SPARTAN SUPERWAY

A Solar Powered Automated Public Transportation System

Summer 2016 Bogie Team

July 22, 2016

By Michael Cahill, Neto Símon and Victor Sanchez

Abstract

During the summer of 2016, our bogie team started off working on the previous team's bogie, which is where a few issues were found. These issues caused the bogie to run inefficiently. After analyzing and troubleshooting the bogie, a new design for the bogie that would be based off the previous design, but also address the problems that were found when troubleshooting. The new design consisted of an automated propulsion system, which used an actuator. The lower control arm wasn't symmetric, which caused there to be a clearance between the bottom wheels on the steering arm and the track. The bogie also had an issue going up or down on the sloped part of the track because the top wheels were touching the wooden ceiling of the track. The last problem that was addressed was to make the bogie more convenient to take off and put the on the track. Our team also was able to program the motor, that the previous team used, to run at different speeds.

When working on the previous team's bogie, the bogie was pushed around the track to figure out what the main issues were. Once an issue was found, then the bogie team would try implementing a new idea to the bogie and see if it would work. For instance, wheels were added at the top of the bogie that would run on the ceiling, so that the other top wheels running on the metal portion of the track wouldn't hit the wooden ceiling. After this prevailed to work, the bogie team began making a completely new design on Solidworks. The new design kept some of the same parts from the previous bogie, but also had to re-design certain parts. Such as the lower control arm for the steering system, and adding the propulsion mechanism. A jack system was implemented into the design to help make the bogie easier to take off and put on the track. The motor was programmed by sending PWM signals from the Arduino to the motor controller.

Implementing the wheels at the top of the bogie to prevent the bogie hitting the ceiling was a success when testing it on the previous bogie. The issue that haunted our team the most was implementing a working jack system, steering system, and the propulsion system, in which each system wouldn't interfere with each other. Our designed had to be changed many times due to the jack system interfering with the steering mechanism. The fabrication of our design wasn't the biggest issue, but it took a significant amount of planning and time to get each part made in a machine shop.

Acknowledgments

Barry Swenson Builder-http://www.barryswensonbuilder.com- (408)287-0246

Brazil Scientific Mobility Program (BSMP) - Institute of International Education

San José State University Charles W. Davidson College of Engineering - Phone: (408)924-3800

Table of Contents

List of Figures

Executive Summary

The bogie is one of the most important components for traveling a passenger along the track. The bogie consists of many sub-teams such as the design or structure, steering, suspension, propulsion and braking. The bogie has to be able to switch tracks and travel up and down a 17° slope. The propulsion system in our design and in the previous years use a hub motor. The propulsion system needed to be automated, which hasn't been done by previous teams because most teams used a spring in their propulsion system to push the motor up against the ceiling. The reason to make the motor be able to move up and down is to provide the same amount of traction for the motor against the ceiling in different scenarios or weather conditions. An actuator was placed underneath the frame of the motor, which could be programmed to accommodate for these situations.

The bogie wasn't able to travel along the sloped part of the track due to a 4-bar linkage, which caused each half bogie's movement dependent of one another. This is the reason why the wheels on the bogie would hit the ceiling. To solve this issue, the motor mount bar was removed and the H-bar that holds the suspension was attached using a ball and socket joint instead of a U-joint. The majority of the steering mechanism design was kept the same as the previous design. Except for the lower control arm that switched the lower wheels to the lower portion of the track and to their respectable side when switching tracks.

Previously, the bogie had to slide in at either end of the track to get the bogie on the track. This was difficult due to the bogie's weight and that you had to climb up a ladder to get it at the end of the track. This would be an issue if you wanted to perform preventative maintenance on the bogie because it would be difficult to take it off. A jack system was designed to be apart of each half bogie so that you could take the bogie off or put it on any portion of the track. To test our design and the new additions, the bogie had to be fabricated. The majority of the bogie was fabricated with MDF wood and minimal steel pieces. The MDF wood was precisely cut with a laser cutter, and the steel pieces were taken to a machinist to be made. The reason the bogie team didn't cut and drill the parts ourselves was to minimize the amount of fabrication errors in our bogie.

Introduction

When traveling in urban areas traffic has always been an issue, and there hasn't been another alternative that helps you get to your destination in a more efficient manner. People think building more roads or making them wider will solve this issue, but it only accommodates for the population increase and doesn't solve the issue. Besides time being an issue, people also have to worry about the money it takes to get to a destination, their life being at risk and the pollution that is being produced in the environment. The Spartan Superway can solve these issues completely, especially in urban areas, for it is a fully automated transportation network(ATN) that is powered solely by solar panels. The Spartan Superway will be able to pick up a maximum of 4 passengers at a station and transport them to the station of their choice with no stopping. This transportation network wouldn't have to stop for other vehicles or any other obstructions, for it will be suspended above the city streets and sidewalks. The main issue the Spartan Superway is trying to solve is to make traveling in an urban environment cost and time efficient for the citizens who work and/or live in the area. This isn't the only beneficial concept of the Spartan Superway, for it would minimize the consumption of fossil fuels. Therefore, it would decrease the pollution by vehicles substantially. This will be done by placing an array of solar panels along the top of the track to generate the energy needed to operate the entire transportations system including, the bogie other electrical devices in the cabin.

Background and Context

The bogie is the key component in traveling the passenger cabin along the track safely and comfortably. The bogie team will be working on implementing and synchronizing most of the sub-teams work onto the bogie such as; the structure, the propulsion system, the braking system, the suspension and the steering system. It has always been a difficult process in the previous years to put on or take off the bogie from the track. A jacking mechanism was implemented to make this process more convenient. Bad weather conditions and other situations could cause issues for the traction of the bogie on the track. To address this issue, the design of the propulsion system is to be automated with an actuator.

Description of Subteam and Objectives

The bogie team worked on troubleshooting and adding to the half-scaled bogie. Our main focus was to redesign the bogie, so it would be able to travel efficiently along the track, especially the 17° sloped portions. Another focus was to make the propulsion system automated and implementing a mechanism so the bogie could be taken on or off the track easily. The bogie team had to consider how the previous steering system and the suspension would be put into our design.

The objectives for the bogie team were to:

- Re-design a bogie that can travel along a 17° incline or decline
- Design a mechanism that will make the propulsion system automated
- Have a mechanism on the bogie to make it easier to put on or take off the track

Design Requirements and Specifications for the Sub-teams Work Products

The design requirements that the bogie will follow were:

- The bogie has to travel up and down a 17° incline or decline

- Have a propulsion system that is automated that can increase the amount of normal force of the motor on the wooden ceiling.
- Be able to implement the previous steering system and suspension

State-of-the-Art/Literature Review for the Sub-team's Sphere of Work

Description of your Design

The bogie needs to be able to run on the entire track without any difficulties. The team read up on what worked and what didn't work well for previous teams before redesigning our version of the bogie. The first week or two of the summer was spent troubleshooting the 2015-2016 bogie team's design and fabrication of the bogie. It was apparent that there were a few problems that needed to be resolved. One of the main obstacles the previous bogie was running into was that the wheels on the top of the bogie were hitting the ceiling when traveling along the 17° incline or decline, which is shown in Figure 1-1.

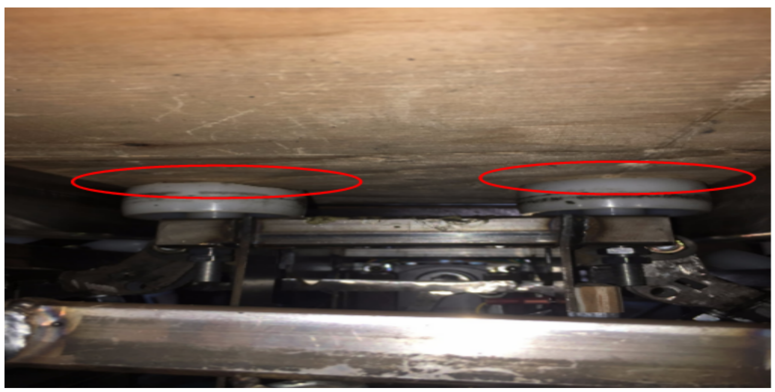

Figure1-1: Top wheels of the previous bogie hitting the ceiling

This was due to a four bar linkage system, shown in Figure 1-2, that connected the half bogies, which made the movement of each half bogie to be dependent on each other. Therefore, if the front half bogie began to go up or down the 17° slope then the back half bogie would try to do the same resulting in the wheels hitting the ceiling.

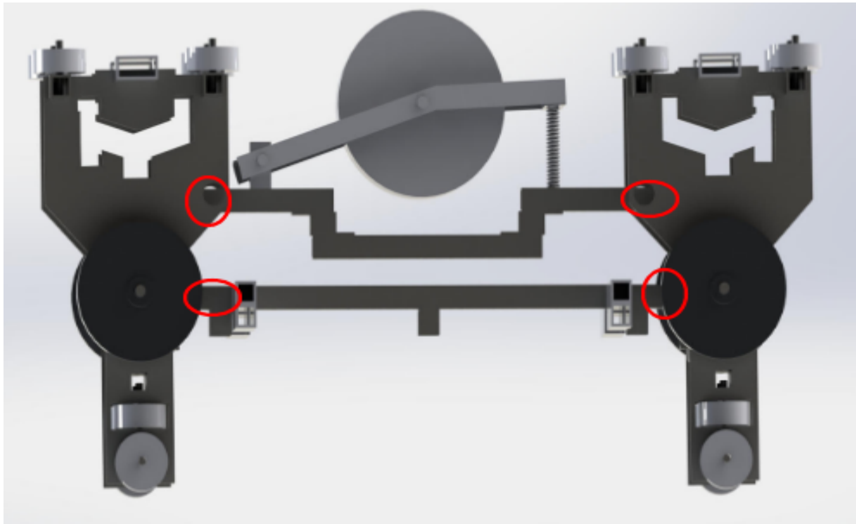

Figure 1-2: Four-bar linkage system on the previous bogie

To solve this issue there were three different ideas that were put into effect on our design. First off, the lower link was initially using U-joint to pivot, but to increase the range of motion for this link a ball and socket joint was substituted in as shown in Figure 1-3.

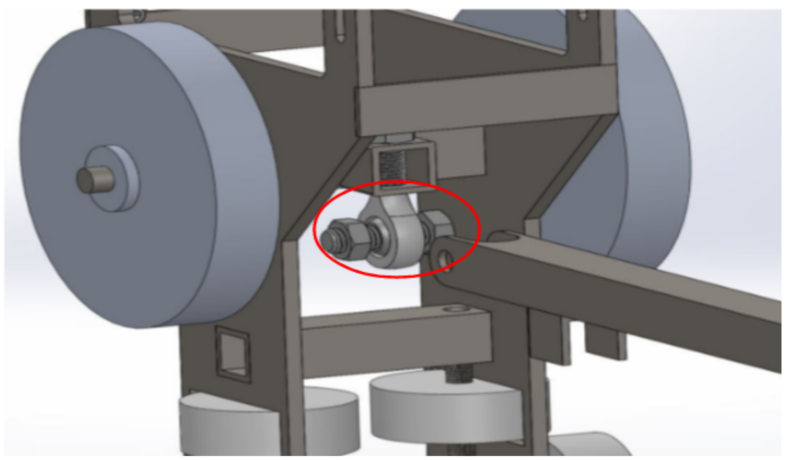

Figure 1-3: Ball and socket Joint on the new design

To make the movement of each half bogie independent of each other and to prevent the wheels from hitting the ceiling an additional two concepts were assembled onto the design of the bogie. The first of these two were to remove the top link motor frame, which would remove the four bar linkage system. The second idea was to place a pair of wheels on the top of the bogie and in between the white wheels that were touching the ceiling. The pair of wheels would roll against the ceiling and would be fixed slightly above the white wheels. These additions can be seen in Figure 1-4.

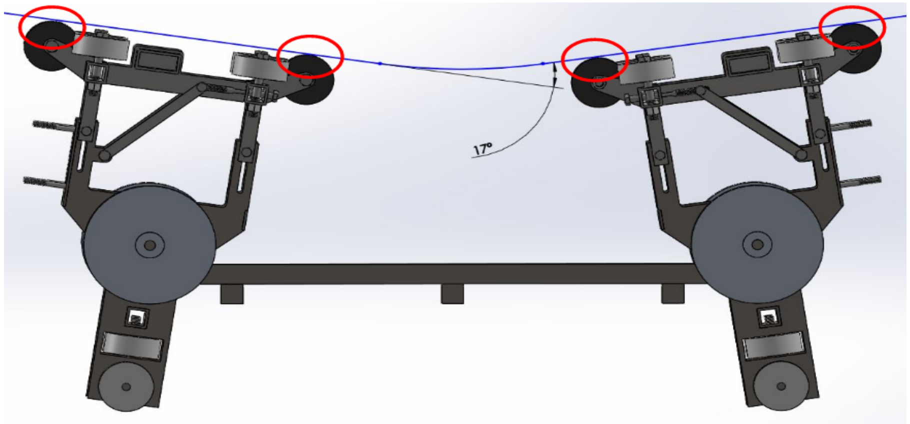

Figure 1-4: The new design without upper link and the added top wheels

The next complication that our design had to address was involving the steering system. There was clearance between the wheels attached to the lower control arm, which caused the bogie not to grip the track when changing tracks like it was supposed to. This is shown in Figure 1-5.

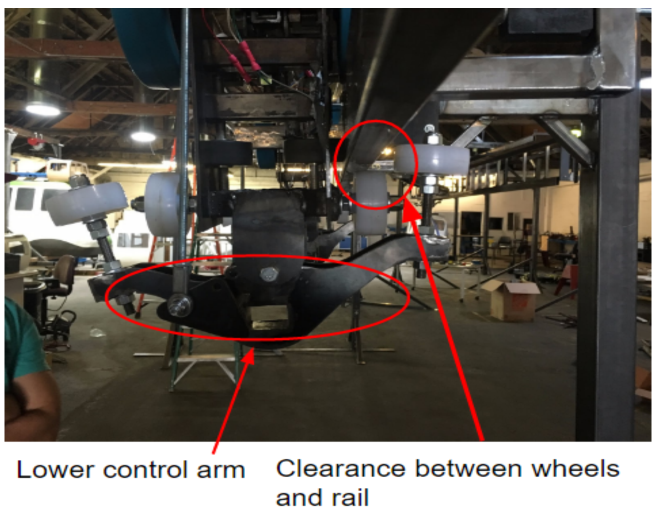

Figure 1-5: Issue with the steering system

After analyzing the design and fabrication of the steering system, it was observed that the lower control arm was not symmetric, which was causing this clearance. The lower control arm was redesigned to be symmetric to solve this problem. The old and new design are shown in Figure 1-6.

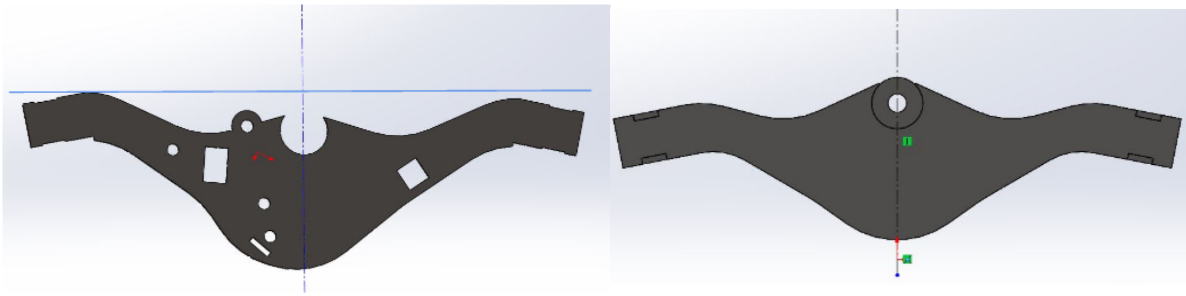

Figure 1-6: Old design of lower control arm(left), New design of lower control arm(right)

To make the bogie easier to put on and take off the track a jack system had to be implemented in our design. The bogie team wanted to have a way where a bolt could be tightened to raise the bogie and loosened to lower the bogie. The main issue with this was how to implement this mechanism and where to implement it. The mechanism our team went with is where you screw in or loosen two bolts, which were originally placed on the inner portion of each bogie, as shown in Figure 1-7. There are two bolts where each red circle is, one that you can see and one directly behind it that is not shown.

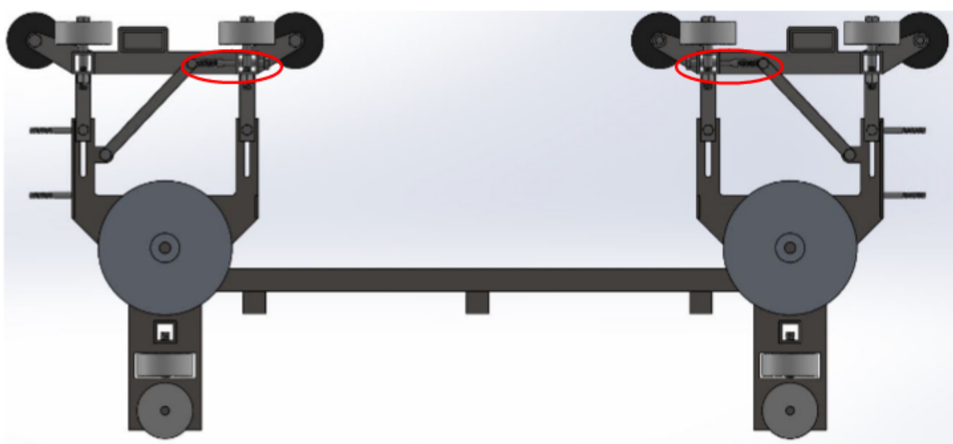

Figure 1-7: Original Implementation of the Jack System

The original placement began to be a problem when implementing the steering mechanisms into the design. At first, the mounts for the upper steering arm obstructed the placement of the jack system. The placement of the jack links was then placed in the middle, but then it was observed that the inner links for the upper steering arms were in the way. To account for this the placement of the bolt was flipped to the outer portion of each half bogie, as shown in Figure 1-8.

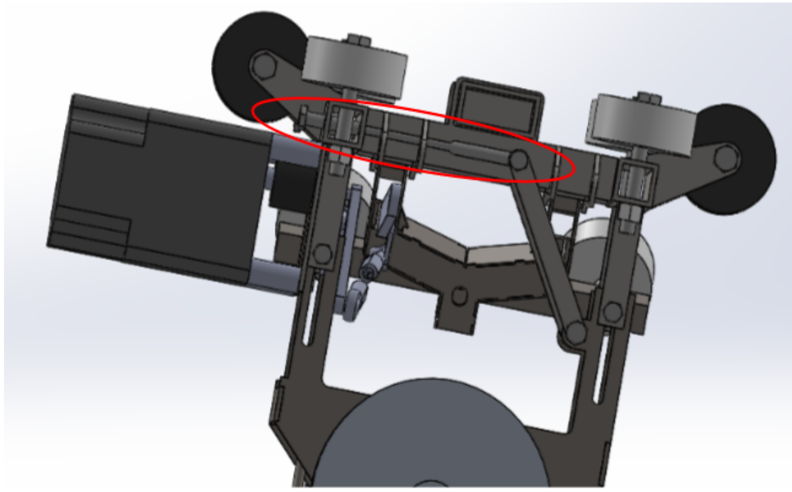

Figure 1-8: Final design of Jack System.

At the beginning of selecting a design for the propulsion system, there were two designs that the bogie team decided to follow start with. Both of them worked off of the previous teams' designs but making them automated. The first system that was designed built off of the 2014-2015 team's propulsion system. However, this design caused sized constraints due to the size of the motor and the actuator that was used. The next design looked similar to last years team, but there were noticeable changes. Both of these designs are shown in Figure 1-9. The final design uses ball and socket joints to mount the motor frame to the h-bar link that holds the suspension.

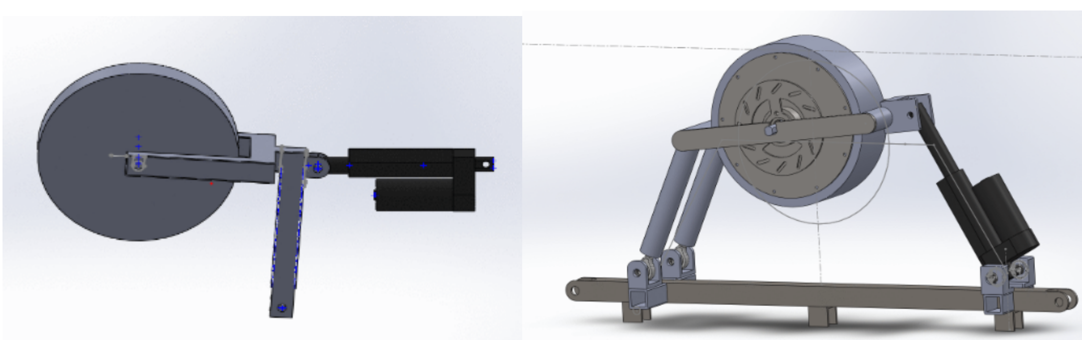

Figure 1-9: First Design using similar design to 2014-2015 team(left), Final design using similar design from last years team(right)

Minor dimension changes had to be made to fit all the systems together on the bogie and to fit the entire bogie on the track. The half bogie also had to demonstrate that the dimensions were correct with the structure and the switching mechanism. This can be shown in Figure 1-10.

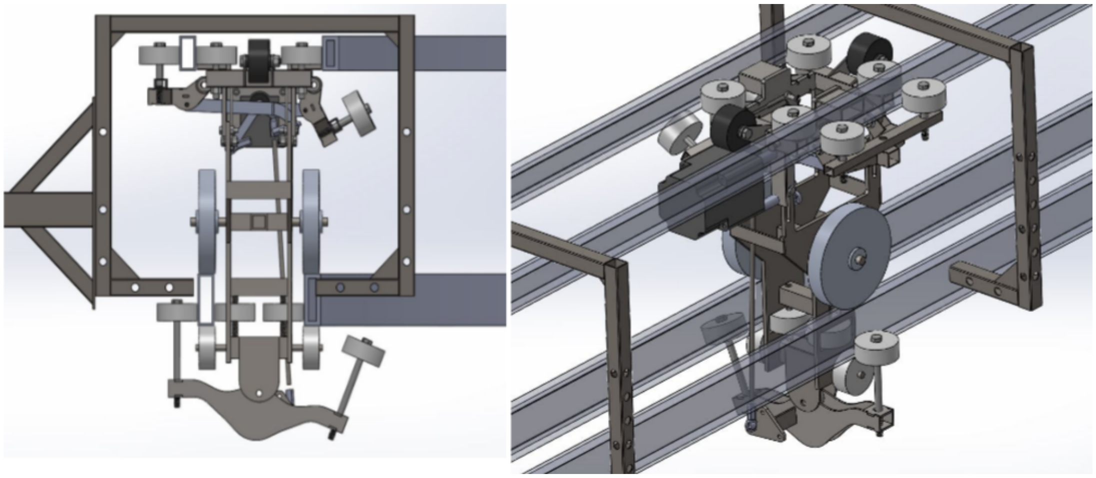

Figure 1-10: Bogie’s steering mechanism switching correctly on the track

After the half bogie was confirmed that the dimensions were correct and it fit on the track, then the half bogies had to be connected with the h-bar and the propulsion system. The entire bogie was then placed on the track to verify that all dimension were correct, which is shown in Figure 1-11, as long as with the final design by itself.

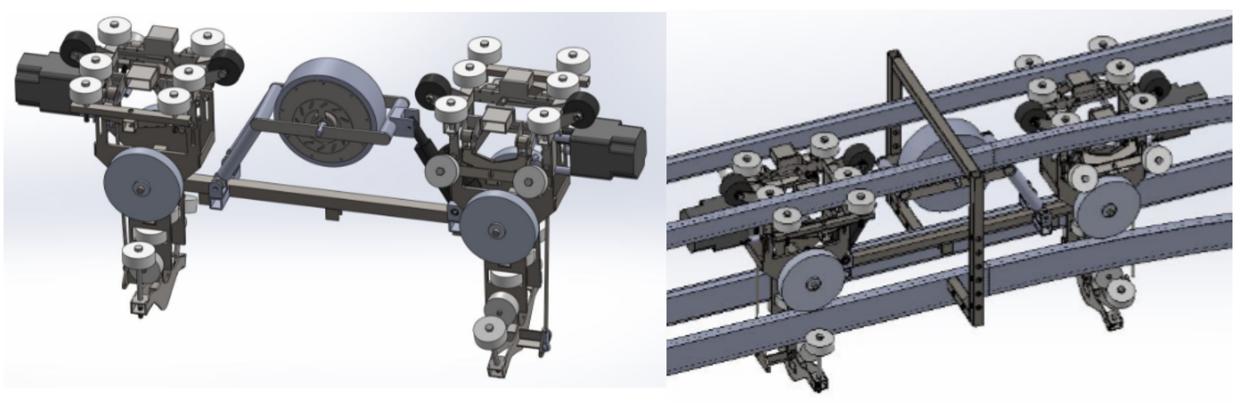

Figure 1-11: Final design by itself(left), Final design on the track(right)

Analysis/Validating/Testing

To test the design, the bogie team planned to make a wooden bogie with a few metal pieces. The wooden pieces were fabricated using a laser cutter. A 2-D template had to be made for the laser cutter to read and cut the pieces precisely. The template that was made for a half bogie is shown below in Figure 1-12. The metal pieces were taken to a machine shop to be made, so there would be no fabrication errors. The purpose for using wood was to test if our design was able to be fabricated.

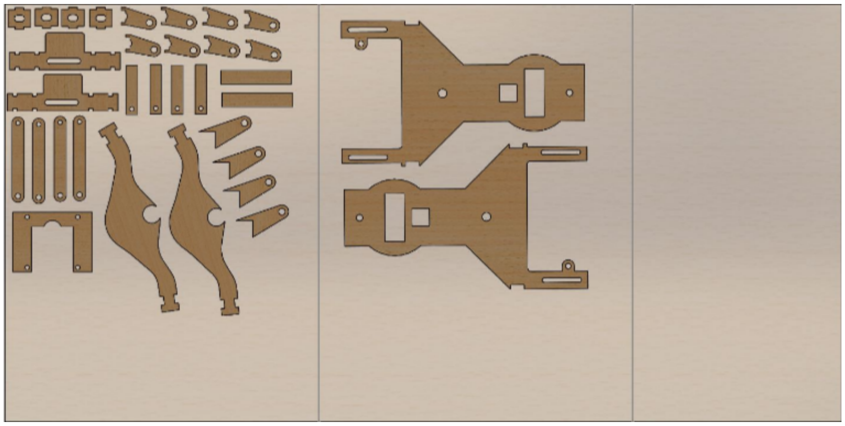

Figure 1-12: 2-D template used for the laser cutter to cut out wooden pieces

To test the function of the design of the bogie, the plan was to use FEA simulations in Solidworks. However, these simulations were never completed.

Results/Discussion

When our design was taken to the machinist, he pointed out many defects in our design. Based off his experience as a machinist it was observed that a few parts of the bogie would be difficult to fabricate without breaking the piece. The machinist also observed that the moving parts in the jack system wouldn't be able to withstand constant use and would break after a short period of time due to general wear and tear. Brainstorming was done with the machinist and our team on how to implement the jack system without all the moving parts that were causing an issue. It was decided that an air compressed piston would be used. This air compressed piston would be placed inside each half bogie. To implement this, a bar would have to connect the failsafe mechanisms at the top of the half bogies, so the pneumatic piston would have something to push up against. The failsafe mechanisms that the bar would connect is shown in Figure 1-13.

Figure 1-13: The failsafe where a bar would be placed in between to connect them

Another bar would have to be placed in the lower portion of the bogie, so the pneumatic piston would have another platform to push against. The bogie could be taken to a maintenance station, where the air from the pneumatic piston can be bled out, which would lower the bogie. To raise the piston and ultimately the bogie, an air house would be used at the station to spray into the pneumatic piston.

Conclusions and Suggestions for Future Work

Our jack system resulted in a failure. This was because the fabrication process for it was too difficult to carry out and because there was too many moving parts that could break from wear and tear. Our suggestions for people working on the bogie in the future is to think about the fabrication of each piece while designing it. If it seems reasonable to fabricate, then think about how durable each piece will be under the conditions that the bogie will be operated many hours every day.

References

Acoba, Mark., Acosta, Cassandra., Aganon, Kenneth., Alvares, Rebecca., Baasandorj, Enkhjin., Bootwala, Ali. A., et al. (2016, June 23)) *Spartan Superway: A Solar Powered Automated Public Transportation System.* Retrieved from http://www.inist.org/library/

Besson, Jared., Carter, Jordan., Chen, Andrew., Cordero, Jacqueline., Dutra, Kyle., Fidel, John., et al. (2015, May 30) *Spartan Superway: A Solar Powered Automated Public Transportation System.* Retrieved from http://www.inist.org/library/