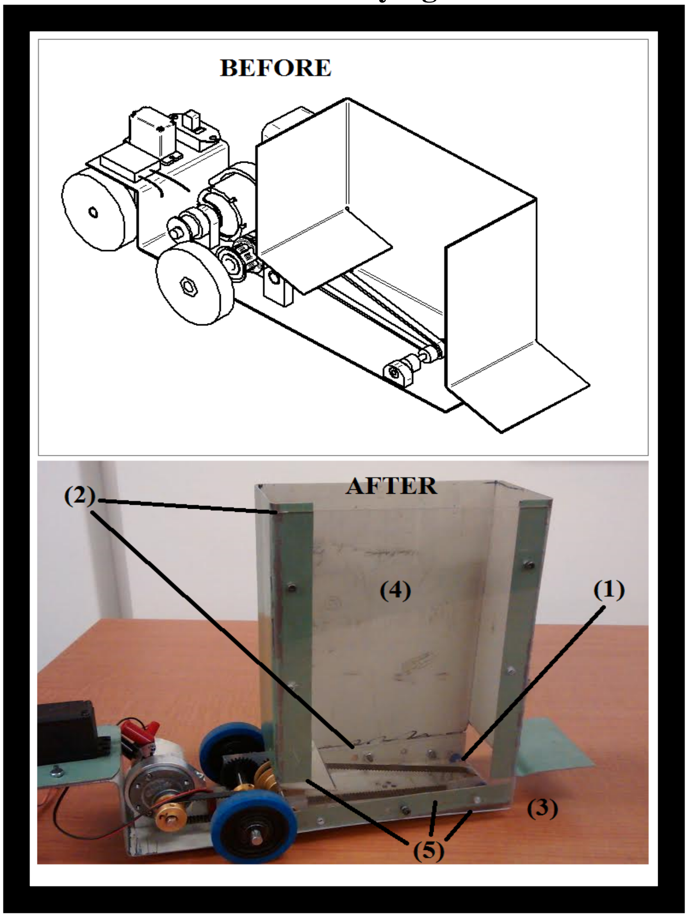


Figure 5.2.2: Above -- pre-analysis model.
Below -- prototype with changes (both made and planned) marked.

The following improvements will be included:

1. The rollers will be moved to the edge of the magazine.
2. The magazine sides and window will be positioned inside the attachment flanges for smooth track loading. The dimensions will be slightly wider to accommodate putting the viewing window on the inside (to cover up the catchy flange).
3. Future designs will include additional wheels to support the weight of the magazine.
4. The final body will be made out of aluminum rather than steel.
5. The sheet metal body will be in two pieces, with a third piece as a viewing window, as opposed to the original 1-piece magazine design.

An aluminum magazine is also necessary when using these magnets. The track ends are the same, so the orientation during loading is of no consequence as long as it is face-up.

5.2.6 Summary of code and standards and their influence. Similarly, summarize the relevant codes and standards identified and how they influence revision of the design.

Our user needs motivated a toy train for the 4-12 age range. Our prototype was cross-checked with the United States Consumer Product Safety Commission's guidelines which describes the ASTM F 693-11 requirements for toys. In their list of regulated products, they reference the Federal Hazardous Substances Act. With an age range above 3 years old, we are allowed small parts. Our prototype also has many sharp edges driving the age range to over 8 years old, but on a final product the edges should be rounded, and they would ultimately have to be tested as described on the U.S. Government Printing Office’s website. The prototype uses a LiPo battery because of its power, duration, and common use in RC-building. Given its possibility of exploding, it violates codes on combustibility in children’s toys.A children’s toy a toy is for ages less than 12. Since 12-year-olds are the top of our age range, we would either have to target that older audience or find a new power source.

6 WORKING PROTOTYPE

6.1 A preliminary demonstration of the working prototype

This was shown during the scheduled lab session during the semester.

6.2 A final demonstration of the working prototype

Refer to the video clip in Section 6.4.

6.3 Initial Working Prototype Images

See the following page.

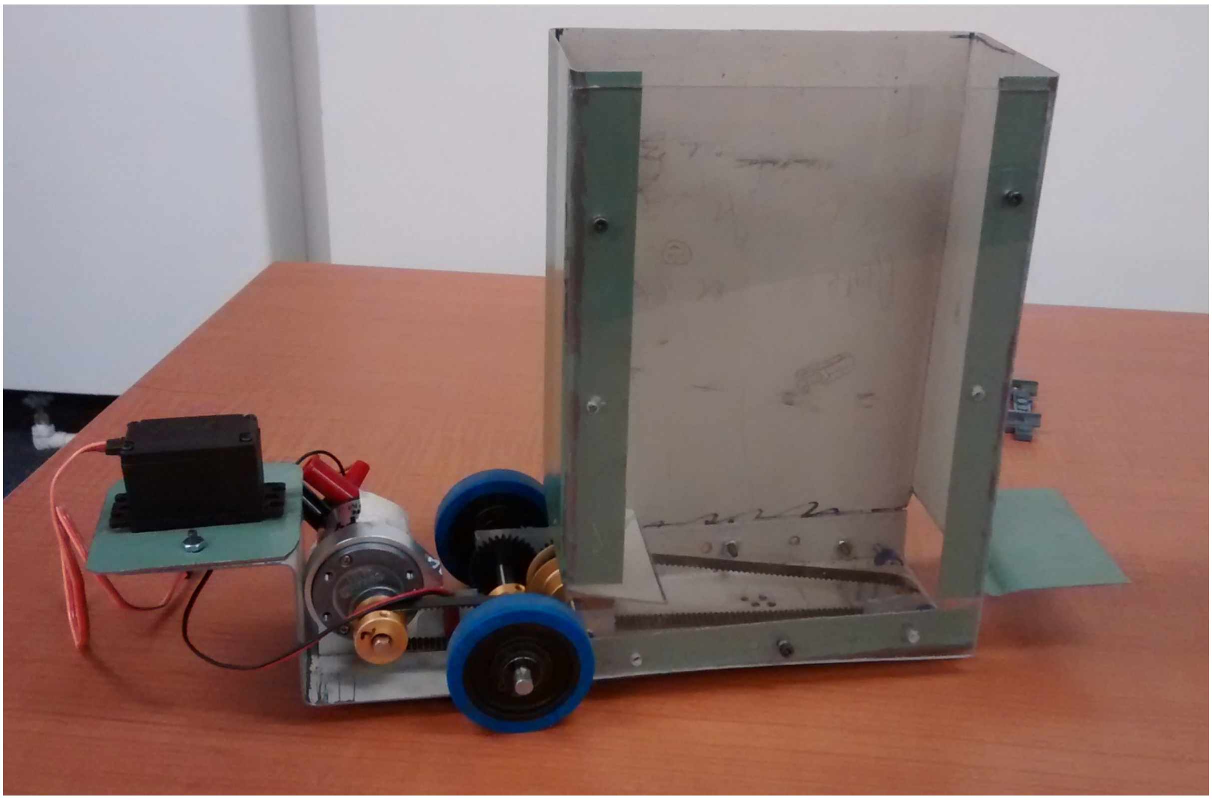


Figure 6.3.1: The working prototype pulleys and gears connect the motor to the wheels and rollers in the magazine to prove the track-laying rate

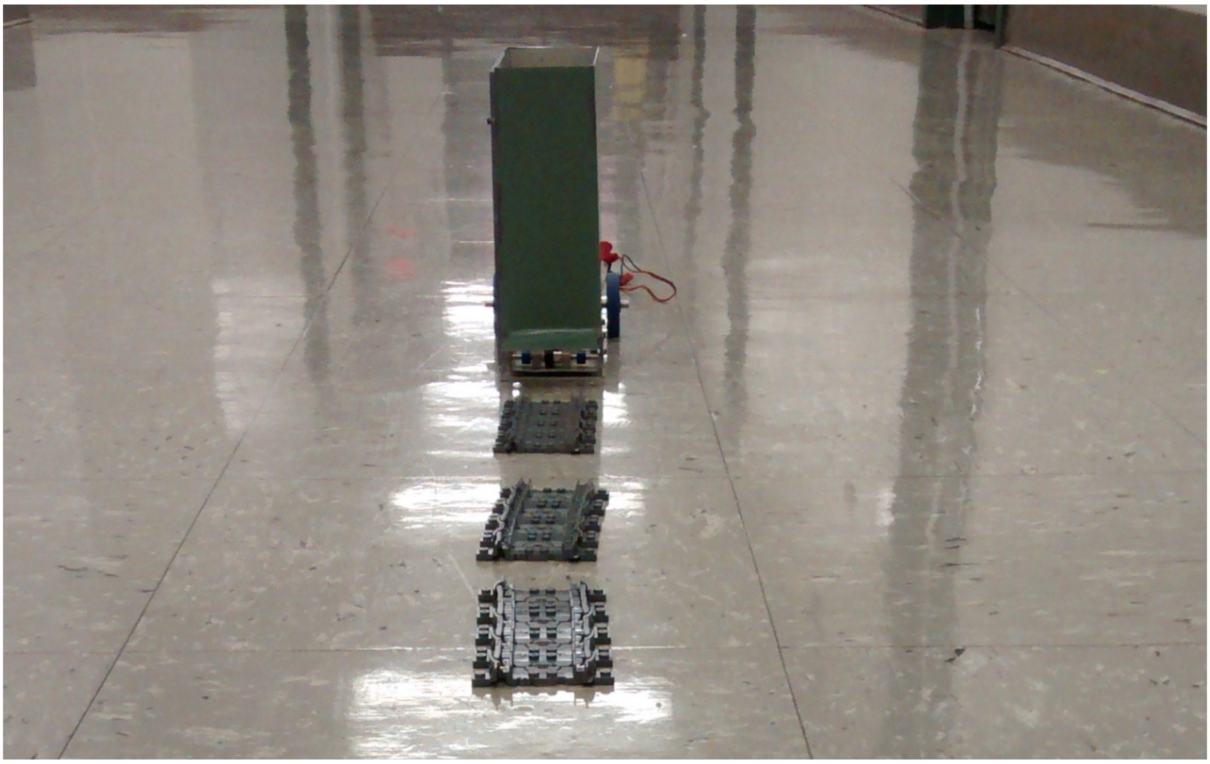


Figure 6.3.2: Working prototype lays only nonmagnetic track in a straight line

6.4 Final Working Prototype Video

A video of our final working prototype can be found at the following website:
https://www.youtube.com/watch?v=4_UgM329TrU&feature=youtu.be

6.5 Final Working Prototype Images

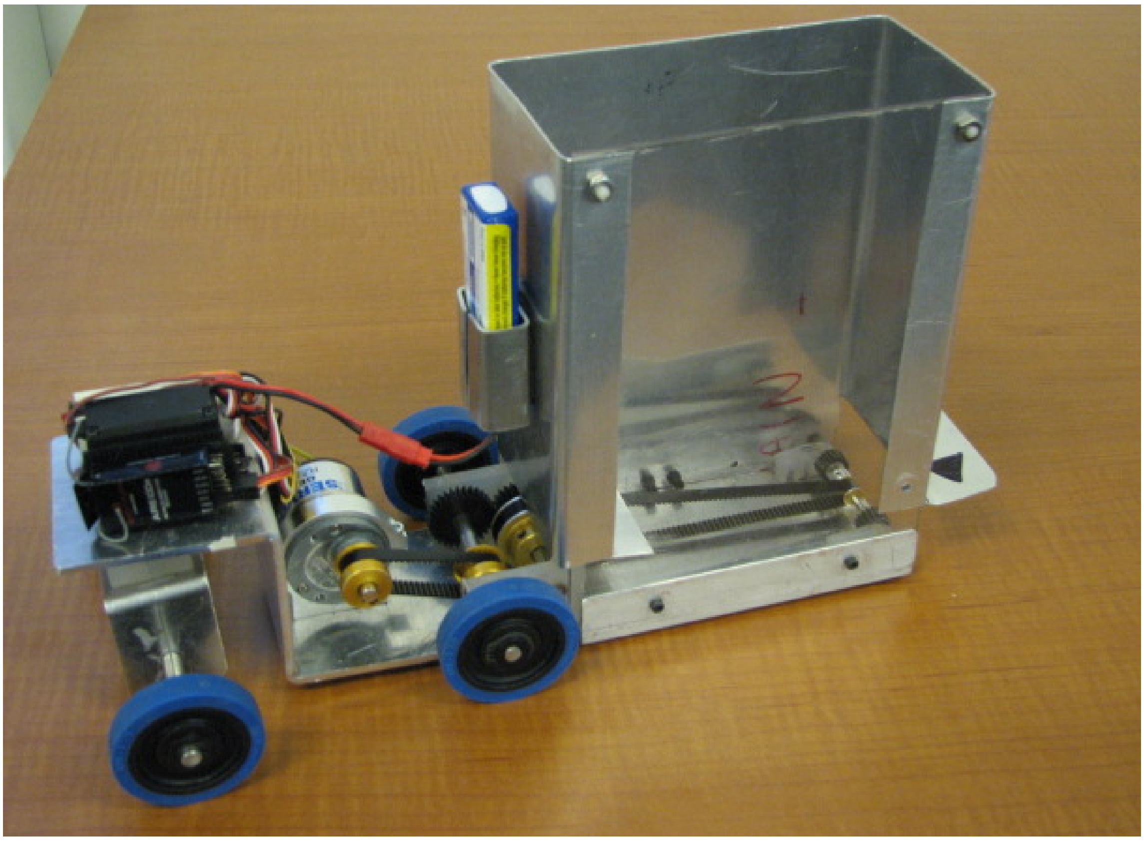


Figure 6.5.1: Complete assembled car

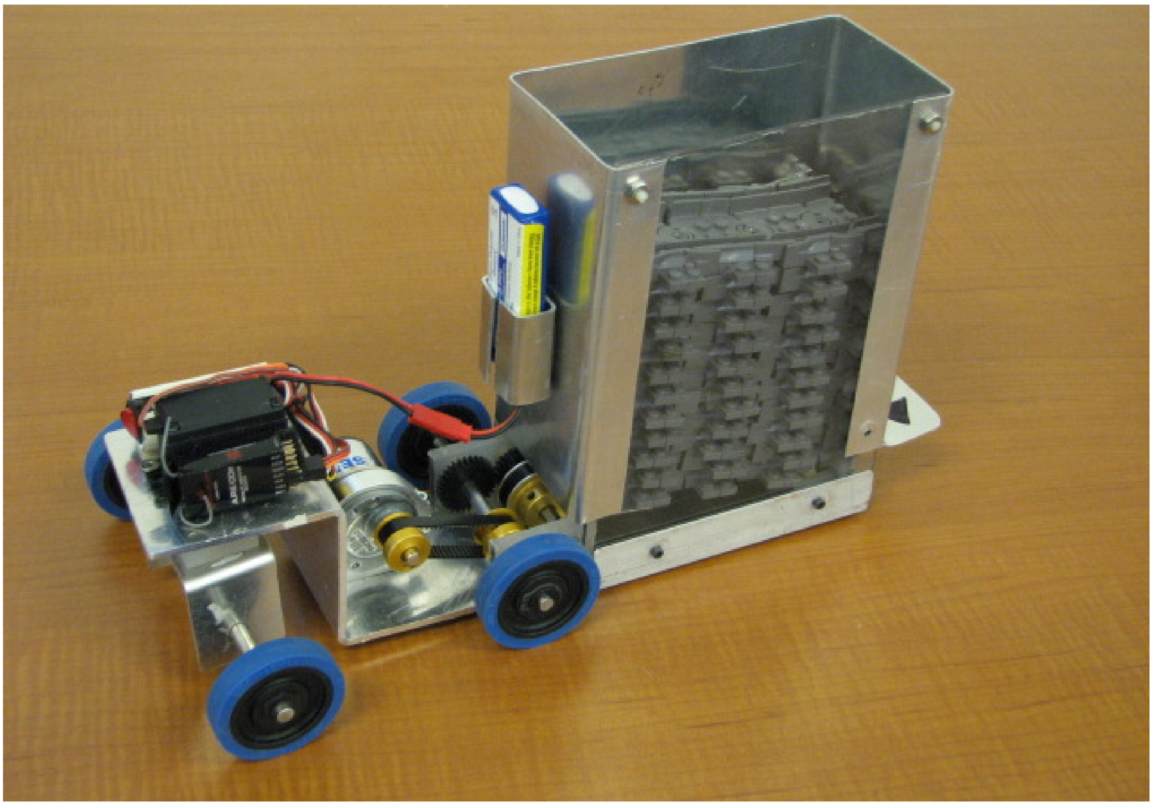


Figure 6.5.2: Complete assembled car with track showing how track fits in the magazine

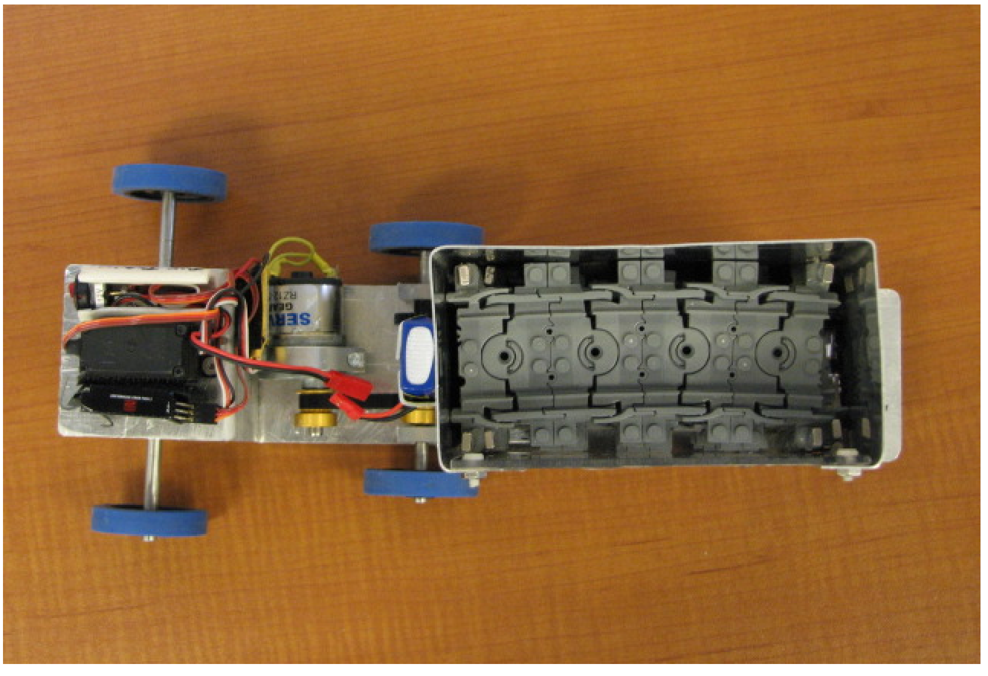


Figure 6.5.3: Top view showing electronic circuit and loaded with track

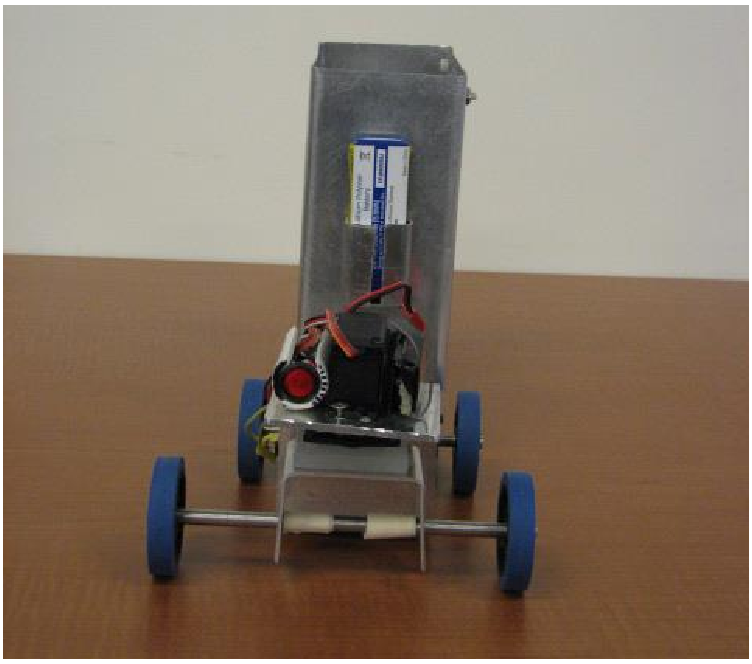


Figure 6.5.4: Front view showing servo attachment to wheels

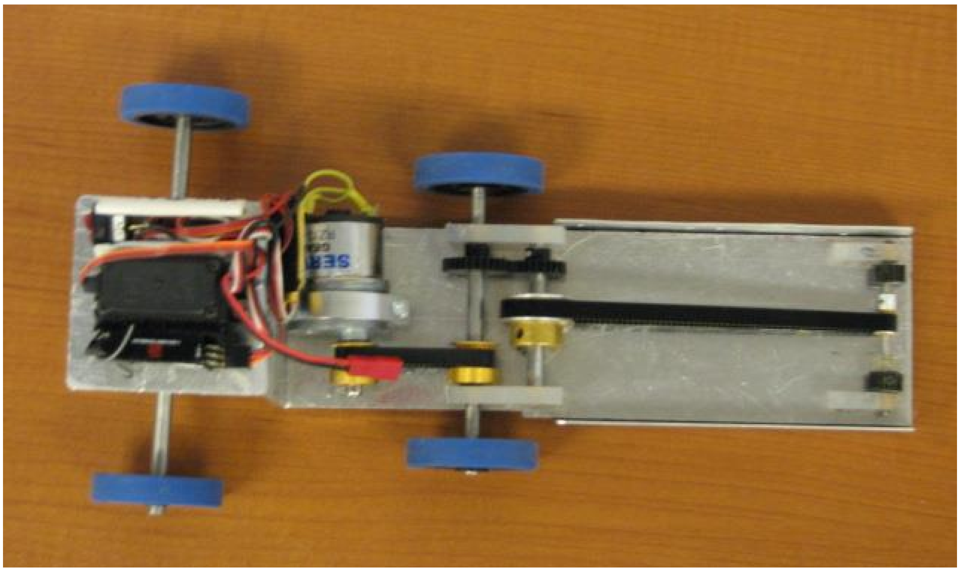


Figure 6.5.5: Top view with the magazine removed to show the pulleys, belts, and improved rollers

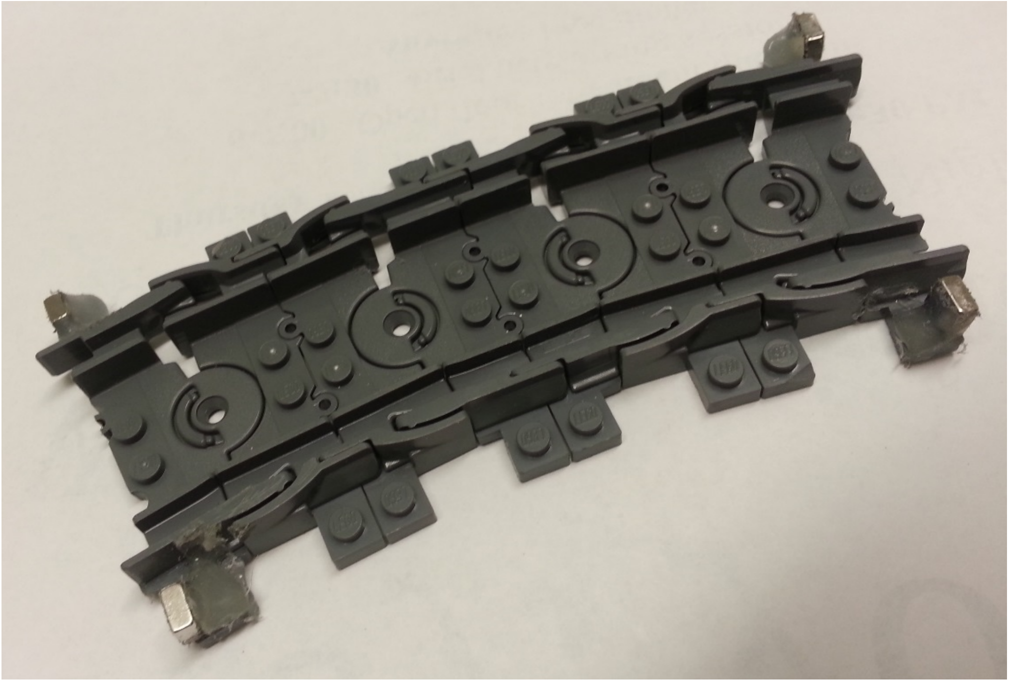


Figure 6.5.6: Assembled track unit

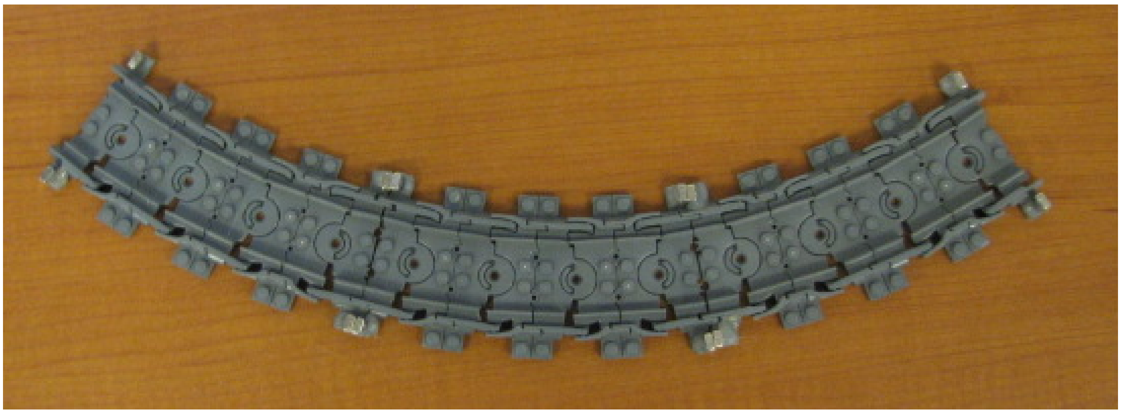


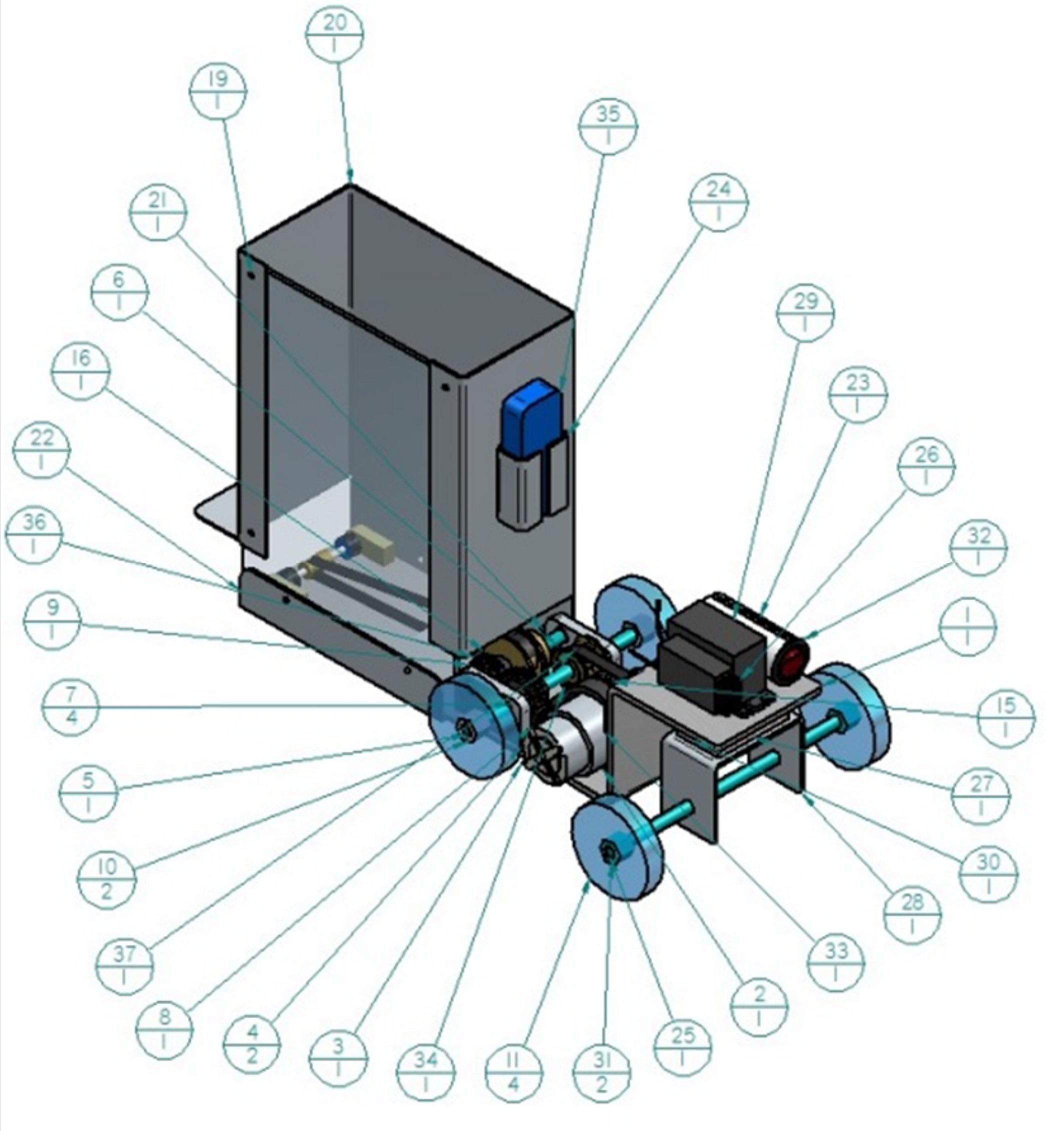
Figure 6.5.7: Sample track connections, illustrating allowable bend

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 complete the CAD models.



PART #	PART	QUANTITY
1	Base	1
2	Motor Mount	1
3	Standard Gearmotor - 51 RPM	1
4	Shaft Mount	2
5	Back Wheel Shaft	1
6	Gear Shaft	1
7	SAE 841 Bronze Sleeve Bearing, 1-4 Shaft	4
8	Servo City 32 Pitch Plain Bore Gears, 30T (30 Teeth)	1
9	Servo City 32 Pitch Plain Bore Gears, 24T (24 Teeth)	1
10	BaneBots Hex Hub	2
11	BaneBots Wheel, 1-78 x 0.4in, 12in Hex Mount, 30A	4
12'	Roller Mount	2
13'	Roller Shaft	1
14'	SAE 841 Bronze Sleeve Bearing, 1-8 Shaft	2
15	Mxl Series Timing-Belt Pulley, 14 Belt Width, .685 OD, 20 Teeth	1
16	Mxl Series Timing-Belt Pulley, 14 Belt Width, 1.210 OD, 40 Teeth	1
17'	Belted Roller	2
18'	Mxl Series Timing-Belt Pulley, 14 Belt Width, .425 OD, 10 Teeth	1
19	Window Pane	1
20	Magazine	1
21	Magazine Flange	1
22	Window Flange	1
23	Wire Holder	1
24	Battery Holder	1
25	Front Wheel Shaft	1
26	Receiver	1
27	Servo Plastic Pad	1
28	Servo Wheel Mount	1
29	Servo	1
30	Turnigy Servo Arm Full Arm	1
31	BaneBots Bushing, 12in Hex mount	2
32	Switch	1
33	Speed Controller	1
34	Mxl Series Timing-Belt Pulley, 14 Belt Width, .740 OD, 22 Teeth	1
35	E-Flite 800mah Double Cell 2S 7.4V 20C Lipoly Pack, JST	1
36	MXL Series Timing-Belt (150MXL)	1
37	MXL Series Timing-Belt (65MXL)	1

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR		
MGR APPR		

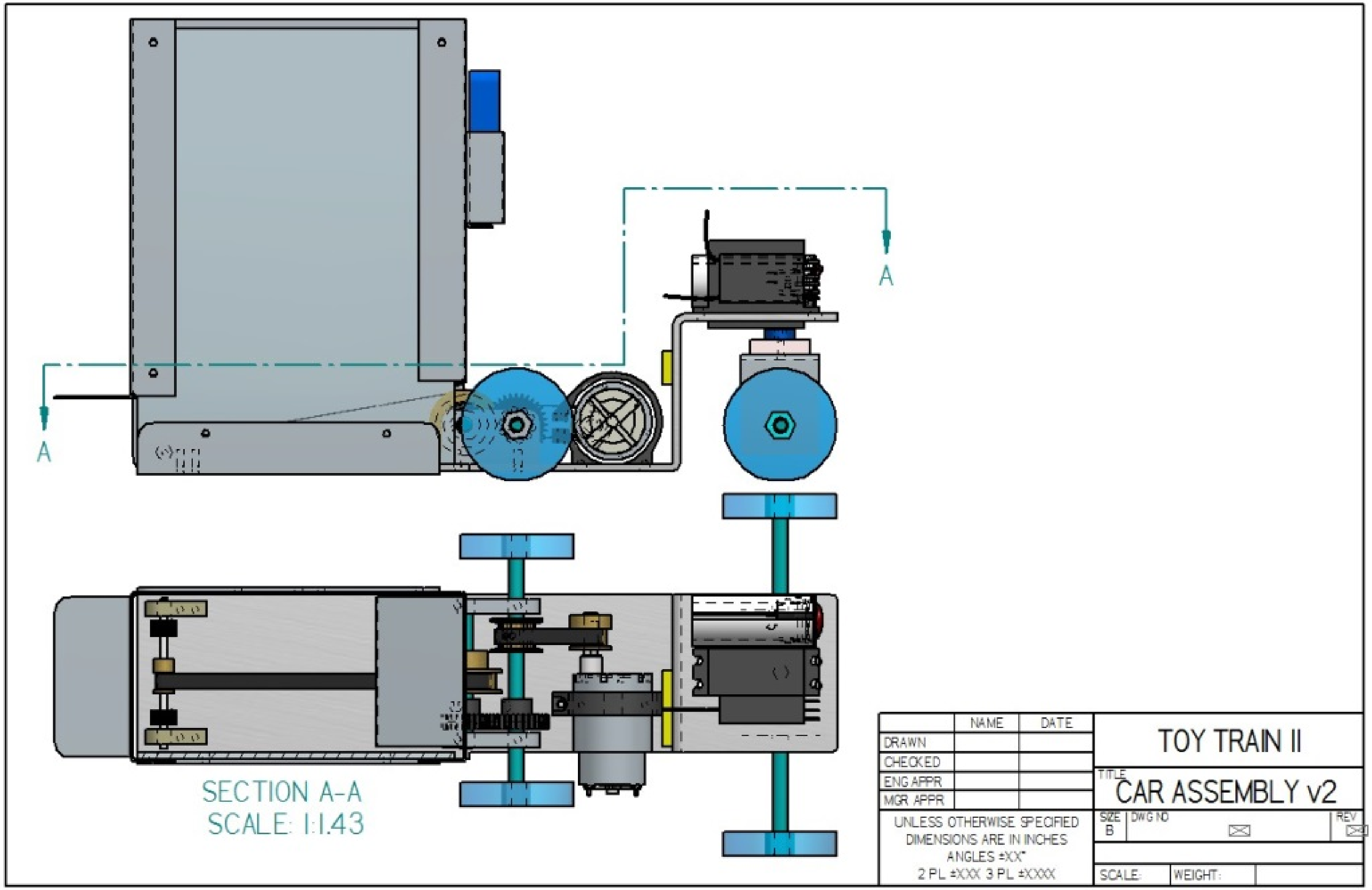
TOY TRAIN II

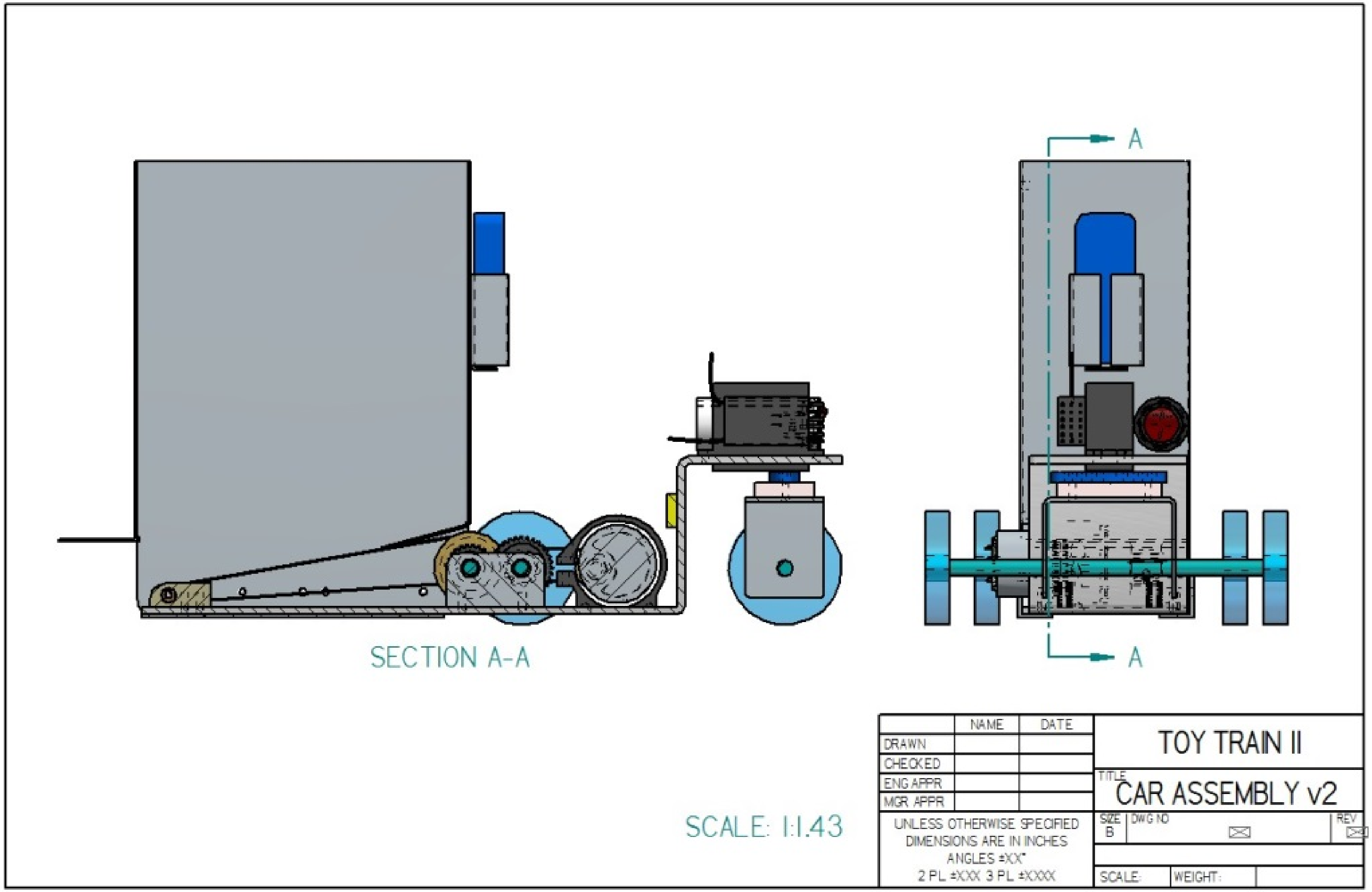
TITLE CAR ASSEMBLY v2

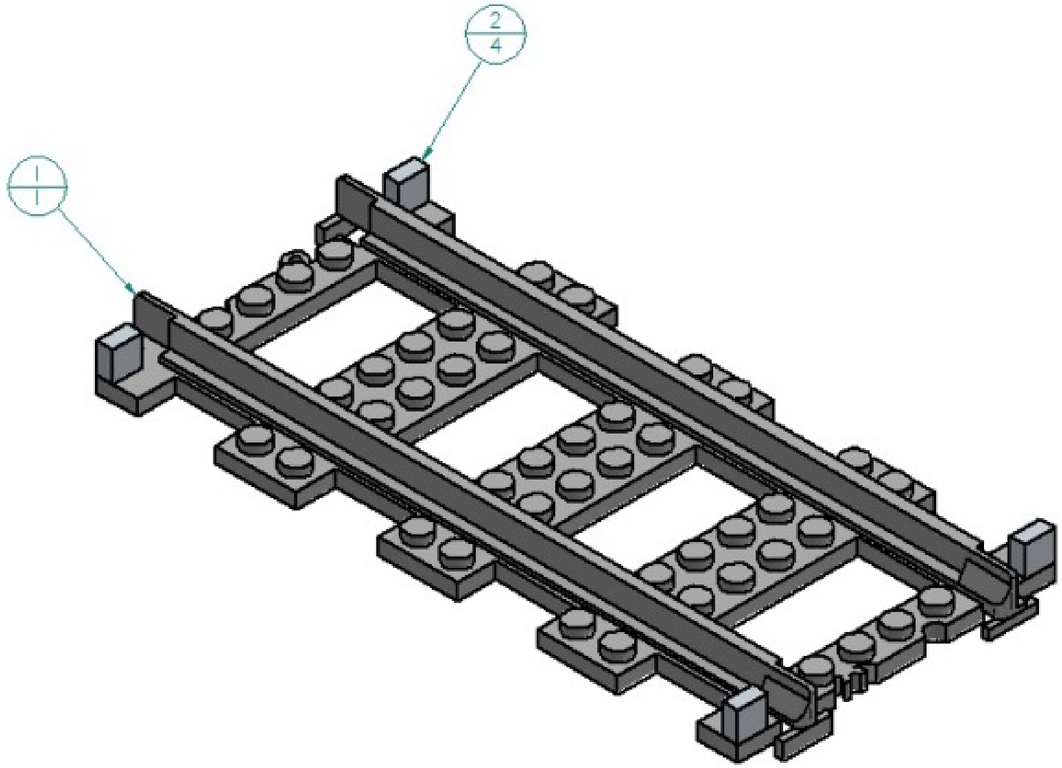
SIZE B | DWG NO | REV

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±XX°
2 PL ±XXX 3 PL ±XXXX

SCALE: | WEIGHT:


A
A
SECTION A-A
SCALE: 1:1.43
NAME
DATE
DRAWN
CHECKED
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±XX°
2 PL ±XXX 3 PL ±XXXX
TOY TRAIN II
TITLE
CAR ASSEMBLY v2
SIZE
B
DWG NO
REV
SCALE:
WEIGHT:


A
A
SECTION A-A
SCALE: 1:1.43
NAME
DATE
DRAWN
CHECKED
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±XX°
2 PL ±XXX 3 PL ±XXXX
TOY TRAIN II
TITLE
CAR ASSEMBLY v2
SIZE
B
DWG NO
REV
SCALE:
WEIGHT:



PART #	PART	QUANTITY
1	Lego Track Unit	1
2	Square Magnet	4

NOTES

1. Track assembly is made from four connected Lego Flexible Train Tracks
2. End connections of each assembly are ground down to allow llinkage
3. End lego studs are ground down to accomodate magnets.
4. Magnets are hotglued onto assembly

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±XX°
2 PL ±XXX 3 PL ±XXXX

TOY TRAIN II

TRACK ASSEMBLY v2

SIZE B | DWG NO | REV

SCALE: | WEIGHT:

7.1.2 Sourcing instructions

Refer to Appendix B, in the column titled "SOURCE".

7.2 Final Presentation

7.2.1 A live presentation in front of the entire class and the instructors

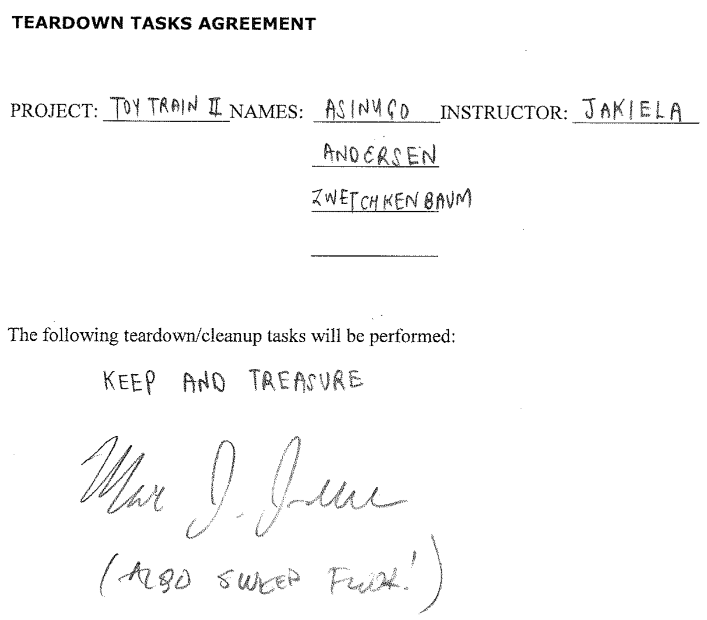
Presentation executed on schedule.

7.2.2 Presentation: Video link

YouTube link: http://youtu.be/LdROvYX59n0

7.3 Teardown

Working prototype archived in ASME models inventory. Machine shop and Jolley 110 cleaned as per teardown recommendation.



TEARDOWN TASKS AGREEMENT

PROJECT: TOY TRAIN II NAMES: ASINUGO INSTRUCTOR: JAKIELA

ANDERSEN

ZWETCHKENBAUM

The following teardown/cleanup tasks will be performed:

KEEP AND TREASURE

[illegible]

(ALSO SWEEP FLOOR!)

Figure 7.3.1: Teardown agreement form

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.

With a track length of 140 cm, we nearly met our more realistic goal for a track length of 150 cm, although we were still far from our best value of 400 cm. We also could travel a good distance without charging, were below our expected price, and made it remote controlled to lay track in 3 forward directions. It is compatible with the existing LEGO trains. Assembly time was in the middle of our acceptable range. The radius of curvature was just about our worst value of 75 cm, and the track-laying rate was 9 tracks per minute which was close to our lowest value of 10 per minute, and still reasonably entertaining.

The following table expounds our performance results.

Table 8.1.1 – Scoring of Prototype by Category

	Units	Best Value	Worst Value	Actual Value	Normalized Metric Happiness
Length of stored track	cm	400	0	140	0.35
Radius of curvature	cm	50	75	75	0.00
Distance traveled without charging	cm	400	0	400	1.00
Total price	$	500	1000	275	1.45
Number of programmed features	int	0	5	0	1.00
Number of user controlled actions	int	3	0	2	0.67
Remote controlled	bin	1	0	1	1.00
Number of track brands it runs on	int	2	0	1	0.50
Maximum distance at which the model can be controlled	cm	200	0	200	1.00
Number of hazardous parts	int	1	5	1	1.00
Total length of track laid	cm	400	0	140	0.35
Number of track laying directions	int	6	0	3	0.50
Percentage of pieces gathered	percent	100	0	0	0.00
User assembly time	min	1	5	2.5	0.63
Laying rate	track/min	30	10	10	0.00
Percent of trials successfully closing loops	percent	100	0	0	0.00
Types of closed track shape	int	3	0	0	0.00
Distance tracks move during use	cm	0	0.5	0.5	0.00
Number of times train falls from track	int	0	2	0	1.00

Table 8.1.2 – Predicted Concept Score vs. Actual Concept Score

TOTAL HAPPINESS	
Theoretical Concept	0.69
Prototype	0.57

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?

Relying on shipped parts was expensive and required us to plan far ahead. At the end of the semester, when “crunch time” hit, we had to have some parts shipped in ASAP and it would have been nice if there had been a local, immediately available source. However, sometimes this is not an option, and given the circumstances, we did fairly well (because we planned ahead – kudos to Chiamaka). None of our vendors were unreasonable in their delivery time, however, this was because we chose them carefully (and with Dr. Jakiela’s input). In future projects, we would recommend scrounging as many parts as possible, because with the help of borrowing ASME's parts we were able to cut down costs and have replacements readily available.

8.3 Discuss the overall experience:

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

The project was far more difficult than we anticipated. Decisions took longer to make than anticipated and research could be at times frustrating. The biggest challenge we ran into was the complexity of the project. Steps such as finding a set of gears and pulleys with the correct ratios for the drive train could actually be quite finicky and slow.

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

We met many of the major requirements of the project, including: the device lays discrete tracks; it is able to turn and pick its own route based on user input; it lays a meter and a half of track; the track successfully self-connects; and a train can follow behind. The one point on which we had to stretch the prompt was that we made a track-laying machine rather than a vehicle that runs on its own tracks. This is fairly significant, but the vehicle still performs all other fundamental tasks, the design was chosen because it scored well on our user-defined metrics, and Dr. Jakiela did not object.

8.3.3 Did your team function well as a group?

Yes, our biggest challenge as a team was overthinking everything, decisions that would have been simple for other groups were frequently drawn out for ours. However, apart from this, everyone was willing to do what it took to work together and accomplish each next step. We also made an effort to plan things so that at any given time, each member was able to contribute in a different way, improving our efficiency.

8.3.4 Were your team member's skills complementary?

Yes. Chiamaka enjoyed certain aspects such as doing CAD models and organizing the Google drive, and in general was very industrious and good at helping us get down to work. Will had a skill set with RC circuits that was necessary for the design chosen, and also was persistent about correctly rating the drive train. Jordan was reliable, a good researcher and always open to performing new tasks.

8.3.5 Did your team share the workload equally?

For most of the steps of this project, we met to work on the project together. We each put a large amount of time and effort into it. When we could, we tried to work to our strengths.

8.3.6 Was any needed skill missing from the group?

We all had one similar trait that held us back. We all care very much about details and doing things *right*. This meant that we were always slow about everything we did, and we frequently had to debate the simplest things for a long time before we could reach any consensus. This meant that we put in far more hours than many other teams. On the flip side, we came out with a high quality design with a working method.

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

We initially consulted with our customer to find out the user needs. From there, we mostly worked off of those specifications. We asked for a few clarifications of contradicting needs such as completing a loop versus a remote controlled path.

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

Yes, as mentioned before, the fact of the train running on the track lessened in importance, with the fact that any train from the Lego brand could follow behind on its tracks it being an important part of coming to terms with this decision. Additionally, early in the semester we had to clarify the meaning of the "no programming stipulation;" We opted to use remote control to operate our circuit, and this means that we did no coding, but we did use simple "computers". However, we did this based on Dr. Jakiela's explicitly expressed user stipulations.

8.3.9 Has the project enhanced your design skills?

The project has enhanced our design skills. Having now experienced the process from start to finish, we know the necessary steps. We practiced engineering analysis as well as using CAD and machining a prototype. We have also developed a consideration for the materials used in a design, such as magnetism.

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

Yes, we feel that we have gained an understanding of the design process as it flows from start to finish, and what general trends and challenges to expect from it. Notably, we noticed that good teamwork skills are indispensable, and that the hypothetical numbers you set for performance metrics at the beginning of the semester are not always as realistic as you think they will be!

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

Will feels more comfortable with the process of setting metrics and trying to achieve them, and would be willing to attempt projects using this as a method of guidance for results, including projects in which you go through multiple revisions based on the numbers. Jordan would be more likely to attempt a project requiring the use of remote control.

9 APPENDIX A - PARTS LIST

Table 8.3

PART #	PART	QUANTITY
1	Base	1
2	Motor Mount	1
3	Standard Gearmotor - 51 RPM	1
4	Shaft Mount	2
5	Back Wheel Shaft	1
6	Gear Shaft	1
7	SAE 841 Bronze Sleeve Bearing, 1-4 Shaft	4
8	Servo City 32 Pitch Plain Bore Gears, 30T (30 Teeth)	1
9	Servo City 32 Pitch Plain Bore Gears, 24T (24 Teeth)	1
10	BoneBots Hex Hub	2
11	BoneBots Wheel, 1-78 x 0.4in, 12in Hex Mount, 30A	4
12'	Roller Mount	2
13'	Roller Shaft	1
14'	SAE 841 Bronze Sleeve Bearing, 1-8 Shaft	2
15	Mxl Series Timing-Belt Pulley, 14 Belt Width, .685 OD, 20 Teeth	1
16	Mxl Series Timing-Belt Pulley, 14 Belt Width, 1.210 OD, 40 Teeth	1
17'	Belted Roller	2
18'	Mxl Series Timing-Belt Pulley, 14 Belt Width, .425 OD, 10 Teeth	1
19	Window Pane	1
20	Magazine	1
21	Magazine Flange	1
22	Window Flange	1
23	Wire Holder	1
24	Battery Holder	1
25	Front Wheel Shaft	1
26	Receiver	1
27	Servo Plastic Pad	1
28	Servo Wheel Mount	1
29	Servo	1
30	Turnigy Servo Arm Full Arm	1
31	BoneBots Bushing, 12in Hex mount	2
32	Switch	1
33	Speed Controller	1
34	Mxl Series Timing-Belt Pulley, 14 Belt Width, .740 OD, 22 Teeth	1
35	E-Flite 800mah Double Cell 2S 7.4V 20C Lipoly Pack JST	1
36	MXL Series Timing-Belt (1150MXL)	1
37	MXL Series Timing-Belt (165MXL)	1

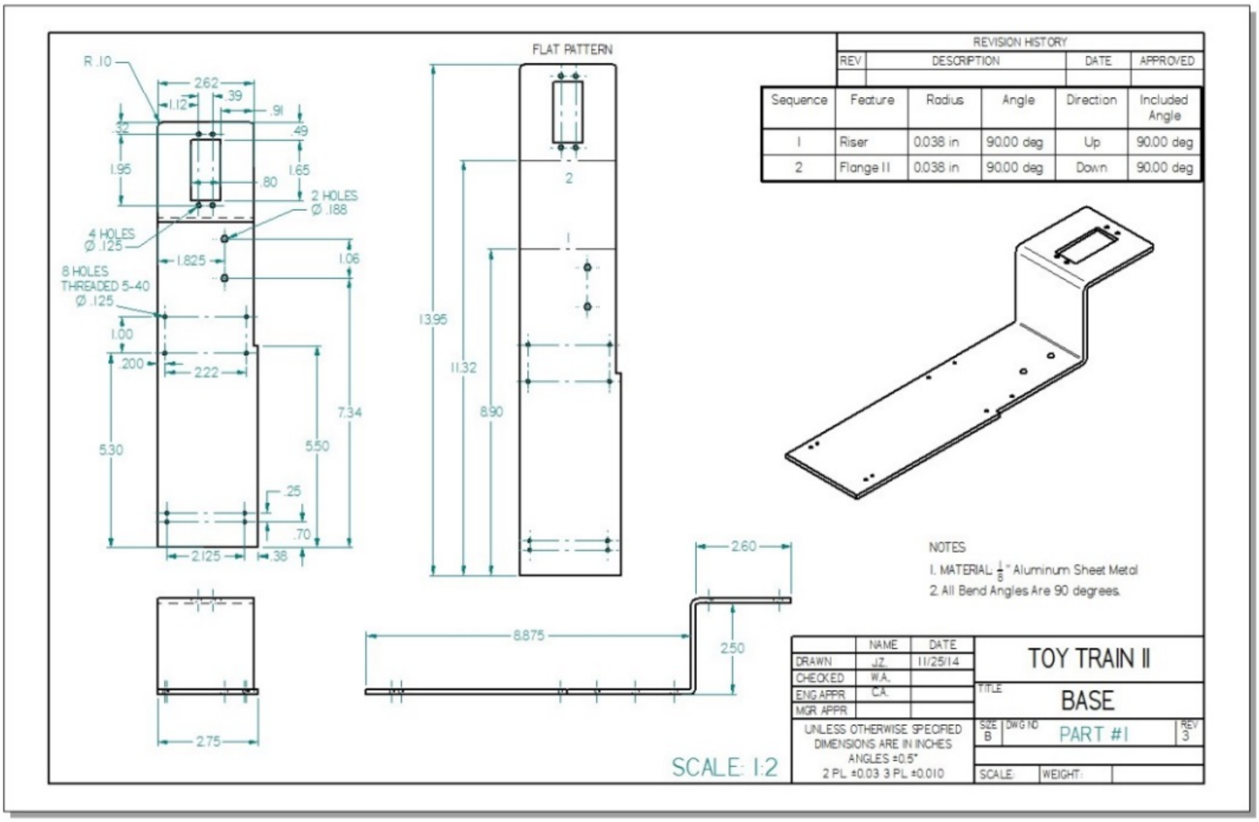
10 APPENDIX B - BILL OF MATERIALS

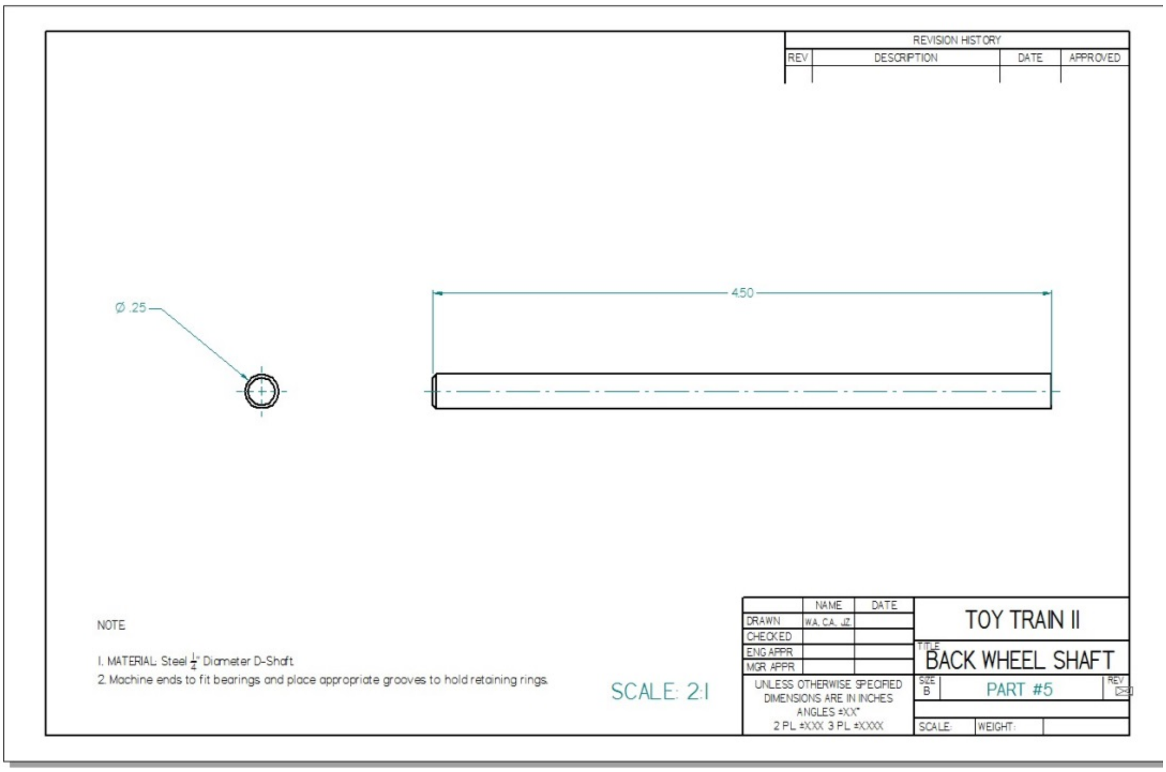
PART	SOURCE	MODEL NO.	QUANTITY	UNIT COST
Aluminum Sheet Metal 1/16"	-	Supplied	1	-
Turnigy TGY-180D 180° Digital Servo	Hobbyking	9458000003-0	1	$9.25
Turnigy Servo Full Arm 1-5/8"	Hobbyking	192000173-0	1	$5.50
Polypropylene Rectangular Bar (per ft)	Mcmaster	8782K12	1	$0.71
Shaft D-Shaft (Stainless; 1/4"D x	Sparkfun	ROB-12548	2	$4.69

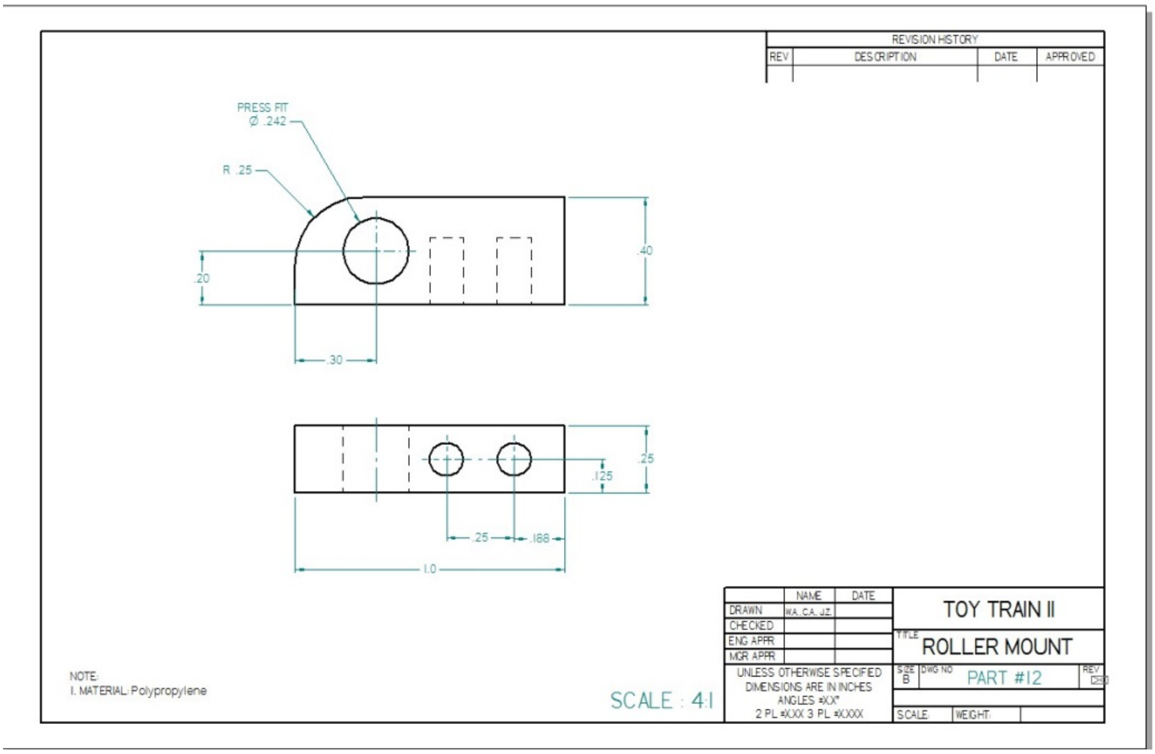
12"L)				
Standard Gearmotor - 51 RPM (3-12V)	Sparkfun	ROB-12150	1	$24.95
Shaft Solid (Stainless; 1/8"D x 6"L)	Sparkfun	ROB-12170	1	$0.89
SAE 841 Bronze Sleeve Bearing, 1/4" Shaft	Mcmaster	6391K126	4	$0.43
BaneBots Wheel, 1-7/8 x 0.4in., 1/2in. Hex Mount, 30A Blue	Banebots	0-T40P-195BA-HS4	2	$2.50
BaneBots Wheel, 1-7/8 x 0.4in., 1/2in. Hex Mount, 30A Green	Banebots	0-T40P-195BA-HS4	2	$2.50
Mxl Series Timing-Belt Pulley, 1/4" Belt Width, .740" OD, 22 Teeth		1375K44	1	$11.11
Motor Mount, Clamp	Sparkfun	ROB-12407	1	$6.99
BaneBots Hex Hub - 6mm	Banebots	0-T40H-SM61	2	$4.00
Precision Urethane Drive Roller - Slimline	Mcmaster	2488K33	2	$24.04
E-Flite 800mah Double Cell 2S 7.4V 20C Lipoly Pack, JST	Robotmarketplace	0-EFLB8002SJ	1	$16.99
GWS R-4S 2.4GHz 4-Channel Receiver and Bind Plug	Robotmarketplace	0-GWRX4SB	1	$13.99
Mxl Series Timing-Belt Pulley, 1/4" Belt Width, .425" OD, 10 Teeth	Mcmaster	1375K29	1	$9.35
Mxl Series Timing-Belt Pulley, 1/4" Belt Width, 1.210 OD, 40 Teeth	Mcmaster	1375K55	1	$14.24
Mxl Series Timing-Belt Pulley, 1/4" Belt Width, .685" OD, 20 Teeth	Mcmaster	1375K39	1	$10.79
Circuit Switch	-	Supplied	1	-
Servo City 32 Pitch Plain Bore Gears, 24T (24 Teeth)	Servocity	SPBD32-34-30	1	$2.27
Servo City 32 Pitch Plain Bore Gears, 30T (30 Teeth)	Servocity	SPBD32-34-24	1	$2.11

Mxl Series Timing-Belt (65MXL)	Mcmaster	1679K69	1	$2.55
Mxl Series Timing-Belt (110MXL)	Mcmaster	1679K96	1	$2.69
BaneBots Bushing, 1/2in. Hex mount (sleeve)	Banebots	T40H-BS21	2	$2.35
SAE 841 Bronze Sleeve Bearing, 1/8" Shaft	Mcmaster	6391K111	2	$0.78
Lego Flexible Train Tracks	Lego	8867	1	$24.99
Square Magnet	Amazingmagnets	Q125B	50	$0.39
Setscrews	-	Supplied	6	-
Machine Screw - Socket Head (6-32 ; 1/4"; 25 pack)	Sparkfun	ROB-12517	1	$1.69
Nut - Metal (6-32, 25 pack)	Mcmaster	PRT-12917	1	$1.50
Speed Controllers (RC controller)	-	Supplied	1	-
External Retaining Ring for 1/8" shaft	Mcmaster	98410A107	1	$5.64
External Retaining Ring, Black-Finish Steel for 1/4" shaft	Mcmaster	97633A130	1	$7.82
Clear Polycarbonate Sheet	Home Depot	987359	1	$14.28
Mxl Series Timing-Belt (50MXL)	Mcmaster	1679K63	1	$2.53
		ESTIMATED TOTAL		**$295.77**

11 APPENDIX C – FINAL CAD MODELS



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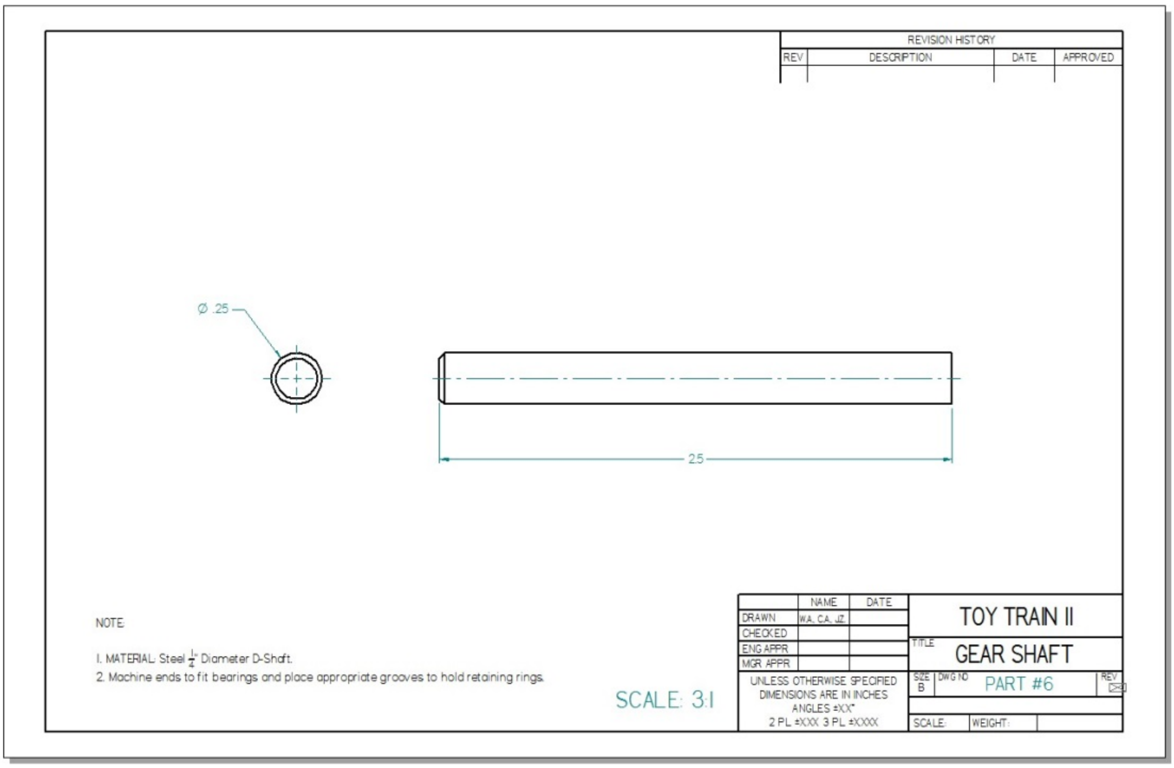
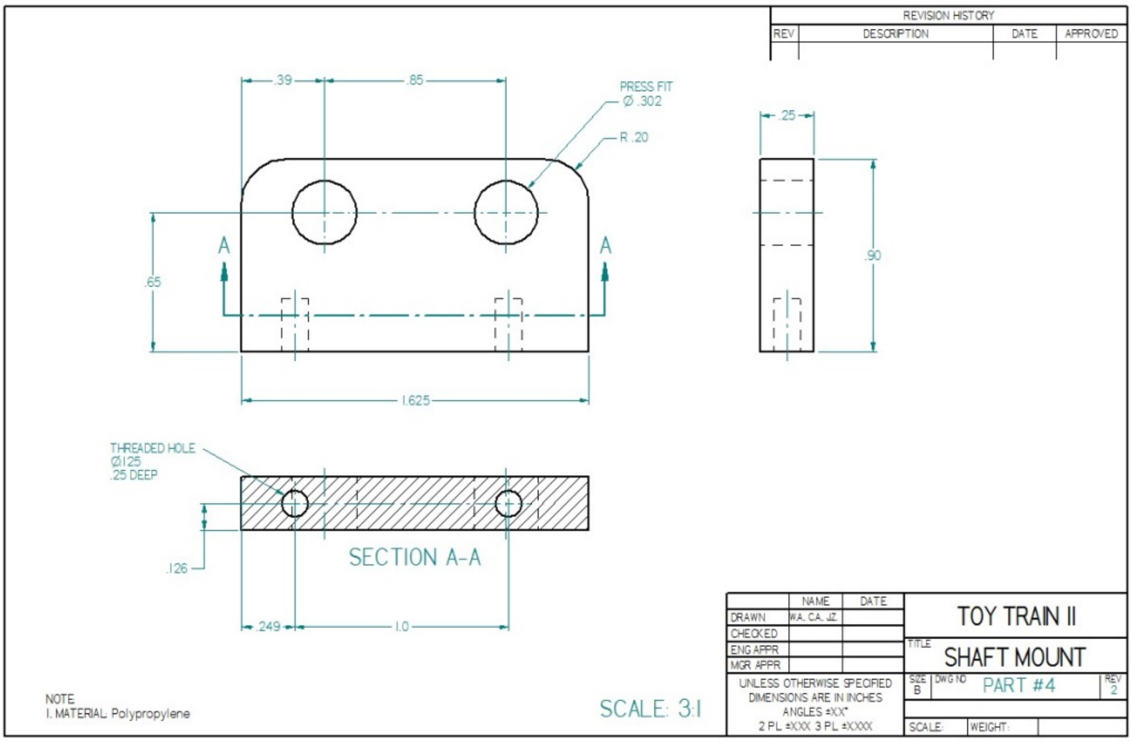
REV
DESCRIPTION
DATE
APPROVED
PRESS FIT
Ø .242
R .25
.40
.20
.30
.25
.125
.25
.188
1.0
NAME
DATE
DRAWN
W.A., C.A., J.Z.
CHECKED
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX
TOY TRAIN II
TITLE
ROLLER MOUNT
SIZE B
DWG NO
PART #12
REV
SCALE
WEIGHT
NOTE:
1. MATERIAL: Polypropylene
SCALE : 4:1


REVISION HISTORY
REV
DESCRIPTION
DATE
APPROVED
Ø .25
2.5
NOTE:
1. MATERIAL: Steel 1/4" Diameter D-Shaft.
2. Machine ends to fit bearings and place appropriate grooves to hold retaining rings.
SCALE: 3:1
NAME
DATE
DRAWN
W.A., C.A., J.Z.
CHECKED
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX
TOY TRAIN II
TITLE
GEAR SHAFT
SIZE B
DWG NO
PART #6
REV
SCALE
WEIGHT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REV
DESCRIPTION
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APPROVED
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.85
PRESS FIT
Ø .302
R .20
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A
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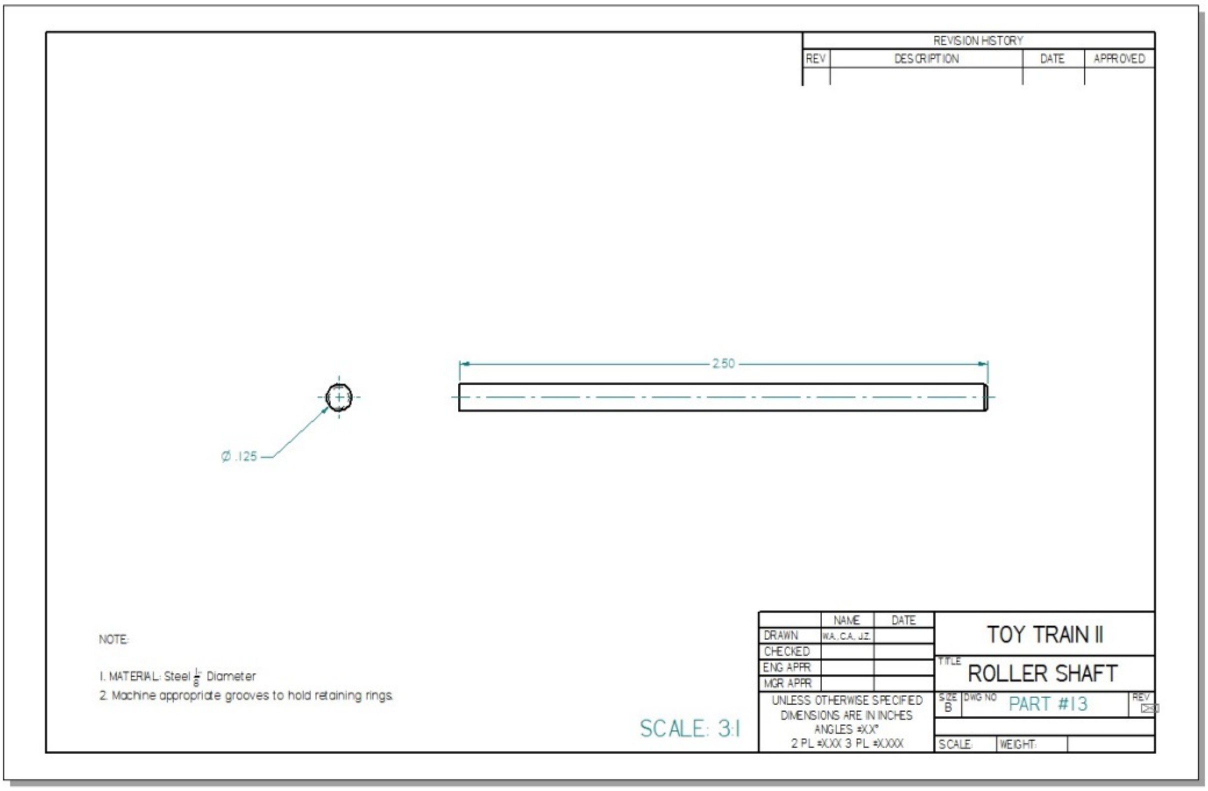
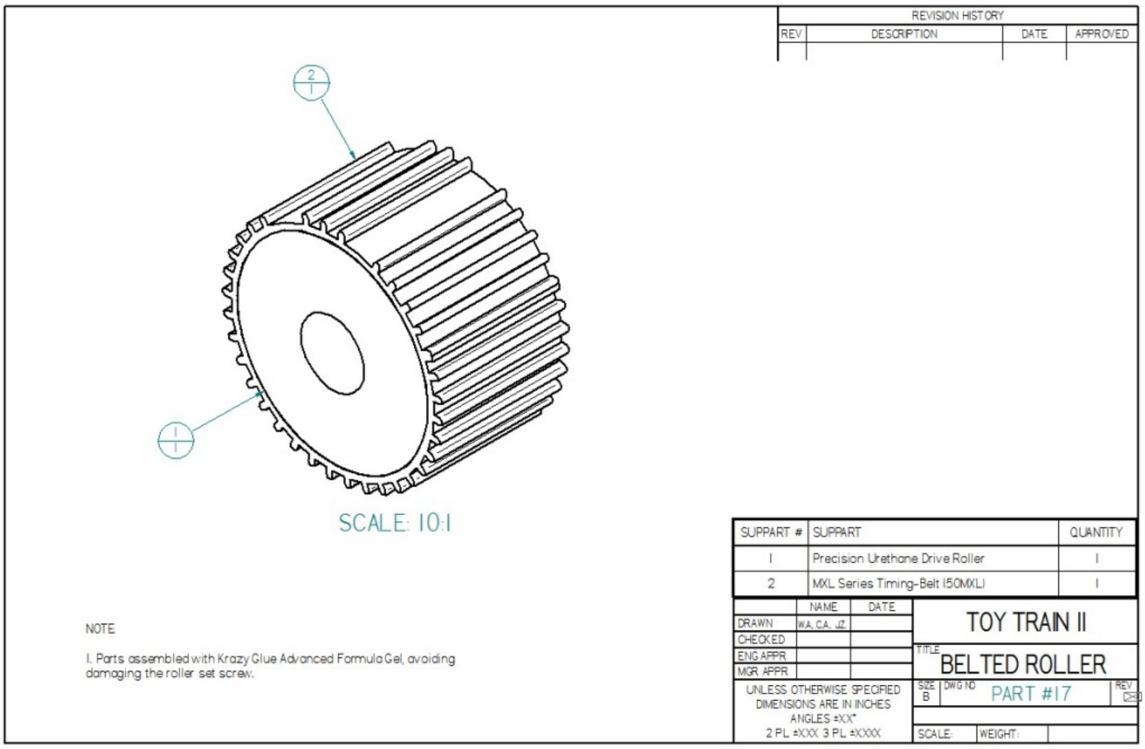
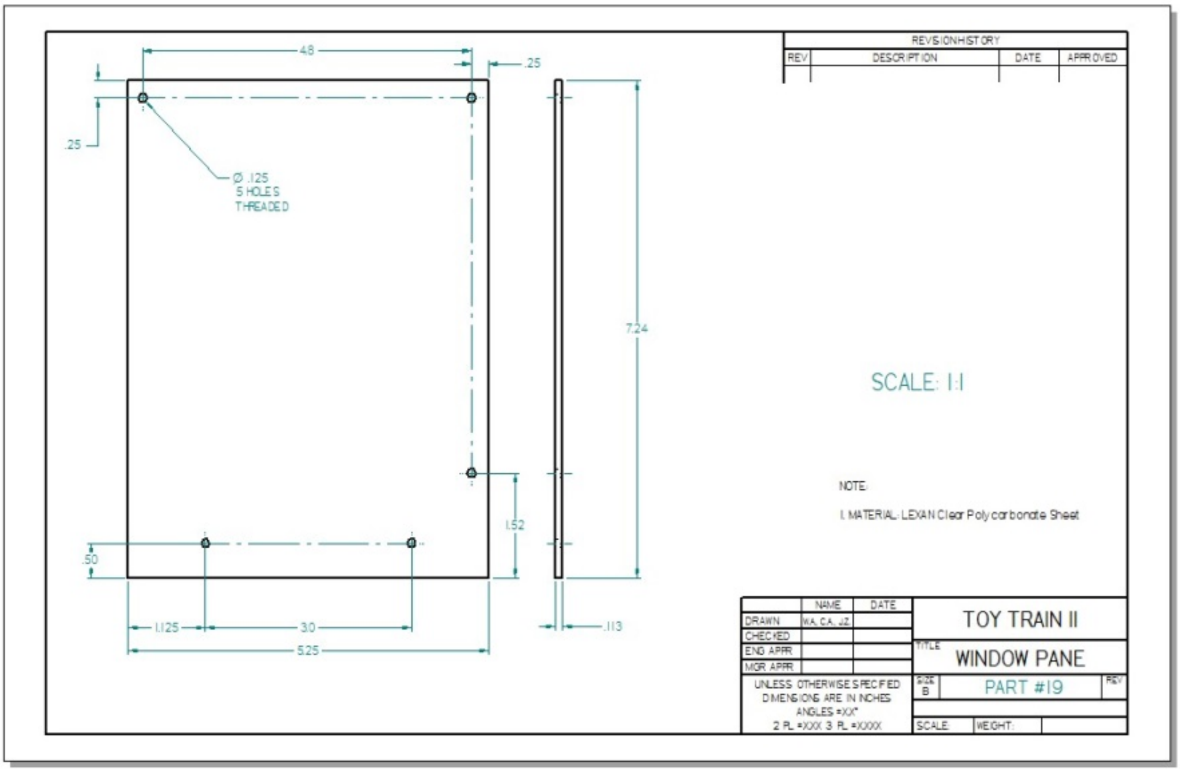
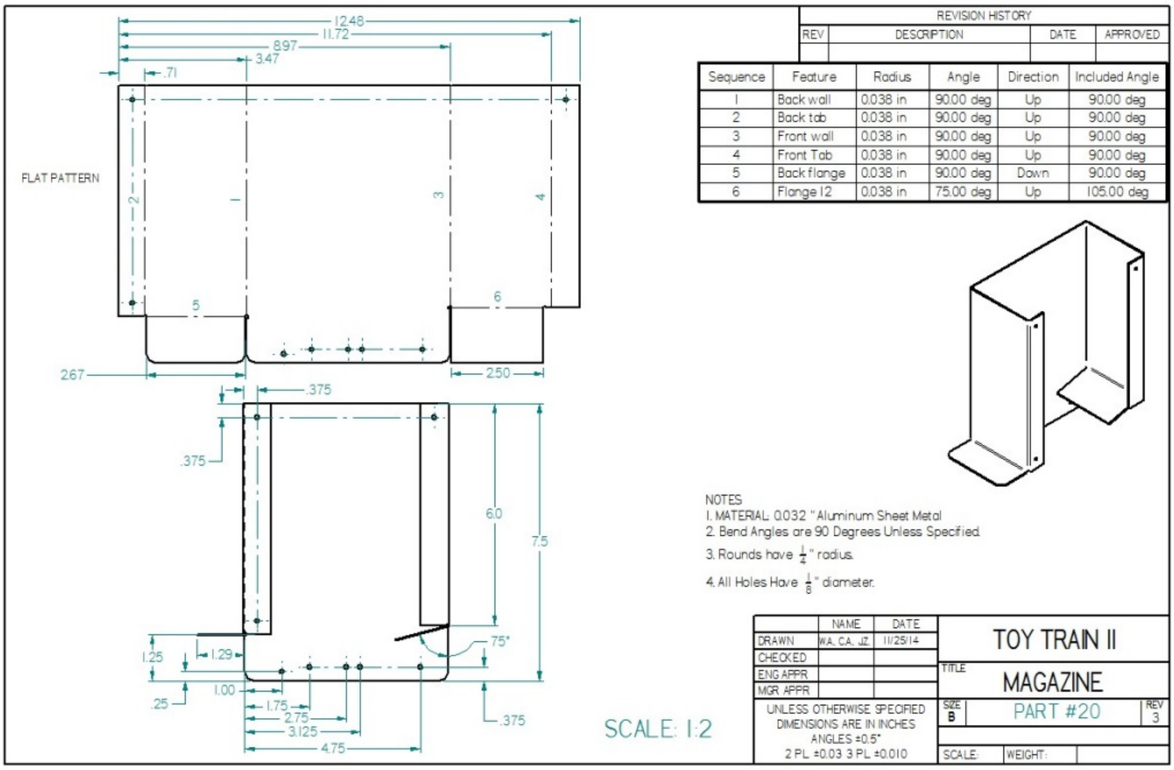
1.625
THREADED HOLE
Ø.125
.25 DEEP
.126
SECTION A-A
.249
1.0
NAME
DATE
DRAWN
WA, CA, JZ
CHECKED
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX
TOY TRAIN II
TITLE
SHAFT MOUNT
SIZE
B
DWG NO
PART #4
REV
2
SCALE
WEIGHT
SCALE: 3:1
NOTE:
1. MATERIAL: Polypropylene

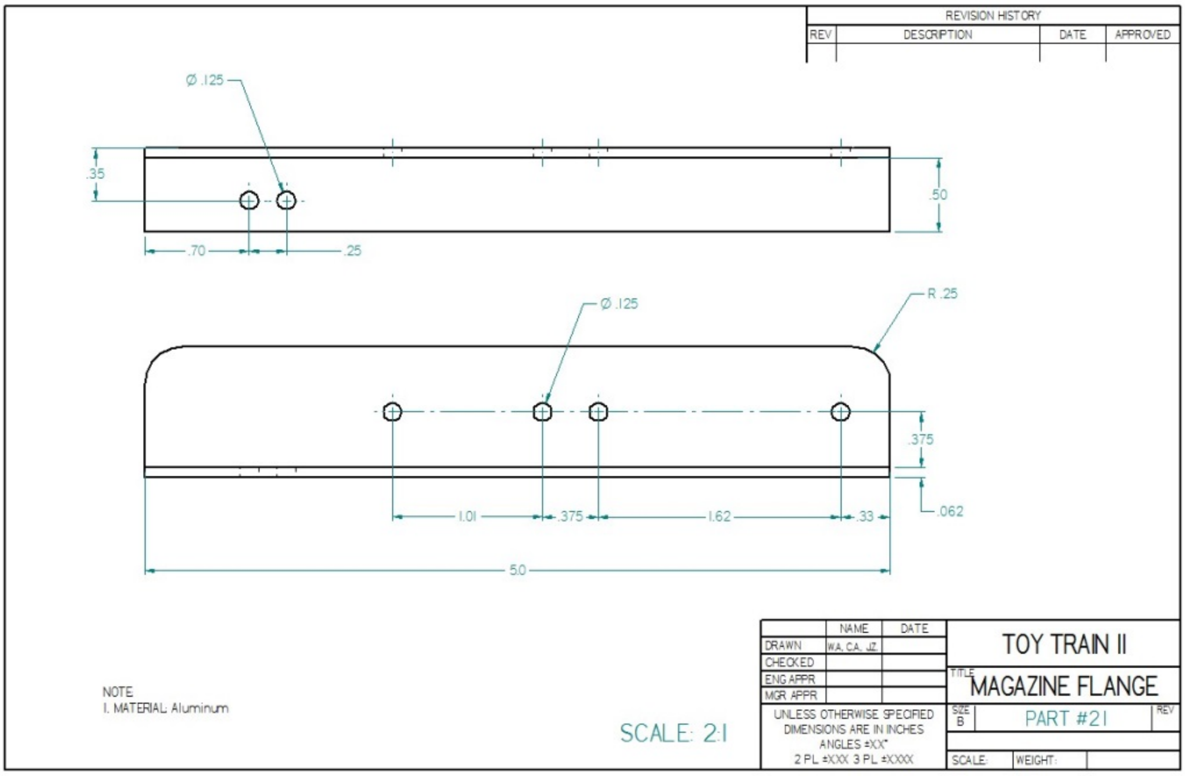

REVISION HISTORY
REV
DESCRIPTION
DATE
APPROVED
2.50
Ø .125
NOTE:
1. MATERIAL: Steel 1/8" Diameter
2. Machine appropriate grooves to hold retaining rings.
SCALE: 3:1
NAME
DATE
DRAWN
WA, CA, JZ
CHECKED
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX
TOY TRAIN II
TITLE
ROLLER SHAFT
SIZE
B
DWG NO
PART #13
REV
SCALE
WEIGHT

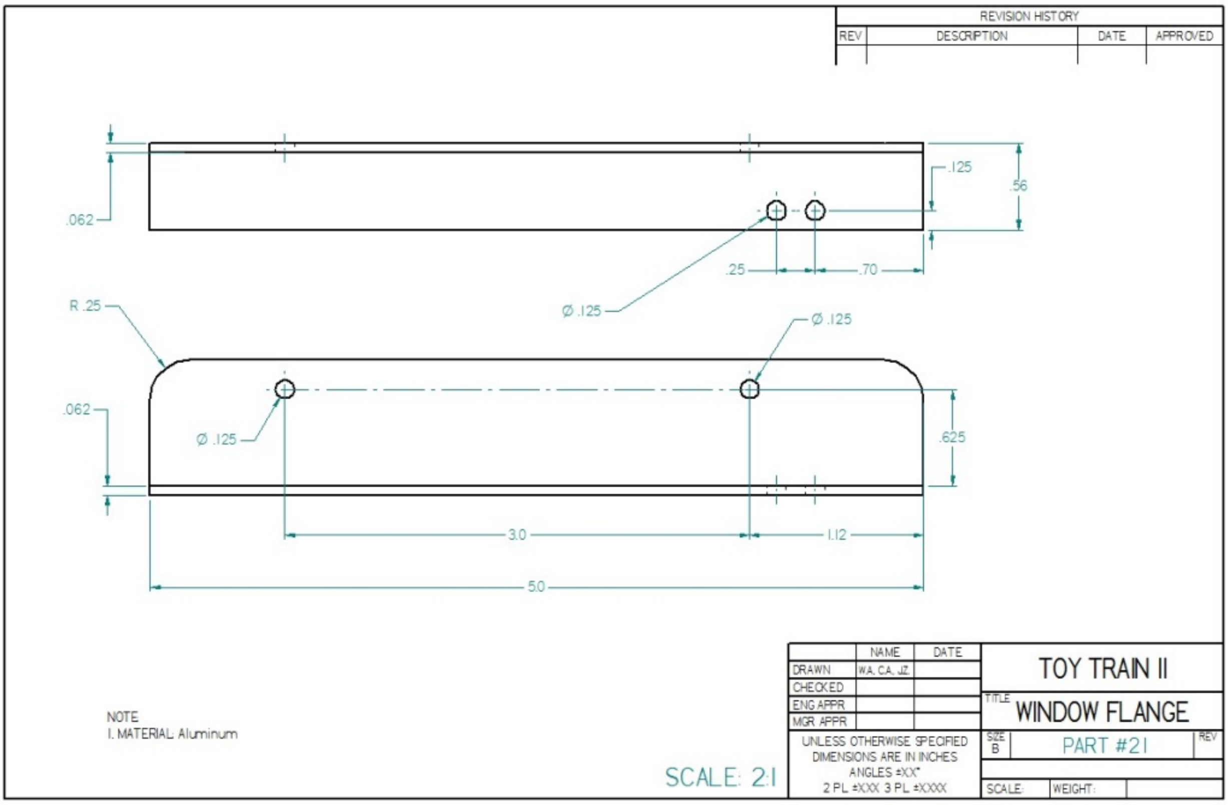

REVISION HISTORY
REV
DESCRIPTION
DATE
APPROVED
2
1
SCALE: 10:1
SUPPART #
SUPPART
QUANTITY
1
Precision Urethane Drive Roller
1
2
MXL Series Timing-Belt (50MXL)
1
NOTE:
1. Parts assembled with Krazy Glue Advanced Formula Gel, avoiding damaging the roller set screw.
NAME
DATE
DRAWN
WA, CA, JZ
CHECKED
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
ANGLES ±XX°
2 PL ±XXX 3 PL ±XXXX
TOY TRAIN II
TITLE
BELTED ROLLER
SIZE
B
DWG NO
PART #17
REV
SCALE:
WEIGHT:

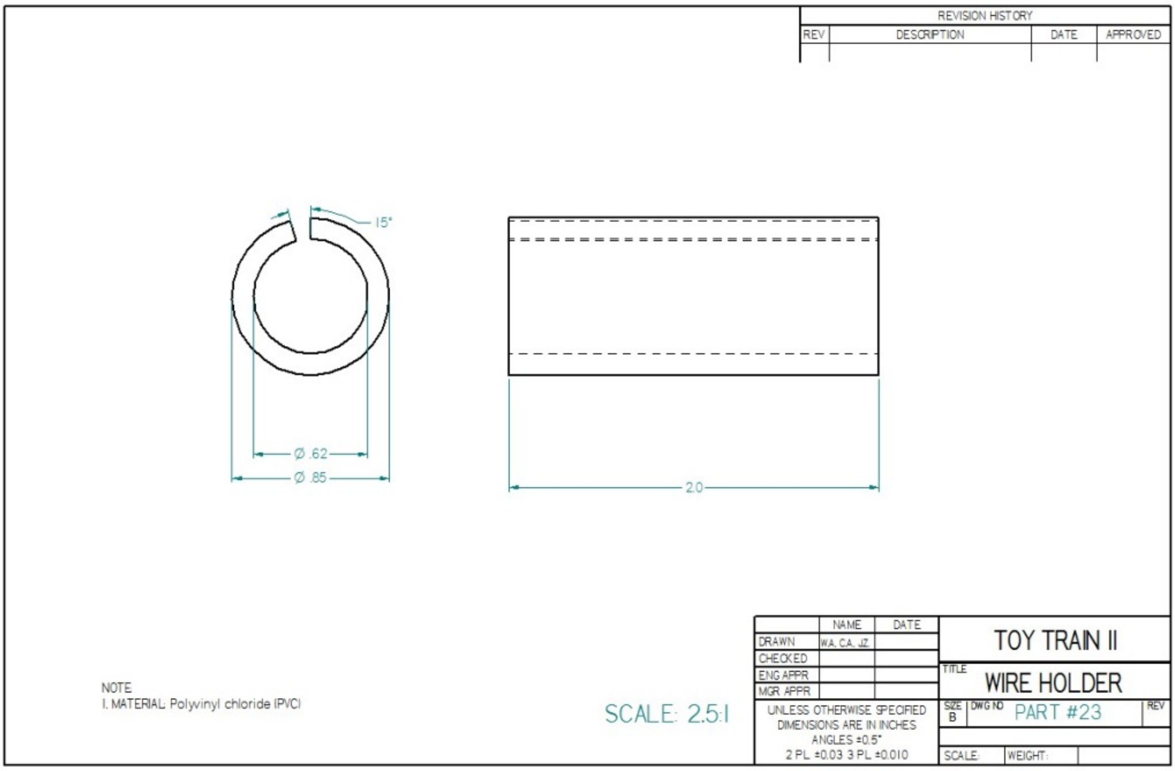

REVISION HISTORY
REV
DESCRIPTION
DATE
APPROVED
4.8
.25
.25
Ø .125
5 HOLES
THREADED
7.24
1.52
.50
1.125
3.0
5.25
.113
SCALE: 1:1
NOTE:
1. MATERIAL: LEXAN Clear Polycarbonate Sheet
NAME
DATE
DRAWN
WA, CA, JZ
CHECKED
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
ANGLES ±XX°
2 PL ±XXX 3 PL ±XXXX
TOY TRAIN II
TITLE
WINDOW PANE
SIZE
B
PART #19
REV
SCALE:
WEIGHT:

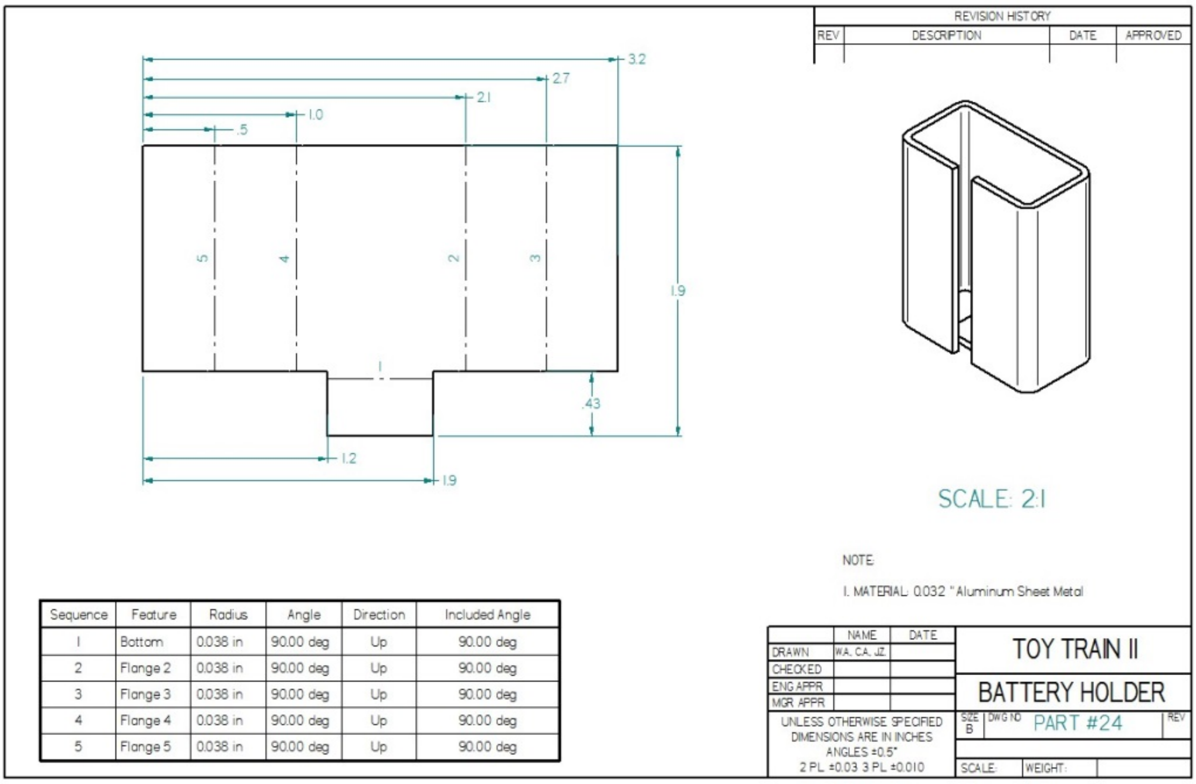


Sequence	Feature	Radius	Angle	Direction	Included Angle
1	Back wall	0.038 in	90.00 deg	Up	90.00 deg
2	Back tab	0.038 in	90.00 deg	Up	90.00 deg
3	Front wall	0.038 in	90.00 deg	Up	90.00 deg
4	Front Tab	0.038 in	90.00 deg	Up	90.00 deg
5	Back flange	0.038 in	90.00 deg	Down	90.00 deg
6	Flange 12	0.038 in	75.00 deg	Up	105.00 deg

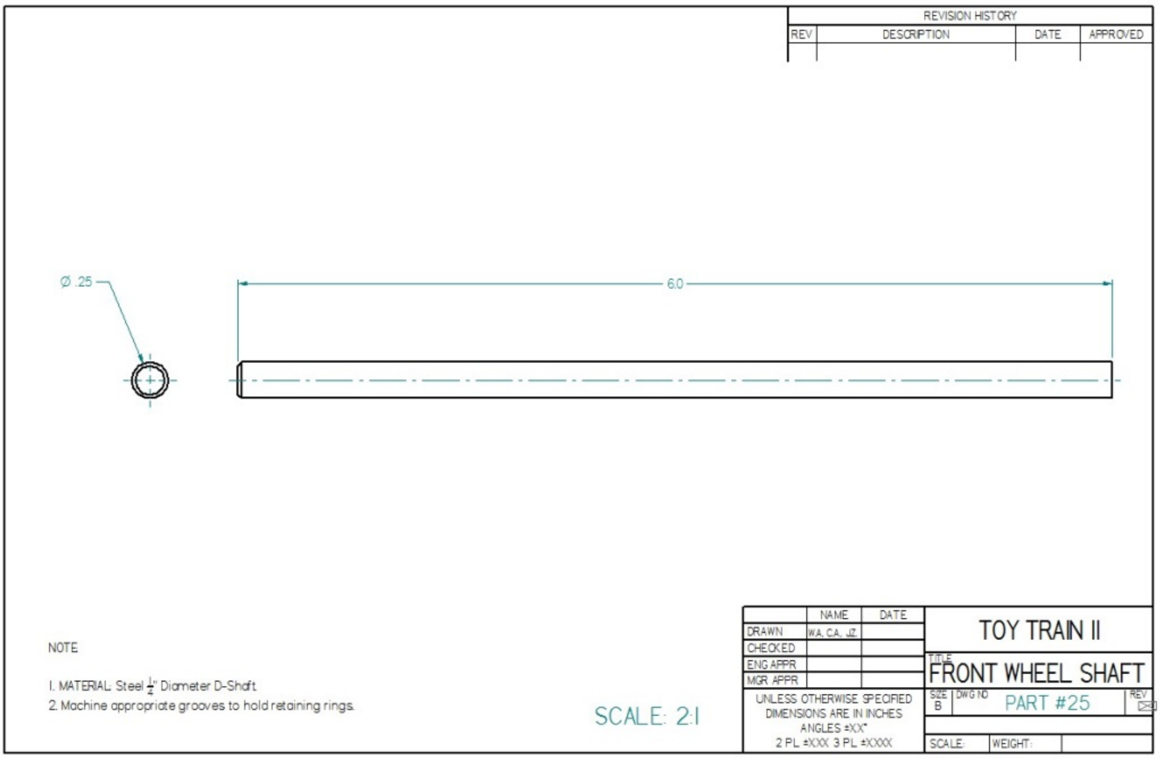


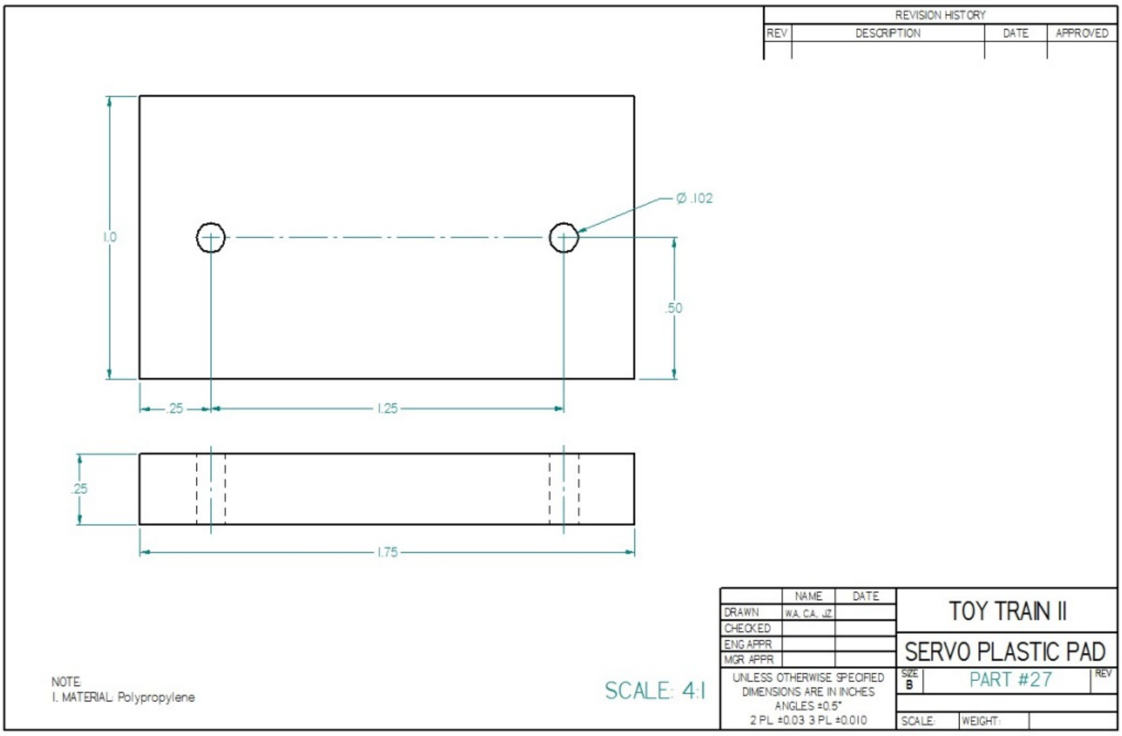

REVISION HISTORY
REV
DESCRIPTION
DATE
APPROVED
.062
.125
.56
.25
.70
Ø .125
R .25
Ø .125
.062
Ø .125
.625
3.0
1.12
5.0
NAME
DATE
DRAWN
W.A. C.A. J.Z.
CHECKED
ENG APPR
MGR APPR
TOY TRAIN II
TITLE
WINDOW FLANGE
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX
SIZE
B
PART #21
REV
SCALE:
WEIGHT:
NOTE:
1. MATERIAL: Aluminum
SCALE: 2:1

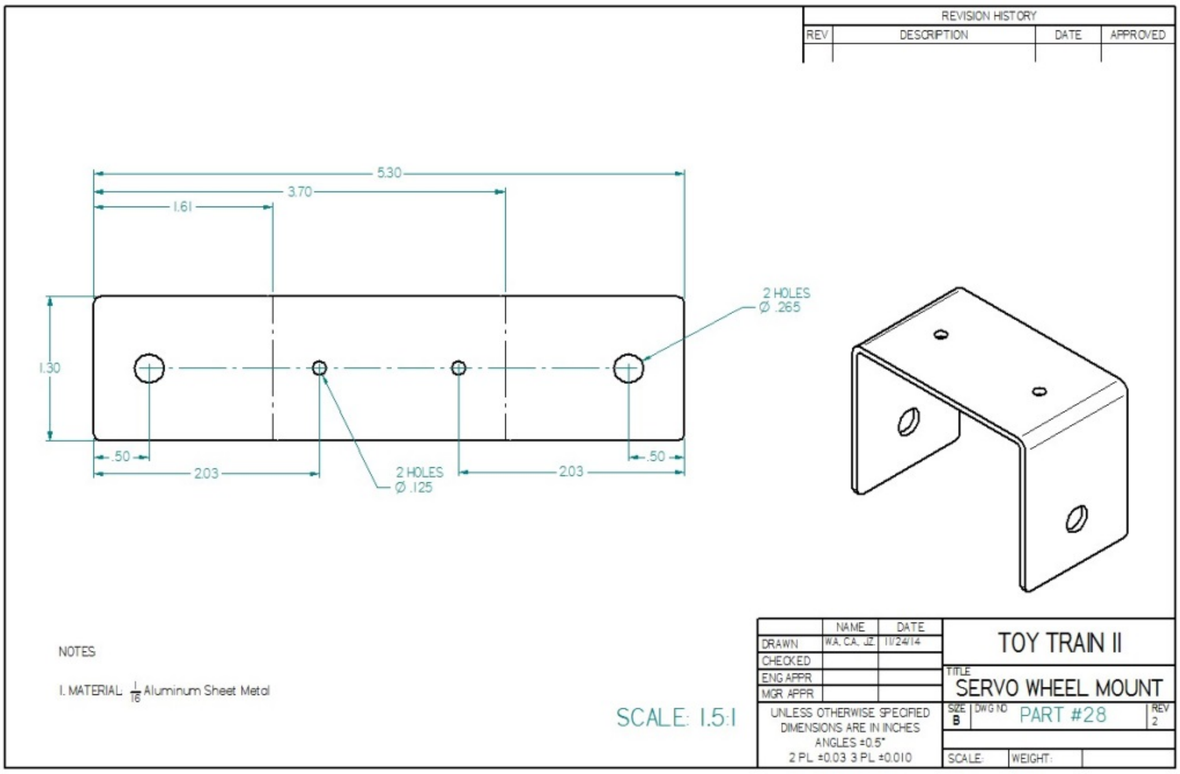

REVISION HISTORY
REV
DESCRIPTION
DATE
APPROVED
15°
Ø .62
Ø .85
2.0
NAME
DATE
DRAWN
W.A. C.A. J.Z.
CHECKED
ENG APPR
MGR APPR
TOY TRAIN II
TITLE
WIRE HOLDER
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±0.5°
2 PL ±0.03 3 PL ±0.010
SIZE
B
DWG NO
PART #23
REV
SCALE:
WEIGHT:
NOTE:
1. MATERIAL: Polyvinyl chloride (PVC)
SCALE: 2.5:1



Sequence	Feature	Radius	Angle	Direction	Included Angle
1	Bottom	0.038 in	90.00 deg	Up	90.00 deg
2	Flange 2	0.038 in	90.00 deg	Up	90.00 deg
3	Flange 3	0.038 in	90.00 deg	Up	90.00 deg
4	Flange 4	0.038 in	90.00 deg	Up	90.00 deg
5	Flange 5	0.038 in	90.00 deg	Up	90.00 deg




REVISION HISTORY
REV
DESCRIPTION
DATE
APPROVED
Ø .102
1.0
.50
.25
1.25
.25
1.75
NAME
DATE
DRAWN
WA, CA, JZ
CHECKED
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±0.5°
2 PL ±0.03 3 PL ±0.010
TOY TRAIN II
SERVO PLASTIC PAD
SIZE B
PART #27
REV
SCALE:
WEIGHT:
SCALE: 4:1
NOTE:
1. MATERIAL: Polypropylene


REVISION HISTORY
REV
DESCRIPTION
DATE
APPROVED
5.30
3.70
1.61
2 HOLES
Ø .265
1.30
.50
2.03
2 HOLES
Ø .125
2.03
.50
NAME
DATE
DRAWN
WA, CA, JZ
11/24/14
CHECKED
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
ANGLES ±0.5°
2 PL ±0.03 3 PL ±0.010
TOY TRAIN II
TITLE
SERVO WHEEL MOUNT
SIZE B
DWG NO
PART #28
REV 2
SCALE:
WEIGHT:
SCALE: 1.5:1
NOTES:
1. MATERIAL: 1/16 Aluminum Sheet Metal

12 ANNOTATED BIBLIOGRAPHY

"ASTM F 963-11 REQUIREMENTS." *CPSC.GOV*. UNITED STATES CONSUMER PRODUCT SAFETY COMMISSION, N.D. WEB. 2 NOV 2014 . <HTTP://WWW.CPSC.GOV/EN/BUSINESS--MANUFACTURING/BUSINESS-EDUCATION/TOY-SAFETY/ASTM-F-963-11-CHART/>

This page describes the regulations for toys which our toy train would have to follow.

Combined Track and Panel Hinge for Folding Toy Railroad Train Boards. Joseph H. Eigenburg, Jr., assignee. Patent US 2998196 A. 29 Aug. 1961. Print.
A combined track and panel hinge for folding toy railroad train boards.

"Definitions." 16 CFR 1500.3. *Electronic Code of Federal Regulations.* U.S. Government Printing Office, 4 Dec 2014. Web. 2 Nov 2014. <http://www.ecfr.gov/cgi-bin/text-idx?SID=3e7636d98dae34c20e70cc20b4522f76&node=16:2.0.1.3.79.0.1.3&rgn=div8>

This code defines hazardous substances. These are banned in children's toys. As a result, our current battery can only be used for ages over 12 years.

Fisher Price Mickey Mouse Clubhouse Magic Choo Choo. Fisher Price, 2009. Web. 8 Dec. 2014. <https://www.youtube.com/watch?v=B_zx9kHfSGo>.
This toy for children ages 3 and up lays its own tracks by feeding them through a cycle of laying and collecting. By contrast, our objective was specifically to lay tracks continuously.

Gil, Wojciech. "Locomotive" *GrabCAD*. GrabCAD, 15 Jan. 2013. Web. 15 Sept. 2014. <http://grabcad.com/library/locomotive>

The CAD of a toy train we used as a base for our concept designs.

Harsco Rail P811 track renewal system. Harsco Rail, n.d. Web. 8 Dec. 2014. <http://www.harscorail.com/equipment/track-construction-and-renewal/ps811-track-renewal-system.html>.

This device is carried by a train and able to both remove tracks, including targeting specifically crossties or spikes. By contrast, our project dealt with tracks as discrete unit segments.

Han, Cheng. Toy Train Track. Mentari Massen International Co., Ltd., assignee. Patent US 20030136857 A1. 24 July 2003. Print.

This common toy train track design was considered by our group but ultimately rejected in favor of Lego's flexible track segments.

Norée, Daniel. "Lego Train Track, Straight w Support." *GrabCAD*. GrabCAD, 10 July 2012. Web. 30 Sept. 2014. <http://grabcad.com/library/lego-train-track-straight-w-support>

The CAD of a lego train track that we added magnets too in order to model our track unit.

"Technical requirements for determining a sharp metal or glass edge in toys and other articles intended for use by children under 8 years of age." 16 CFR 1500.49. *Electronic Code of Federal Regulations.* U.S. Government Printing Office, 4 Dec 2014. Web. 2 Nov 2014. <http://www.ecfr.gov/cgi-bin/text-idx?SID=64b22586d47f20e7468274a7b8c52707&node=16:2.0.1.3.79.0.1.23&rgn=div8>

This code describes the test for sharp edges which are banned for ages under 8 years. It is a test a final product would have to undergo if we wanted it to be for children below that age.