SKATEBOARD TRUCK TESTING DEVICE

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Abstract

Skateboard trucks are one of the three major components that, when assembled together, make up a skateboard along with the skateboard deck and wheels. The truck connects the deck to the wheels and translates the tilting motion of the deck to a turning motion of the truck to cause a turning response. As such, there is a relationship between how much the deck tilts to how much the trucks turn. Furthermore, the truck itself can come in varying sizes and configurations. The axle length, hardness of the bushings used and the angle that the truck sits on relative to the deck all can vary to provide a different feel and response for the rider of the skateboard. Although skateboards have been used since the early 1960's, no device has been created to quantify the feel that skateboard riders feel with varying configurations of the truck. The purpose of this device is to provide quantitative data and results for each truck configuration tested so that the response of differing setups can be compared and provide valuable results for either riders or companies that design skateboard trucks.

The team was presented with a skateboard truck test device that was in its second iterative design process from previous capstone project groups and required further iterative design improvements and optimization or a complete redesign and manufacturing from scratch. The team decided that with the time limitations and the scope of the project, it was best to pursue the former option. The device had three major systems to examine: mechanical, electrical and pneumatic. All components had to be researched and thoroughly analyzed in order to determine how each component could be further improved, optimized or replaced with a more suitable solution. The team generated concepts for the aspects of the device that could be improved. The selected concepts were selected and then manufactured based on feasibility, cost, difficulty of manufacturing and assembly, ease of use and difficulty of implementation.

The result was a third iteration of the skateboard truck test device that was revised and optimized for efficiency, ease of use, safety, accuracy and compactness. Not only were previous designs optimized, but new designs were implemented to further improve the device. Tests were conducted with varying skateboard truck bushings and rider pad angles. These results include valuable information as they represent the quantitative data that describes the skateboard deck tilt, truck turn, and the forces required to obtain said tilt and turn. The relationship between the tilt and turn was also a result of this project as it provides information on how the handling of the skateboard is affected by differing riser pad angles. Another result of this project was to show the hysteresis that is present during the motion of a skateboard truck.

In conclusion, the project was seen as a success by the team and the project sponsor. Majority of the items to be improved were revised including the mounting and orientation of the cylinders, addition of riser pad plate, operating the pressure transducers within their required specifications, improved data acquisition components and test procedure and a cleaner, safer and more compact device. Plots of the results were produced along with a method of displaying user inputted information about the truck configuration on said results. These plots included deck tilt vs force, truck rotation vs force and truck rotation vs deck tilt. These results proved to be valuable in quantifying the feel of differing truck setups along with being able to easily compare between truck configurations.

Acknowledgements

This project could not have been completed without the expertise and advice from the BCIT School of Energy faculty and staff. All the knowledge and experience from the faculty has been a major contributor to the success and completion of this project.

Special appreciation to the following BCIT faculty members:

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- Taco Niet:
    - Providing electrical equipment and advice during the instrumentation and circuit set up process
- Jason Brett:
    - Providing electrical equipment and advice during the instrumentation and circuit set up process
- Johan Fourie:
    - Providing advice and expertise on project documentation and administrative requirement

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Chapter 1. Introduction

1.1 Problem Statement

This project is a continuation and optimization of a skateboard truck test device that has been worked on by multiple project groups over the years, beginning four years ago. The first group to work on this project had the task of designing a majority of the device that laid the foundation for the groups to come. The groups in the following years were tasked with the objective of optimizing the device, redesigning components that could be done better and adding components to improve the overall functionality, quality and accuracy of the device. However, despite the groups that have worked on it in the past, there were many aspects of the device that could still be further improved upon. When the device was initially inspected by the current group, it became apparent that the device could not run in its current state. There were many bugs and issues that needed to be resolved before work on improving the device could commence. The original design had the intent of being able to measure skateboard trucks of all sorts of shapes and sizes.

The immediate previous design for the device had several problems. One of these problems included the data acquisition (DAQ) system of the device. The specific brand of the DAQ was not directly compatible with the chosen software (Matlab) to collect and convert data. This required additional code, drivers and a procedure that had to be performed in a specific order for the analysis to be performed correctly. However, the specific procedure/steps required to run the DAQ system was not provided by the previous group, so there was no way to know the procedure besides trying all the possible combinations. Also, the group was very unfamiliar with the software required to be installed to use this DAQ system. The DAQ device would not turn on, which meant a need for a new DAQ device. Furthermore, the code was outdated and had many functions that were not supported by Matlab and would not work with a DAQ device of a different brand. This required developing a new code that was dependent on the selected DAQ. Additionally, the electrical wiring was fairly disorganized which meant it was easier to revise the wiring rather than trying to work with what was present.

Another problem that the previous device had was that it was difficult to quickly swap skateboard trucks. The process required loosening an excessive number of fasteners which were placed in areas that were both hard to reach and difficult to see. The team felt this should be not only a quicker process but a process that could be performed more conveniently, as if the operator is testing multiple trucks, it would become frustrating with the current set up. The device should also be able to account for the fact that skateboard trucks come in many shapes and sizes.

People who skateboard often want to try not only different truck widths and sizes, but also the angle at which the truck sits on relative to the deck. These angles can range from 2-20° and are able to provide the rider with a unique feel when riding and performing tricks with the skateboard which is dependent on the angle. However, the current device set up did not allow for an adjustable angle. This was another task the team felt was necessary if the team were to test varying trucks and truck configurations.

A device that measures and stores the characteristics of a skateboard truck would be useful for anyone that is trying to select a skateboard truck for their board. To perform comparisons of different trucks and configurations accurately, a database of multiple different truck sizes and configurations would be required. The device would have to output repeatable results so that the data is representative and comparable. The data that would be considered valuable would be plots of the force being applied compared to the deck tilt and turning angle. Although the previous code collected data and created these plots, it did not produce a database nor store values that could implemented into a database.

Furthermore, the transfer functions of the instrumentation devices were approximations rather than exact functions, which meant the team had to derive new transfer functions for the devices. Along with this, there was no direct way to measure the forces being applied by the two cylinders. A device that either measured the force being applied by the cylinder or the pressure being inputted into the cylinder, which could be routed back to the DAQ, is required for accurate plots involving applied force. Also, according to the previous group, the accelerometer on the device was not functioning as expected, therefore an analysis into the measurement devices was required and whether the measurement devices were suitable for the application of this project.

1.2 Objectives

The objective of this project is to further improve and optimize the skateboard truck testing device prototype that has been worked on by previous capstone project groups. This entails implementing new features and components to the testing device while also modifying some of the existing ones. The working prototype at the end should also be safe and easy to use, by an operator who could have minimal technical expertise. The purpose is to implement and improve features so that the device can account for trucks of all sorts of shapes and sizes while also considering that some riders prefer to incorporate a riser pad to adjust the angle of the truck relative to a skateboard deck. Another objective is to create a database of trucks that have been tested so that the users, such as customers or skateboard truck manufacturers, can easily compare the performance and response of multiple trucks. Also, improving the accuracy of the data collected from the device is critical so that the data is representative of the response of the trucks.

Although it is not a high priority for this project, efficiency is directly related to both time and cost in industry. Therefore, it is important for the processes involved to run the device, including switching the truck for another one or the test duration itself, to be completed as efficiently as possible. After this project has been completed, the amount of time required to swap different skateboard trucks in and out will be reduced.

The results that the device provides would be considered unreliable unless the data that it collects represents the actual response of the truck. The test must also provide repeatable results. Therefore, another objective of this project is to improve the precision and accuracy of the device. What this means is that there will be a trade-off between the speed of the test and the accuracy of the results. Therefore, the duration of the test will be optimized to reduce time while collecting accurate data.

1.3 Project Background

Some of the important key qualities of a skateboard truck that need to be measured by this testing device includes the steering angle of the skateboard truck relative to the amount of tilt that the deck experiences. The amount that the deck tilts or truck turns corresponds to how much force is applied to the skateboard deck by the rider in a real-world scenario. The force that both the skateboard deck and truck experience vary for different cases. Whether the person riding the skateboard is doing a trick, is turning around a steep corner, or is riding downhill or uphill. The device should also consider the fact that the skateboard truck may be installed on the skateboard deck with a certain riser angle, which is to add stability to the ride or to improve steering and control for the rider.

1.4 Scope

The focus of the Skateboard Truck Testing Device project is to improve the state of the previous prototype completed by a previous design team at BCIT, the focus of this improvement includes the following:

- Accuracy and the precision of the different measurements
- Code functionality and operation
- Electrical circuitry and wiring organization
- Reduction of the overall device's size/footprint
- A simpler and easier to use DAQ (data acquisition device)
- Ensure the tests are repeatable, and a zeroing process must be implemented
- Allow for all types of skateboard trucks to be implementable including

The group must ensure that the prototype is fully operational once the project reaches the end date. In order to consider the device fully functional a number of measurements throughout the device's test procedure are required to be taken, and are the following:

- Skateboard deck tilt
- Skateboard trucks angle of rotation
- Force applied to the "skateboard deck" component of the device

Proper data collection of the aforementioned measurements will allow for the production of three different graphs which will be used to compare different skateboard trucks quantitatively. The three graphs which will be generated are:

- Truck Rotation vs. Applied Force
- Deck Tilt vs. Applied Force
- Truck Rotation vs. Deck Tilt

Throughout the duration of the Skateboard Truck Testing Device Project the project group will not be spending any of their time focusing on the structural integrity of the Skateboard Truck Testing Device. Since the structural integrity of the skateboard truck is not being considered there will be no destructive testing on the device or the project since it is unrelated to the scope of the project.

1.5 Technical Requirements

The Skateboard Truck Testing Device has a number of technical requirements pertaining to the force in the system, accuracy, range of motion, adaptability, and power requirements for device operation. When considering the technical requirements the design team assembled a table to visually represent the Skateboard Testing Device's different specifications along with commentary on the reasoning behind the specification.

Some of the requirements (all of which can be seen in the table of specifications in Appendix F) such as the accuracy for the sensors being used for deck tilt or the truck size requirements have some flexibility. What is meant by this is that all of the specifications given are minimum requirements and the design team has freedom to exceed the minimum requirements indicated in the table to provide a product which exceeds the specifications required.

1.6 Product Background

There are currently devices on the market which test skateboards for strength and durability. However, there are currently no skateboard truck testing devices that exist on the market that measure the quantitative values the design team is interested in. There is also no device which measures deck tilt and truck rotation based on the amount of turning force applied to the skateboard. Due to a device that can do all these things not existing, it makes it troublesome for different types of skateboards to be quantitatively compared. This device will allow for a specific niche in the market that hasn't been identified before to be filled.

1.7 Resources

In order to complete the project a number of resources were required, this includes: Google Scholar, BCIT library research, SolidWorks and Excel. Additionally, the use of human resources at BCIT, this included a number of industry experts as follows:

- Stephen McMillan – Project Sponsor
    - Provided feedback throughout iterative design process, and provided shop assistance as necessary throughout the duration of the project
- Taco Niet
    - Provided advice on wiring, controls, and sensors as necessary throughout the duration of the project
- James Brett
    - Provided advice on wiring and sensors as necessary throughout the duration of the project
- Johan Fourie
    - Provided advice on administrative requirements for the capstone project

Chapter 2. Detailed Description of the Current Status

2.1 Overall Prototype Assembly (Frame)

The overall assembly of the original Skateboard Truck Testing Device can be seen in Figure 2.1, it consists of a number of components which will be discussed in further detail as the report progresses.

The device executes its movements as a result of the force being applied to the top cross-beam by the two pneumatic cylinders on the right of Figure 2.1. The pneumatic cylinders were previously mounted at an angle of 70 degrees to try and simulate real life forces more accurately but lacked any support for the choice of this angle.

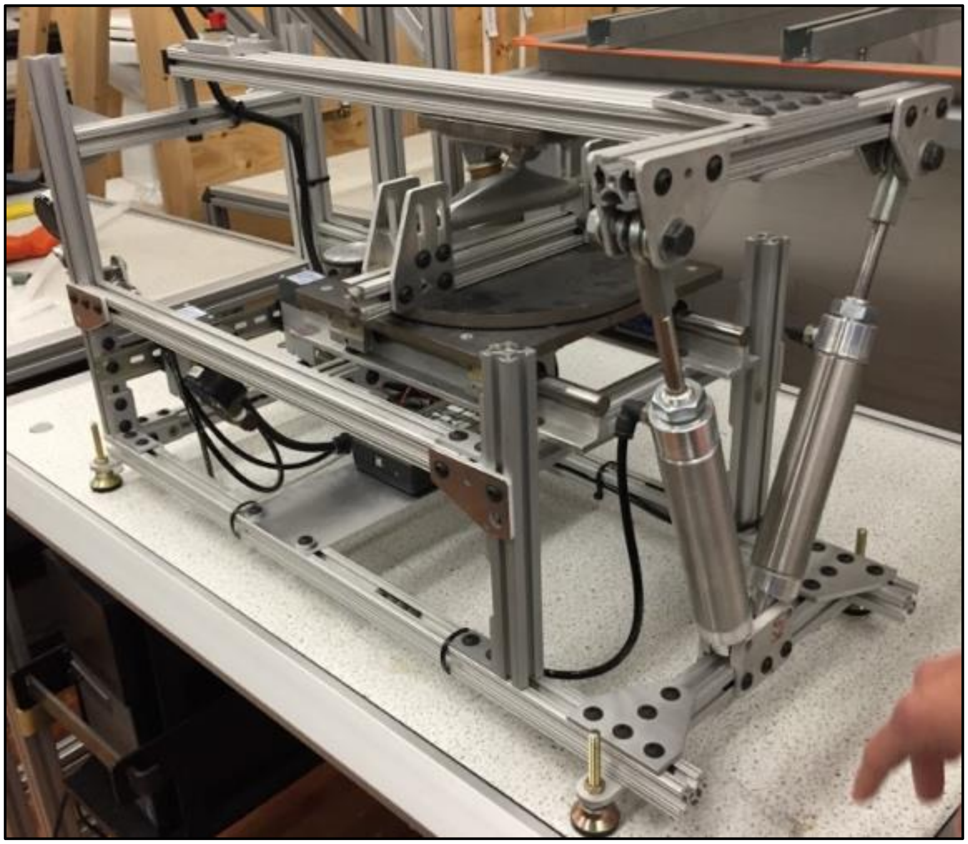


Figure 2.1 - Prototype (as received)

Examining the cylinder mounting more closely it was identified that reconfiguring and redesigning the upper and lower mounting components could allow for a saving of approximately 2.5” vertically overall in the footprint of the device. The device as a whole is larger than necessary in terms of the footprint, a lot of the real-estate taken up by the device is unused and adds additional weight which could be avoided.

Another issue with the overall device was the method of attaching the different cross members. What was observed by the design team was that when a certain amount of force was applied to the device, a number of locations where beams were mounted together by plates would experience torsion and bending, rendering the tests non-repeatable as it was impossible to take that deformation into consideration.

Overall the device’s frame and structural integrity as it was received from the previous design team requires attention to ensure that the device is safe to use and that the results are not only accurate, but also repeatable.

2.2 Top Cylinder Mount

The device as it was received had a method of attaching the top of the pneumatic cylinders that used four plates, one on either side of the cylinder rod ends. The assembly and plates are shown in Figure 2.2 seen below.

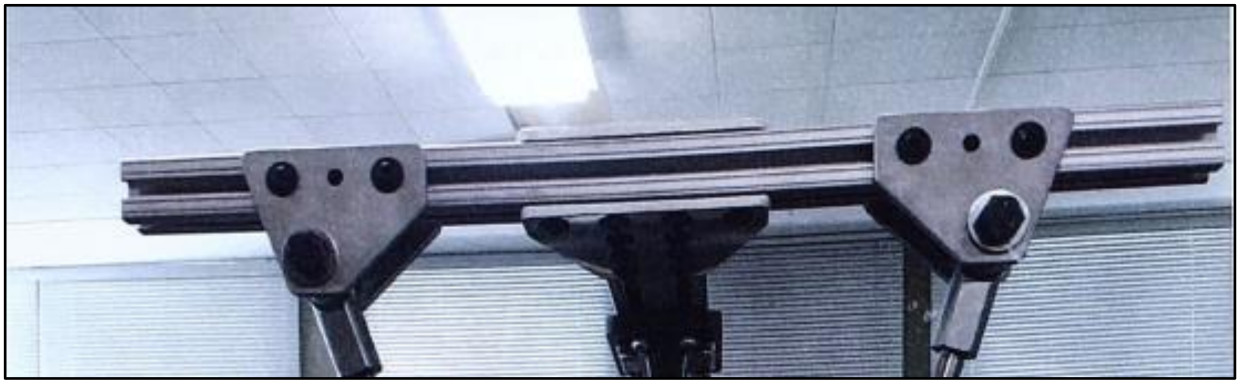


Figure 2.2 - Top Cylinder Mount (as received)

From this figure, it can be observed that the t-slot cross beam component is actually much larger than is required (as it extends past the mounts). The reasoning for the excess cross beam length is to allow for extra adjustability by loosening the bolts and sliding the upper mounts along the beam. However, it is unnecessary to have this much freedom since for the device to operate as desired the upper cylinder mounting shouldn't be too wide apart due to the orientation of the cylinders being placed at a very specific angle (70 degrees from the horizontal).

Additionally, the mounting for the rod end of the cylinder is approximately one inch below the t-slot resulting is a larger device overall. Since the set-up in Figure 2.2 causes the device to be larger than necessary, the device ends up having extra mass and extra overall dimensions which is not desirable and should be mitigated in the design process moving forward.

2.3 Bottom Cylinder Mount

The way the device was received incorporated a lower cylinder mounting assembly that can be seen in Figure 2.3.

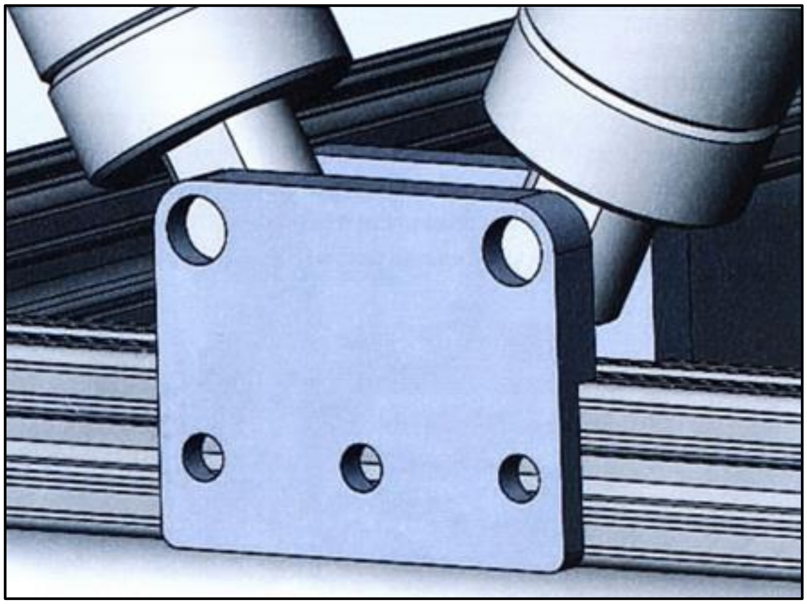


Figure 2.3 - Bottom Cylinder Mount (as received)

This set-up implemented two plates, one on either side which neglected the use of bushings resulting in a poor (rough) motion due to the aluminum on aluminum friction present. Another issue with the previous design is that the plates result in the cylinders being mounted above the framing. The problem with that is that it adds approximately one inch of overall height to the device that can be avoided by mounting the lower end of the cylinders in line with the t-slot framing. The set-up did provide a simple assembly, but finding a solution that deals with the previously mentioned issues could result in an overall smaller and lighter Skateboard Truck Testing Device.

2.4 Electrical Components, DAQ and Wiring

The electrical components and the data collection device in use (Keithly DAQ) had a number of issues associated with them which will be broken down and explained in this section.

Firstly, over the past couple of years the device has been moved around a number of times and some of the electrical connections came undone. A challenge with the wiring coming apart was that no wiring diagrams had been provided for the device throughout the past iterations of the project.

Additionally, the cleanliness of the wiring was a cause for concern, but more specifically the avoidance of using a breadboard meant all wiring went directly into the DAQ which is not an ideal method in terms of organization. In Figure 2.4 below it can also be seen that the DAQ is directly mounted on an aluminum (conductive) plate and in no way enclosed which would be problematic if exposed to the elements.

The DAQ was also used to power two pressure transducers, the problem with this was that the DAQ couldn't control the transducers to their full capacity due to not being able to support the amount of current being drawn by the transducers.

The previous design team also used an accelerometer to determine the amount of deck tilt being experienced. The issue with this was that they decided to only use one of the available three axis' leading to potentially more inaccuracies in the results.

Finally, the system is operating with a large amount of force at any given time and therefore should have incorporated an emergency stop as a safety precaution. Neglecting an emergency stop was problematic as there are several locations throughout the device where getting pinched or caught somewhere can occur easily.

Overall the electrical system worked, but required a number of key issues to be addressed to ensure the device operates as safely and efficiently as possible.

2.5 Coding and Control Sequence

The coding for the device was created for the aforementioned Keithly DAQ, but since Keithly isn't a recognized device by Matlab, it required a number of drivers to be installed before each and every use. The required drivers and sequence of installing the drivers to operate the code properly was not identified anywhere by the previous design team rendering the code and ultimately the device unusable. Furthermore, the device's zeroing sequence at the beginning of the code wasn't set up in a manner that allowed for a repeatable solution to properly determine the offset at the beginning of each test.

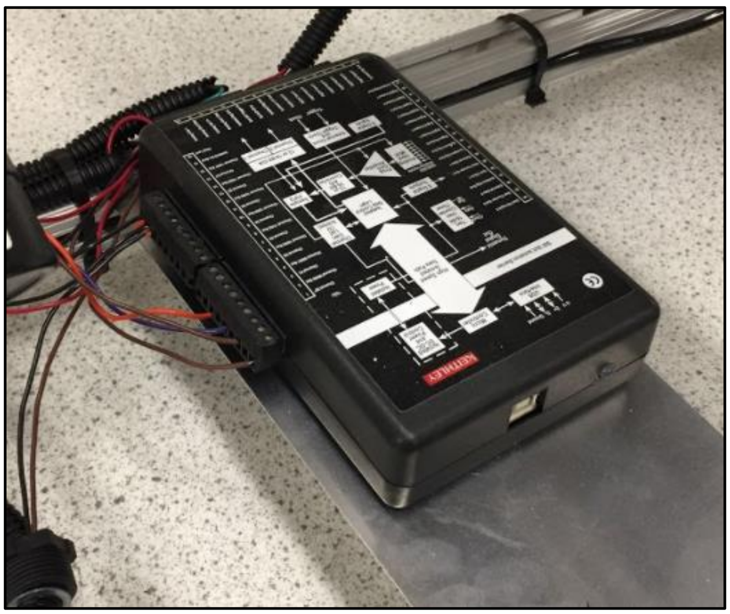


Figure 2.4 - Keithly DAQ

2.6 Truck Mount

When a truck is to be tested using the device, one side is mounted below the top beam, which represents the skateboard deck, and the other side sits on an axle mounting below. This can be clearly seen in Figure 2.5. The mounting between the top beam and the truck was something the team felt could be improved upon. Before any changes were made on the previous prototype, the truck was mounted onto a thick steel plate which was mounted onto the beam. The mounting to the beam, which is a t-slot aluminum extrusion, allowed for some adjustability for minor tweaking of position as the t-slot has sliding nuts in the slots for mounting.

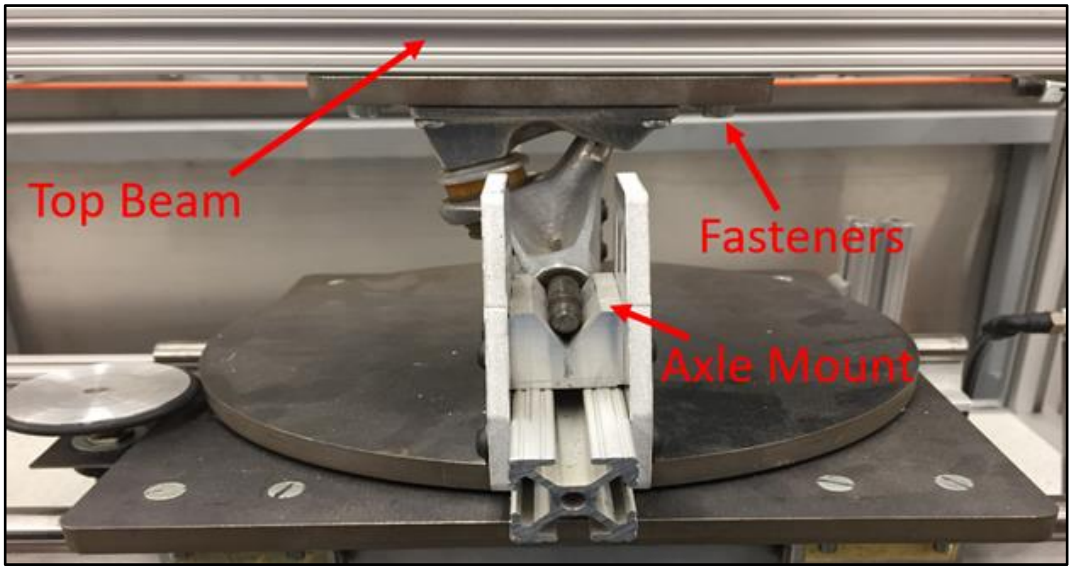


Figure 2.5 - Truck Mounting System (as received)

However, there were some issues with this design. Firstly, the team felt that one of the main objectives of this project was to increase ease of use, but the previous mounting design made changing trucks challenging. This was because the fasteners that mounted the truck to the beam were located underneath the beam, providing a hard to reach area which was also difficult to see. Once the truck is removed and a new truck is ready to be mounted to the beam an additional problem occurs, which was the alignment of the fasteners to the nuts that were inserted into the slot of the beams, as trying to align the screw, the hole in the mounting plate and the nut in the beam slot while unable to see the nuts presented an issue trying to mount the new truck. The difficulty of this procedure was further increased due to the nuts being able to slide very easily in the slot.

The other main issue with this design was not an issue with the functionality of the design but rather a feature that the team felt should be included. This feature was the simulation of riser pads, as skateboarders sometimes tend to change the angle that the truck sits on relative to the skateboard deck to change the handling of the skateboard. Overall, the team felt this design was very simple but required some improvement.

2.7 Ball Joint Orientation

The top beam, which represents the skateboard deck, has three contact points. The first being the beam that mounts the pneumatic cylinders. The second being where the skateboard truck is mounted, which was discussed in an earlier section. Lastly, the beam is mounted to a rod end, which serves as a ball joint to provide freedom for the beam to be rotated along all three axes. This last mounting was the area of concern as the team felt that previous design did not provide an accurate representation of the motion of a real skateboard deck. The contact points can be seen in Figure 2.6.

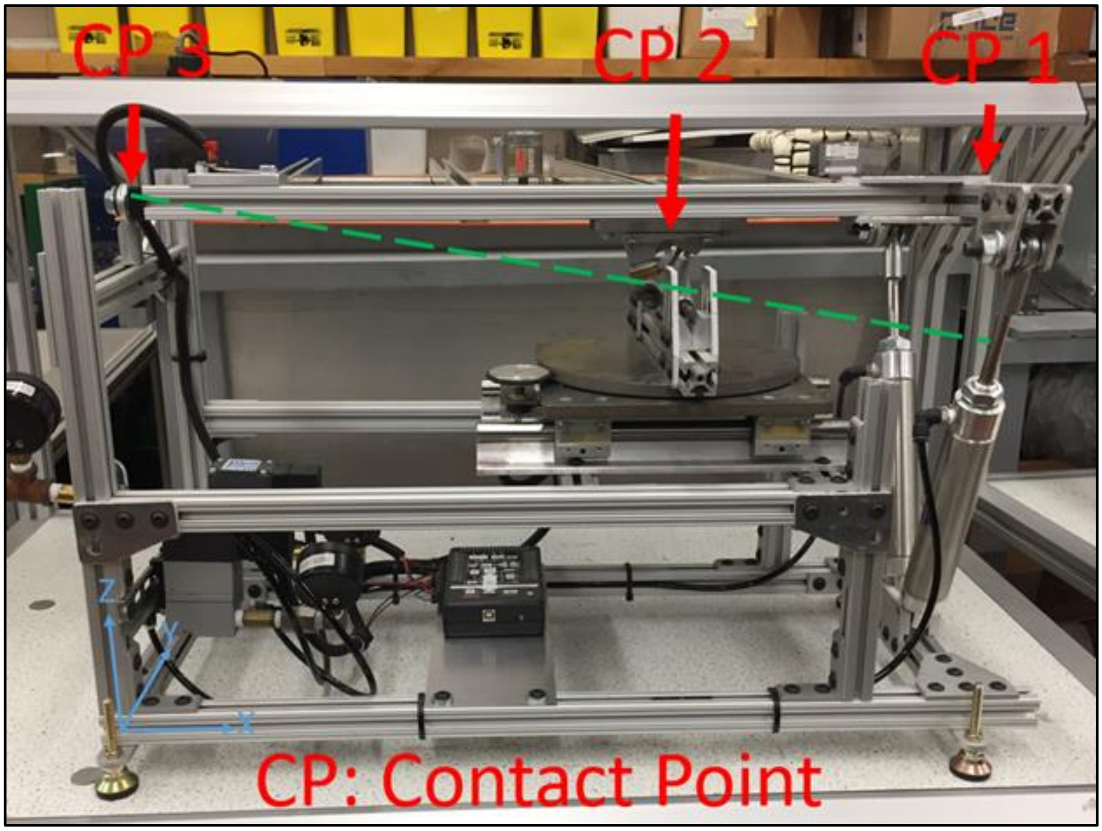


Figure 2.6 - Line of Rotation (as received)

The motion of a real skateboard deck can be represented by the Figure 2.7 below. The deck is mounted to the truck, which has a point of rotation, allowing for the deck to experience close to only pure rotation about the x axis (denoted in blue) and offset so that the deck rotates about a radius. This line of action or axis of rotation is located between the points of rotation of the two trucks (x axis). However, previously the design did not account for or simulate this motion on both sides. The side that is connected to the beam that the pneumatic cylinders are mounted on (contact point 1) closely resembles the required motion but the side that is connected to the ball joint (contact point 3) does not, as it only allows for rotation along the axis of the beam rather than along the axis of rotation between the trucks. Due to this asymmetric motion, the ball joint end experiences pure rotation about the x axis while the other end experiences not only rotation about the x axis but a large swaying or translation motion along the y axis. This line of action is represented by the dashed green line in Figure 2.6. This does not accurately represent the motion of a skateboard deck and would provide data that would be not representative of the conditions that the skateboard truck would experience.

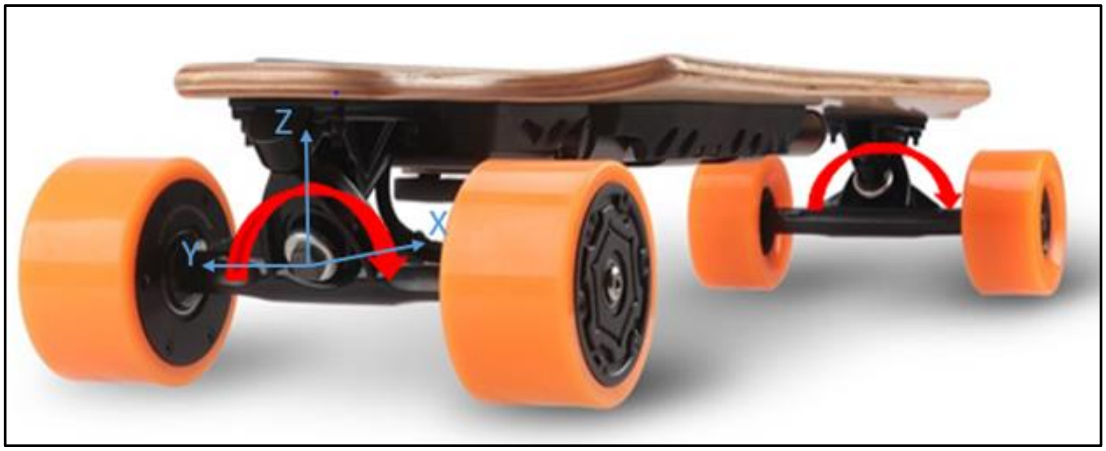


Figure 2.7 - Skateboard Truck Rotation [1]

2.8 Top Beam / Skateboard Deck

Based on the configuration of the previous year's skateboard truck testing device, the device was using a 2" x 1" beam at the top of the device to represent the skateboard deck. This component runs along the entire length of the device, attaching to the pivot end, the pneumatic cylinders, and the skateboard truck. It is important that this component does not experience any deflection or torsional displacement as it is critical in providing the user with accurate measurements of the skateboard truck being tested. Also, the accelerometer providing readings of the tilt of the truck was attached to this top beam. The setup of the previous device is shown below in Figure 2.8.

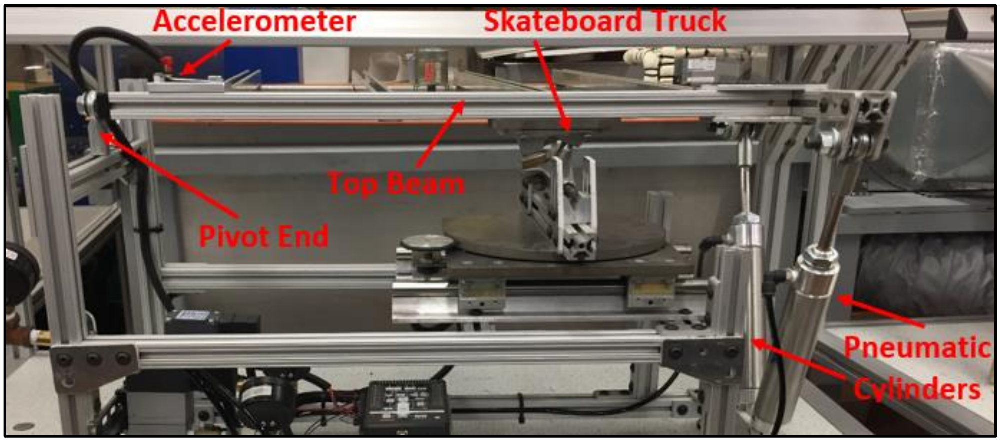


Figure 2.8 - Side View of Test Device

The deflection that the top beam experiences is apparent when the cylinders apply large forces on the beam. After careful analysis of the system, it was determined that the reason behind this is due to the top beam being longer and more undersized than it is required for the loads being experienced. The reduction of this component would not only reduce the deflection, but will also allow the device to be shorter and more compact.

2.9 Pneumatic Components

The previous prototype used pneumatic power as a means of generating force onto the skateboard truck to cause the motion required. This was done by using the supply air available and connecting the supply to the device. This supply was then diverted to two pressure transducers. Matlab code was then used to send voltage signals to the pressure transducers, through the data acquisition device, to introduce the required pressure to the system. This pressure was then sent to the pneumatic cylinders which then imparted a force, through the top beam, onto the truck. Although the team did not encounter or foresee any issues with this process in general, after some analysis the team did realize that were some issues with physical implementation and inherent issues with the pressure transducers that could be solved to further improve the device.

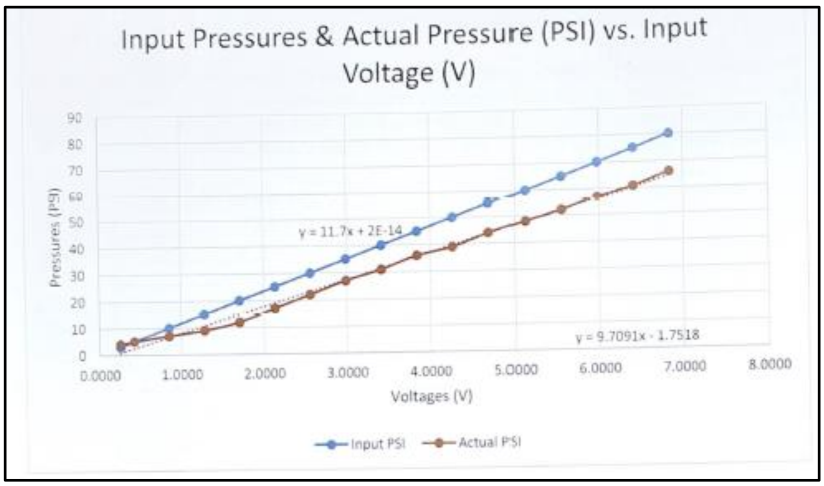


Figure 2.9 - Pressure Results (as received) [2]

When running tests on the previous prototype, the team had used the implemented pressure gauges to see how closely the pressures coming out the pressure transducers matched the values sent to the transducers from the Matlab code. The team realized that there were some calibration issues as these values did not match. Although small discrepancies can usually be described by the limitations of accuracies presented by the computer used, the data acquisition device and the transducers, the discrepancies were too large to be negligible. Upon further examination, it also seemed as though the previous group had encountered this same issue but could not fully resolve it. The data from the test results performed by the previous group can be seen in Figure 2.9 [2]. From this data it is evident that the pressure leaving the transducers did not match the pressure values sent to the transducers. After further inquiry, the team found two key causes of these discrepancies. The first issue was that the pressure transducers are specified to have an input pressure between 130 – 150 psi. However, the supply air used for the device was the supply air available on campus at BCIT, which is closer to roughly 90 psi. This presented an issue as the transducers were not operating in their required range of input pressures, which in turn caused some of discrepancies noticed. The second issue that was noticed was that the pressure transducers were not calibrated correctly. Both the span and the gain settings were not only different between the two transducers, but they were far from optimal. This further magnified the discrepancies.

Although this did not affect the functionality of the device itself, the team felt that the manner in which the pneumatic components, namely the pressure transducers, pressure gauges, and pressure input were implemented could be improved upon to more efficiently use the space present while also providing a cleaner design and interface with the device. The reasons for this were that the pressure transducers were clipped onto a rail, which allowed for the pressure transducers to slide along the rail, which was not ideal. Another issue was how the input pressure was mounted on the device. This mounting was not ideal and looked to be a temporary solution. The final issue was the implementation in general, the team felt as though the overall organization and cleanliness of the system could be largely improved.

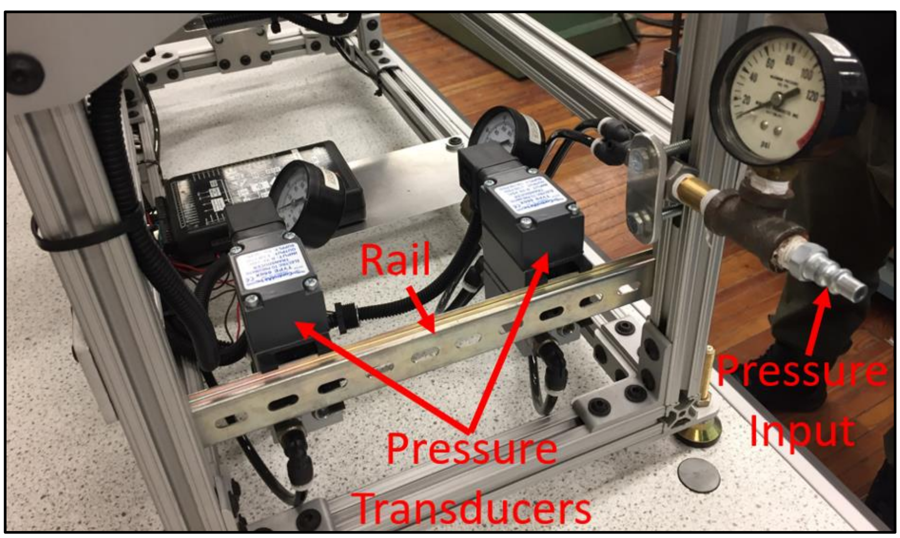


Figure 2.10 - Pneumatic Configuration (as received)

Chapter 3. Theoretical Background

3.1 Skateboard Theory

In this section of the report, the theoretical background associated with several parts of the Skateboard Truck Testing Device are going to be examined in some detail.

3.1.1 Overall Skateboard

The skateboard is a device which consists of a number of components in order to provide a means for transportation. The skateboard is comprised of a deck, wheels, grip tape, additional hardware and what this report is focussing on testing, the skateboard truck. The skateboard truck is the primary component in providing the turning feature to skateboards by implementing bushings to create an axis to which the truck rotates around as the rider leans on the skateboard deck. As the rider leans on the skateboard deck, the deck responds by transferring the force onto the trucks, this transferred force causes a response in the truck which allows for truck rotation. In Figure 3.1 the response described above can be seen; the amount of angle the trucks turn results in the turning radius of the skateboard.

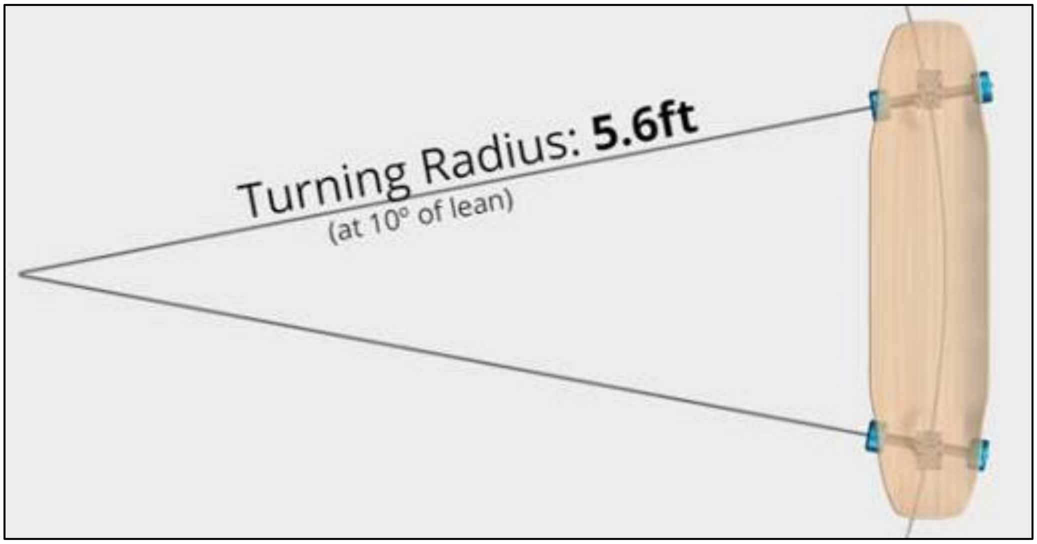


Figure 3.1 - Skateboard Truck Turning Radius [3]

3.1.2 Skateboard Truck

The skateboard truck is the focus of the testing device, therefore an understanding of the theory of a skateboard truck is crucial. A truck consists of a number of components that can be seen below in Figure 3.2. Several of these components such as the sizing of axle and hanger width, bushing harnesses and the tightness applied to the bushings result in different truck responses.

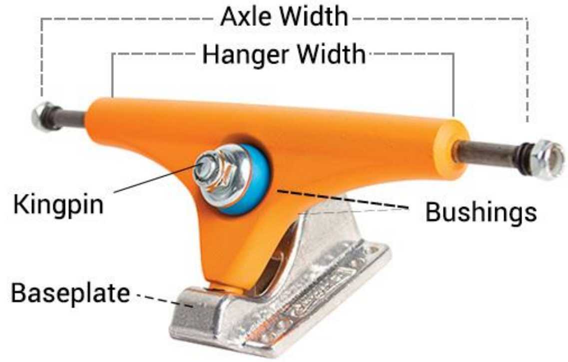


Figure 3.2 - Skateboard Truck Components [4]

What is meant by "response" is that a certain amount of force is required on the skateboard deck to get a certain amount of turning from the skateboard truck which can be seen in Figure 3.3. Therefore, depending on the truck set-up, there will be a required force to turn the skateboard which in comparison with another truck set-up can be quite different. The issue is that this makes it troublesome for customers to determine what type of response they like and how to set up a truck get that same response. Ideally there should be a simple means to test and ensure the skateboard truck is giving the customer the quantifiable response they are is looking for.

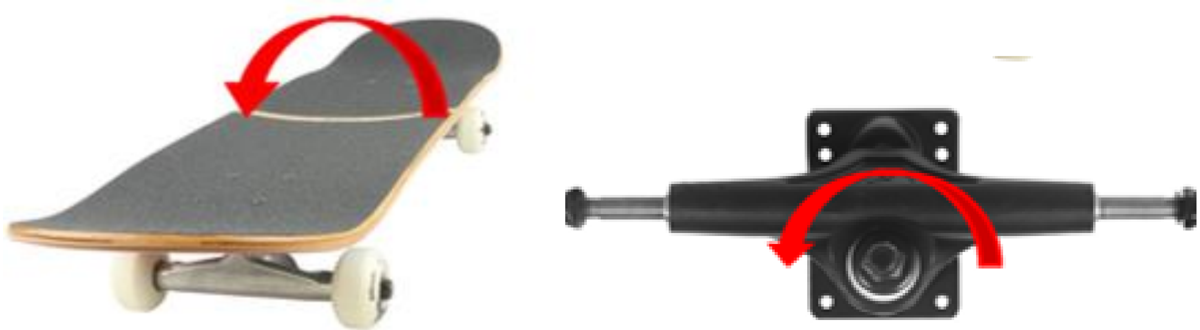


Figure 3.3 - Deck Tilt and Truck Rotation [5] [6]

3.1.3 Skateboard Bushings

Skateboard bushings are one of the main components that riders use to effect the response that is experienced based on force applied to the edge of the board. These bushings range in hardness and that hardness' effect on the feel of the skateboard can be seen in Table 3.1.

Cruising / Carving Weight Guide

	Flexy	Medium	Stiff
50 - 100 lbs	65a	78a	81a
75 - 125 lbs	80a	83a	85a
100 - 145 lbs	85a	87a	88a
125 - 175 lbs	87a	89a	91a
145 - 195 lbs	88a	93a	94a
175 - 220+ lbs	91a	93a	97a+

Freeride Weight Guide

	Flexy	Medium	Stiff
50 - 100 lbs	68a	80a	81a
75 - 125 lbs	80a	83a	84a
100 - 145 lbs	83a	85a	87a
125 - 175 lbs	87a	89a	92a
145 - 195 lbs	89a	91a	93a
175 - 220+ lbs	91a	93a	97a+

Downhill Weight Guide

	Flexy	Medium	Stiff
50 - 100 lbs	65a	78a	81a
75 - 125 lbs	80a	83a	85a
100 - 145 lbs	85a	87a	88a
125 - 175 lbs	88a	90a	93a
145 - 195 lbs	90a	93a	94a
175 - 220+ lbs	91a	93a	100a

Table 3.1- Truck Hardness' [7]

This particular table is representative of longboards, but similar tables can be found that also portray the effects of bushing hardness on the skateboards feel. As was previously mentioned, bushings are one of the main variables riders can control when setting up a skateboard therefore the Skateboard Truck Testing Device must be able to properly test trucks that implement varying hardness' of trucks.

3.1.4 Skateboard Truck Riser Wedge

When it comes to skateboard trucks and users trying to adjust the response of the skateboard trucks in response to the deck tilt, many users will implement a riser wedge in-between the skateboard deck and truck as can be seen in Figure 3.4.

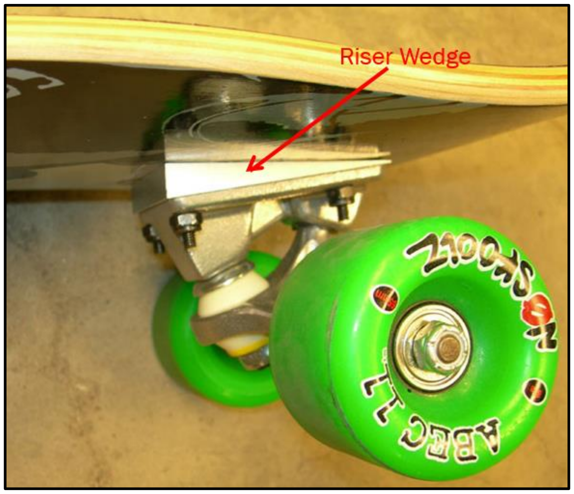


Figure 3.4 - Riser Wedge [8]

By implementing different wedge angles, and in different positions (front truck, back truck, sloping inward and sloping outwards), the overall "feel" of the ride changes which ultimately changes the steering responses in the front and rear as indicated in diagram below. In order to ensure the testing device can test all skateboard truck orientations, this detail will need to be accounted for.

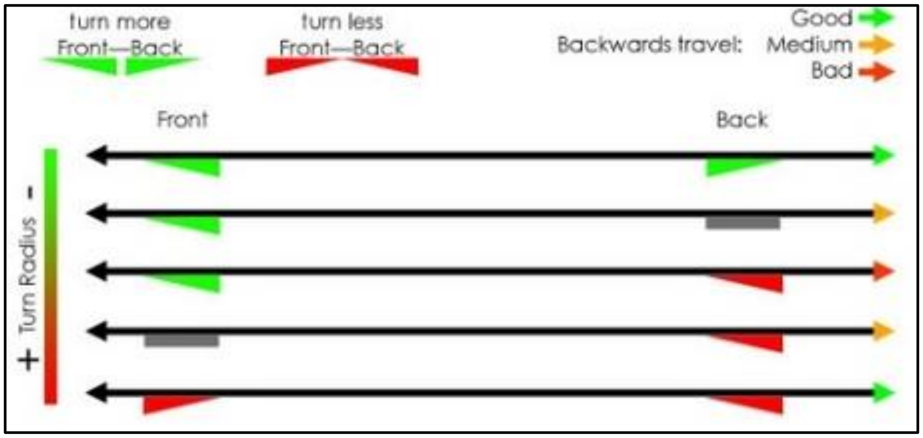


Figure 3.5 - Riser Wedge Steering Response [9]

3.2 Skateboard Tilt Motion

3.2.1 Skateboard Truck Rotational Axis

In order to ensure the Skateboard Truck Testing Device is properly operational, the motion of the skateboard truck along its' various axes needed to be investigated. For a proper understanding of a skateboards motion, the team decided that examining different skateboards and longboards that were made available to the team would be suitable. The findings that that team made indicated a response very closely resembling what can be seen below, the skateboard deck inherently rotates around the trucks located below the deck itself.

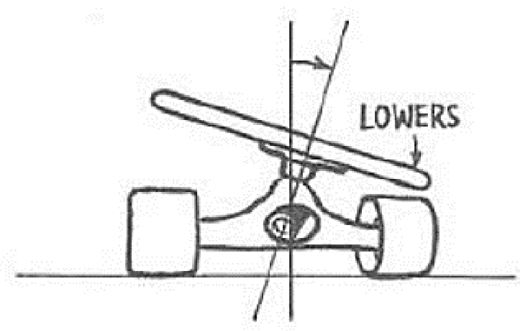


Figure 3.6 - Deck Tilt

From the information determined about the inherent rotation, the ball joint orientation needed to allow for a similar axis of rotation. By applying a ball joint closely in-line with the skateboard truck, it allowed for the motion of rotation that is identified in Figure 3.7 providing a response that resembled the actual motion seen above.

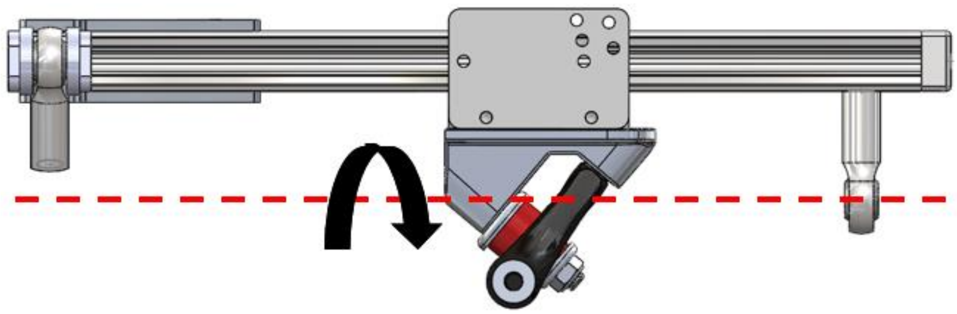


Figure 3.7 - Testing Device Rotation

3.3 Mechanical Orientation

Additionally, to represent the turning of a skateboard deck, the position at which the forces are applied to the "skateboard deck" need to be considered. In order for a rider to achieve a turning response from the skateboard truck, forces must be applied as follows:

Figure 3.8 - Deck Forces Experienced [10]

What can be seen is that the rider applies a weight at a given distance from the center of the skateboard truck which creates a moment arm allowing the deck to tilt and therefore cause turning. One other thing worth noting is that the turning motion along with whatever velocity the rider is travelling at causes an inward centripetal force.

As a result of this, the cylinder placement will need to allow for a moment arm that can create the force that represents the rider weight. Additionally, the cylinder placement needs to allow for forces in both the x and y directions since both the rider weight force and centripetal force must be created.

3.4 Pneumatic Cylinders

3.4.1 Pneumatic Cylinder Forces

In order to operate the Skateboard Truck Testing Device, a means of applying force to the skateboard truck is a necessity. The design team determined that using cylinders would allow for control over the direction of the acting forces, and pneumatically controlled cylinders would meet the force requirements.

The chosen cylinders are from BIMBA and have a bore diameter of 1.5". The BIMBA catalogue [11] provides the diagram seen in Figure 3.9 which can be used to allow for conversion from pressure to force.

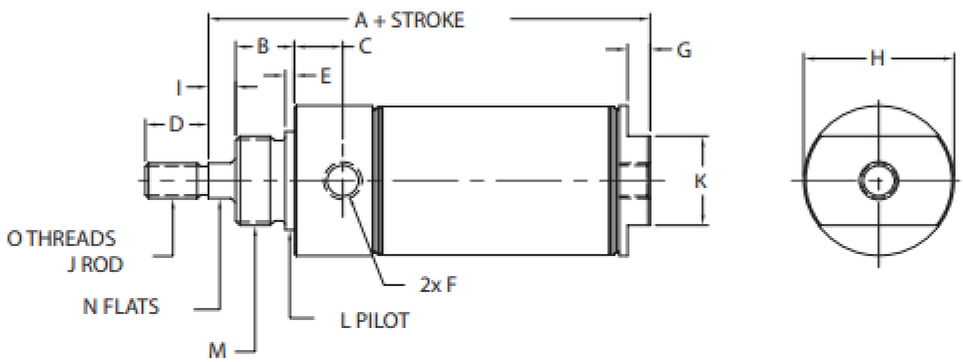


Figure 3.9 - Pneumatic Cylinder Diagram [11]

Using the know bore size (1.5") and the rod (N) size from the catalogue that's affecting the area (3/8") the active area can be determined.

$$a = \pi\left(\left(\frac{1.5}{2}\right)^2 - \left(\frac{.375}{2}\right)^2\right) = 1.6567\ in^2 \qquad \text{(Equation 1)}$$

Therefore, calculating the resulting force from the cylinders is simply multiplying the cylinder pressure by the calculated area.

$$F = P * a = 1.6567P \qquad \text{(Equation 2)}$$

3.4.2 Pressure Transducers

Controlling the pressures being inputted into the cylinders is of importance in order to properly control the Skateboard Testing Device's motion. Therefore pressure transducers are being implemented to convert specific voltage inputs into pressure outputs. In order to do so, the ControlAir 550x pressure transducers are being implemented into the pneumatic/electrical system. The following specs are of importance when coming up with the transfer functions for the device.

Pressure Transducer	
Type 550x	
Output (psi)	3-120
Input (volts)	0-10

Table 3.2 - Pressure Transducer Values

Using the above information the following transfer function can be derived:

$$Sensitivity = \frac{(120-3)}{(10-0)} = 11.7 \frac{psi}{volt} \qquad \text{(Equation 3)}$$

The transfer function above allows for the output of the pressure transducer to be controlled with the voltage input provided from the DAQ USB-6211. In order to ensure the pressure transducers were operating as necessary the design team executed an iterative process that required the span and zero of the transducers to be changed. Upon multiple iterations the output of the pressure transducers matched what was expected based on the transfer function.

3.5 Accelerometer - Deck Tilt

3.5.1 Accelerometer Angle Equation

In order to determine the amount of tilt the beam representing the skateboard deck experiences, it was necessary to implement a specific sensor to take on this task. In this instance the design team determined that using a 3-axis accelerometer would suit the requirements for the Skateboard Truck Testing Device. In order to maximize the accuracy while considering the motions the beam experiences, the team determined using all three of the available axes as necessary. The following diagram from "Tilt measurement using a low-g 3-axis accelerometer" [12] clearly identifies the different angles which can be measured, and how the design team will be using the accelerometer.

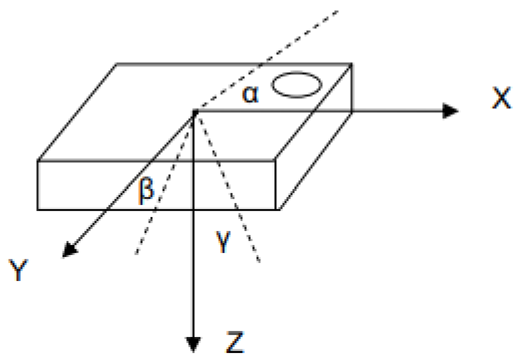


Figure 3.10 - Accelerometer Diagram

From Figure 3.10 above, and the placement of the accelerometer on the testing device it can be noted that α is the angle of interest. The document mentioned above also provides a variety of different equations to solve the required unknown, and in this case they provide the following [12]:

$$Pitch = \alpha = arctan\left(\frac{A_{x1}}{\sqrt{(A_{y1})^2+(A_{z1})^2}}\right) \qquad \text{(Equation 4)}$$

Where A represents acceleration [g's] in a given direction denoted by the subscript.

3.5.2 Accelerometer Calibration

In order to ensure the results from the accelerometer are valid and useful, there was a requirement to ensure the code properly zeros the data and implements the proper sensitivity for each axis. In order to ensure this was the case it was a necessity to test the voltages of the accelerometer in different orientations as represented in the following table:

	Orientation [degrees]		
Axis	**90**	**0**	**-90**
x	0.695	1.415	2.137
y	0.801	1.517	2.240
z	1.323	0.617	1.327

Table 3.3 - Accelerometer Test Results

Upon testing the different orientations the following sensitivities were determined:

Axis	Sensitivity [volt/90°]
x	0.721
y	0.727
z	0.709

Table 3.4 - Accelerometer Sensitivities

The sensitivities identified in Table 3.4 are used in addition to a zeroing sequence that takes the mean of 1000 data points while the device is in its neutral position. Using both the tested sensitivities and the accelerometer zero values allow for accurate deck tilt results to be achieved.

Additionally, the results above (sensitivities) also represent [volts / g]. In order to understand this it is necessary to examine Figure 3.10. While the accelerometer is in the position of the figure, gravity is fully acting in the z-direction. Whereas when the accelerometer is shifted either 90 or -90 degrees, there is 0 g's acting in the z-direction. Therefore, there is a direct relationship between volts/90° and volts/g which allowed the design team to directly convert voltage change to acceleration which was to be used in Equation 4.

3.6 Potentiometer – Truck Rotation

3.6.1 Potentiometer Rotation Equation

In order to determine the amount of rotation the skateboard truck experiences, a sensor is required that experiences a voltage change as a result of rotation. In order to measure the truck rotation, the design team determined that a potentiometer would meet the design requirements.

As a result of the device set-up the potentiometer cannot be directly mounted to the turn table, therefore it is required to have the potentiometer separate and connected via contact with the turntable as seen below:

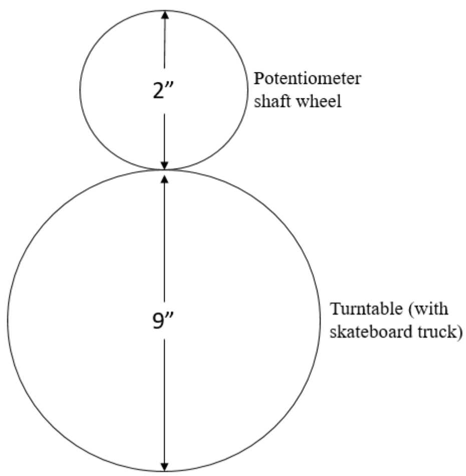


Figure 3.11 - Turntable/Potentiometer Diagram

As a result the following relation becomes:

$$Turntable\ rotation = Potentiometer\ rotation * \frac{2"}{9"} \qquad \text{(Equation 5)}$$

3.6.2 Potentiometer Calibration

The potentiometer sensitivity needed to be determined in order to ensure the results were accurate from the potentiometer. In order to do so, the design team conducted calibration testing that led to the following results:

Potentiometer Test Results	
Degrees Travelled	90
Voltage Change	0.7255

Table 3.5 - Potentiometer Test Results

Using the above results the sensitivity of the potentiometer was determined to be:

$$Pot\ Sensitivty = \frac{90}{.7255} = 124.1\ \frac{degrees}{volt} \qquad \text{(Equation 6)}$$

Furthermore, applying the relation investigated in section 3.6.1 to Equation 4 allows for the sensitivity of the turntable (skateboard truck rotation) to be calculated:

$$Skateboard\ Rot\ Sensitivty = \ Pot\ Sensitivity * \frac{2"}{9"} \qquad \text{(Equation 7)}$$

$$Skateboard\ Rot\ Sensitivty = \ 124.1 * \frac{2"}{9"} = 27.57\ \frac{degrees}{volt} \qquad \text{(Equation 8)}$$

In addition to applying the skateboard rotation sensitivity, the potentiometer must also be zeroed. In order to do so there is a zeroing sequence implemented in MATLAB that takes the mean of 1000 data points while the device is in its neutral position to determine what the offset of the potentiometer is. Applying the offset and the sensitivity allows for the skateboard truck rotation to be accurately determined from the potentiometer.

3.7 Skateboard Truck Position

The position of the skateboard truck within the device was taken into careful consideration. The design team considered that taking advantage of the mechanical advantage available within the device was important. Considering this in the design process would allow for the maximum force to be acting at the skateboard truck and allow for less required pressure at the pneumatic cylinders.

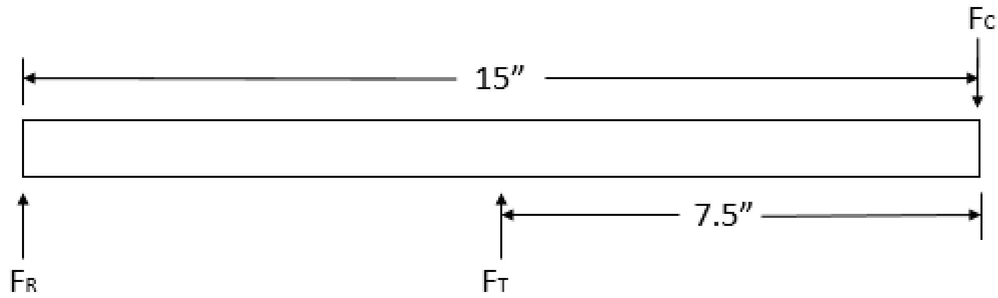


Figure 3.12 - Top Beam Diagram

F_C = Force of Cylinders
F_T = Force of Truck
F_R = Force of Rod End

As a result of the optimal orientation of the beam (representing the skateboard deck) as is seen above, the force on the truck is determined as:

$$F_T = 2F_C \quad \text{(Equation 9)}$$

Chapter 4. Description of the Project Activity and Equipment

4.1 Work Breakdown Structure

The purpose of creating a work breakdown structure for the Skateboard Truck Testing Device project was to ensure that the project tasks were broken up in a flow dependent and independent way. By doing so, the design team is able to easily plan for all the tasks in the flow chart and ensure no hang ups occur due to task dependencies. Having the work breakdown structure allowed the team to identify important tasks; and allocate time depending on how critical specific tasks were. The work breakdown structure can be seen in in Appendix B.1.

4.2 Gantt Chart

The Gantt Chart shows both the major and minor project tasks that must be completed before the project can be considered completed. Both the minor and the major tasks that are shown in the Gantt Chart are based on the tasks that were identified in the Work Breakdown Structure, which was described in Section 4.1. The Gantt Chart has been continually updated throughout the project as task durations became more clear. The chart can be referred to in Appendix B.2.

4.3 RACI (Responsible, Accountable, Consulted, Informed) Chart

The RACI chart is a tool that was implemented by the design team to ensure that the individual team members understood their roles when it came to specific project tasks. The four different responsibility levels (responsible, accountable, consulted and informed) were given to the three team members and the project sponsor for the nine different tasks identified in Appendix B.3.

4.4 Concept Generation

When it comes to the problems presented in Chapter 2, there are multiple concepts that can deal with solving the issues that the device was experiencing. For all of the concepts, the project team must consider the footprint, advantages and disadvantages while making sure the designs meets all of the necessary specifications and requirements.

4.4.1 Cylinder Configuration

Although it is not entirely important that the device represents perfectly how a skateboard behaves, it is important that the truck does experience reasonable forces, similar to those experienced by a truck while a skateboard is being ridden. It is also important that the pneumatic cylinders are used to turn the truck so that it reaches the maximum required turning angle. The footprint of the device must also be considered when evaluating potential cylinder configurations. Some concepts for setting up the pneumatic cylinders of the device are shown below in Table 4.1.

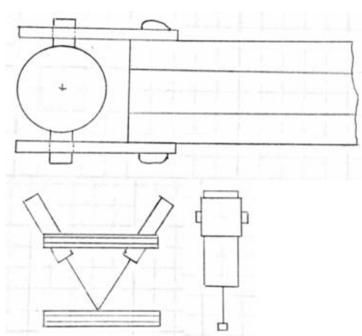
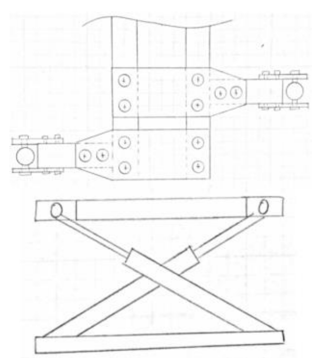
	Trunnion	*Cross-Cylinder*	*Angled*
Visual Representation			
Pros	- Major decrease in device height possible - Minimal assembly - Minimal manufacturing	- Better representation of real-world forces while riding a skateboard - Adjustable - Height reduction possible	- Smaller device width - Adjustable - Correctly represents forces experienced by a skateboard truck
Cons	- Safety concern due to cylinders not being contained in device - Would require components from cylinder supplier or must manufacture trunnion - Height would be reduced too much	- Increased assembly & manufacturing complexity - Increased number of components required - High risk of potential error - High cost - Different moments caused by each cylinder due to differing placements along length of top beam	- Complex mounting required - Increased manufacturing - High cost

Table 4.1 – Cylinder Orientation Concepts

4.4.2 Cylinder Top Mount

The top mounting of the cylinder must allow for some adjustability so that the angle of cylinders from the horizontal can be changed. The mount should also be rigid and strong enough to resist bending due to the forces applied by the cylinders. The following concepts were generated for this design.

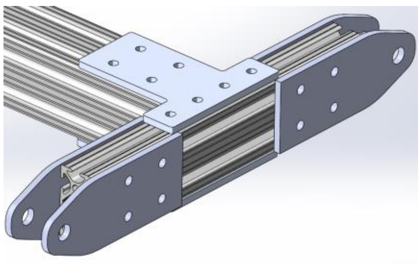
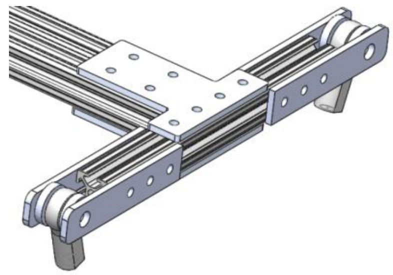
	2” Beam	*1” Beam*
Visual Representation		
Pros	- Rigid; bending will not occur	- Slimmer design - Smaller footprint - Lighter
Cons	- Larger footprint - Heavier	- Not rigid; bending may occur

Table 4.2 - Upper Cylinder Mounting Concepts

4.4.3 Solutions to Low Pressure Error from Pressure Transducer

As mentioned in chapter two, there were some issues with the pressure transducers having discrepancies between the expected pressures (as a result of voltage sent to the transducers) and the actual pressure coming out of them. To provide accurate readings of pressures, the team generated the following design ideas.

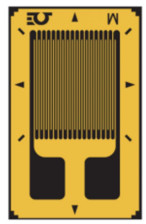
	Pressure Sensor	*Strain Gauge*	*S Type Load Cell*	*Provide Required Pressure*
Visual Representation				
Pros	- Allows for more space and size - Accurate - Easy to implement	- Inexpensive - Would require minimal space - Team has knowledge & experience on how to use these gauges	- Provides very useful data; implemented in line with cylinders	- Easier pressure control - Easy to implement - Provided by BCIT - Will meet pressure transducer requirements
Cons	- Expensive - Pressure gauges can provide the same information	- Difficult to implement - May not provide relevant or useful data due to location of implementation - Extra electrical components	- Difficult to implement - Would require device to be designed around load cell - Expensive	- Doesn't allow for a compact device - Heavy and loud - Requires pressure to be built up before use - Expensive

Table 4.3 - Low Pressure Error Solution Concepts [13] [14] [15] [16]

4.4.4 Riser Pad Plate

The riser pad design should allow for adjustability of the angle of the truck relative to the skateboard deck. There should be enough range of angles to cover the common riser pad angles used by skateboarders regularly. The design should provide ease of use to the operator so that the angle may be changed quickly. The design should also be sturdy enough to withstand the forces applied by the cylinder. The following concepts were generated for this design.

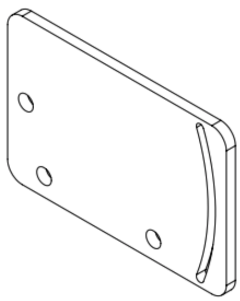
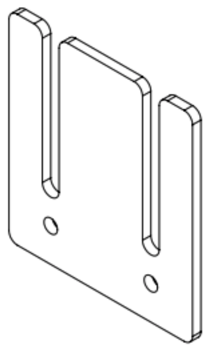
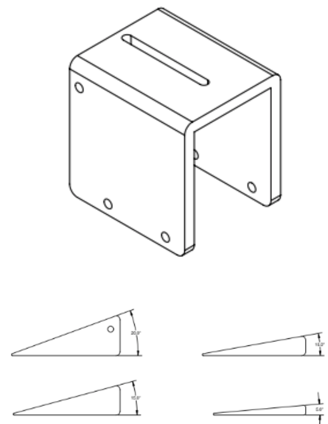
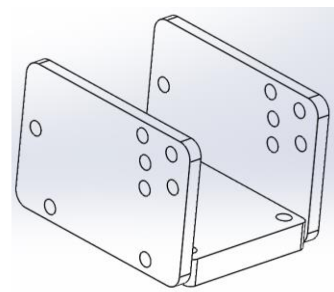
	Concept 1	*Concept 2*	*Concept 3*	*Concept 4*
Visual Representation				
os	- Ease of use - Less components required - Precise control of angles required	- Less components required - Precise control of angles required	- Sturdy; will not slip - Can implement riser pad from rider	- Less components required - Simple components - Easy to manufacture - Sturdy; will not slip - Ease of use
Cons	- Potential sliding can occur from slots	- Potential sliding can occur from slots	- Too many additional components required - Overly complex - Difficult to manufacture	- Fixed angles

Table 4.4 - Riser Pad Plate Concepts

4.5 System Flowchart

In order for the team to organize the work to be done, to understand the flow of information, data and signals throughout the device, and to help others understand how the device functions, a flow chart was created (see Figure 4.1 below).

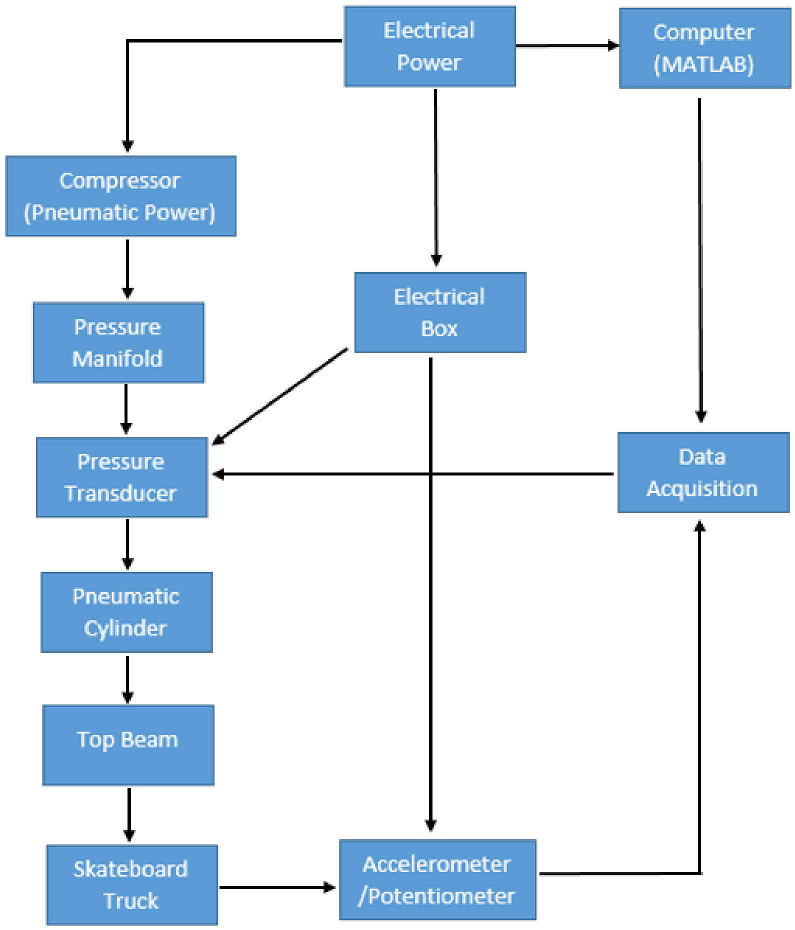


Figure 4.1- System Flowchart

Creating the above flowchart helped the team understand which components are necessary, how each components are interrelated and what the flow of the device would be. It can be seen that the electrical power is the most important component along with pneumatic power for the functionality of the device whereas all other components are necessary for the proper testing of a skateboard truck and flow of information that is required from and for those tests.

4.6 Final Manufactured Components

In this section of the report the team will be investigating the different components that were manufactured and the manufacturing processes required to create them. The full completed Skateboard Truck Testing Device being examined in this section can be seen in Figure 4.2 below.

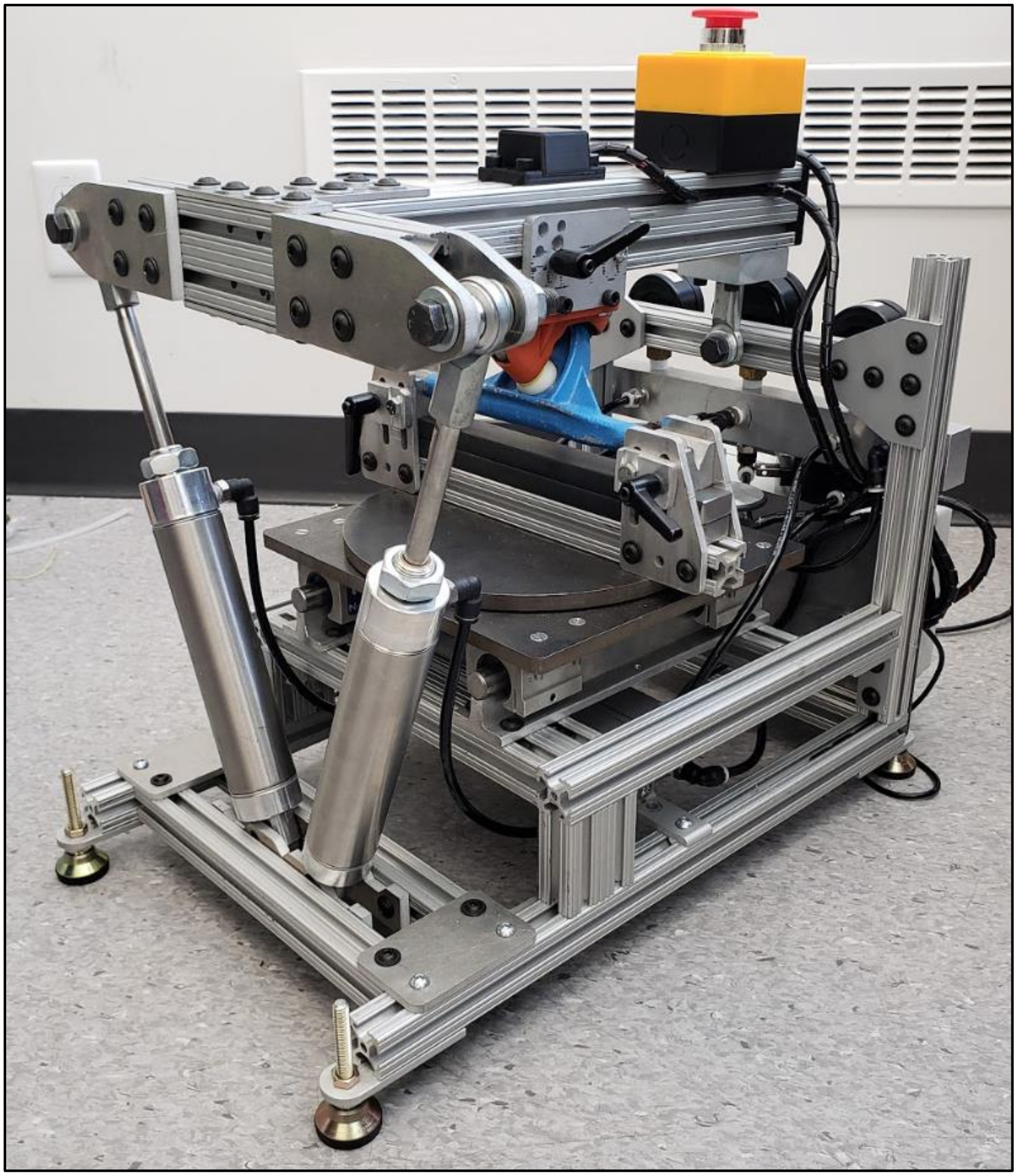


Figure 4.2 - Final Assembled Prototype

4.6.1 Riser Pad

The riser pad design that was chosen and manufactured can be seen in Figure 4.3. It was chosen for several reasons mentioned in section 4.4.4 of this report. The reasoning for going with this design is as follows:

- Allows for riser pad angles from 0 – 20 degrees in 5 degree increments
- Won't slide downwards due to force from cylinders
- Easy angle adjustability

Upon choosing the concept, the process of manufacturing the components required for the assembly was underwent as a team. The process consisted mainly of implementing water-jet technology on aluminum from DXF files to create the three separate components seen in Figure 4.3. Following the cutting of the three components, the base piece required additional manufacturing processes. This included drilling and tapping of the two side holes to allow for assembly. Implementing handles rather than bolts for assembly allowed for additional ease of use and simple angle adjustment which was an overall design goal.

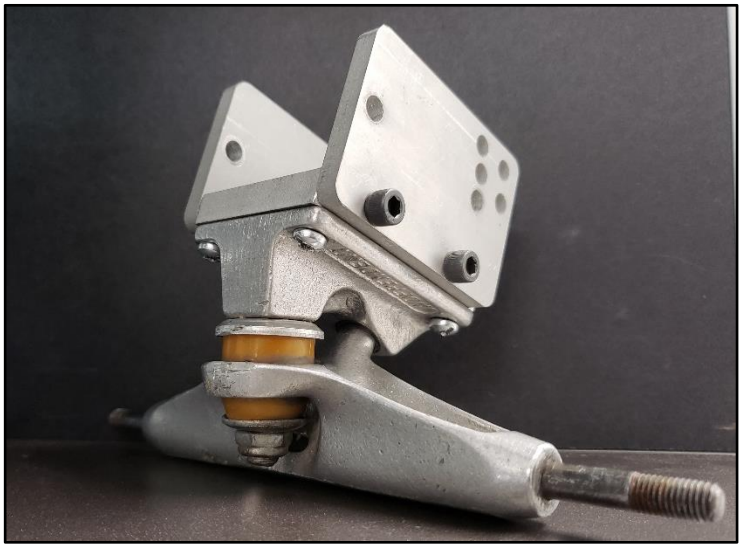


Figure 4.3 - Riser Pad Assembly

4.6.2 Lower Cylinder Mounting Assembly

Designing of the lower cylinder mounting brackets required extra attention to be put onto ensuring clearance wouldn't be problematic throughout the cylinders range of motion. The final design chosen and the full assembly can be seen below, and the reasons for choosing this design and assembly is as follows:

- Reduces height of overall device due to dropping lower end of cylinders between t-slot
- Provides clearance through full range of cylinder motion
- Allows for adjustability of lower cylinder mounting positions
- Includes space for bushings to ensure smooth operation

Overall the assembly and mounting brackets dealt with several issues the previous design had and saved extra space, but it requires additional parts and assembly as seen in Figure 4.4. The slotted plate is incorporated to allow for additional ease while assembling this section of assembly and the slot is necessary to allow for slight freedom in how "perfect" the components are assembled.

Figure 4.4 - Lower Cylinder Assembly

The plate seen in Figure 4.5 was designed and implemented in order to allow for the cylinders to have ample clearance while going through the range of motion required for a test.

The manufacturing processes for these components (the mounting plate and slotted plates) only required use of the Water-Jet and did so by using DXF files. The assembly itself simply requires t-slot nuts and bolts.

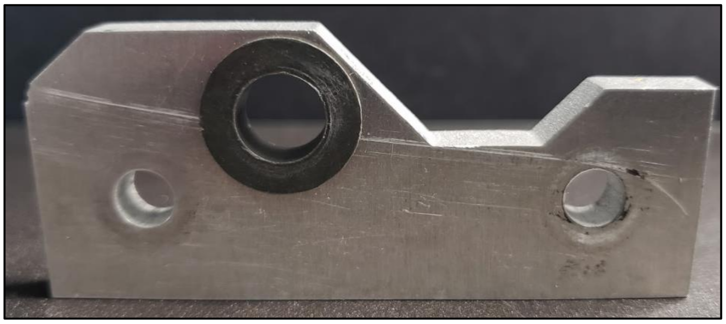


Figure 4.5 - Custom Mounting Plate

Figure 4.6 – Slotted Plate

4.6.3 Upper Cylinder Mounting Assembly

The upper cylinder mounting assembly primarily had to designed and manufactured with a focus on cylinder rod-end clearance and optimal device height. Upon testing it was also determined the t-slot beams required to be enlarged to deter bending and twisting as it was a clear problem. In Figure 4.7 it can be seen that the beams are 2” x 2” and 2” x 1” which is double that of the previous prototype. Additionally, in Figure 4.7 the upper cylinder mounting plates that were designed and manufactured can be referred to. The reasoning behind this design are as follows:

- Strength, no bending or twisting
- Optimal height achieved
- Clearance from rod ends of cylinders
- Cylinder placement adjustability (sliding along t-slot)

The assembly of the components is simple and requires t-slot nuts, bolts, and an additional bolts and washers for the rod ends to be assembled.

When it comes to manufacturing the components, the Water-Jet machine was implemented to cut the upper cylinder mounting plates. Additionally, the CNC was used to ensure the t-slot was cut precisely, the ends were made perfectly square and to drill precise holes for mounting into the 2” x 1” beam. Finally, for additional strength the end of the 2” x 2” t-slot was tapped and mounted directly to the 2” x 1” which was previously drilled by the CNC as mentioned previously.

Figure 4.7 - Upper Cylinder Mounting Assembly

4.6.4 Axle Mounting Assembly

The axle mounting assembly requires the most adjustment when it comes to changing out to new trucks since the vertical height of trucks can vary. In order to deal with this ease of adjustability the team decided to make improvements to the previously implemented height adjust plates.

Firstly, the team created plates of varying widths (1/8", ¼" and ½") which allow for ease of levelling the two sides. This allows for 1/16" precision which for the device purposes is ample. Two ½" plates being implemented can be seen as part A in Figure 4.8.

Secondly, the design team implemented handles that would allow for simpler tightening of the device, but taking it one step further the team wanted the device to self-tighten the non-handle end of the bolt. In order to do so, custom nuts were created that have a slot which match the nut head diameter as seen in Figure 4.8 as part B. This ensures no additional tools are required when adjusting the device height.

Overall the ease of use sees a large improvement due to these simple yet effective design changes.

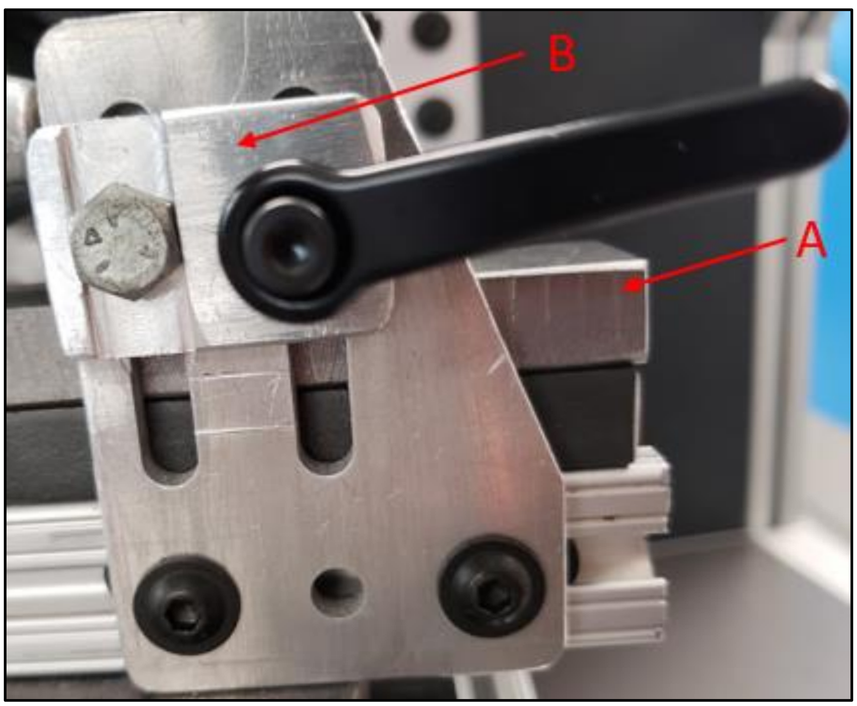


Figure 4.8 - Axle Mounting Assembly

4.6.5 Top Beam / Ball Joint Assembly

The connection of the top beam to the rear of the device had to be redesigned so that rotation of the beam better represented the rotation of a skateboard deck (see section 2.7). This design that the team went with can be seen in Figure 4.9 below.

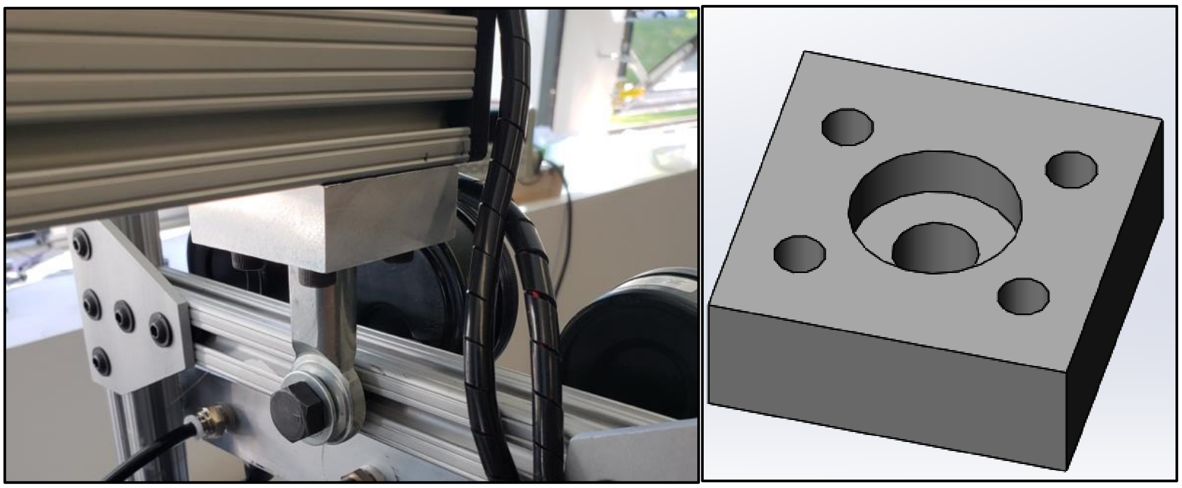


Figure 4.9 - Ball Joint Mounting Plate

This design has two major changes to it from the previous design. The first is that the ball joint was rotated and mounted 180 degrees so that instead of the top beam experiencing pure rotation, the beam would experience rotation about a point that is offset by a small distance, therefore rotating more like a skateboard deck would rotate.

Secondly, the mounting of the ball joint to the top beam had to be redesigned to account for this change. This designed component allowed for mounting on the underside of the beam instead of behind the beam as it previously was. This part was manufactured using the horizontal band saw to cut correct dimensions required. Due to the uneven surface that the band saw produces, the mill machine was used to produce flat faces on all sides. The mill machine was used again to drill the through holes required. The 3D model of the component can be seen in Figure 4.9 above.

The overall assembly was relatively simplistic and required bolts, washer, nuts and sliding nuts for the t-slot.

4.6.6 Frame

Although not an issue related to the functionality of the device, the team felt it was necessary to redesign the overall frame of the device to decrease the footprint as the previous prototype was oversized. The reduction to the frame along with the final assembly of the device can be seen in Figure 4.10.

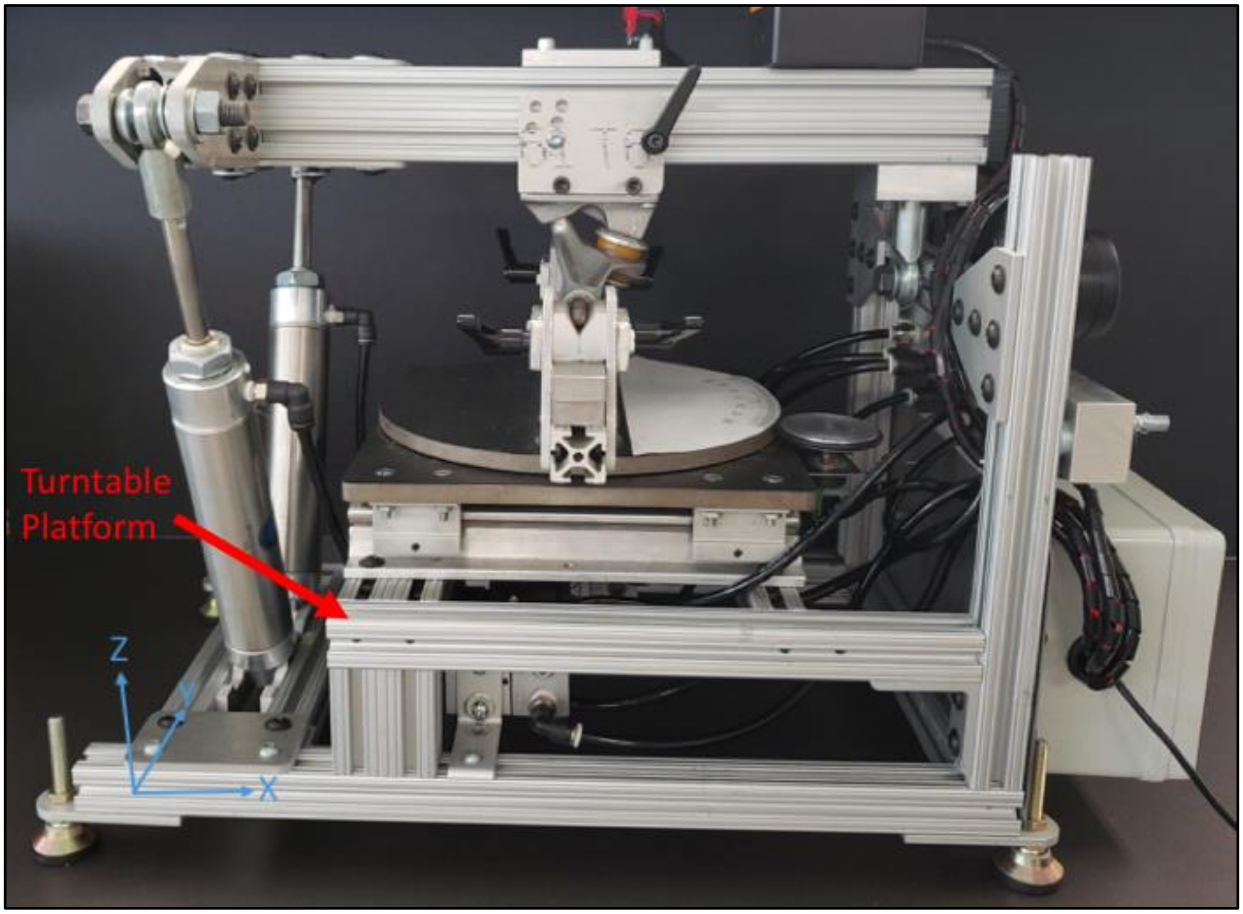


Figure 4.10 - Testing Device Assembly

The reductions in footprint that were made were for height (z axis) and length (x axis). The width (y axis) of the device was not altered due to constraints.

Due to reorganizing the placement of the pressure regulators (below the turntable) and the electrical components (in an enclosure on the rear of the device) the design team managed to free up the required space to shrink the device as desired in the x and z directions.

The connections and mounting between the t-slot extrusion beams were also redesigned to provide a sturdier connection as well as fixed positions due to the slippage that would occur with high forces in the previous device. Instead of using a plate or corner bracket to provide connections between beams, the team decided to go with a cleaner approach that involved drilling holes in the beam parallel to their cross section and tapping the holes on the end of the connecting beams. A bolt was then slid into the slot of the beam with the hole and aligned with the hole. The beam was then fastened to the perpendicular beam with the tapped hole by fastening the bolt by inserting an Allen key through the drilled hole. See Figure 4.11 below for a visual representation.

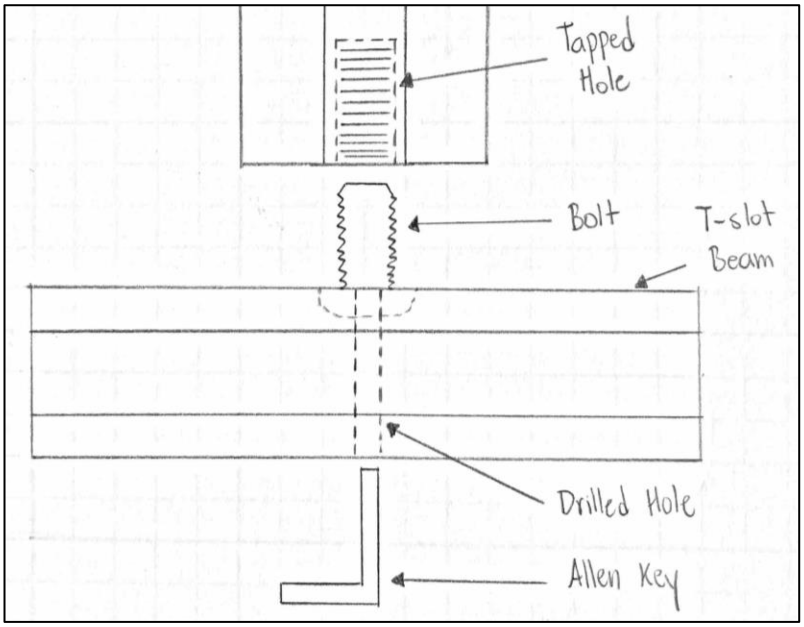


Figure 4.11 - T-slot Assembly

4.7 Electrical Components

In order to properly operate the Skateboard Truck Testing Device a number of electrical components needed to be incorporated into the system. In this section the design team will be explaining each component, their significance and how they are incorporated into the electrical system. The electrical circuit in the device can be seen in Figure 4.12 below and is contained within an electrical box on the back of the device to ensure safety and containment of the electronics.

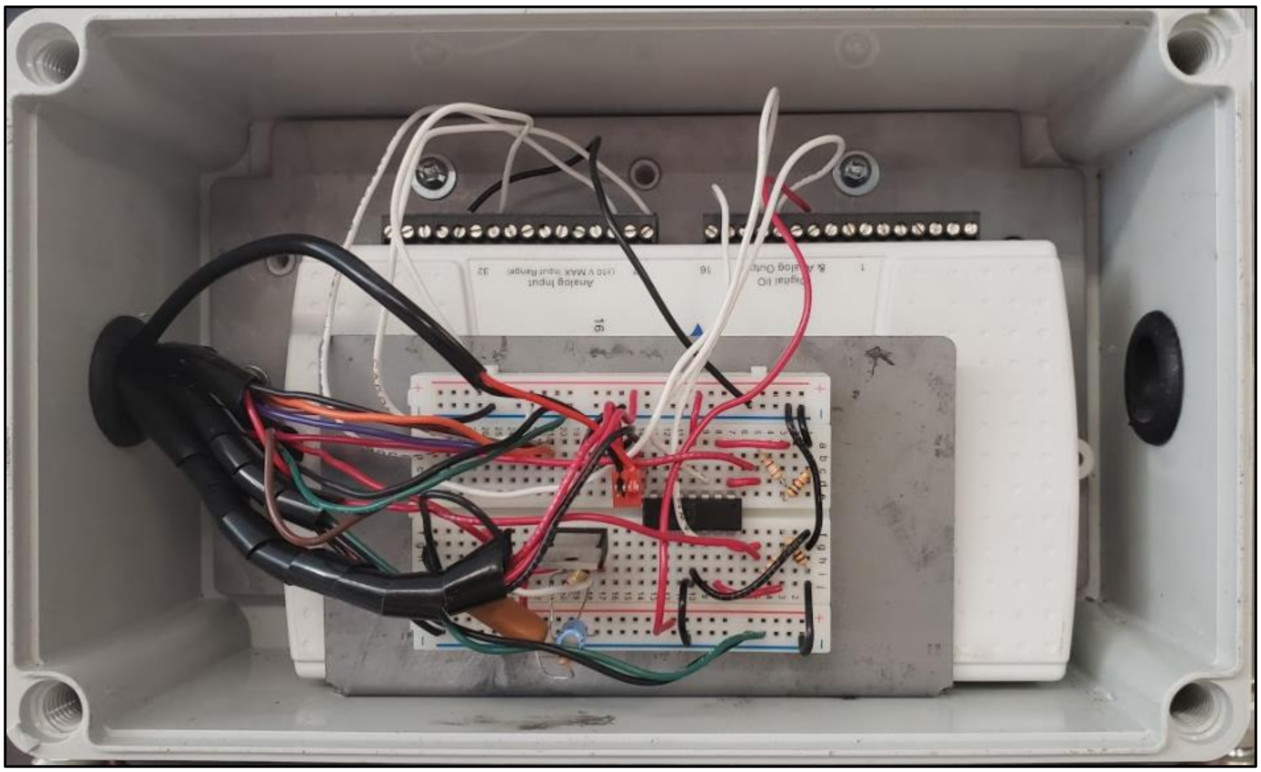


Figure 4.12 - Electrical Wiring & DAQ

4.7.1 DAQ – USB 6211

In order to output signals to control the pressure transducers and to receive data from the sensors (accelerometer and potentiometer) the system required a component that could achieve this. For this instance, due to capabilities and availability, the design team implemented the USB-6211. The device has a number of analog inputs and four of them were used for the previously mentioned sensors (note: accelerometer is returning three signals, x, y and z). The USB is also outputting two signals to the two pressure transducers that control the pressure in the two pneumatic cylinders. The data acquisition device easily achieves the necessities of the Skateboard Truck Testing Device.

4.7.2 Pressure Transducers – ControlAir 550x

As mentioned previously the USB is outputting two signals to the pressure transducers used to control the pressure in the pneumatic cylinders. The chosen pressure transducers are from ControlAir and are the 550x. These pressure transducers operate in the range of 0-10 volts which cannot be achieved by the USB. In order to mitigate this problem, the design team implemented an op-amp circuit with the LM 324 (voltage regulator) as can be seen in Figure 4.14. The team opted to use 1.0 and 4.0 kilo-ohm resistors to achieve a gain of five and then limited the output of the USB to 2.0 Volts. By doing so, the range of voltages being inputted into the transducers are from 0-10 Volts perfectly matching the specs associated with the 550x. As mentioned in section 3.4.2, the output of the pressure transducers is 3-120 psi and this results in a sensitivity of 11.7 psi/volt.

4.7.3 Accelerometer – MMA7361LC

The accelerometer is being used as a means of determining the skateboard deck tilt, and in doing so requires three sets of data to be returned to the USB-6211. The x, y and z axes are being used to increase accuracy which is why three signals are being sent to the USB. In order to ensure the data is as clean as possible, it was important to ensure that there was a clean signal going into the accelerometer. To be able to do so the team implemented an adjustable voltage regulator circuit which is the circuitry associated with the LM 317 in Figure 4.14. By using this circuit and two different resistors (330 ohm and 240 ohm) the voltage was regulated to a clean 2.97 volts to ensure no fluctuations occur with the output signal as a result of a non-clean input signal.

4.7.4 Potentiometer – Vihay Model 357

The potentiometer is being used as a means of determining the angle of rotation the skateboard truck experiences as a result of the “skateboard deck” tilting. As a result, the potentiometer is required to send a signal back to the USB to be conditioned. The potentiometer also requires a clean voltage input to ensure that the output signal doesn’t experience any unnecessary variations. In order to do so, the same voltage regulator circuit that is being used for the accelerometer is being used for the potentiometer as seen in Figure 4.14. The voltage input is therefore the same 2.97 volts as mentioned in the previous section of the report.

4.7.5 Power and Emergency Stop

An additional item worth noting is how the team is ensuring the pressure transducers receive the required amount of power to operate within their specifications. As was mentioned earlier in section 4.7.1, section an op-amp was required for the pressure transducers, but the additional power source used in that circuit is that of a 12 volt power supply that plugs into a wall outlet. This provides the system with ample power.

Finally, an e-stop was incorporated in line with the power supply to ensure safety precautions are taken in the event of the device causing harm to someone or operating in an unsafe manner. This is a requirement due to the forces being applied from the pneumatic cylinders.

4.7.6 Electrical Enclosure

As mentioned in section 2.4 of this document, having all of the electrical wiring go directly into the DAQ system is not the most ideal method in terms of organization but, an alternative is to use a breadboard. This mean that extra components that may increase clutter have to be implemented. Unnecessary clutter not only serves as a safety hazard to the user, but also makes the device look unfinished as well as unorganized.

The method with which the project group have decided on resolving this issue is by using an electrical box, which is shown below in Figure 4.13. This electrical box would help contain both the DAQ and the breadboard. Also, spiral cable wrap that was implemented also increased organization and could fit directly into the electrical box, avoiding any electrical cable from being exposed.

Figure 4.13 - Electrical Enclosure [17]

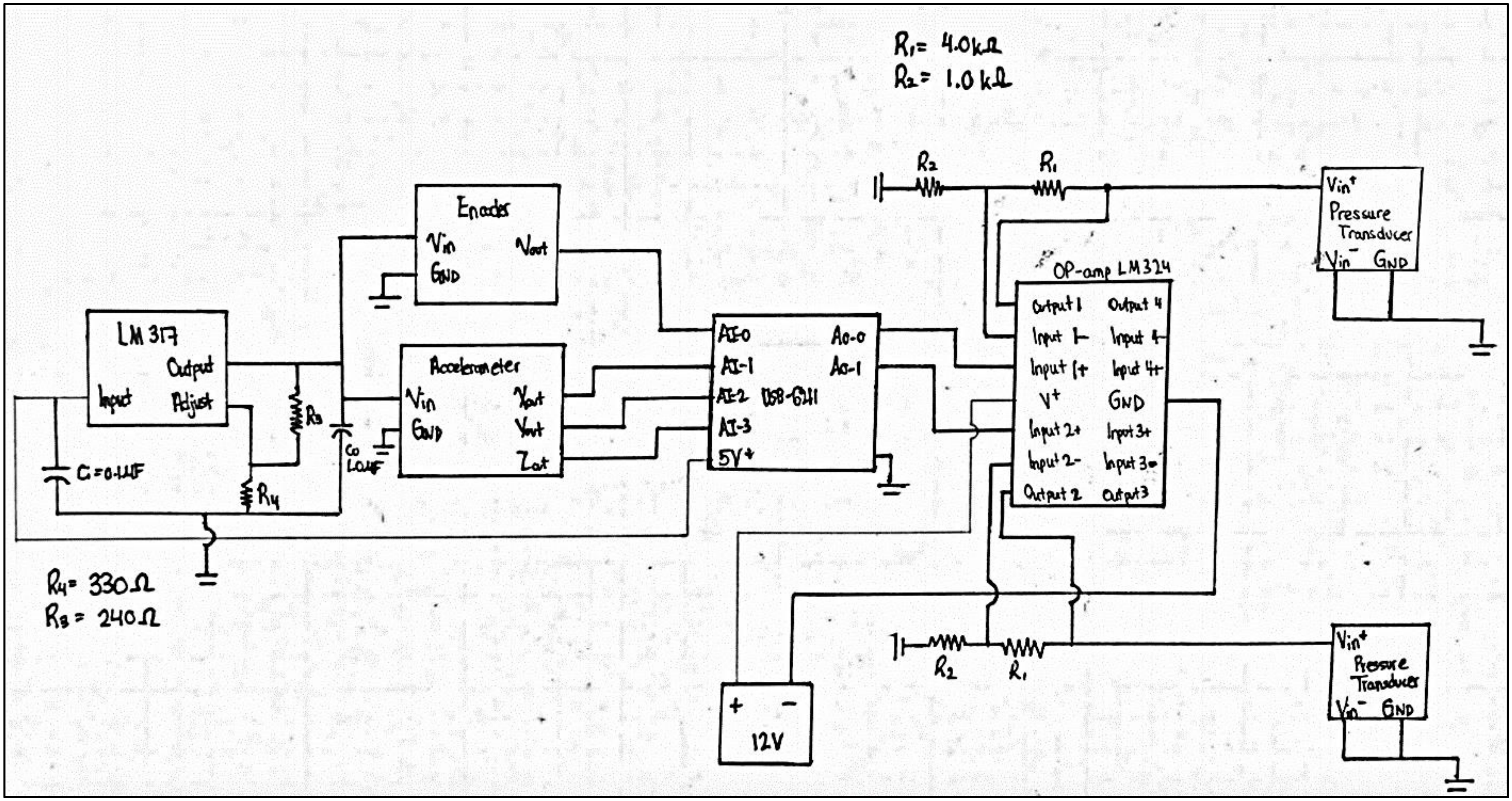


Figure 4.14 - Electrical Block Diagram

4.8 Pneumatic System

In order to apply force to the skateboard truck it was determined that pneumatic cylinders was a viable solution based on:

- Required force
- Angle of force
- Simplicity of implementation

The pneumatics is laid out in Figure 4.15, which consists of a manifold to simplify the circuit, two pressure regulators, two pneumatic cylinders and three pressure gauges used to verify results.

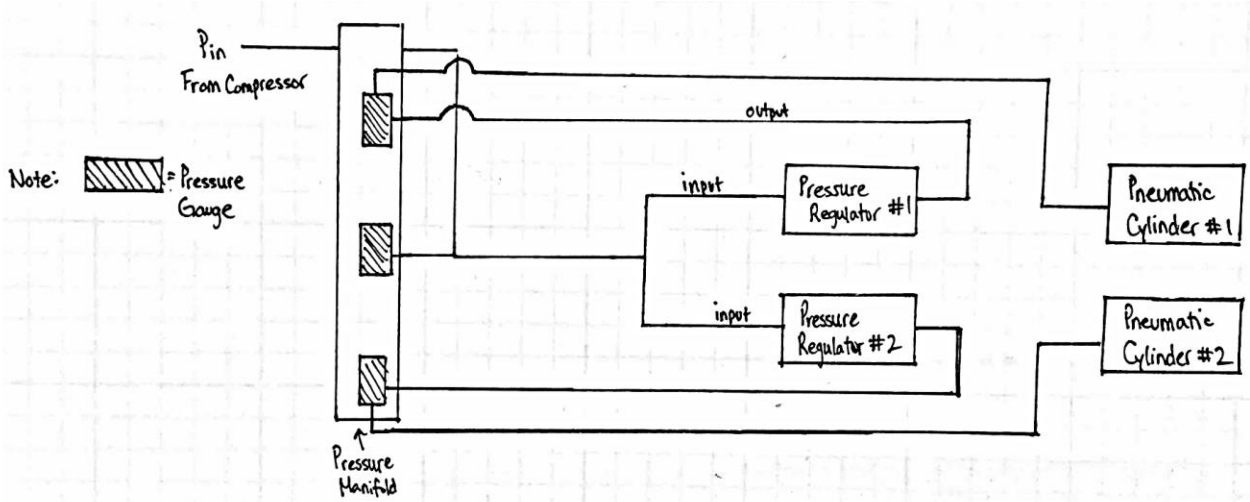


Figure 4.15 - Pneumatic Block Diagram

The two pressure regulators can control pressures between 3 – 120 psi which allows for sufficient force to be applied to the skateboard truck (recall the 1.6567 factor used to convert pressure to force).

The manifold was important to deal with clutter associated with the number of pneumatic lines being used in the system, as well as providing a well defined location to place the pressure gauges.

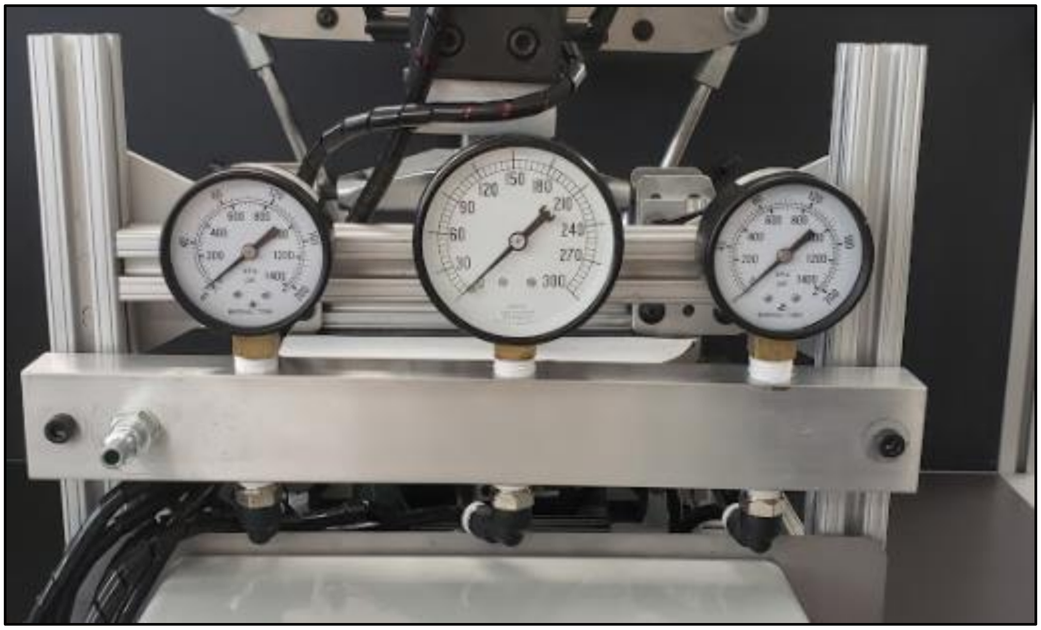


Figure 4.16 - Pressure Gauges at Back of Device

Overall the pneumatics are now more elegant and organized, including a well defined location for the pressure gauges that allow for user ease of use.

4.9 MATLAB Code

4.9.1 User Input

In order to generate a report of the results (following the testing of a skateboard truck configuration using the device), the team implemented code at the beginning to allow the user to input the information regarding the set up. The information to be inputted is as follows:

- Truck Brand
- Date
- Test Number
- Truck Model
- Truck Width
- Bushing Hardness
- Riser Pad Angle
- Notes

The code can be seen below:

```
%--------------------------------------------%
%               User Input                   %
%--------------------------------------------%
% The user input is used to provide information about the truck set up in
% the printed report
prompt = {'Enter Truck Brand:','Enter Date (dd-mm-yy):', 'Enter Test
Number','Enter Truck Model:','Enter Truck Width (in):','Enter Bushing
Hardness:','Enter Riser Angle (deg):','Notes:'};
name = 'Truck Configuration Info.';
dims = [1 50];
questions = ["\bfTruck Brand:           \rm";"\bfDate(dd-mm-yy):
\rm";"\bfTest Number:          \rm";"\bfTruck Model:           \rm";"\bfTruck
Width (in):     \rm";"\bfBushing Hardness: \rm";"\bfRiser Angle (deg.):
\rm";"\bfNotes:                       \rm"];
input = string(inputdlg(prompt,name,dims));
str = questions + input;
dash = '-'; % Dash for strings
A = 'A'; % Force vs Deck Tilt
B = 'B'; % Force vs Truck Turn
C = 'C'; % Truck Turn vs Deck Tilt
D = 'tilt';
E = 'Rotation';
F = 'Force';
dat = '.dat';
fileName1 = input(2)+ dash + input(3) + dash + A;
fileName2 = input(2)+ dash + input(3) + dash + B;
fileName3 = input(2)+ dash + input(3) + dash + C;
dataName1 = input(1)+ dash + input(2) + dash + D + dat;
dataName2 = input(1)+ dash + input(2) + dash + E + dat;
dataName3 = input(1)+ dash + input(2) + dash + F + dat;
```

The above code opens a dialog box where the user can input all of the required data, the information is then stored as strings and is later displayed on the resulting three plots. This section of the code also executes the set up to save the plots along with the data in separate files named from the input date and test number.

4.9.2 Setup

This section of the code includes all of the variables required to run the code and perform calculations such as sensitivities and gains for each measurement or electronic device, the maximum voltage or pressure to be used and the total number of data points to be collected at each step. The code can be seen below:

```
%--------------------------------------------------------------------%
%                               Setup                                %
%--------------------------------------------------------------------%
%****************Calculate op-amp gain from circuit*****************
R2 = 1; %k-ohm
R1 = 4; %k-ohm
OpAmpGain = (R1+R2)/R2;

%*****************************Constants******************************
maxVOutput = 10.0;                          %Max V output of USB; NOTE: CANNOT
EXCEED 10
maxAllowableP = 75;                         %Max P to use in test (Changes
depending on bushing hardness to obtain full range of motion)
minPOutput = 3.0;                           %Min P through transducer
maxPOutput = 120.0;                         %Max P through transducer
maxPperV = (maxPOutput-minPOutput)/maxVOutput * OpAmpGain; %Pressure/Volt
g = 9.81;                                   %Gravity
pi = 3.14159265359;                         %PI
pRegConstant = (maxVOutput/(maxPOutput-minPOutput))/OpAmpGain; % Volt/psi
input V to P transducer/output P of transducer
dataPoints = 1000;                         %Number of data points to collect
areaFactor = pi/4*(1.5^2 - (3/8)^2);       %Used for cylinders
radtoDegrees = 180/pi;                     %Rads to Degrees Conversion
initializeP = 60;                          %psi used to represent initial rider
weight

%Sensor Calibration Factors (From testing)
vChange = 2.63-1.9045;              %90 degree V change
degTravelled = 90;                  %Distance pot travels in test
potRadFactor = 2/9;                 %Convert angle from pot to angle of
skateboard truck
potGain = (degTravelled/vChange)*potRadFactor; % degrees/volt

% Accelerometer Sensitivity x, y, z-axis'
accelSensX = 0.721;
accelSensY = 0.727;
```

```
accelSensZ = 0.709;

%Convert Parameters to Voltages for testing
adjustedMaxVOutput = maxVOutput/OpAmpGain*(maxAllowableP/maxPOutput);
minVOutput = (pRegConstant * 15);                %15psi is always minimum
allowable P in a cylinder
riderWeightVoltageOutput = (pRegConstant * initializeP); %rider weight for
the cylinders

%Test Parameters; Adjustment changes test duration
pauseTime = 4.5;             %Pause time between steps
steps = 20;                  %Number of steps/change period
datapoints = 6*steps;        %Total data points
potValue = zeros(datapoints); %Zeroing data
datastep = 0;                %Used for incrementing
```

The key variable that needs to be discussed in order to both provide an understanding of how the code functions and because it’s a variable that may require adjusting for each test is *maxAllowableP*. This is the maximum allowable pressure to be sent through the transducers and into the cylinders. It will be adjusted for each test depending on the truck configuration but will mostly be dependent on the hardness of the bushings. Harder bushings will require a higher pressure whereas softer bushings will require a lower maximum pressure to obtain the full range of motion of the truck. Too much pressure coupled with soft bushing will cause the cylinders to fully retract causing the data to unrepresentative of the true range of motion of the truck.

4.9.3 Initialization

In order to utilize the data acquisition device (USB 6211) to both collect data and send output signals. This section of the code can be seen below:

```
%----------------------------------------------------------%
%                    Initialize the DAQ                    %
%----------------------------------------------------------%
daq.reset
devices = daq.getDevices;
s = daq.createSession('ni');

%******Inputs: potentiometer, accelerometer, 2 load cells****
ch1 = addAnalogInputChannel(s,'Dev1',0,'Voltage'); % Potentiometer
ch2 = addAnalogInputChannel(s,'Dev1',1,'Voltage'); % Accelerometer (x-axis)
ch3 = addAnalogInputChannel(s,'Dev1',2,'Voltage'); % Accelerometer (z-axis)
ch6 = addAnalogInputChannel(s,'Dev1',5,'Voltage'); % Accelerometer (y-axis)
```

```
ch1.TerminalConfig = 'SingleEnded'; % without this, the signal is default as
differential
ch2.TerminalConfig = 'SingleEnded'; % without this, the signal is default as
differential
ch3.TerminalConfig = 'SingleEnded'; % without this, the signal is default as
differential
ch6.TerminalConfig = 'SingleEnded'; % without this, the signal is default as
differential

%***********Outputs: 2 pressure regulators*****************
addAnalogOutputChannel(s,'Dev1',0,'Voltage'); % Pressure Regulator 1
addAnalogOutputChannel(s,'Dev1',1,'Voltage'); % Pressure Regulator 2
```

This section of the code performs the following functions:

- Initializes the input and output channels to be used
- Sets the signal as single ended since it is defaulted as differential for the DAQ

The input channels are used to collect data from the potentiometer and the three axes of the accelerometer. The output channels are used to send signals to the pressure transducers.

4.9.4 Collecting Offset/Zeroing Data

This section of the code collects data required to zero the measurement devices by simulating a rider standing on the board. The code can be seen below:

```
%----------------------------------------------------------%
%                      Offset / Zero                       %
%----------------------------------------------------------%
s.Rate = 5000; % Sampling Rate

%********** Process to Levelize the Test Device ************
zeroingOutputSignal = linspace(0, riderWeightVoltageOutput, steps);

duration = s.DurationInSeconds;
outputSingleScan(s, [0 0])

%Loop Slowly Pressurizes Both Cylinders Evenly
for j=1:steps
    zeroOutputSignal = linspace(zeroingOutputSignal(j),
zeroingOutputSignal(j),dataPoints);
    zeroOutputSignal = zeroOutputSignal';
    queueOutputData(s, [zeroOutputSignal zeroOutputSignal]);
    duration = s.DurationInSeconds;
    Pvalue = zeroingOutputSignal(j) * maxPperV
    pause(pauseTime);
    offset_data = s.startForeground;
```

```
end

%Using Actual Values to determine Offset
potOffset = mean(offset_data(:,1));
accelOffsetX = mean(offset_data(:,2));
accelOffsetY = mean(offset_data(:,4));
accelOffsetZ = mean(offset_data(:,3));
```

After setting the sampling rate of the DAQ, the code is set up to gradually send identical pressure values to both cylinders at the same time in order to both simulate a rider standing on the skateboard while also attempting to level the device. Once this part of the code is executed, data is collected from the potentiometer and accelerometer in order to zero both devices. This is done by taking the mean of each individual data set to obtain one singular value that can be used in a later section of the code to calculate the required results.

4.9.5 Setup for Pressure Transducer Output Signals

This section of the code is used to set up the array of signals to be outputted to each pressure transducer, and in turn each cylinder. The code can be seen below:

```
%-------------------------------------------------------------------%
%         Signal to control pressure's in cylinder A and B          %
%-------------------------------------------------------------------%
OutputSignal1A = linspace(riderWeightVoltageOutput,adjustedMaxVOutput,steps);
OutputSignal1B = linspace(riderWeightVoltageOutput,minVOutput,steps);

OutputSignal2A = linspace(adjustedMaxVOutput,riderWeightVoltageOutput,steps);
OutputSignal2B = linspace(minVOutput,riderWeightVoltageOutput,steps);

OutputSignal3A = linspace(riderWeightVoltageOutput,minVOutput,steps);
OutputSignal3B = linspace(riderWeightVoltageOutput,adjustedMaxVOutput,steps);

OutputSignal4A = linspace(minVOutput,riderWeightVoltageOutput,steps);
OutputSignal4B = linspace(adjustedMaxVOutput,riderWeightVoltageOutput,steps);

OutputSignal5A = linspace(riderWeightVoltageOutput,adjustedMaxVOutput,steps);
OutputSignal5B = linspace(riderWeightVoltageOutput,minVOutput,steps);

OutputSignal6A = linspace(adjustedMaxVOutput,riderWeightVoltageOutput,steps);
OutputSignal6B = linspace(minVOutput,riderWeightVoltageOutput,steps);

OutputSignalA = [OutputSignal1A, OutputSignal2A, OutputSignal3A,
OutputSignal4A, OutputSignal5A, OutputSignal6A];
```

```
OutputSignalB = [OutputSignal1B, OutputSignal2B, OutputSignal3B,
OutputSignal4B, OutputSignal5B, OutputSignal6B];
```

The above code uses the minimum and maximum pressures to be sent and divides them evenly depending on the number of steps required for the testing procedure. This code determines the pressures that each cylinder will experience at any given time. As it is set up, the cylinders will both start at a pressure that simulates the rider weight and then both cylinders will either further pressurize or depressurize depending on whether the truck is to be turned clockwise or counter clockwise. The procedure is as follows:

1. Pressurize cylinder A & depressurize cylinder B for a full range of motion on one side
2. Depressurize cylinder A and pressurize cylinder B to return cylinders back to zero position
3. Repeat step 1 with opposite cylinders
4. Return cylinders back to zero
5. Repeat steps 1 and 2

Step five is executed in order to fill in the gaps that are present in the results if step five isn't performed in order to represent a full range of motion.

4.9.6 Deck Tilt Procedure

This section of the code is used to both execute the procedure from the previous section (3.8.5) by outputting the signals to the pressure transduce and to collect data from the measurement devices. The code can be seen below:

```
%-----------------------------------------------------------------%
%                  Tilting of the deck procedure                  %
%-----------------------------------------------------------------%
for j=1:datapoints

    outputSignal1 = linspace(OutputSignalA(j), OutputSignalA(j), dataPoints);
    outputSignal2 = linspace(OutputSignalB(j), OutputSignalB(j), dataPoints);
    outputSignal1 = outputSignal1';         %Transpose output into column
    outputSignal2 = outputSignal2';         %Transpose output into column
    queueOutputData(s, [outputSignal1 outputSignal2]);
    duration = s.DurationInSeconds;
    pause(pauseTime)

    data = s.startForeground;
```

```
    %Print out pressure values being sent to compare with actual
    pressureValue1 = OutputSignalA(j)/pRegConstant
    pressureValue2 = OutputSignalB(j)/pRegConstant

    %Take each set of data and find the corresponding means
    potValue = mean(data(:,1));
    accValueX = mean(data(:,2));
    accValueY = mean(data(:,4));
    accValueZ = mean(data(:,3));

    %Place each set of mean data into an array
    potData(j) = potValue;
    accDataX(j) = accValueX;
    accDataY(j) = accValueY;
    accDataZ(j) = accValueZ;
    pressureData1(j) = pressureValue1;
    pressureData2(j) = pressureValue2;

end
```

This process is performed in a "for loop" so that for each step, or cylinder configuration depending on the pressures, data can be collected from each measurement device. The collected data is then averaged to obtain a singular value for each step.

4.9.7 Deck Tilt Procedure

This section of the code conditions and converts the collected data from the previous sections to useful values. The code can be seen below:

```
%--------------------------------------------------------------%
%          Condition the data with gains and offsets            %
%--------------------------------------------------------------%
%**************** Apply Sensor Offsets *****************

Ax = (accDataX - accelOffsetX)./accelSensX;
Ay = (accDataY - accelOffsetY)./accelSensY;
Az = ((accelSensZ + accelOffsetZ)-accDataZ)./accelSensZ;

potData = potOffset - potData;

%*******************Apply Gain*************************

truckRotAngle = potData*potGain;

%******* Apply Accelerometer to Angle Conversion *********
```

```
num = Ax;                    %Equation Numerator
denom = sqrt(Ay.^2 + Az.^2); %Equation Denominator

for j=1:datapoints
    decktilt(j) = atan(num(j)/denom(j));       %Deck tilt calculation
    decktilt(j) = decktilt(j) * radtoDegrees; %Convert to degrees
end

%*********** Apply Pressure to Force Conversion *********
force1 = pressureData1*areaFactor;
force2 = pressureData2*areaFactor;
forceDiff = force1 - force2;
```

Firstly, the offsets are applied to the measurement devices along with sensitivities to the accelerometers to convert the data to accelerations. Next, both sets of data are converted to degrees to present the deck tilt angle (from the accelerometer data) and truck turn angle (from the potentiometer data) by using the related transfer functions. Next, the forces in each cylinder are calculated to be used to find the force difference between the cylinders.

410 Testing Procedures

Tests on the components used on skateboard truck test device had to be performed to ensure that the components and the device as a whole were working as expected. The four main components to be optimized and tested once implemented are: pressure transducers, cylinder stroke, accelerometer and potentiometer.

4.10.1 Pressure Transducers

As mentioned in chapter two, the pressure transducers were not being used within their optimal input requirements while also having calibration issues. To be able to test the calibration of the transducers, they had to be running within the required range of input pressures. The team implemented a compressor that met the air supply input requirements so that the team could run the device at its required specifications and run the required tests accurately.

To test the calibration of the pressure transducers the design team ran the code that was created and examined in chapter 4.9. In doing so, the design team could compare the results that were expected to be output from the transducer to the actual pressures being outputted.

The team then decided that it would be best to use pressure gauges as a means of reading the pressures coming out of the pressure transducers. Although this test proved to be slightly lacking due to the pressure gauges not being as precise as the pressure values sent from the code, the gauges provided enough precision and accuracy for an inexpensive, quick and easy-to-run test that would provide fairly accurate calibration.

Next, the team adjusted the zero and span settings of each transducer separately by running the tests iteratively, sometimes with different pressure values, to ensure the full and accurate calibration of each transducer. First the zero was adjusted for multiple tests and then the span was changed to provide minor adjustments.

This test was very important as there is no direct method of measuring the force or pressure that was implemented into the device. The project sponsor ensured that the transducers had a linear response if they run within their required input values.

4.10.2 Cylinder Stroke

The resting position of the cylinder stroke and the extension and retraction of the cylinders were tested. This test was performed to ensure that the top beam would rest at the center of the cylinder stroke length so that the team could take full advantage of the full stroke length of the cylinders. This was also done to minimize the chances of the cylinders either bottoming out or fully extending during testing procedures of trucks. This was because the team wanted the data collected to be limited by the movement of the truck; if the cylinder bottomed out or fully extended then some of the data collected would not only be inaccurate in terms of the movement of the truck but also unusable to compare differing truck set ups.

The test of the resting position of the cylinder stroke initially seemed to be fairly simple but proved to be challenging in practise due to the complexity of the device. It involved adjusting not only the angle of the cylinders but also the height of the beam that the top beam is attached to (A) and height adjust of the truck mount (B) (see Figure 4.17 below) while also trying keep the top beam level. The test was simple: measure the stroke length of each cylinder after either a height or angle adjustment until the cylinders were at middle of their stroke length. It was important to keep in mind that although the angle of the cylinders were not fixed, it should not be adjusted by more than a few degrees to maintain a reasonable amount of motion of the truck during truck testing to obtain satisfactory results.

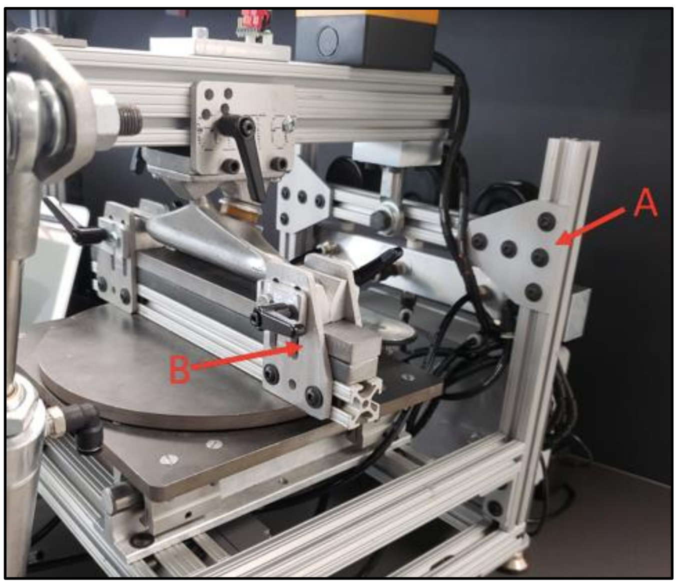


Figure 4.17 - Height Adjust Locations

Next, a test was done to limit the full extension and retraction of the cylinders. This was done by testing maximum pressures that could be sent to the cylinders before the maximum and minimum stroke was reached. The test was also fairly simple: generate code in MATLAB that would send increasing pressures until the cylinders either fully extended or retracted and then generate the same plots that would be generated during a standard truck test to see the response of the truck. These plots were Force vs. Deck Tilt and Force vs. Truck Turn. These plots were used because not only can the full extension/retraction be clearly seen but the team had to ensure that the truck was both tilting and rotating at a large enough angle to test the full motion of the truck. The pressure value that hit this limit was over 100 psi but the team initially decided that 100 psi would be set as the maximum pressure as it provided enough force on the truck for a large enough truck motion. However, after further consideration of how much force is applied on a truck in a realistic scenario, the maximum pressure was reduced to 60 psi.

4.10.3 Accelerometer

Due to the fact that the accelerometer is being used differently than how it was used by the previous design team, the accelerometer output had to be tested to see if it produced accurate measurements of angles due to the tilt of the deck.

The test performed to analyze the deck tilt angle was performed by running the team's standard truck test procedure and converting the output of the accelerometer to angles. These angles were then compared to the values read on an inclinometer that was placed on the same beam that the accelerometer is mounted to. The pressure values to cause tilt were sent one at a time with a breakpoints in the code so that two angle values, one from each device, could be compared. The test set up can be seen in Figure 4.18 below.

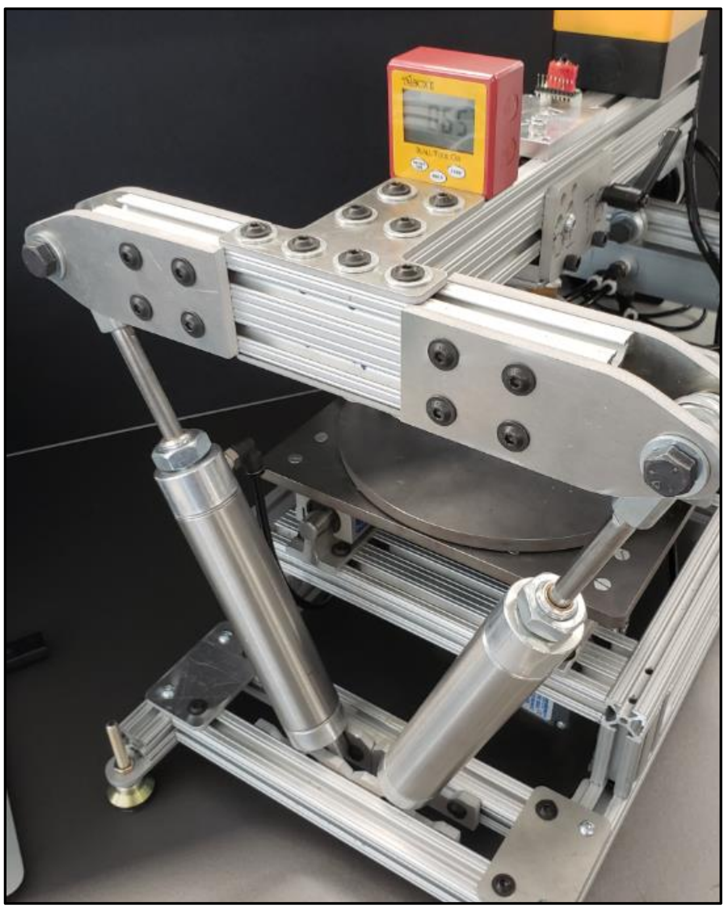


Figure 4.18 - Inclinometer for Calibration

The test proved to be successful as the new means of using the accelerometer provided an accurate and precise reading of the deck tilt angle when compared to an inclinometer.

4.10.4 Potentiometer

A test had to be performed on the potentiometer to determine whether the potentiometer output provided accurate measurements of the angles due to the rotation caused by the skateboard truck onto the turn table.

The test performed to analyze the truck turn angle was performed by, once again, running the team's standard truck test procedure and converting the output of the potentiometer to angles. These angles were then compared to the values read on a protractor that was fixed onto the turn table. The pressure values to cause turn were sent one at a time with a breakpoints in the code so that two angle values, one from the potentiometer and the other from the protractor could be compared. The test set up can be seen in Figure 4.19 below.

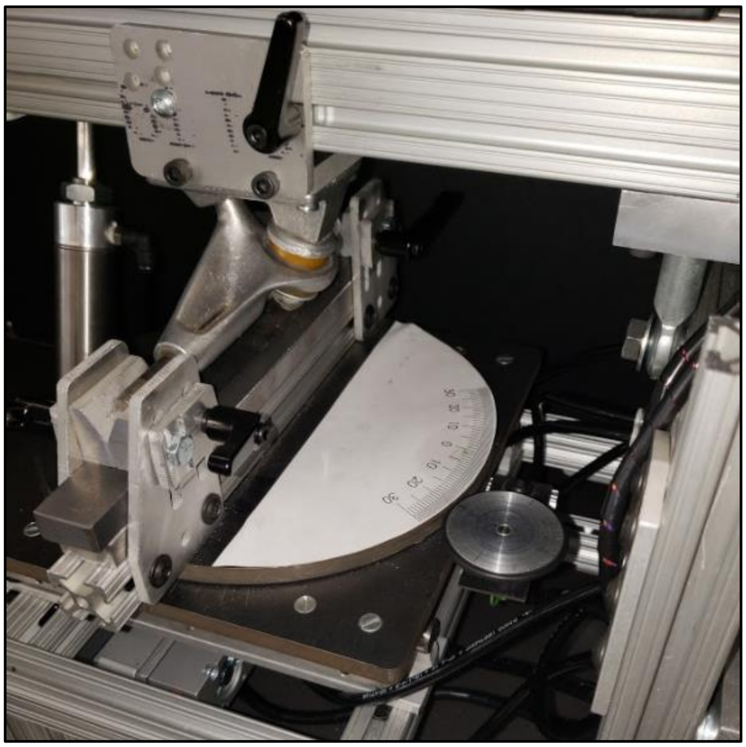


Figure 4.19 - Protractor for Calibration

The test proved to be successful as the potentiometer provided an accurate and precise reading of the deck tilt angle when compared to a scale.

Chapter 5. Discussion of Results

In this section of the report the design team will be examining the results from the Skateboard Truck Testing Device, and what changes effect the results.

5.1 Varying Bushing Hardness'

One of the main factors when it comes to determining how a skateboard truck responds is the hardness of the truck bushing as was discussed in section 3.1.3. Bushing hardness varies largely so the design team compared the effects of three different hardness' to understand the effect this has and additionally to gain quantitative results of varying bushings.

To ensure the only variable being examined is bushing hardness, the team performed the tests on the same skateboard truck (the Randal R-II), only changing the bushings in-between experiments. The results of this test can be seen below in Figure 5.1 or seen full scale in Appendix E.2.

Valuable information can be deduced from Figure 5.1, some of which was expected and some of which was slightly unexpected and must be examined further to fully understand the results,

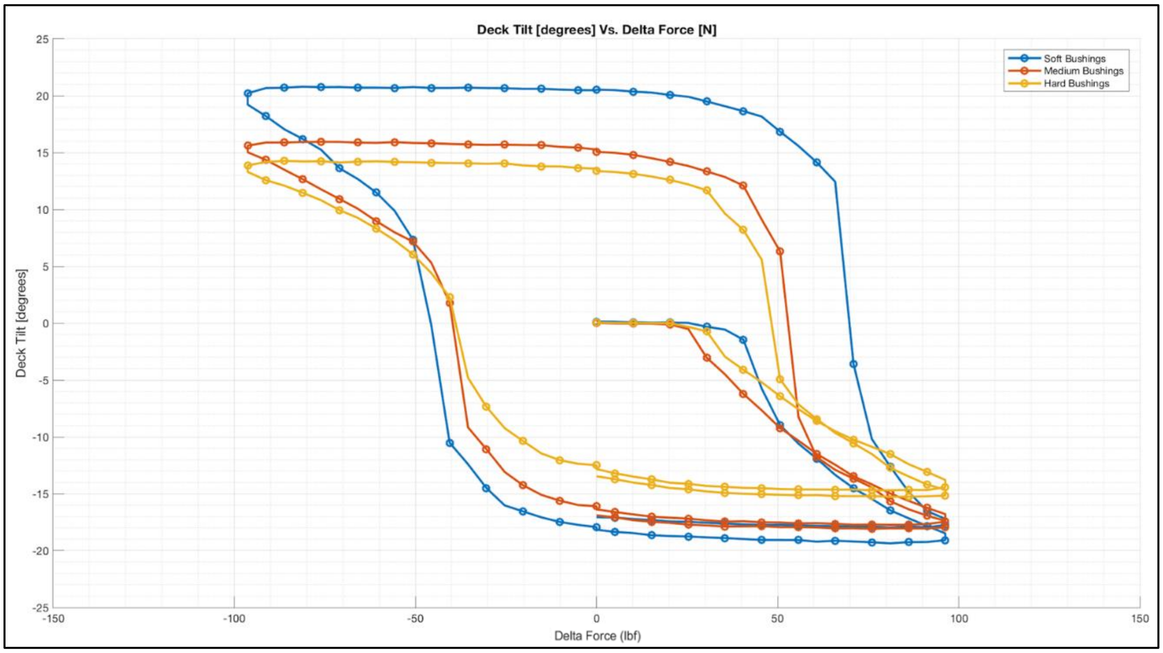


Figure 5.1 - Deck Tilt vs. Delta Force Test Results

which will be discussed shortly. In Table 5.1 below, the critical values from the graph are tabulated.

	Bushing Hardness		
	Soft	Medium	Hard
Max Deck Tilt (Direction 1) [deg]	14.18	15.94	20.76
Max Deck Tilt (Direction 2) [deg]	15.21	17.96	19.36
Minimum Delta Force to Begin Turn [N]	25.58	15.2	20.27

Table 5.1 - Test Results

The results indicated that the harder the bushings were, the less deck tilting response there was. This was expected since the harder bushings are more difficult to deflect, and while a skateboard is executing a turn the bushings are deforming due to the assembly of a skateboard truck.

The results which the team did not expect was the required delta force to begin a turn. In this case it would be expected that the softer bushings would begin movement soonest. The team believes these results occur because of how loose the softer bushings are in the middle range of a trucks movement. Therefore, the pneumatic cylinders must exert a certain amount of force, depending on the hardness of the bushing, before the skateboard trucks react.

Overall, this data provides a good starting point to show how different skateboard set-ups can be compared quantitatively. It becomes much simpler to see how a slight tweak to your skateboard truck system will impact the overall results.

The results from the skateboard truck test device provides a quantitative means to compare different skateboard trucks and different skateboard truck set-ups. This quantitative data allows for skateboard tilt, truck rotation and hysteresis to be visually examined and compared

5.2 Varying Baseplate Angle

Another key set-up parameter that skateboarders have control over is the angle to which they mount their skateboard truck relative to the skateboard deck. As mentioned in the theory section (chapter 3) of this report, skateboarders can place their skateboard trucks on varying angles which either result in requiring less skateboard tilt to achieve more truck turning angle or vice versa. A plot of the deck tilt vs. force and truck rotation vs. force can both be seen below in Figure 5.2, or can be seen full scale in Appendix E.1.

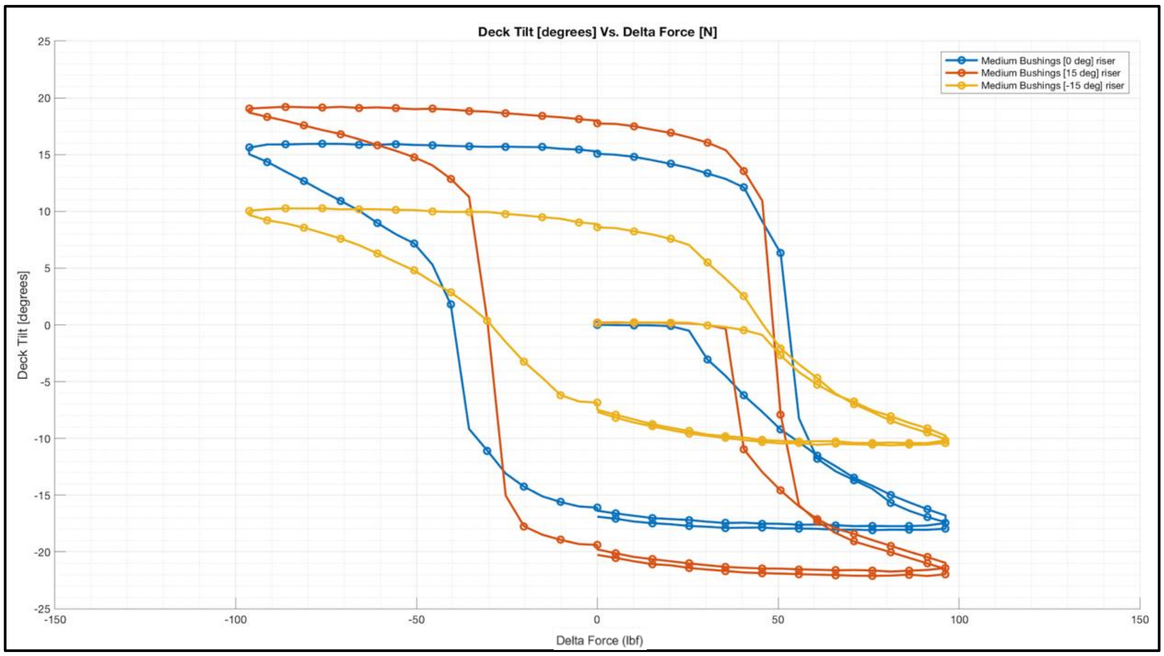


Figure 5.2 - Deck Tilt vs. Delta Force

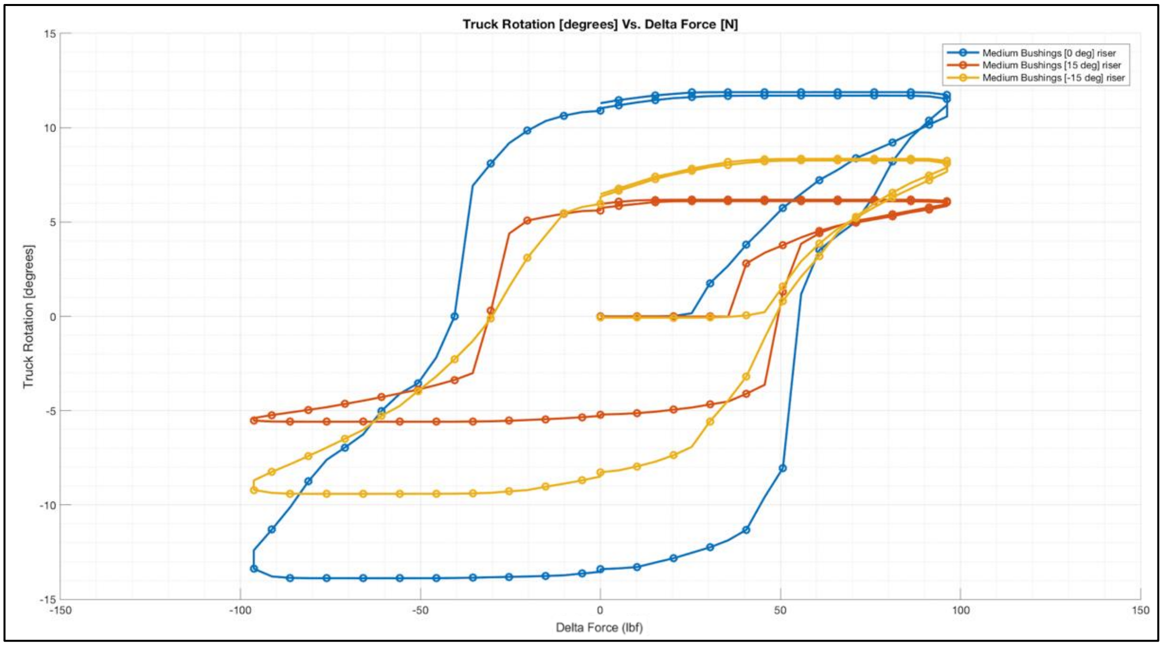


Figure 5.3 - Truck Rotation vs. Delta Force

The results obtained from the Skateboard Truck Testing Device agree with what the design team had expected, incorporating a riser plate resulted in either greater or diminished response in terms of deck tilt. This was dependent on which side the riser plate was applied to on the skateboard truck.

Additionally, the corresponding effects to the amount of skateboard truck rotation can be seen in Figure 5.3. Both of the skateboard truck set-ups experienced a diminished amount of truck rotation, but both for differing reasons.

The set-up identified as 15-degree riser experienced a decrease in truck rotation due to the adjustment of the trucks angle. This change in angle caused the relationship between the amount of deck tilt and resulting amount of truck rotation to differ.

Also, the set up identified as -15-degree riser was a result of the large decrease in the amount of deck tilt that was experienced. This set-up resulted in a stiffer response to the force being applied to the trucks.

In Figure 5.4 and 5.5 or in Appendix E for a full scale plot, the effect that adjusting the riser pad angle has on the relationship between deck tilt and truck rotation can be clearly seen.

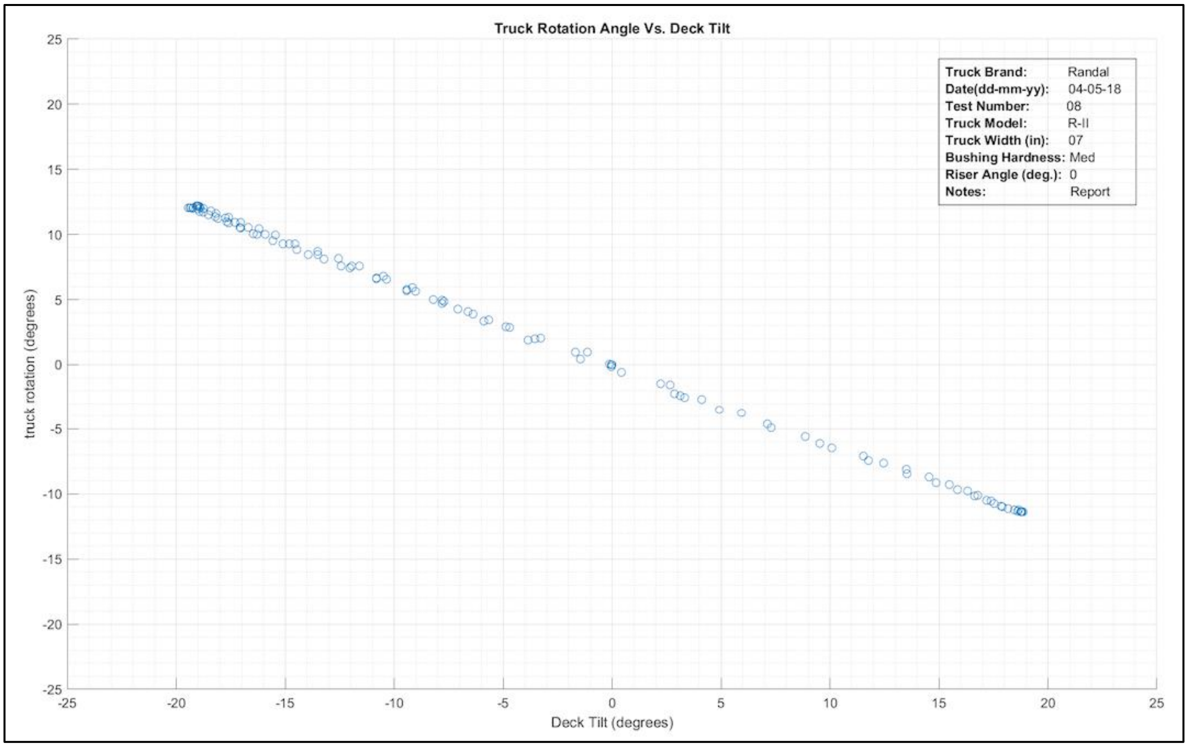


Figure 5.4 - Truck Rotation vs. Deck Tilt at 0 degrees

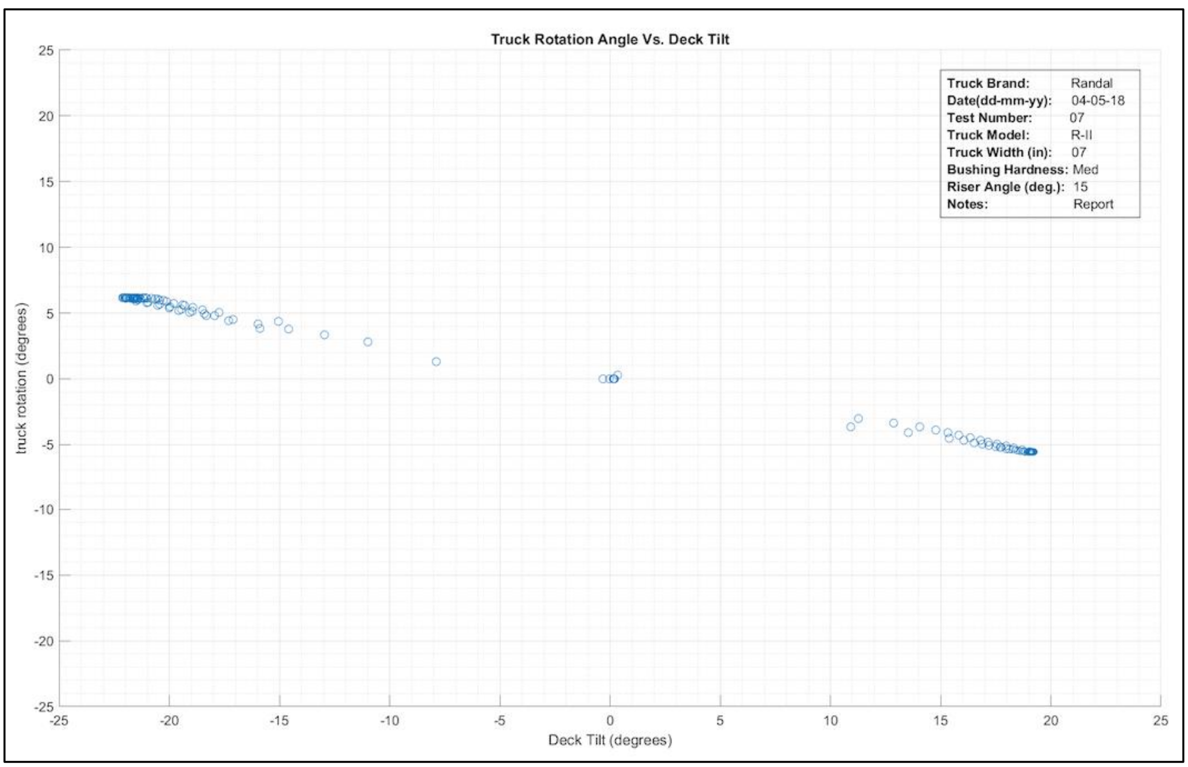


Figure 5.5 - Truck Rotation vs. Deck Tilt at 15 degrees

What can be identified is that there is a relationship between the angle the skateboard truck is placed in and the transfer function relating deck tilt and truck rotation. This result was expected since the angle that the truck is rotating about is what is causing the skateboard deck tilt to be converted into truck rotation.

This experiment identified that the implementation of a riser plate does have a large impact on the resulting response from different skateboard trucks that can clearly be identified from the Skateboard Truck Testing Device.

5.3 Hysteresis Experiment

The last experiment the design team executed on the device implemented some changing to how the device's code was being implemented. Rather than immediately applying the riders weight to the skateboard deck, the team decided to begin with zero pressure in the cylinders. This would allow for the cylinders to not be battling one another throughout the device's test. By doing this the team could determine the inherent hysteresis present within a specific skateboard truck which would allow for this comparison to be made between different trucks.

The results from this experiment can be seen in Figure 5.6 below or as a full scale plot in Appendix E.3.

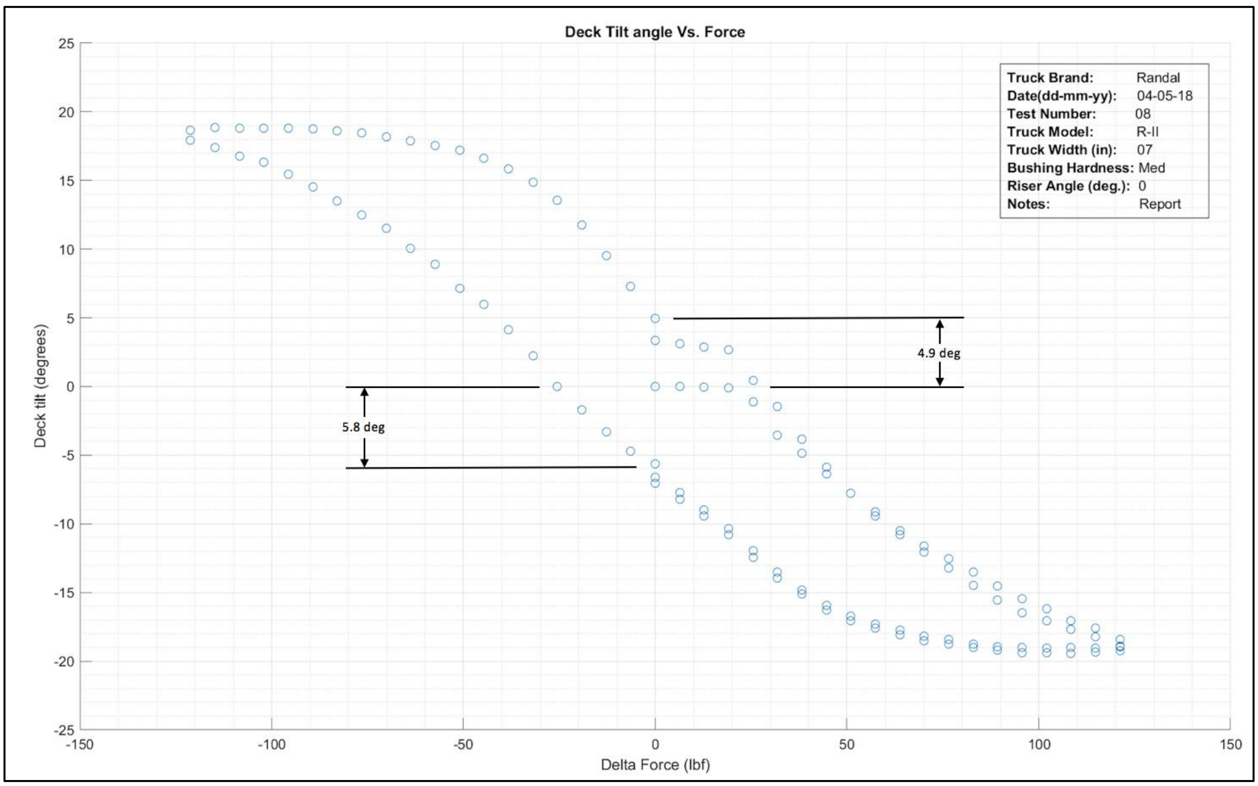


Figure 5.6 - Hysteresis Plot

As can be seen in Figure 5.6, the amount of hysteresis has a slight variation on either side. The two values being 4.9 and 5.8 degrees. This indicates the specific trucks (Randal) with its current configuration during the test has a delayed response in terms of getting the truck back into a neutral position. This is an interesting observation since one may expect the truck to go back to the neutral once forces are no longer applied to the skateboard truck.

This provides an additional characteristic that skateboarders can consider when configuring a skateboard deck. Although, this hysteresis effect is more difficult to understand qualitatively.

In terms of choosing a skateboard truck set-up, the design team concluded this information (hysteresis) is of less importance than the actual deck tilt and truck rotation responses to the applied forces.

Chapter 6. Conclusion

Skateboards have been used widely across the world by many for both leisure and transportation purposes. They can be highly customized to provide various responses and types of feel for the rider. However, this feel experienced by the rider has not yet been quantified until the completion of this project. The skateboard truck test device allows users to test the response of their specific truck configuration and obtain useful results that can be compared to other configurations.

The previous prototype was greatly improved both mechanically, electronically and pneumatically by using project management techniques along with concept generation and selection techniques for design. The device has been improved in the following ways:

- Pneumatic cylinder orientation
- Upper & lower cylinder mount
- Addition of riser pad angle plate
- Improved method of adjusting and leveling truck axle mounting
- Improved motion of top beam along with improved mounting assembly
- Reduced footprint for a more compact device
- Running pressure transducers at their required specifications along with calibration of transducers
- Improved data acquisition device and electrical circuitry placed within a compact electrical box
- Pneumatic manifold for an improved and cleaner pneumatic system
- More accurate calibration of measurement devices
- Improved code, test procedure and data acquisition process
- Cleaner and safer method of electrical and pneumatic wiring to relevant devices
- Safer device with the implementation of an emergency stop and stronger mounting of the frame

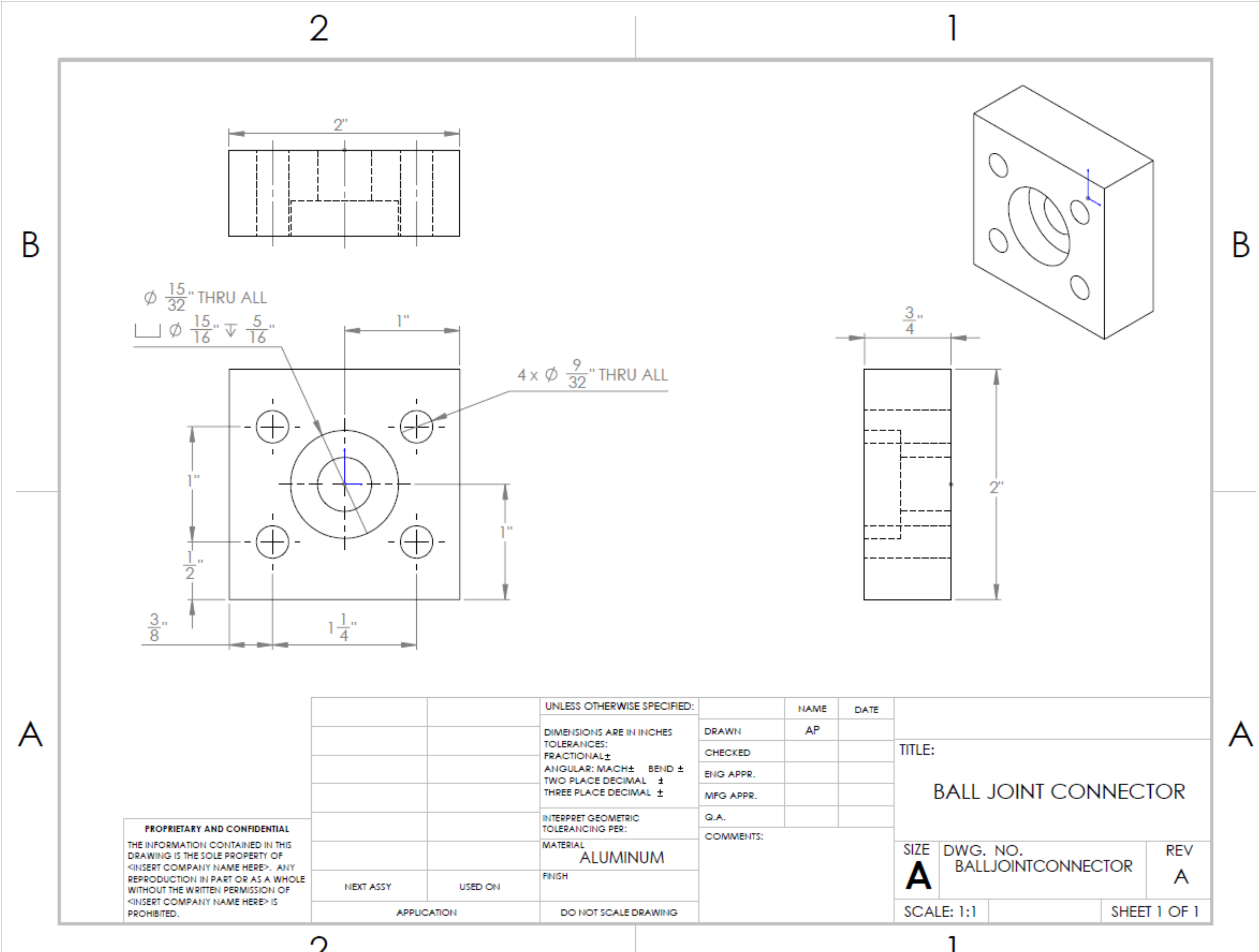
However, there are some issues that are still present in the device that were not eliminated. One of these issues is that the calibration of the pressure transducers is not perfect. This is due to the team trying to calibrate the devices by using the pressure gauges implemented, which are not as precise as the pressure values that are sent to the transducers. This is also due to both transducers responding at differing speeds and accuracies. This issue can be resolved by implementing either pressure sensors or load cells that could more directly measure pressure or force into the cylinders. Another way to resolve this issue would be to use pressure transducers that do not have errors when operating with lower pressures.

Another issue is that the procedure of changing trucks is not as easy or quick as the team would have preferred. A redesign of the components that the trucks need to be mounted onto may improve or completely mitigate this issue.

An issue that was realized after the implementation of a top beam that had a larger cross section and the redesigned mounting of the top beam using the ball joint was that depending on the truck used, the top beam can sway and produce translation motions that impact results from the tests. A revised method of simulating a more realistic motion of a skateboard deck should be considered to mitigate this issue so that the device can test all trucks rather than trucks that are used for longboards or downhill riding.

Overall the project was a success in the eyes of the team and the project sponsor. Majority of the upgrades that the project sponsor wanted were implemented into the device. The device was cost effective as it used many components that were already available and the team purchased components that were fairly inexpensive. Many components were also provided by the BCIT faculty. Plots of the results were generated, evaluated and were determined to be useful in quantifying the difference in feel noticed by riders when riding differing skateboard trucks.

APPENDIX A: SHOP DRAWINGS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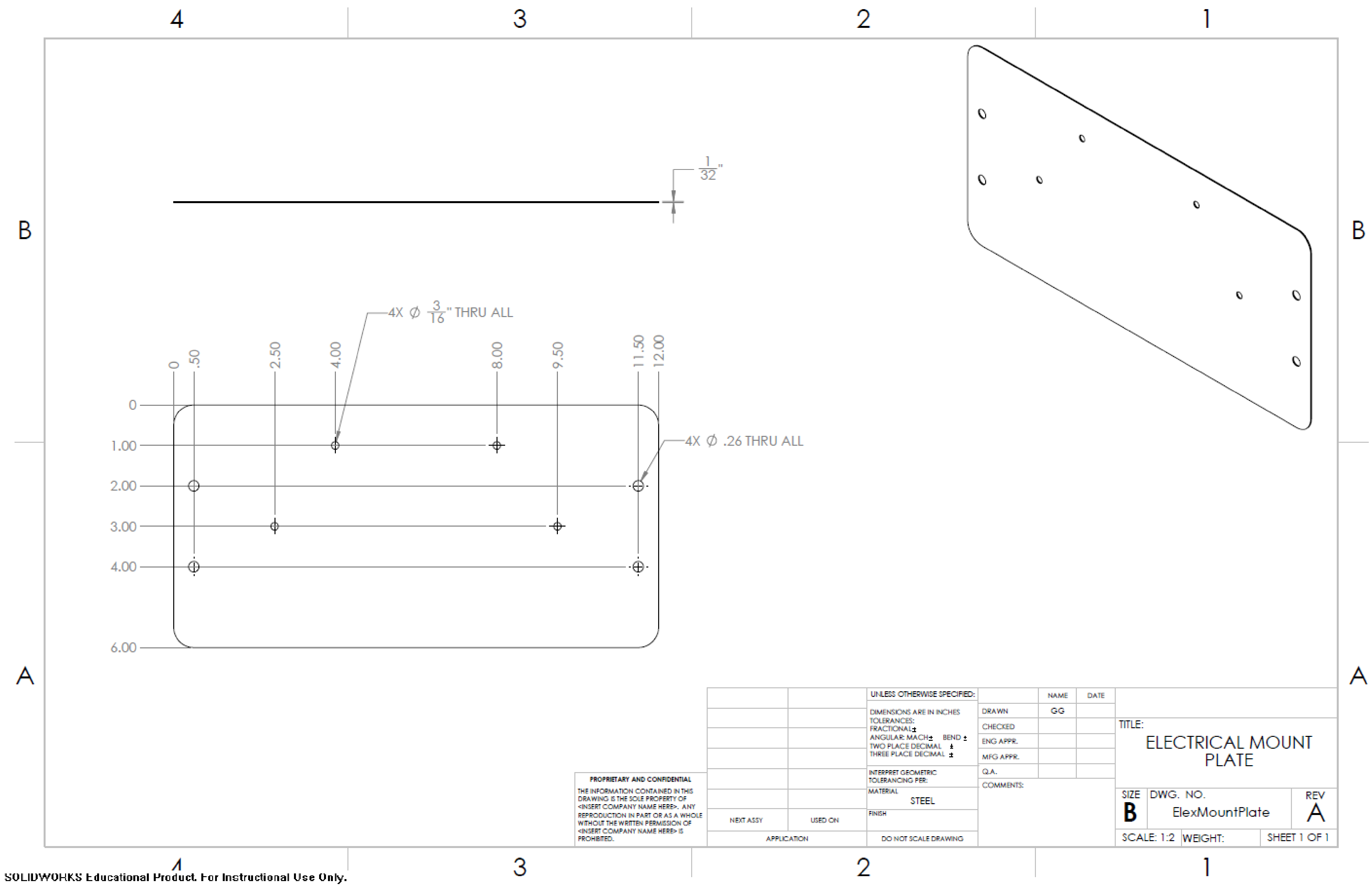
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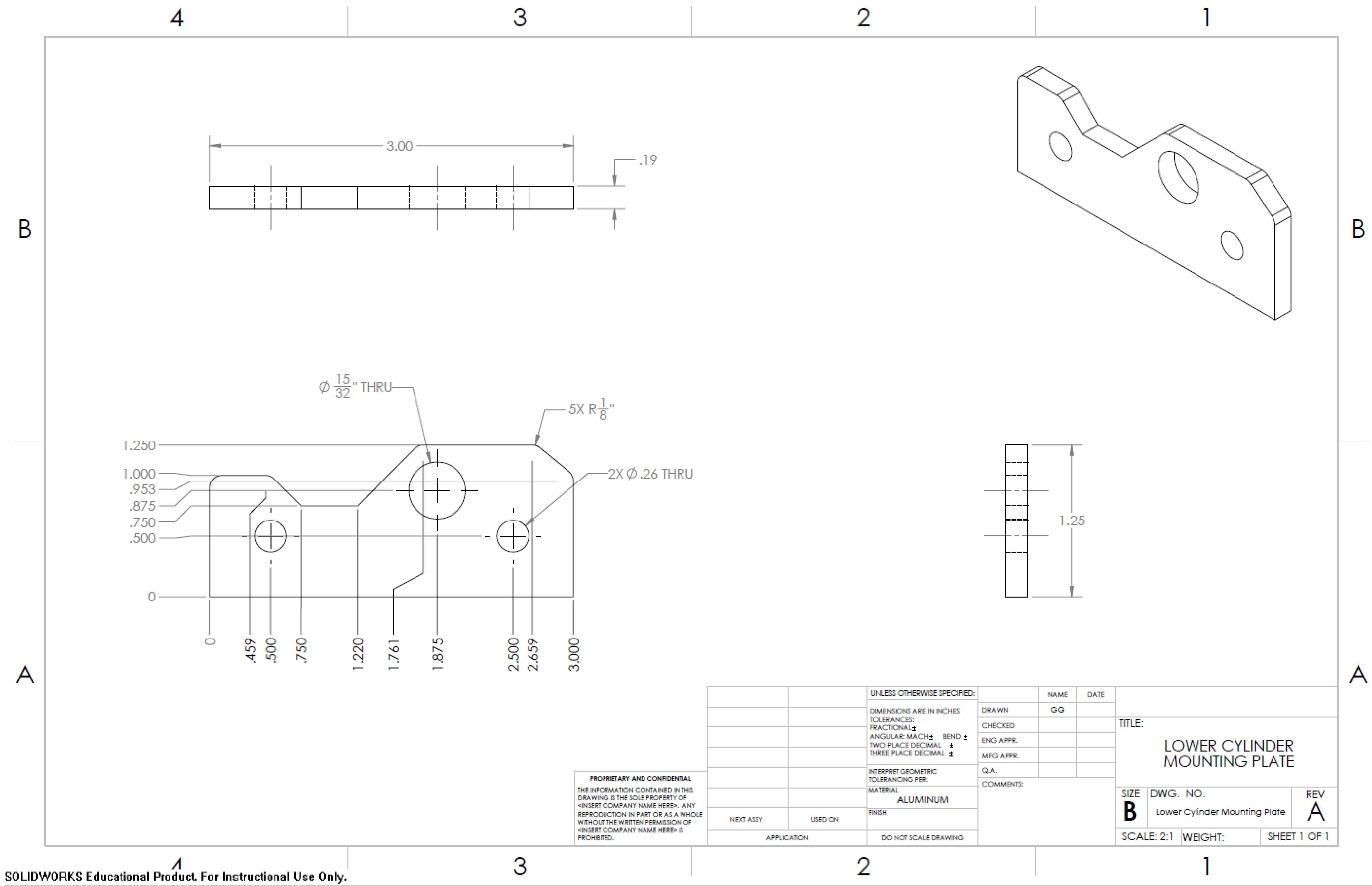

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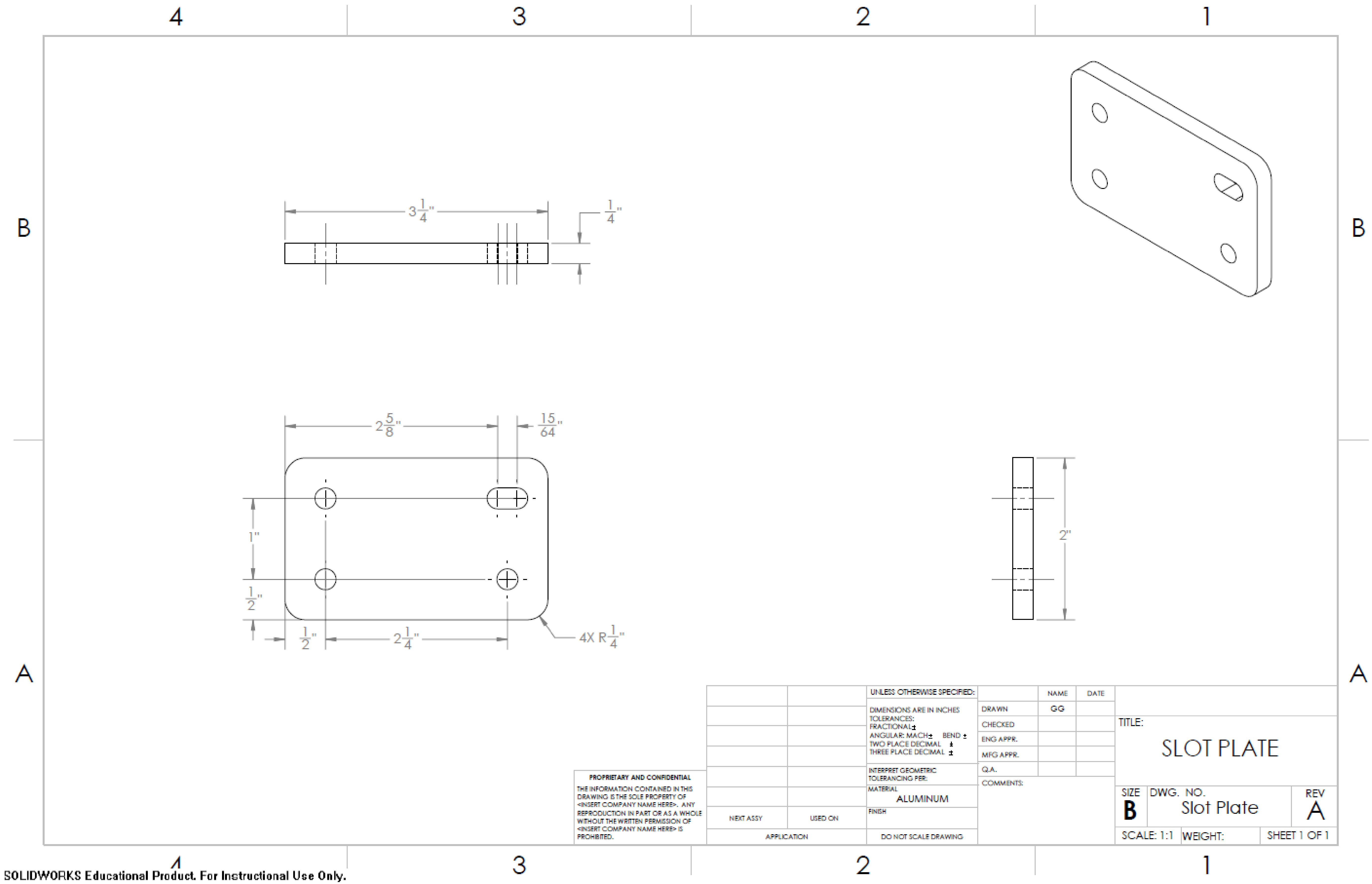
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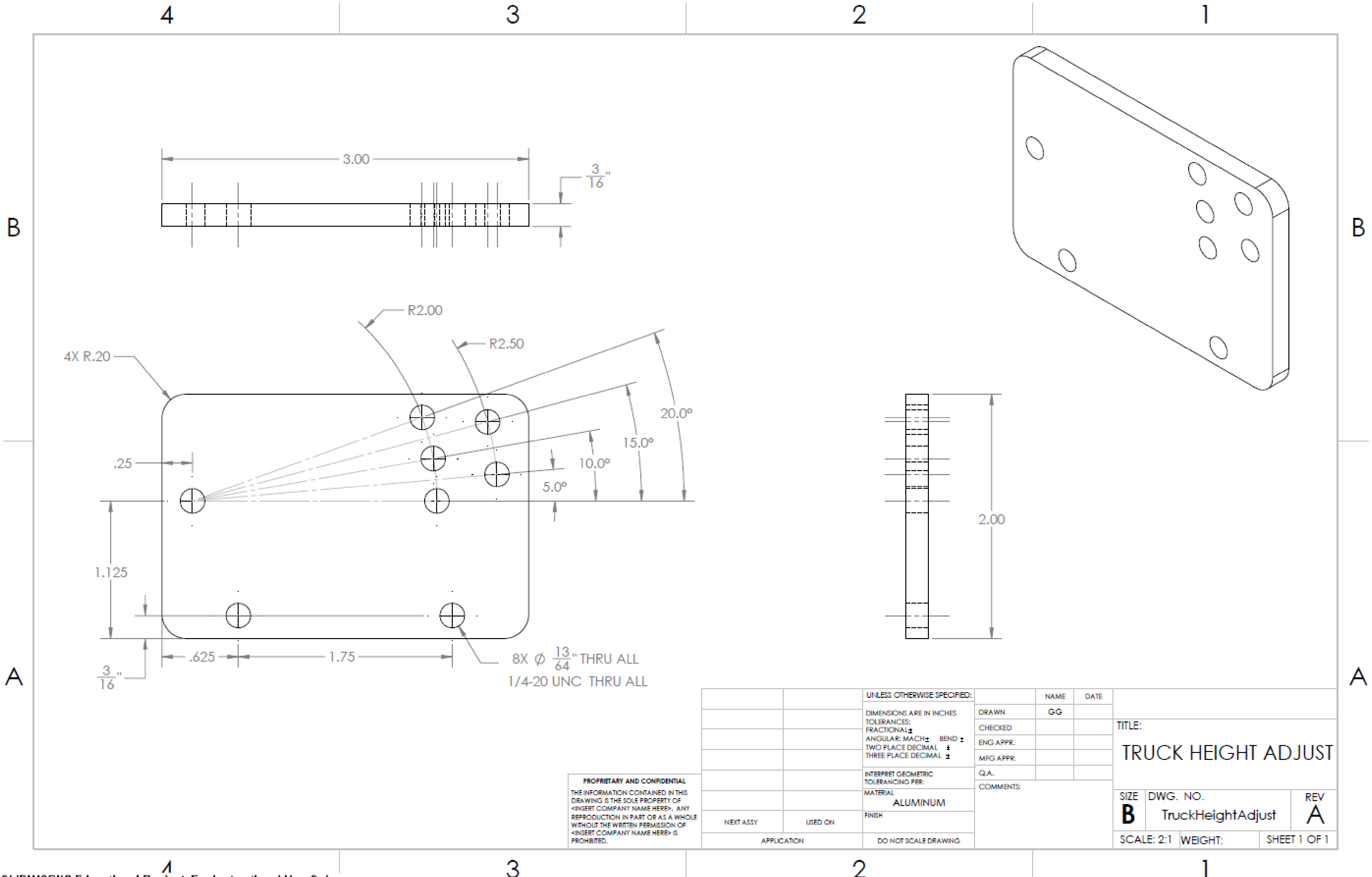

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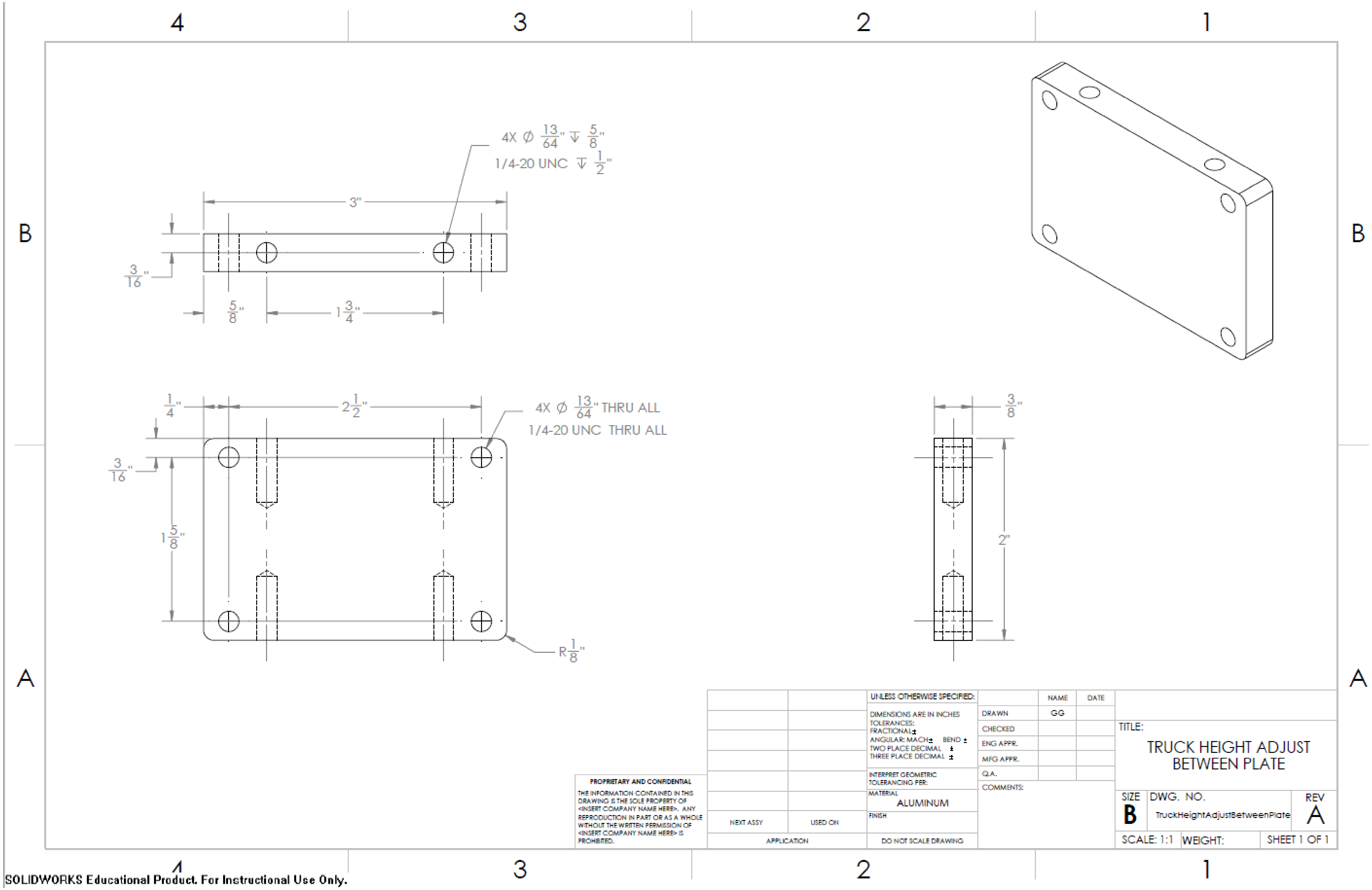
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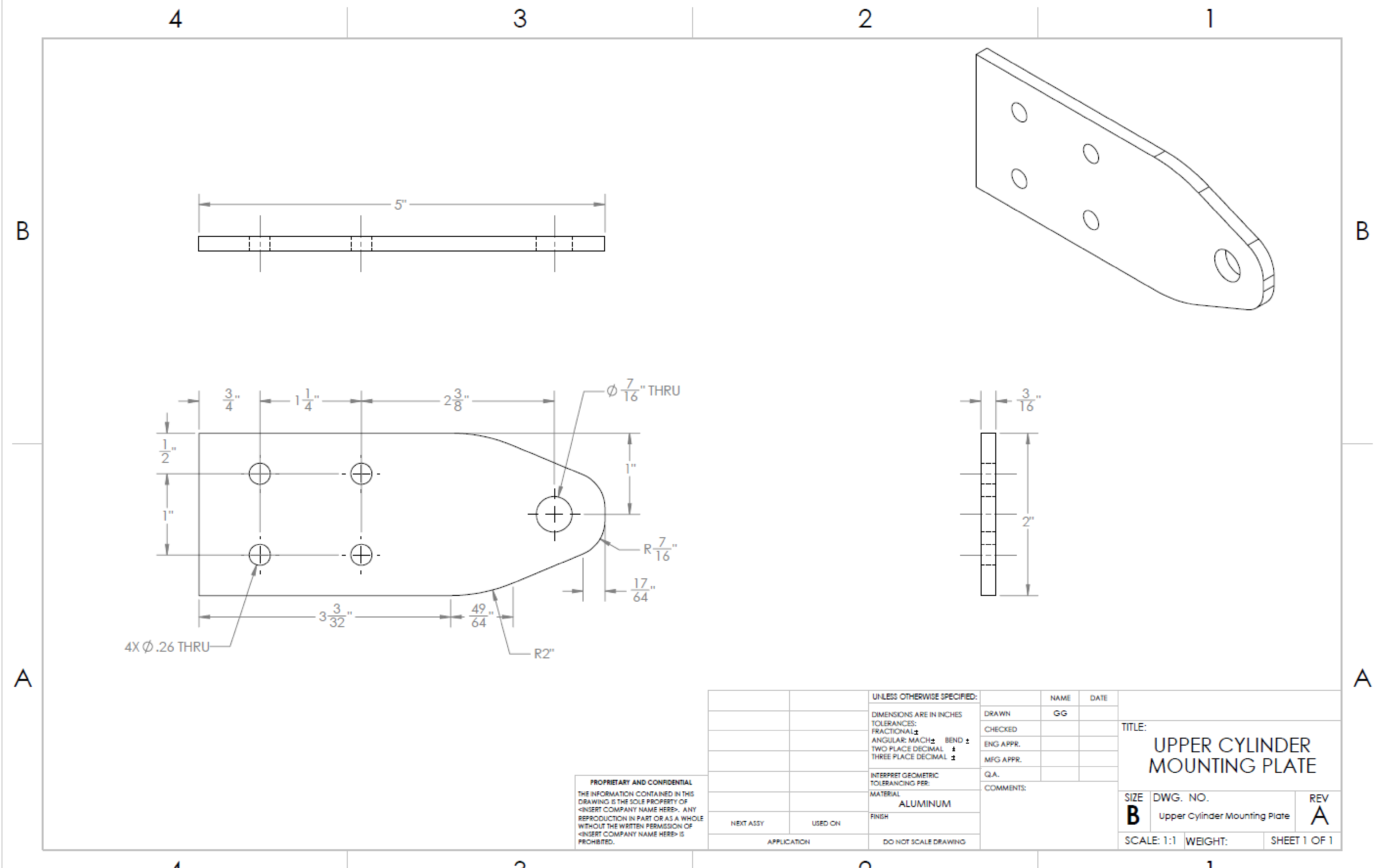
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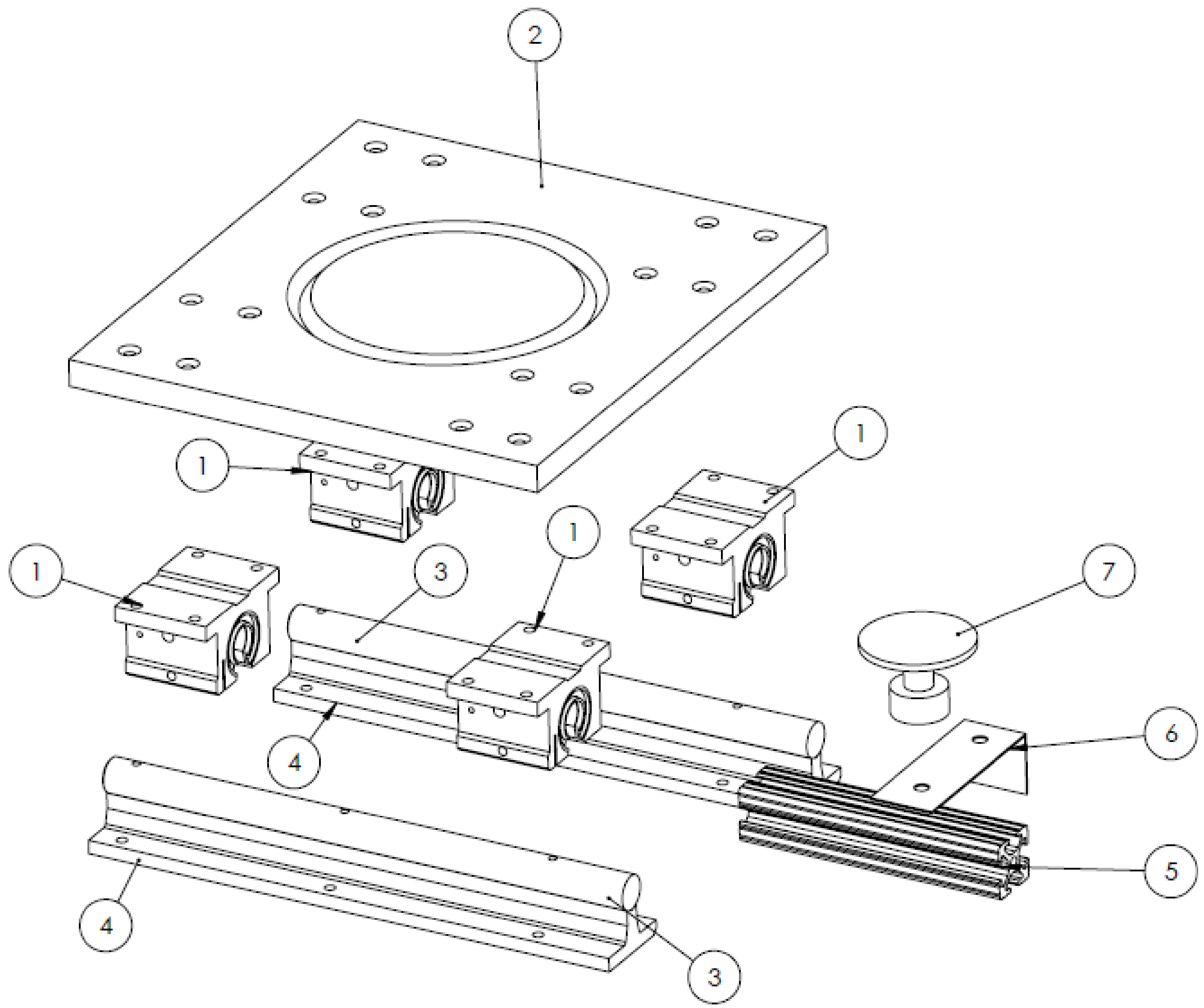

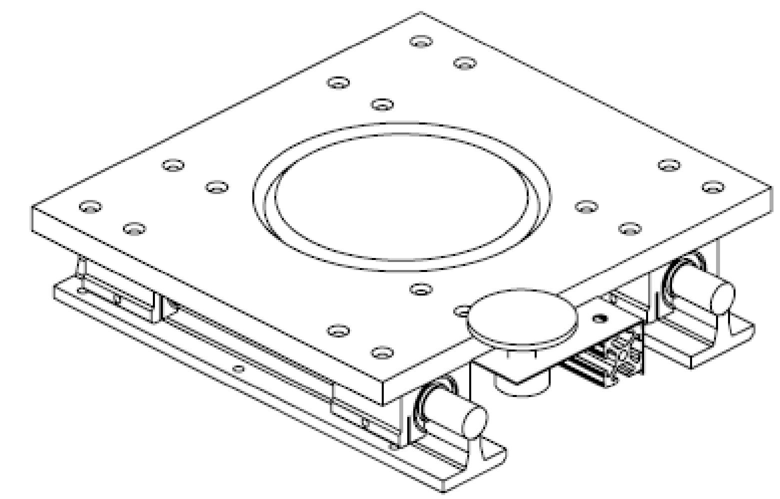

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6	1	PotentiometerMount
7	1	Potentiometer

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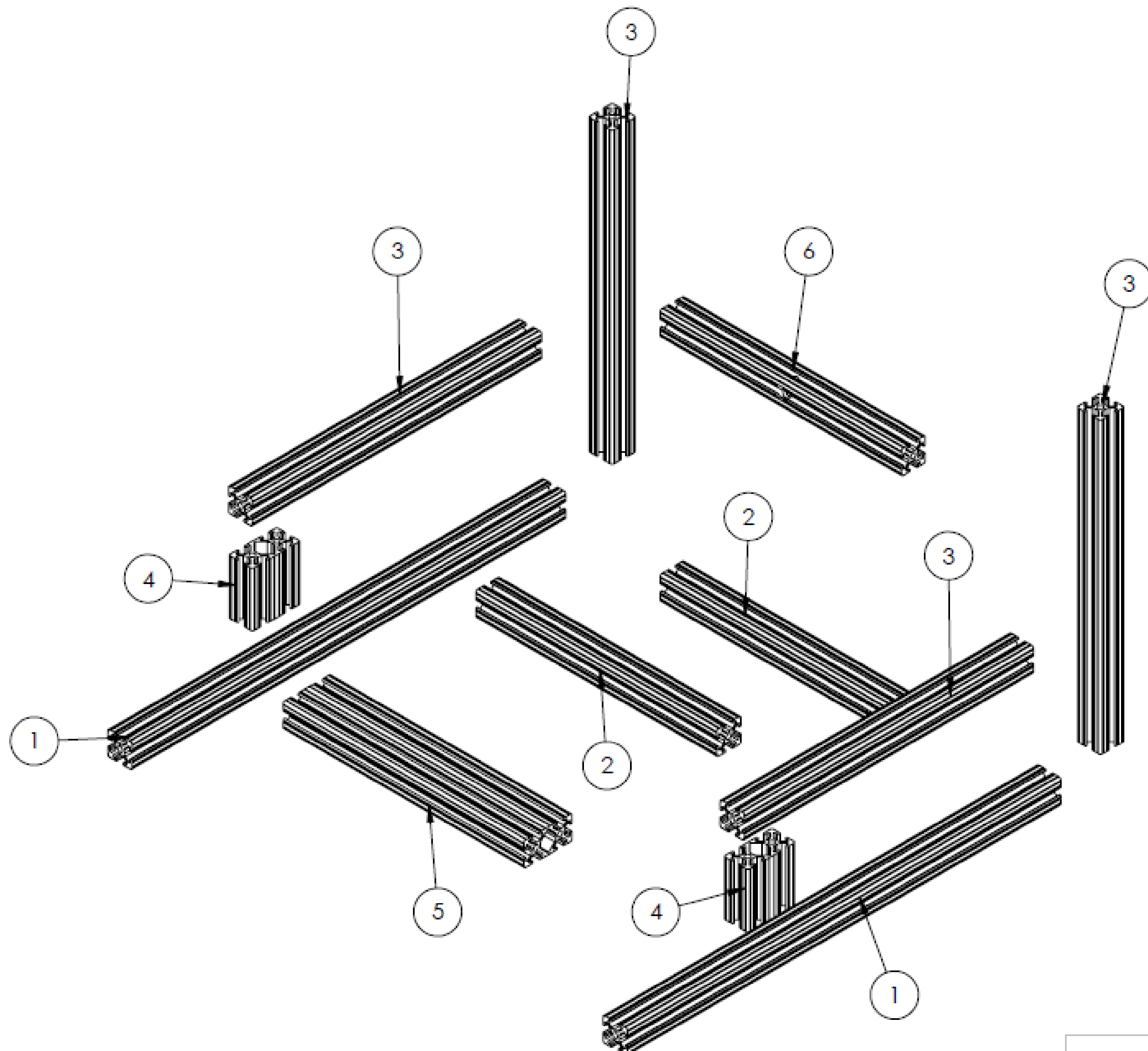

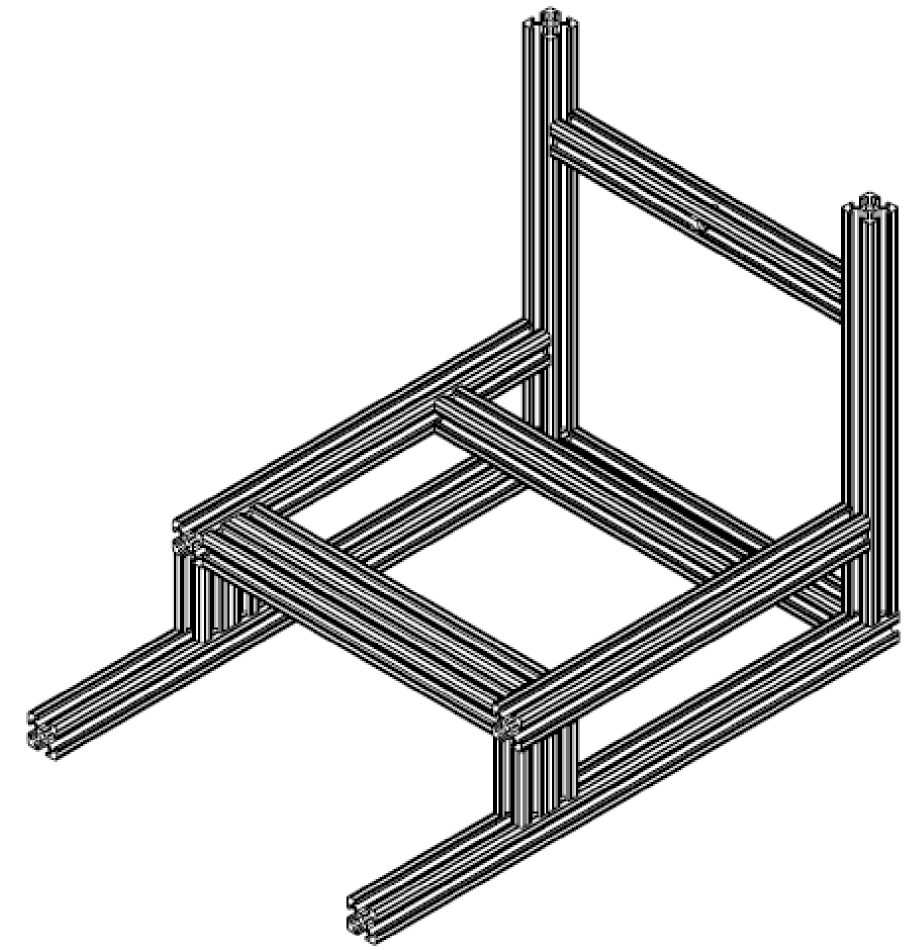

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3	4	8020-1x1-12in
4	2	8020-2x1-2.25in
5	1	8020-2x1-10in
6	1	8020-1x1-10in_hole

A

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL ALUMINUM
FINISH
DO NOT SCALE DRAWING

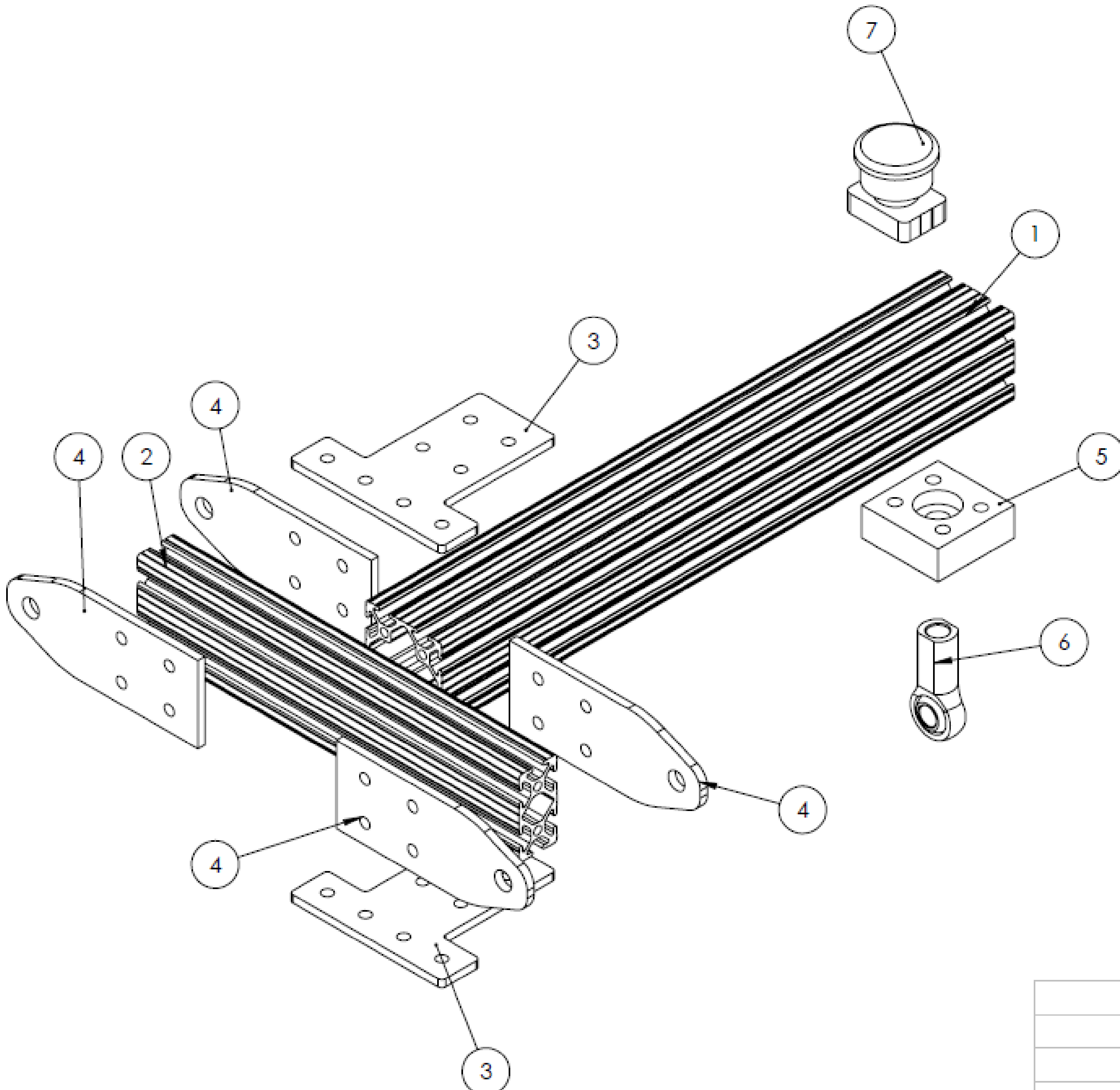
	NAME	DATE
DRAWN	GG	
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

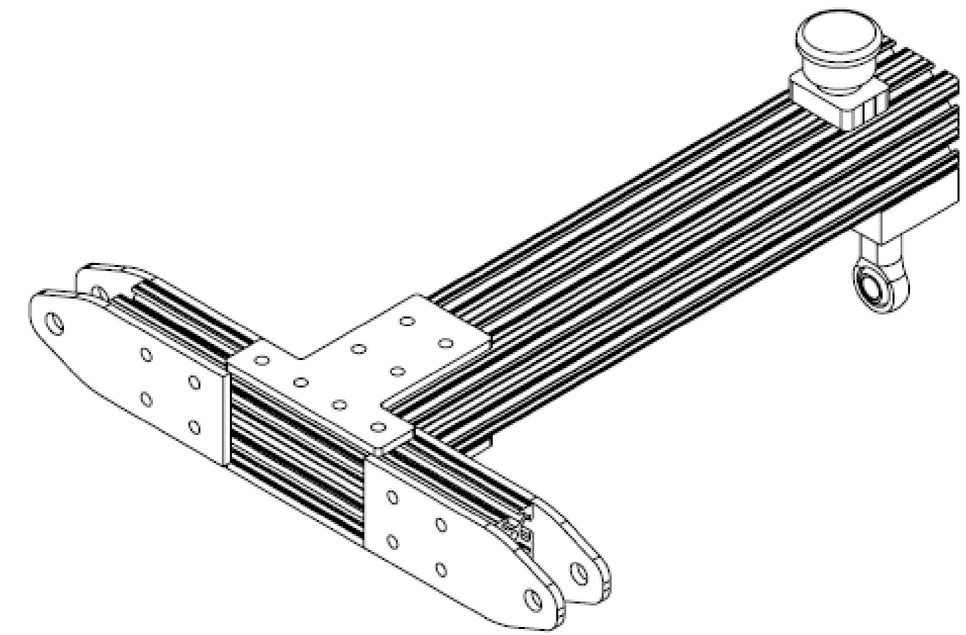
NEXT ASSY USED ON
APPLICATION

TITLE:
FRAME ASSEMBLY

SIZE B DWG. NO. Frame_Assembly REV A
SCALE: 1:8 WEIGHT: SHEET 1 OF 1

4 3 2 1





ITEM NO.	QTY.	PART NO.
1	1	8020-2x2-15in
2	1	8020-2x1-10in
3	2	Tee Gusset
4	4	Upper Cylinder Mounting Plate
5	1	BeamConnector
6	1	Female Rod End
7	1	E-Stop

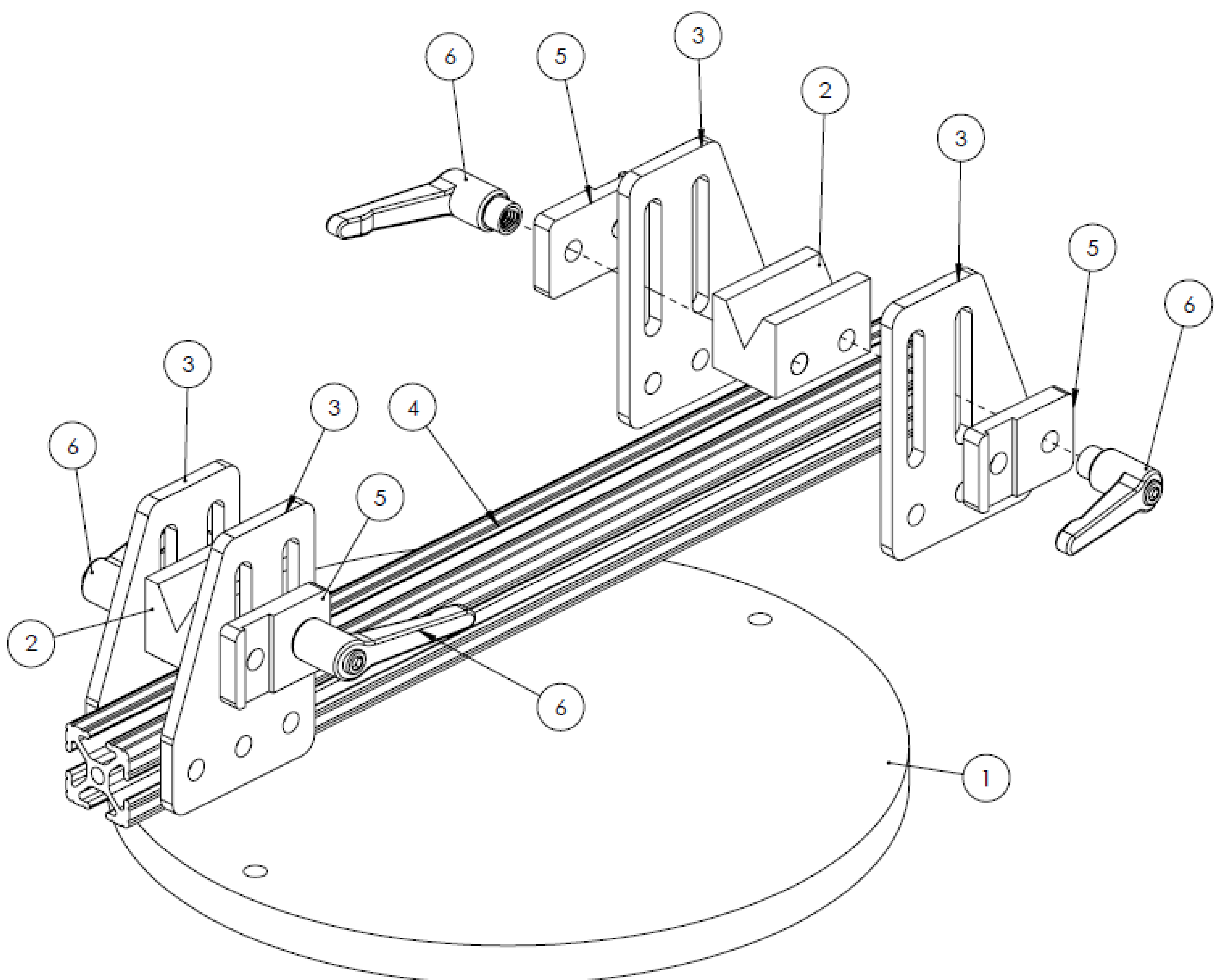
NEXT ASSY | USED ON
APPLICATION

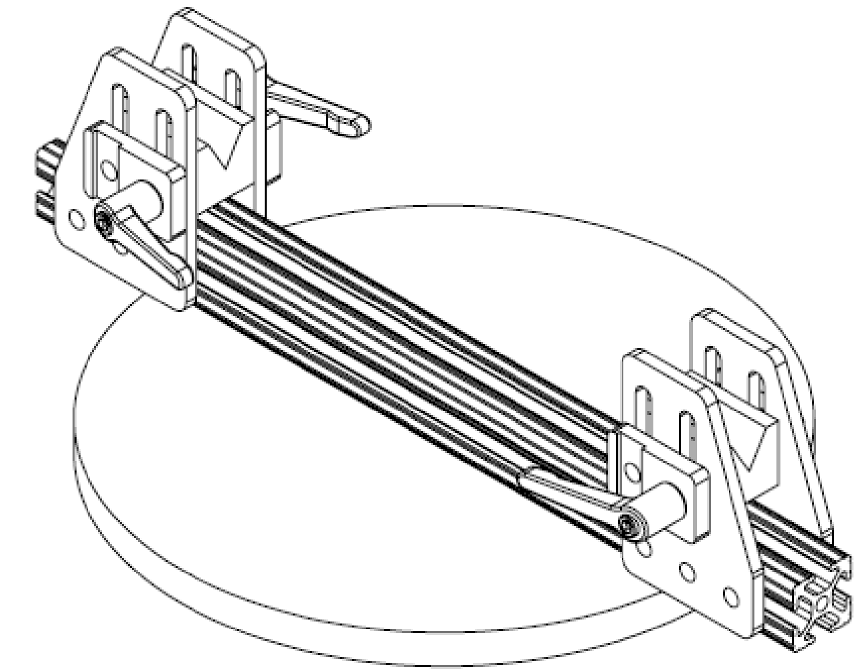
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	GG	
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:
TOP BEAM ASSEMBLY

SIZE B | DWG. NO. Top_Beam_Assembly | REV A
SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1





ITEM NO.	QTY.	PART NO.
1	1	TopTable
2	2	Truck Holder
3	4	L Holder
4	1	8020-1x1-13in
5	4	HeightAdjustSpacer
6	4	Handle - Threaded Hole

NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

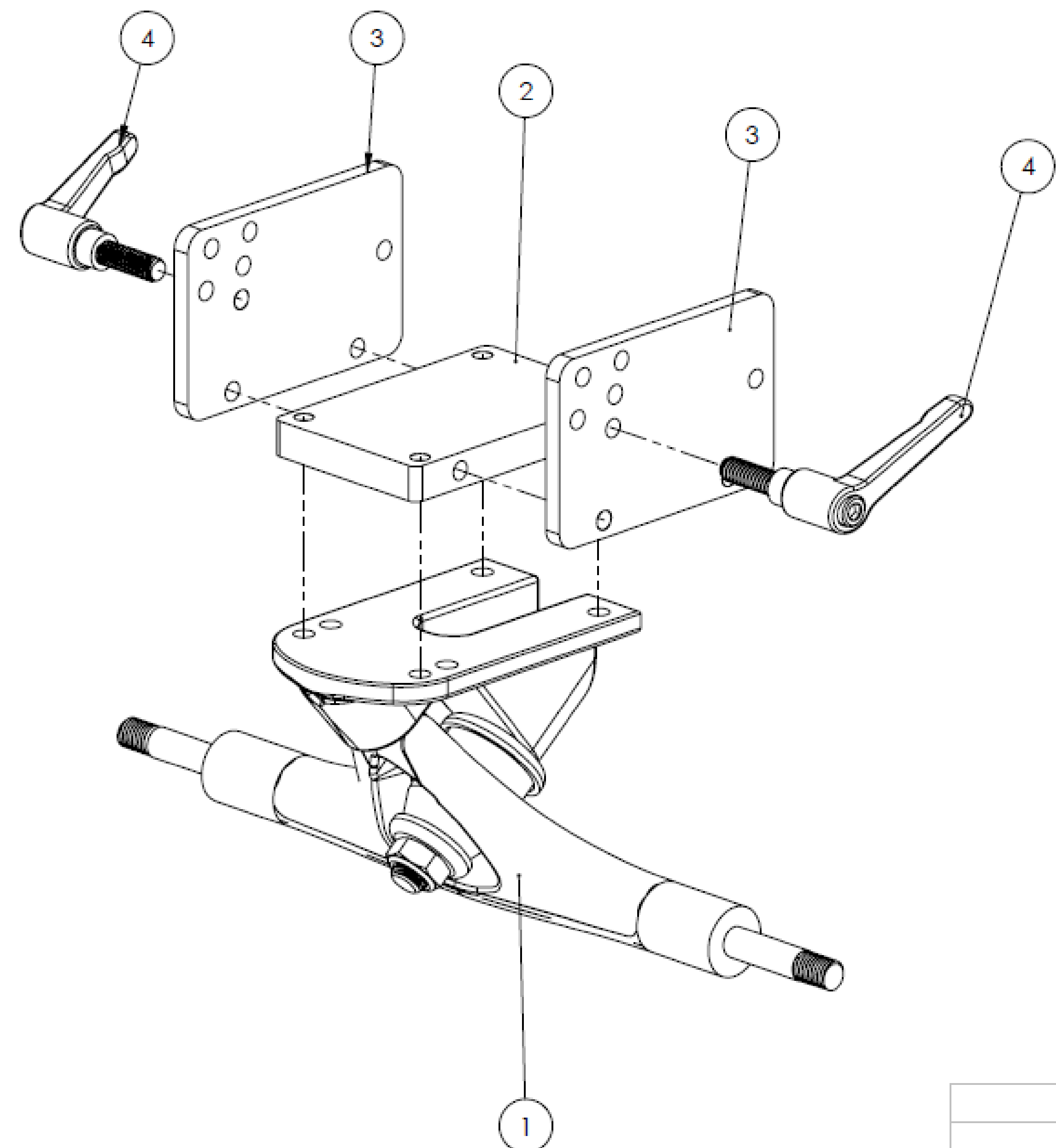
	NAME	DATE
DRAWN	GG	
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

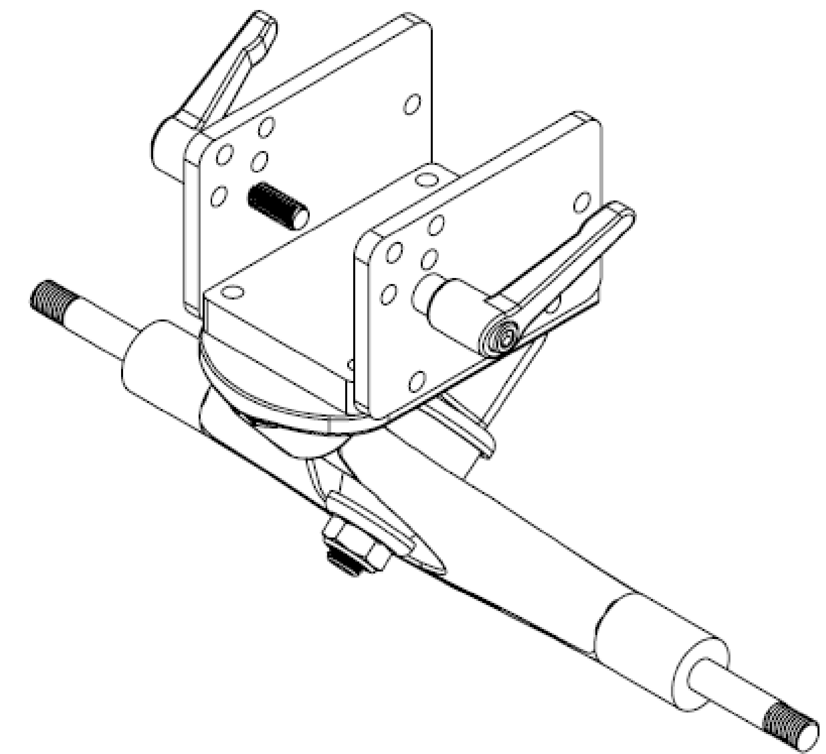
TITLE:

TOP TABLE ASSEMBLY

SIZE B | DWG. NO. TopTableAssembly | REV A

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1





ITEM NO.	QTY.	PART NO.
1	1	Truck
2	1	TruckHeightAdjustBetweenPlate
3	2	TruckHeightAdjust
4	2	Handle - Threaded Stud

PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

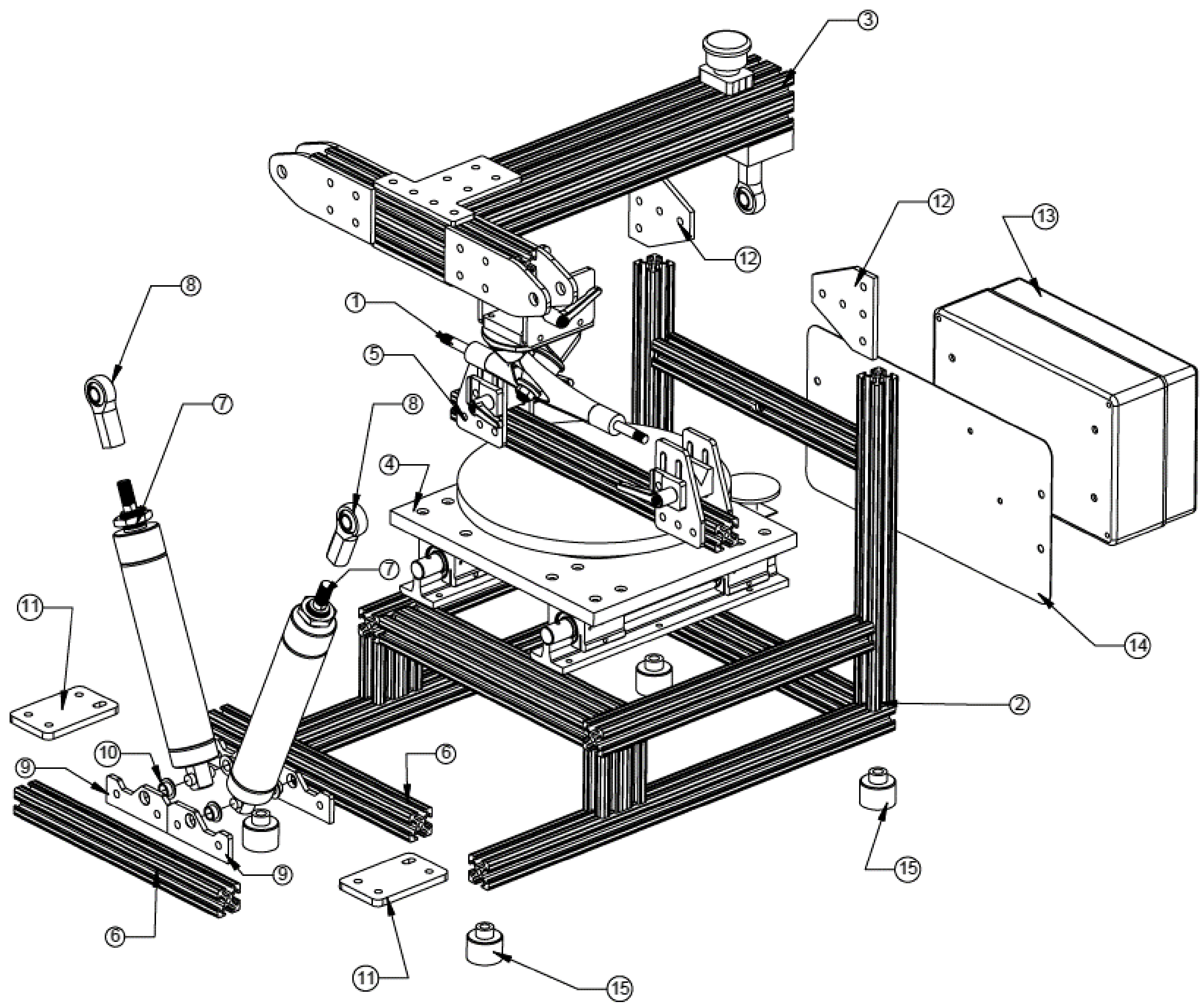
	NAME	DATE
DRAWN	GG	
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

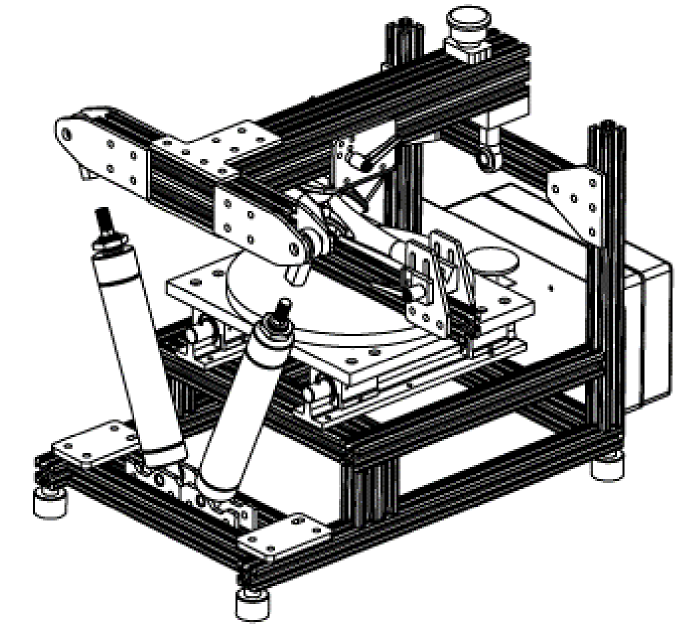
COMMENTS:

TITLE:
TRUCK ASSEMBLY

SIZE B | DWG. NO. Truck_Assembly | REV A
SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

SOLIDWORKS Educational Product. For Instructional Use Only.





ITEM NO.	QTY.	PART NO.
1	1	Truck_Assembly
2	1	Frame_Assembly
3	1	Top_Beam_Assembly
4	1	BottomTableAssembly
5	1	TopTableAssembly
6	2	8020-1010-10
7	2	HyrdraulicCylinder
8	2	Female Rod End
9	4	Lower Cylinder Mounting Plate
10	4	Bushings
11	2	Slot Plate
12	2	SupportPlate
13	1	Electrical Box
14	1	ElexMountPlate
15	4	Plastic Leg

BCIT BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY A POLYTECHNIC INSTITUTION

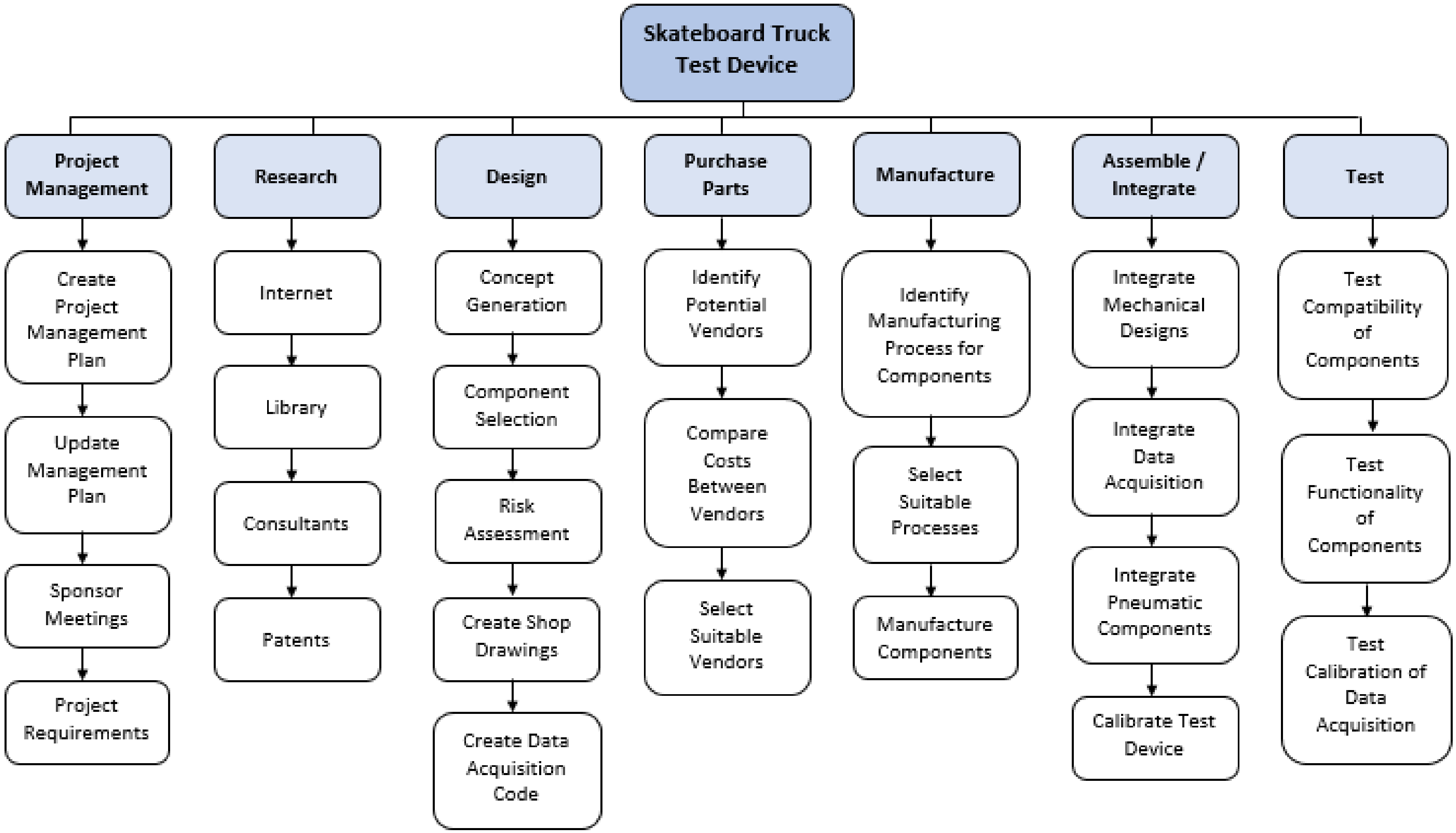
NAME: GG
CHECKED BY: -
STUDENT NUMBER: -
CHECKED NUMBER: -
DATE: -
CHK DATE: -

DIMENSIONS ARE IN Inches
TOLERANCES, UNLESS NOTED OTHERWISE:
NO DECIMAL: ± .05 In
ONE PLACE DECIMAL: ± 0.01 In
TWO PLACE DECIMAL: ± 0.001 In
ANGULAR: ± 0.5 deg

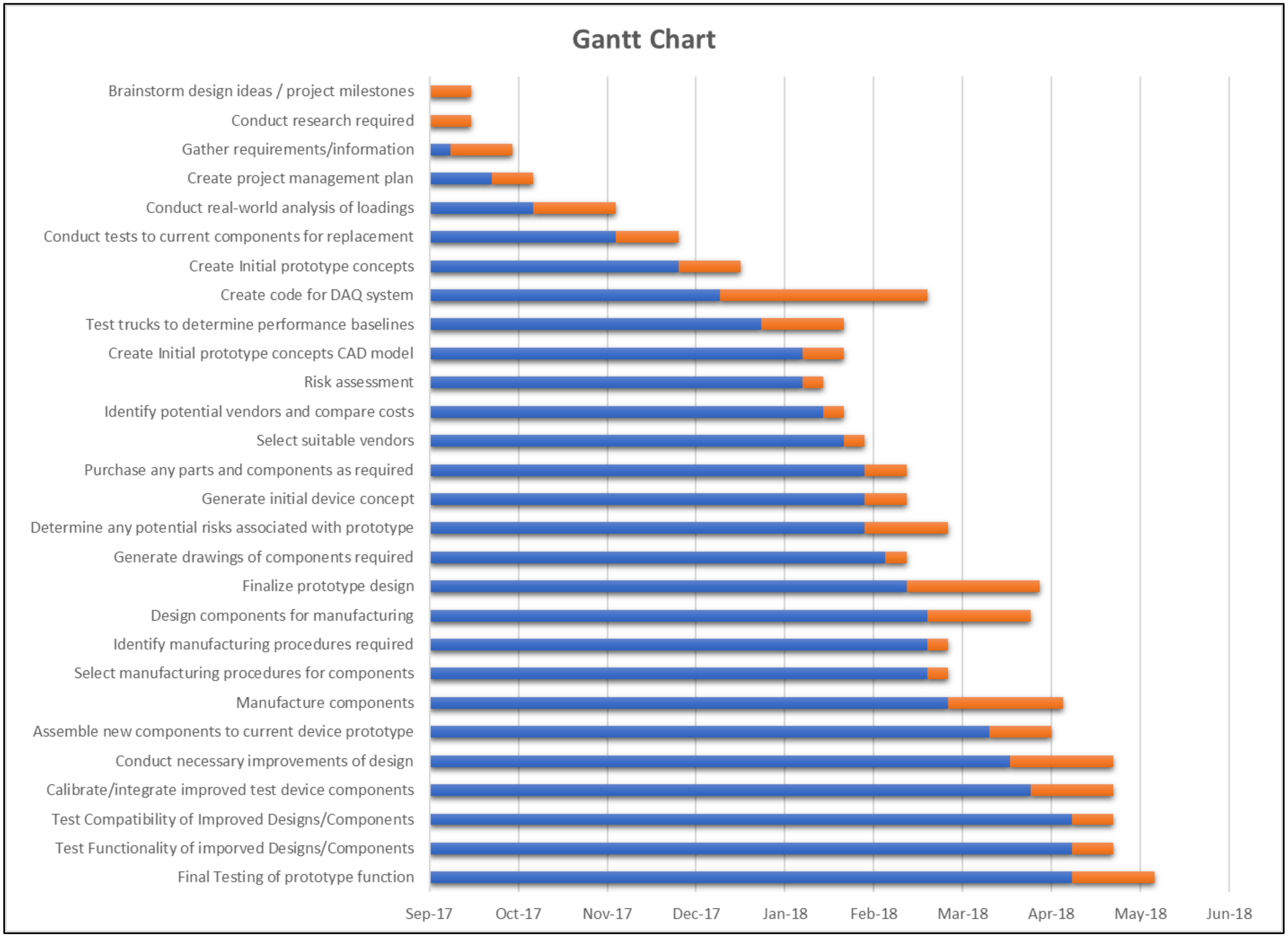
SIZE: B
TITLE: Skateboard Truck Test Device
DWG NUMBER: -
REV: -
SCALE: -
COURSE: -
SET: -

APPENDIX B: PLANNING AND PROJECT MANAGEMENT

B.1 Work Breakdown Structure



B.2 Gantt chart



B.3 RACI (Responsible, Accountable, Consulted, Informed) Chart

RACI Chart	Person			
Activity	**Gurkaran**	**Anthonye**	**Rohan**	**Steven**
Researching	R	A	A	I
Part Design	A	R	A	C
Part Selection	R	I	A	C
Code Development	A	R	C	I
Manufacture Components	A	A	R	I
Assemble Components	A	A	R	I
Perform Prototype Testing	A	R	R	I
Update Project Plan	R	C	I	I
Documentation	R	C	C	I
R = Responsible; A = Accountable; C = Consult; I = Inform				

APPENDIX C: PROJECT CODE

```
% Code to Output to Hydraulic Cylinders
% Notes: DAQ Output range = -10v to 10v Pressure Reg Takes 0 - 10v
clc
clear
%---------------------------------------------%
%               User Input                    %
%---------------------------------------------%
% The user input is used to provide information about the truck set up in
% the printed report
prompt = {'Enter Truck Brand:','Enter Date (dd-mm-yy):', 'Enter Test Number','Enter Truck
Model:','Enter Truck Width (in):','Enter Bushing Hardness:','Enter Riser Angle (deg):','Notes:'};
name = 'Truck Configuration Info.';
dims = [1 50];
questions = ["\bfTruck Brand:           \rm";"\bfDate(dd-mm-yy):     \rm";"\bfTest Number:
\rm";"\bfTruck Model:           \rm";"\bfTruck Width (in):     \rm";"\bfBushing Hardness:
\rm";"\bfRiser Angle (deg.):  \rm";"\bfNotes:                       \rm"];
input = string(inputdlg(prompt,name,dims));
str = questions + input;
dash = '-'; % Dash for strings
A = 'A'; % Force vs Deck Tilt
B = 'B'; % Force vs Truck Turn
C = 'C'; % Truck Turn vs Deck Tilt
D = 'tilt';
E = 'Rotation';
F = 'Force';
dat = '.dat';
fileName1 = input(2)+ dash + input(3) + dash + A;
fileName2 = input(2)+ dash + input(3) + dash + B;
fileName3 = input(2)+ dash + input(3) + dash + C;
dataName1 = input(1)+ dash + input(2) + dash + D + dat;
dataName2 = input(1)+ dash + input(2) + dash + E + dat;
dataName3 = input(1)+ dash + input(2) + dash + F + dat;
%%
%-------------------------------------------------------------------%
%                              Setup                                %
%-------------------------------------------------------------------%
%*****************Calculate op-amp gain from circuit*****************
R2 = 1; %k-ohm
R1 = 4; %k-ohm
OpAmpGain = (R1+R2)/R2;
%******************************Constants******************************
maxVOutput = 10.0;                        %Max V output of USB; NOTE: CANNOT EXCEED 10
maxAllowableP = 75;                      %Max P to use in test
minPOutput = 3.0;                         %Min P through transducer
maxPOutput = 120.0;                       %Max P through transducer
maxPperV = (maxPOutput-minPOutput)/maxVOutput * OpAmpGain; %Pressure/Volt
g = 9.81;                                 %Gravity
pi = 3.14159265359;                       %PI
pRegConstant = (maxVOutput/(maxPOutput-minPOutput))/OpAmpGain; % Volt/psi input V to P
transducer/output P of transducer
dataPoints = 1000;                       %Number of data points to collect
areaFactor = pi/4*(1.5^2 - (3/8)^2);     %Used for cylinders
radtoDegrees = 180/pi;                   %Rads to Degrees Conversion
initializeP = 60;                        %psi used to represent initial rider weight
%Sensor Calibration Factors (From testing)
vChange = 2.63-1.9045;            %90 degree V change
degTravelled = 90;                %Distance pot travels in test
potRadFactor = 2/9;               %Convert angle from pot to angle of skateboard truck
potGain = (degTravelled/vChange)*potRadFactor; % degrees/volt
% Accelerometer Sensitivity x, y, z-axis'
accelSensX = 0.721;
accelSensY = 0.727;
accelSensZ = 0.709;
%Convert Parameters to Voltages for testing
adjustedMaxVOutput = maxVOutput/OpAmpGain*(maxAllowableP/maxPOutput);
minVOutput = (pRegConstant * 15);                %15psi is always minimum allowable P in a
cylinder
riderWeightVoltageOutput = (pRegConstant * initializeP); %rider weight for the cylinders
%Test Parameters; Adjustment changes test duration
pauseTime = 4.5;               %Pause time between steps
steps = 20;                    %Number of steps/change period
```

```
datapoints = 6*steps;          %Total data points
potValue = zeros(datapoints); %Zeroing data
datastep = 0;                  %Used for incrementing
%%
%--------------------------------------------------------%
%                   Initialize the DAQ                    %
%--------------------------------------------------------%
daq.reset
devices = daq.getDevices;
s = daq.createSession('ni');

%******Inputs: potentiometer, accelerometer, 2 load cells****
ch1 = addAnalogInputChannel(s,'Dev1',0,'Voltage'); % Potentiometer
ch2 = addAnalogInputChannel(s,'Dev1',1,'Voltage'); % Accelerometer (x-axis)
ch3 = addAnalogInputChannel(s,'Dev1',2,'Voltage'); % Accelerometer (z-axis)
ch6 = addAnalogInputChannel(s,'Dev1',5,'Voltage'); % Accelerometer (y-axis)

ch1.TerminalConfig = 'SingleEnded'; % without this, the signal is default as differential
ch2.TerminalConfig = 'SingleEnded'; % without this, the signal is default as differential
ch3.TerminalConfig = 'SingleEnded'; % without this, the signal is default as differential
ch6.TerminalConfig = 'SingleEnded'; % without this, the signal is default as differential

%************Outputs: 2 pressure regulators******************
addAnalogOutputChannel(s,'Dev1',0,'Voltage'); % Pressure Regulator 1
addAnalogOutputChannel(s,'Dev1',1,'Voltage'); % Pressure Regulator 2
%%
%--------------------------------------------------------%
%                     Offset / Zero                       %
%--------------------------------------------------------%
s.Rate = 5000; % Sampling Rate

%********** Process to Levelize the Test Device ************
zeroingOutputSignal = linspace(0, riderWeightVoltageOutput, steps);

duration = s.DurationInSeconds;
outputSingleScan(s, [0 0])

%Loop Slowly Pressurizes Both Cylinders Evenly
for j=1:steps
    zeroOutputSignal = linspace(zeroingOutputSignal(j), zeroingOutputSignal(j),dataPoints);
    zeroOutputSignal = zeroOutputSignal';
    queueOutputData(s, [zeroOutputSignal zeroOutputSignal]);
    duration = s.DurationInSeconds;
    Pvalue = zeroingOutputSignal(j) * maxPperV
    pause(pauseTime);
    offset_data = s.startForeground;
end

%Using Actual Values to determine Offset
potOffset = mean(offset_data(:,1));
accelOffsetX = mean(offset_data(:,2));
accelOffsetY = mean(offset_data(:,4));
accelOffsetZ = mean(offset_data(:,3));
%%
%------------------------------------------------------------------%
%        Signal to control pressure's in cylinder A and B          %
%------------------------------------------------------------------%
OutputSignal1A = linspace(riderWeightVoltageOutput,adjustedMaxVOutput,steps);
OutputSignal1B = linspace(riderWeightVoltageOutput,minVOutput,steps);

OutputSignal2A = linspace(adjustedMaxVOutput,riderWeightVoltageOutput,steps);
OutputSignal2B = linspace(minVOutput,riderWeightVoltageOutput,steps);

OutputSignal3A = linspace(riderWeightVoltageOutput,minVOutput,steps);
OutputSignal3B = linspace(riderWeightVoltageOutput,adjustedMaxVOutput,steps);

OutputSignal4A = linspace(minVOutput,riderWeightVoltageOutput,steps);
OutputSignal4B = linspace(adjustedMaxVOutput,riderWeightVoltageOutput,steps);
```

```
OutputSignal5A = linspace(riderWeightVoltageOutput,adjustedMaxVOutput,steps);
OutputSignal5B = linspace(riderWeightVoltageOutput,minVOutput,steps);

OutputSignal6A = linspace(adjustedMaxVOutput,riderWeightVoltageOutput,steps);
OutputSignal6B = linspace(minVOutput,riderWeightVoltageOutput,steps);

OutputSignalA = [OutputSignal1A, OutputSignal2A, OutputSignal3A, OutputSignal4A, OutputSignal5A,
OutputSignal6A];
OutputSignalB = [OutputSignal1B, OutputSignal2B, OutputSignal3B, OutputSignal4B, OutputSignal5B,
OutputSignal6B];
%%
%---------------------------------------------------------------%
%                 Tilting of the deck procedure                 %
%---------------------------------------------------------------%
for j=1:datapoints

    outputSignal1 = linspace(OutputSignalA(j), OutputSignalA(j), dataPoints);
    outputSignal2 = linspace(OutputSignalB(j), OutputSignalB(j), dataPoints);
    outputSignal1 = outputSignal1';         %Transpose output into column
    outputSignal2 = outputSignal2';         %Transpose output into column
    queueOutputData(s, [outputSignal1 outputSignal2]);
    duration = s.DurationInSeconds;
    pause(pauseTime)

    data = s.startForeground;

    %Print out pressure values being sent to compare with actual
    pressureValue1 = OutputSignalA(j)/pRegConstant
    pressureValue2 = OutputSignalB(j)/pRegConstant

    %Take each set of data and find the corresponding means
    potValue = mean(data(:,1));
    accValueX = mean(data(:,2));
    accValueY = mean(data(:,4));
    accValueZ = mean(data(:,3));

    %Place each set of mean data into an array
    potData(j) = potValue;
    accDataX(j) = accValueX;
    accDataY(j) = accValueY;
    accDataZ(j) = accValueZ;
    pressureData1(j) = pressureValue1;
    pressureData2(j) = pressureValue2;
end
%%
%-------------------------------------------------------------%
%          Condition the data with gains and offsets          %
%-------------------------------------------------------------%
%**************** Apply Sensor Offsets *****************

Ax = (accDataX - accelOffsetX)./accelSensX;
Ay = (accDataY - accelOffsetY)./accelSensY;
Az = ((accelSensZ + accelOffsetZ)-accDataZ)./accelSensZ;
potData = potOffset - potData;

%*******************Apply Gain**************************
truckRotAngle = potData*potGain;

%******* Apply Accelerometer to Angle Conversion *********
num = Ax;                       %Equation Numerator
denom = sqrt(Ay.^2 + Az.^2);    %Equation Denominator
for j=1:datapoints
    decktilt(j) = atan(num(j)/denom(j));      %Deck tilt calculation
    decktilt(j) = decktilt(j) * radtoDegrees; %Convert to degrees
end
%*********** Apply Pressure to Force Conversion *********
```

```
force1 = pressureData1*areaFactor;
force2 = pressureData2*areaFactor;
forceDiff = force1 - force2;
%%
%--------------------------------------------------%
%                      Plots                       %
%--------------------------------------------------%
% -- A: Force vs Deck Tilt --%
figure(1)
figure('units','normalized','outerposition',[0 0 1 1])
hold on
% plot(forceDiff, decktilt, 'LineWidth', 2);
plot(forceDiff, decktilt, 'o');
title('Deck Tilt angle Vs. Force');
xlabel('Delta Force (lbf)')
ylabel('Deck tilt (degrees)')
xlim([-150,150]);
ylim([-25,25]);
grid on
grid minor
dim = [.75 .6 .3 .3];
annotation('textbox',dim,'String',str,'FitBoxToText','on')
saveas(gcf, fileName1, 'png')
hold off

%-- B: Force vs Truck Turn --%
figure(2)
figure('units','normalized','outerposition',[0 0 1 1])
hold on
plot(forceDiff, -truckRotAngle, 'o');
% plot(forceDiff, truckRotAngle, 'LineWidth', 2);
title('Truck Rotation Angle Vs. Force');
xlabel('Delta Force (lbf)')
ylabel('Truck Rotation (degrees)')
xlim([-150,150]);
ylim([-20,20]);
grid on
grid minor
dim = [.75 .6 .3 .3];
annotation('textbox',dim,'String',str,'FitBoxToText','on')
saveas(gcf, fileName2, 'png')
hold off

%-- C: Truck Turn vs Deck Tilt --%
figure(3)
figure('units','normalized','outerposition',[0 0 1 1])
hold on
% plot(decktilt, truckRotAngle, 'LineWidth', 2)
plot(decktilt, (truckRotAngle), 'o');
title('Truck Rotation Angle Vs. Deck Tilt');
xlabel('Deck Tilt (degrees)')
ylabel('truck rotation (degrees)')
xlim([-25,25]);
ylim([-25,25]);
grid on
grid minor
dim = [.75 .6 .3 .3];
annotation('textbox',dim,'String',str,'FitBoxToText','on')
saveas(gcf, fileName3, 'png')
hold off

%Set output pressure back to zero
outputSingleScan(s, [0 0])
```

APPENDIX D: IEEE CITATION REFERENCE

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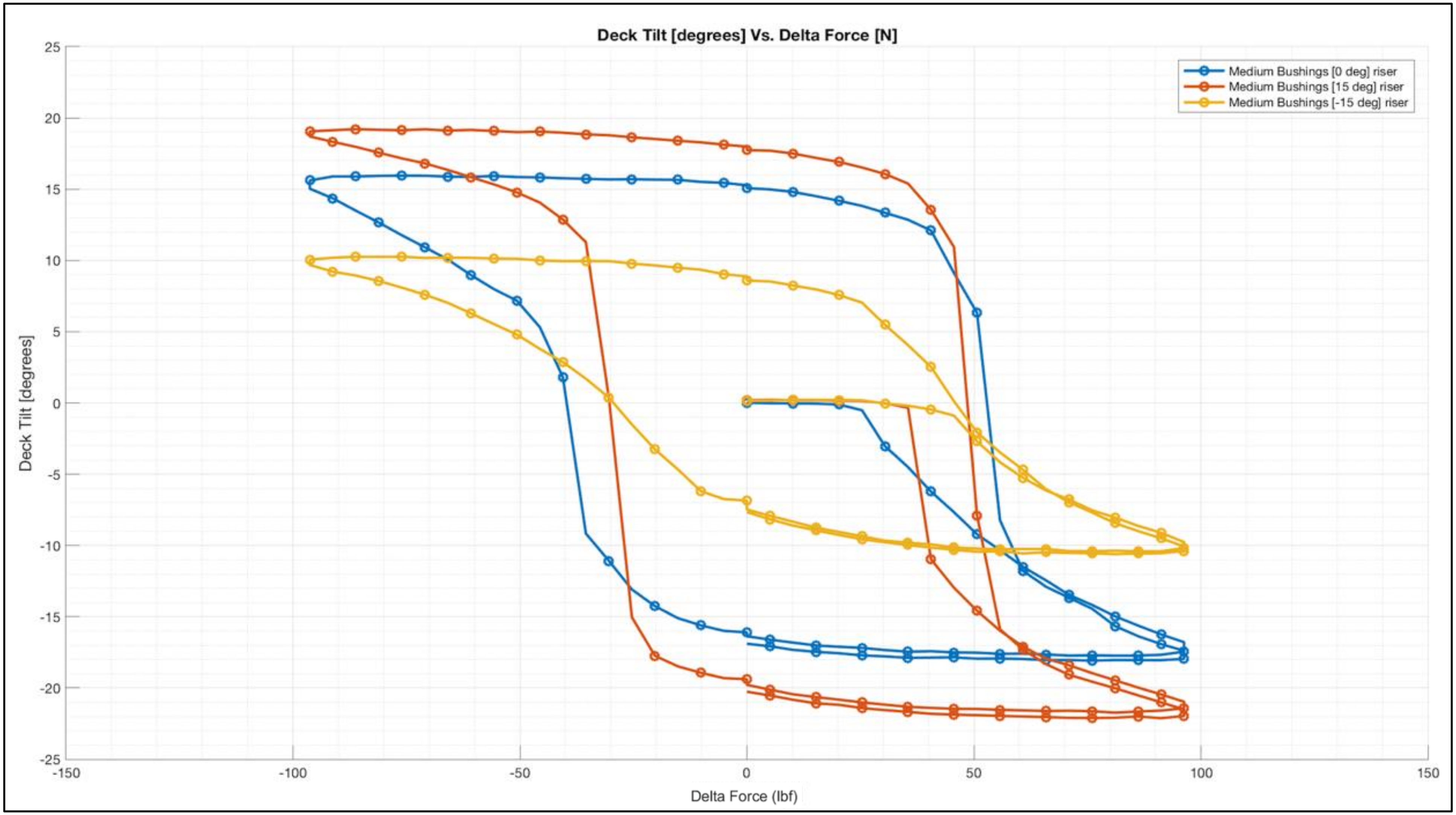
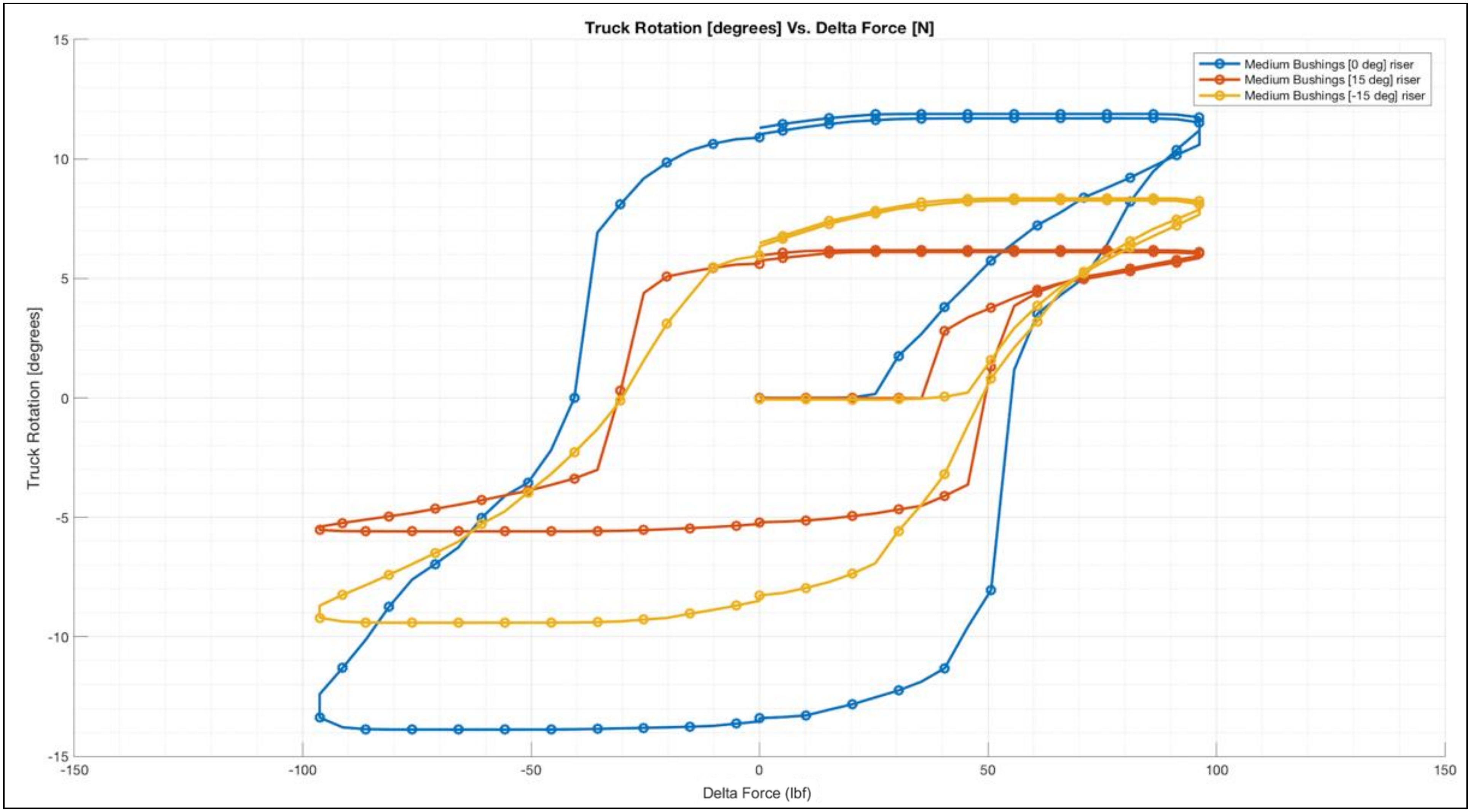
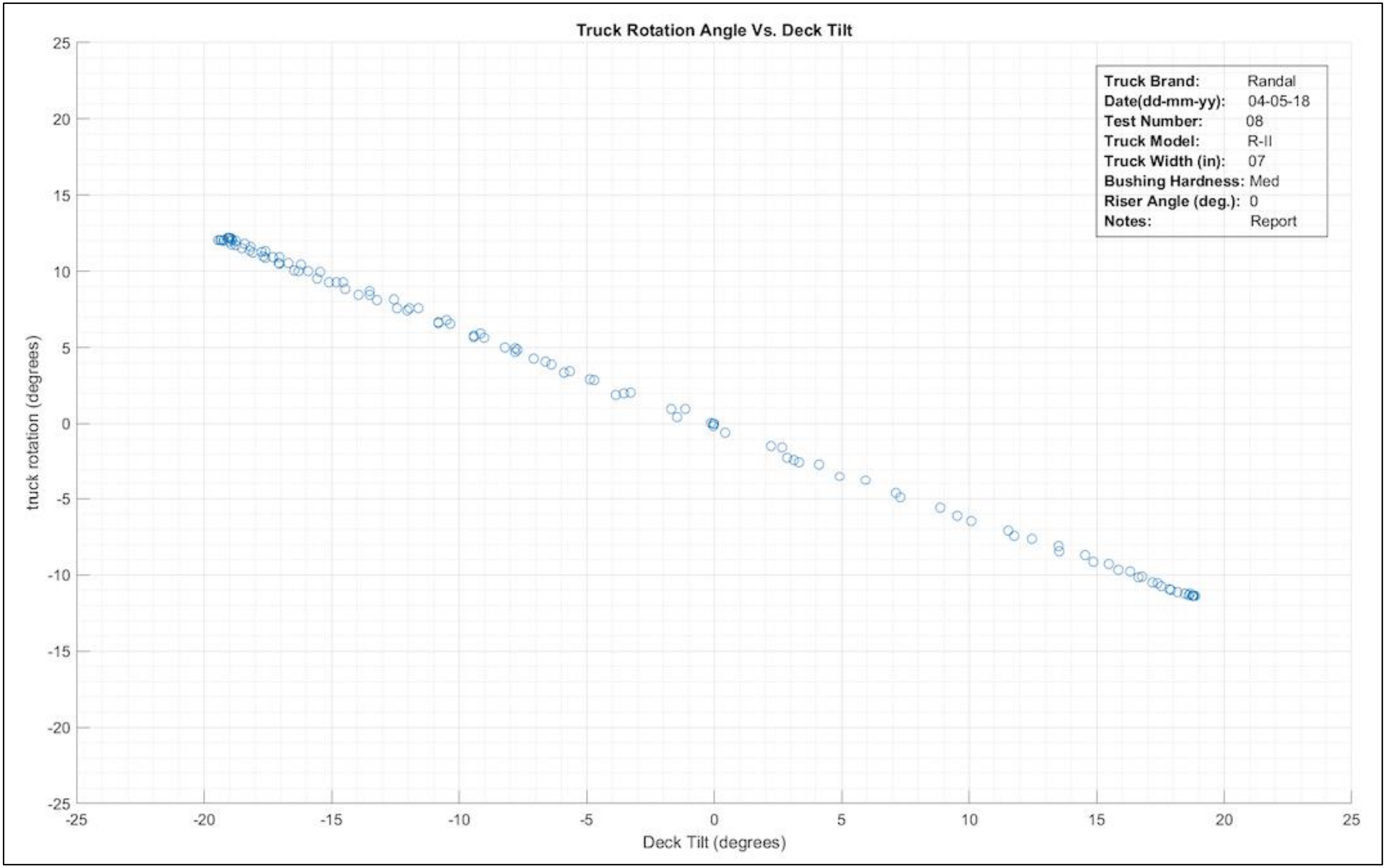
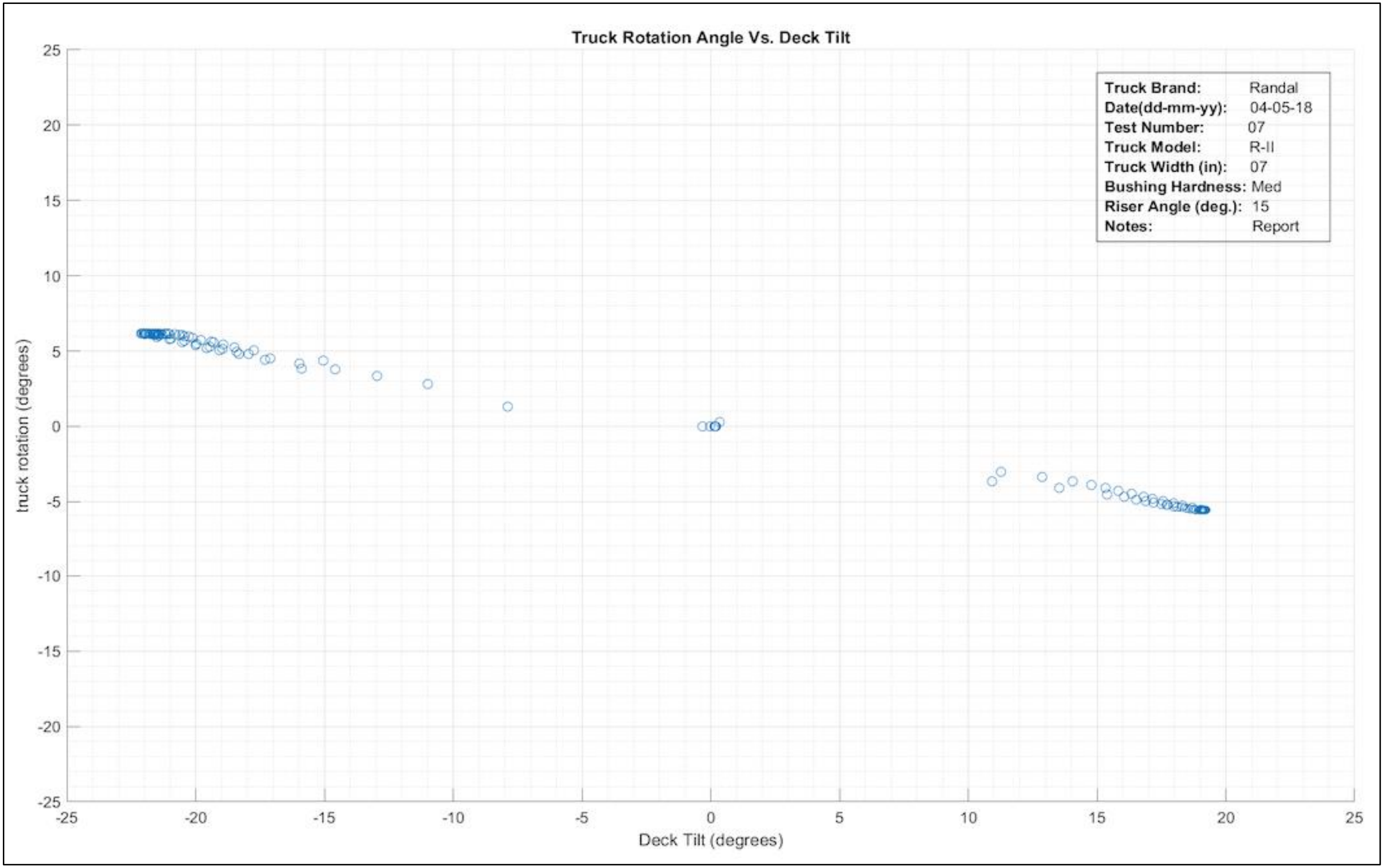
APPENDIX E: TEST RESULTS

E.1 Testing Truck Angles

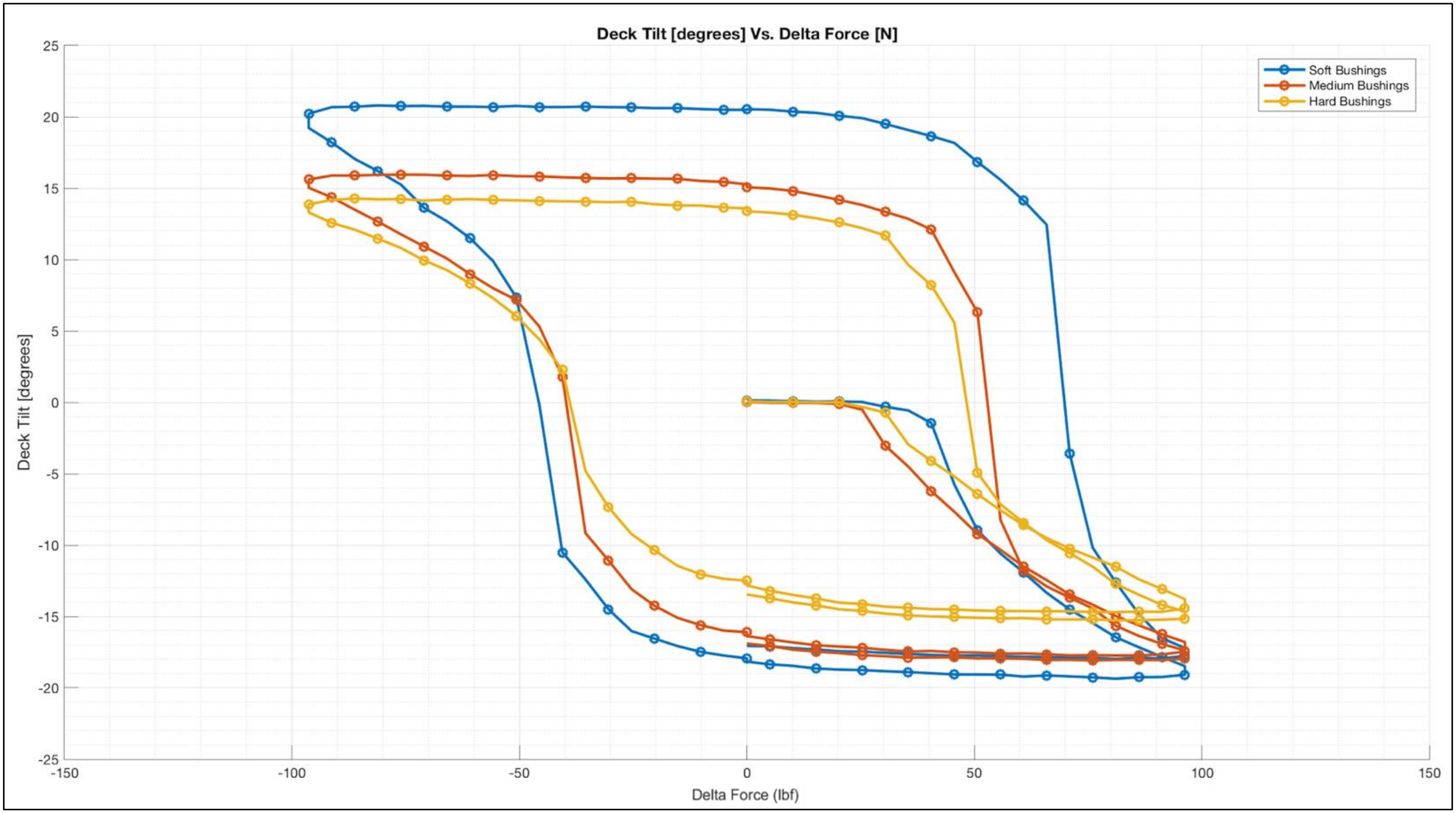



Truck Rotation [degrees] Vs. Delta Force [N]
Medium Bushings [0 deg] riser
Medium Bushings [15 deg] riser
Medium Bushings [-15 deg] riser
Truck Rotation [degrees]
Delta Force (lbf)
15
10
5
0
-5
-10
-15
-150
-100
-50
0
50
100
150

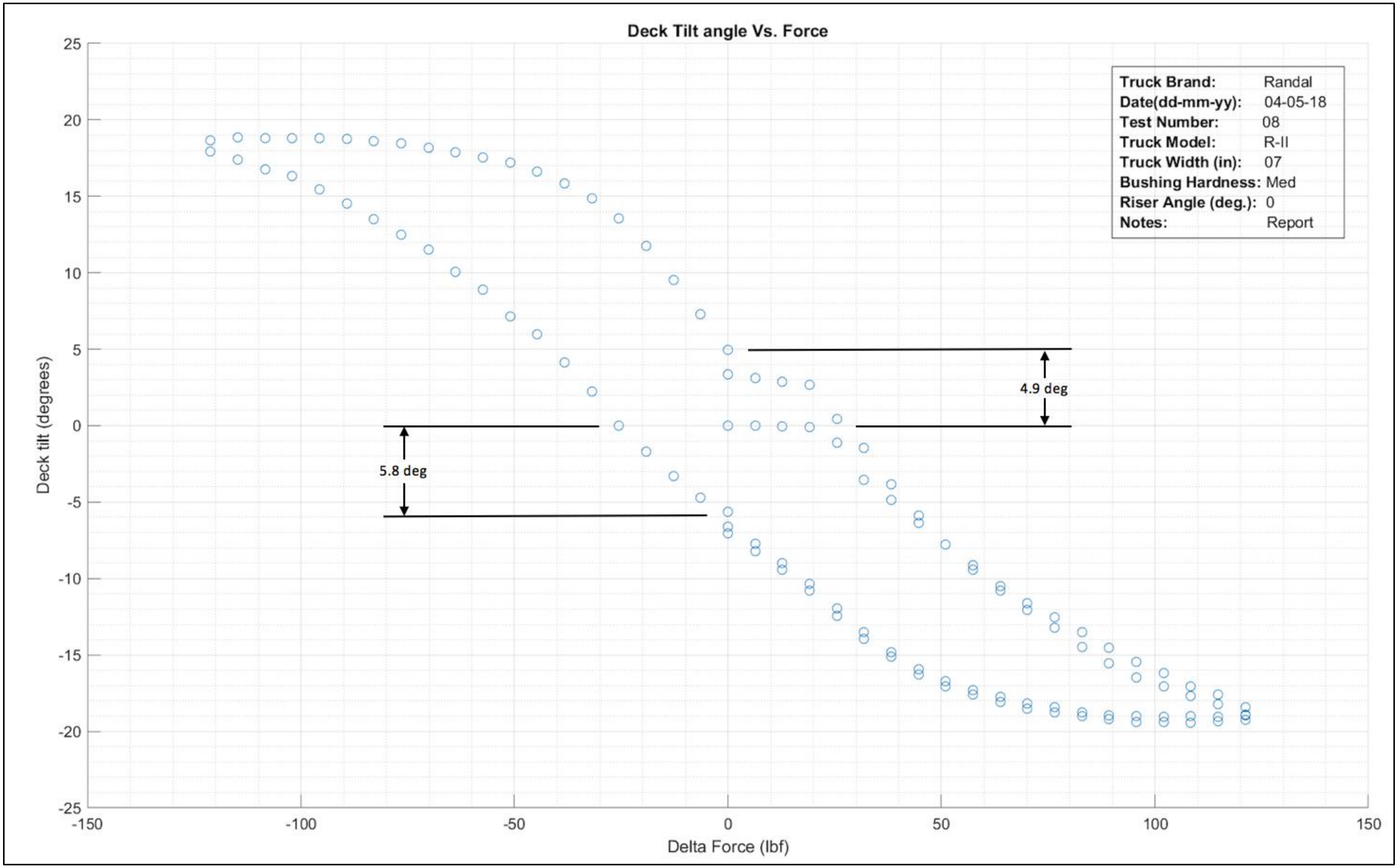

Truck Rotation Angle Vs. Deck Tilt
Truck Brand: Randal
Date(dd-mm-yy): 04-05-18
Test Number: 08
Truck Model: R-II
Truck Width (in): 07
Bushing Hardness: Med
Riser Angle (deg.): 0
Notes: Report
truck rotation (degrees)
Deck Tilt (degrees)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-25
-20
-15
-10
-5
0
5
10
15
20
25


Truck Rotation Angle Vs. Deck Tilt
Truck Brand: Randal
Date(dd-mm-yy): 04-05-18
Test Number: 07
Truck Model: R-II
Truck Width (in): 07
Bushing Hardness: Med
Riser Angle (deg.): 15
Notes: Report
truck rotation (degrees)
Deck Tilt (degrees)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-25
-20
-15
-10
-5
0
5
10
15
20
25

E.2 Testing Bushing Hardness'



E.3 Testing Hysteresis



APPENDIX F: TECHNICAL SPECIFICATIONS

Category	Specification	Comment
Force	150 lbs	Analysis of half of maximum rider weight on one truck
Accuracy	± 2 PSI	Components used for measurements must be this accurate
	± 0.5 degree	
Range of Motion	Max. Deck Tilt Angle: 25°	Specifications are results from previous group
	Max. Turning Angle: 20°	
Adaptability	Max. Hangar Width: 7.5"	Trucks must complete full range of motion before cylinders bottom out or else data will be invalid after that point
	Max. Riser Pad Angle: 20°	Changing riser angle will introduce added vertical height
	Added Height from Riser Pad: Min. 1"	
Sufficient Power Supply	Min. Pressure Input: 130 PSI	Specified by pressure transducer
	Min. Voltage: 10 V	
Key Measurements Required	Deck Tilt	
	Turning Angle	
	Force / Pressure	
Intrumentation	Laptop/Desktop with Matlab	
	Data acquisition device	
	Measurement devices for key measurements	
Controlled Variables	Pressure into cylinders	
Safety	Framing that withstands min. 400 lbs	Each cylinder outputs max. 200 lbs
	Emergency shut down	

APPENDIX G: REQUEST FOR PROPOSAL

SKATE CORP

Skateboard Truck Test Device

Request for Proposal

RFP#171804

Issued by: Gurkaran Gill, Rohan Chawla, Anthonye Palma

Group: 171804

Date: October 24th/2017

Contact #: 1-226-6788-9919

1672 Sunny Boulevard, California, United States of America

Statement of Purpose

Skate Corp is excited to work with an engineering firm that would design and deliver a test device for our line of trucks. We will provide our products and extensive knowledge in the field to help assist with this test device. In general, we would like a test device that can be an addition to our already extensive quality control process. This truck device will also be implemented in our research and design departments so that we may test prototypes to quantify certain qualities such as feel, force and hysteresis. Two key measurements will include deck tilt angle vs. force (or torque) and deck tilt angle vs steering angle.

Background

Skate Corp is a company leading in the skateboard design industry that was founded in the early 1960's, shortly after the skateboard was invented and was becoming popular. Our company quickly became an industry leader with our first line of skateboards up to our newest line of skateboards that feature ground-breaking technology in this industry. We sell all types of boards ranging from Old School boards (used for skating on streets), Shortboards (used for performing tricks) and Longboards (used for downhill racing or just simply for transportation). What sets us apart from our competitors is that we at Skate Corp are very passionate about designing and building skateboards. This can be seen from our newest product lines as we are constantly innovating and designing to try and create the perfect skateboard for anyone.

Similar Products (Examples)

Here at Skate Corp, we are currently very interested in a test device for our line of trucks. We have done extensive research but have not come across any products similar to what we are interesting in. We have reached out to an engineering firm in the past to develop a test device but after some years of use, we have realized that there must be more efficient ways to design and build this device so that it may be easy to use and easy to interchange trucks while also providing the accurate measurements we are interested in. The previous test device includes two pneumatically controlled cylinders that provide the forces required on the truck. There is an accelerometer connected to a data acquisition system that would measure and store the data. This data was then read and represented on a computer using the Matlab software.

Project overview:

As skateboards are becoming increasingly popular among teens and young adults, there needs to be a system that tests the quality of the skateboards before they are used in the sport. A major component of the skateboard is the skateboard truck, since it heavily influences the ride quality and the safety of the skateboard. A system or device is requested to be designed and manufactured for Skate Corp to test the skateboard trucks after they have been manufactured and during R&D.

The device itself will test the amount of torque that is applied on the skateboard truck and to measure the forces that would be applied to the skateboard truck if it were to be used in the sport. This is of high importance since testing a device before using it can ensure the product is performing safely and as desired. The device should consist of a means for measuring the forces on the truck accurately, the amount of turning the truck undergoes, and displaying the results in software to has a visible representation of the results.

Scope of Work:

It is expected that the project will provide measurements of key qualities. Therefore, an iterative/refinement approach in designing the device/system should be used. Since a device that was designed in the past is already being used, the older device can either be improved or used as a reference. Since the truck is manufactured completely separately from the board itself, the testing of the board is beyond the scope of this project. The focus is to provide measurements and to ensure the safety and quality of the skateboard trucks only.

3D modelling software, such as Solidworks or Autodesk Inventor, along with analytical calculations should be used to verify that the designs of the skateboard truck testing device will meet the device specifications before manufacturing and assembling the device.

Project Timeline

After Skate Corp has selected the team that will design and manufacture the testing device in September 2017, the design for the device should be started immediately onward. The skateboard truck testing device should be completed and functioning by early April 2018, so that the final prototype can be demonstrated at the BCIT Mech Expo 2018.

Assistance / Resources:

During the course of the design of the skateboard truck testing device, assistance will be provided by Skate Corp where it can be provided. Technical advice and resources, such as our products to be tested, that can be provided by employees at Skate Corp will be provided upon request by the project team.

Deliverables

A fully operational skateboard truck testing device that will be demonstrated at the British Columbia Institute of Technology Mech Expo. This device needs to measure deck tilt angle vs. force (or torque) and deck tilt angle vs steering angle as key measurements including measurements such as force and hysteresis. In addition to a fully operational device, a detailed analysis of different skateboard truck's performance characteristics is expected to be provided. This analysis is based on performing a broad sample of tests on a variety of styles of skateboard trucks. An analysis of the results along with any conclusions established in the project is expected to be included in the report to be delivered alongside the testing device.

Budget

In terms of the budget allocated for the project materials there is approximately a $400.00 to $800.00 range that has been deemed appropriate for one working prototype. Please enclose a cost estimate in terms of materials, labor, resources and any other expected expenses to be included in the overall budget of the project.

Term of Contract

Contract Duration: November 20th/2017 - May 18th/2018

Contractual Conditions:

- Material cost for one unit cannot exceed the material cost budget deemed appropriate
- Working prototype must be provided before the BCIT expo date
- Bi-monthly updates, and monthly meetings for updates on project completion

Failure to uphold the contractual conditions set out in this document may be just-cause for contract termination.

Evaluation & Award Process

The successful suitor for this project will be determined based on the following criterion:

- Examples of previous projects that fall under a similar scale
- References from previous clients
- Project timeline (including milestones, time to completion)
- Initial proposed design ideas

Please include the above information in the project proposal, this will allow for the best applicant to be determined as per the important award process criterion.

Process Schedule

The following process schedule is set out to provide important deadlines for the next steps in the process for determining the successful company to take on this project:

Letter of Intent: October 27th

Questions regarding the project: November 3rd

Proposal Submission: November 10th

Please feel free to contact me with my above contact information with any questions you may have regarding this request for proposal.

APPENDIX H: DESIGN REVIEW PACKAGE

Skateboard Truck Test Device

Design Review Package

Prepared For:
Stephen McMillan
Johan Fourie

Prepared By:
Anthonye Palma
Gurkaran Gill
Rohan Chawla

Table of Contents

1.0 Background

A skateboard truck represents a means of steering for a skateboard. Depending on the type of trucks, brand, wear and tear, or type of bushings, the truck can provide a wide range of different steering resistances. These varying resistances to turning have been qualitatively described by riders as the "feel" of a skateboard. To allow for actual quantitative results to represent a skateboard trucks "feel", the skateboard truck test device was envisioned and created. Due to several issues pertaining to the devices size, repeatability, ease of use and accuracy, a new and advanced take on the previously existing skateboard truck test device has been embarked on.

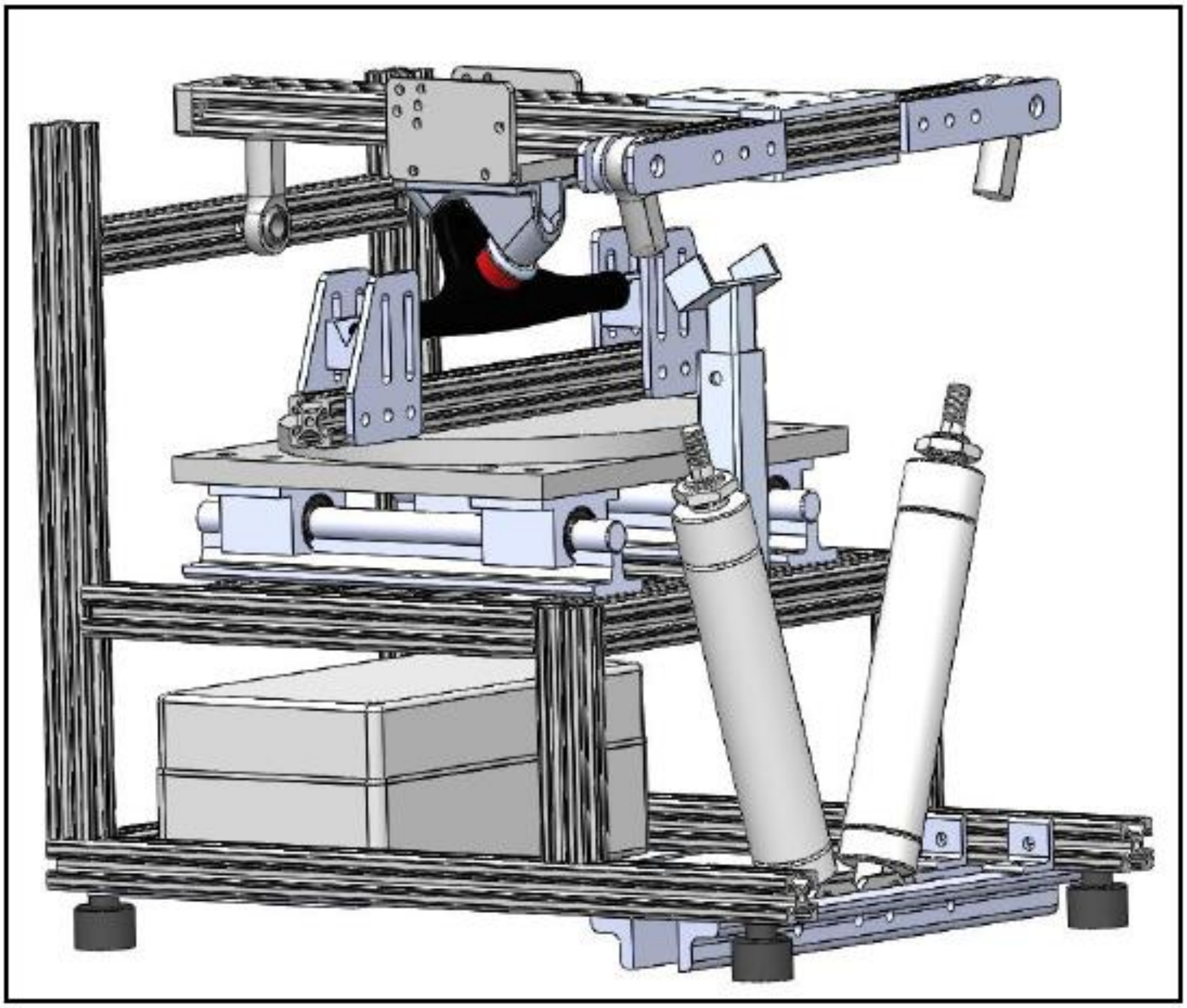


Figure 1: Current Design Iteration

2.0 Mechanical Designs

Lower Cylinder Mounting Components

Lower Mounting Assembly

To minimize the overall height of the device, some specialized components were necessary to deal with the cylinder mounting and arrangement. As seen below, the overall assembly allows for the cylinders to be mounted within the components. Also, by remounting the assembly below the extrusion T-slot as seen in Figure 1, approximately 1.5 inches is saved.

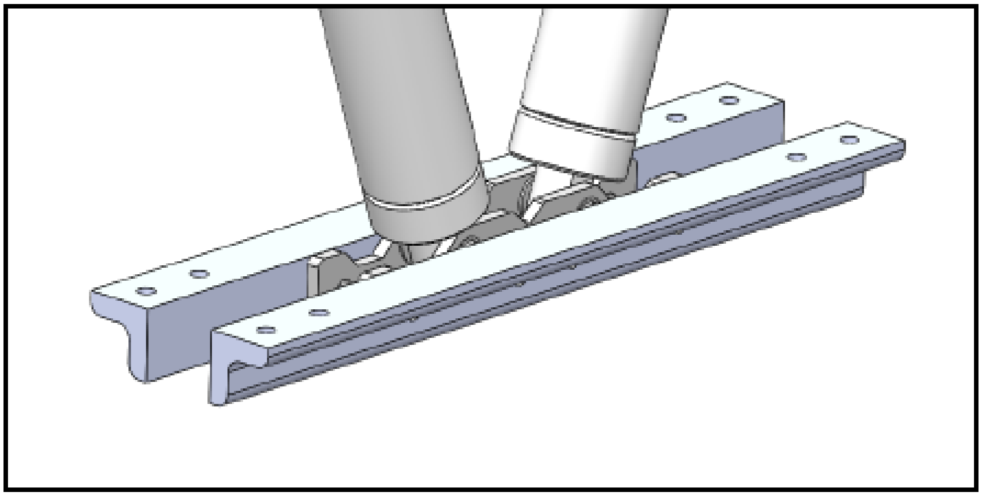


Figure 2: Lower Mounting Assembly

Angle Iron Cross Beam

To improve strength and allow for proper mounting of the lower portion of the cylinders, an angle iron component will be used and modified. Several holes are necessary to allow for the mounting of the beam to the overall frame and to allow for mounting of the custom component seen in Figure 4.

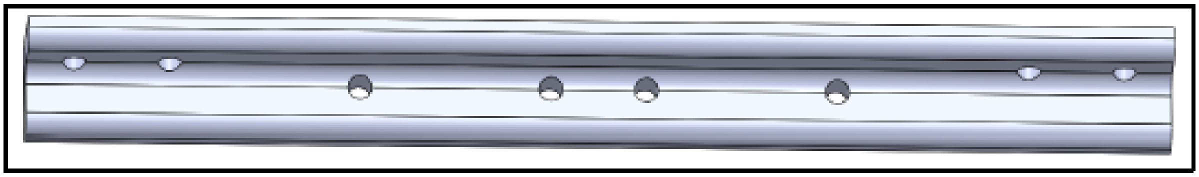


Figure 3: Angled Iron Cross Beam

Cylinder Attachment Plate

This custom place allows for full and resistance free range of motion for the cylinders by implementing bushings and allowing clearance required due to the diameter of the cylinders. The component requires water jet cutting to be manufactured.

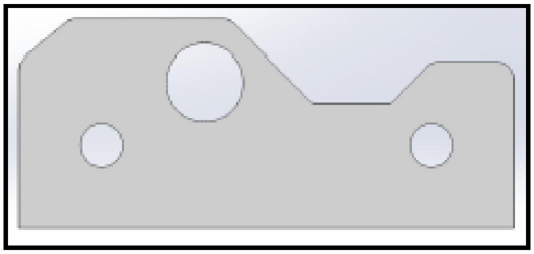


Figure 4: Cylinder Attachment Plate

Upper Cylinder Mounting Components

The need to adjust the cylinder angle is no longer required going forward, thus allowing for a simpler upper cylinder mount design and saved space.

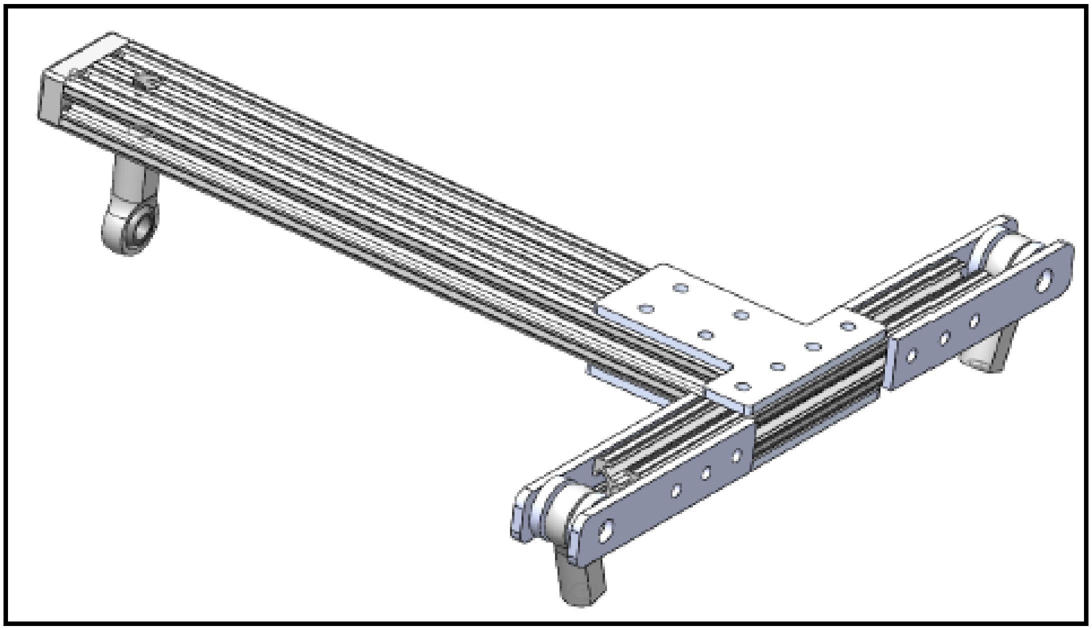


Figure 5: Upper Cylinder Mounting

Upper Cylinder Mounting Plate

To ensure maximum simplicity and space saving, the design on the right was determined as ample. The ease of manufacturing and assembly makes this a viable option.

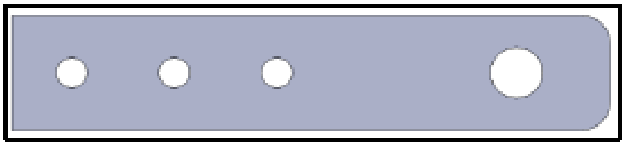


Figure 6: Upper Cylinder Mounting Plate

Baseplate Angle Adjust Assembly

One of the key changes skateboard riders make to change their ride is by adjusting the angle at which their truck sits relative to the board. These changes can be accounted for by implementing the Baseplate Angle Adjust Assembly which allows for angles between 0° and 20°.

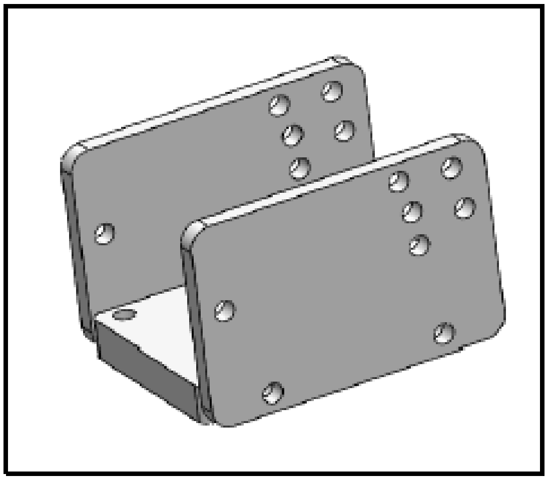


Figure 7: Baseplate Angle Adjust Assembly

Support Member

To simplify the truck changing process, a simple device which can hold the top section of the device up and prevent side to side movement was required. By erecting this and pinning it into position, the process of exchanging trucks is greatly simplified.

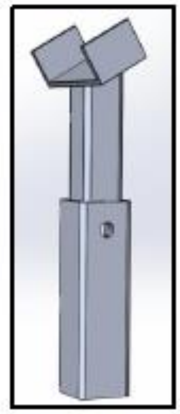


Figure 8: Support Member

Rod End Orientation

The rod end orientation was changed to better represent the tilt of an actual deck. It also allows for a line of action that is more closely aligned with the truck.

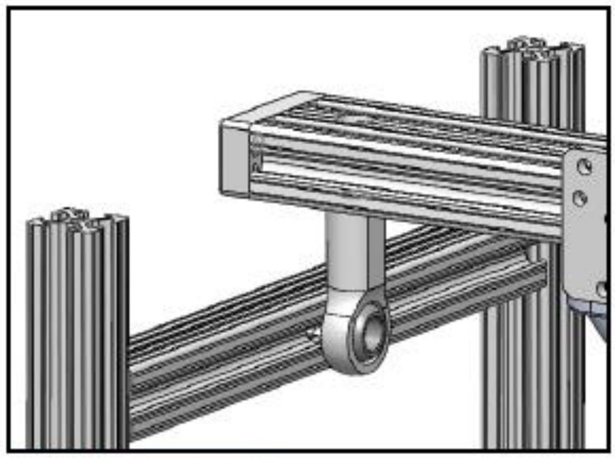


Figure 9: Rod End Orientation

Mechanical Advantage Analysis

In order to determine the ideal size for the frame of the skateboard testing device, the systems mechanical advantage was taken into consideration. As seen above, the current design wasn't utilizing their layout to maximize the amount of force acting at the truck. However, by shrinking the device by 8 inches, we are utilizing the mechanical advantage while lowering overall size drastically.

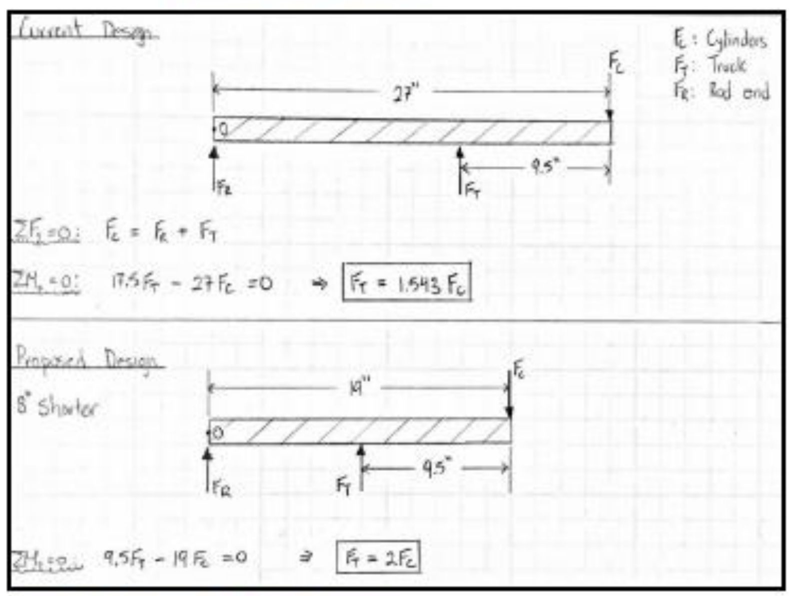


Figure 10: Mechanical Advantage Analysis

In determining an ideal orientation to place the two pneumatic cylinders to replicate centrifugal force and rider weight force, an excel spreadsheet was used with an iterative process testing different cylinder angles. The example spreadsheet seen below is with an angle of 70 degrees and assuming the mass of the rider is 90 kg. Currently the angle chosen to move forward with is 70 degrees but this is part of a continuous iterative design and could be changed depending on the spatial limitations present on the device. Below also are the hand calculations to derive the equations used in the excel calculations.

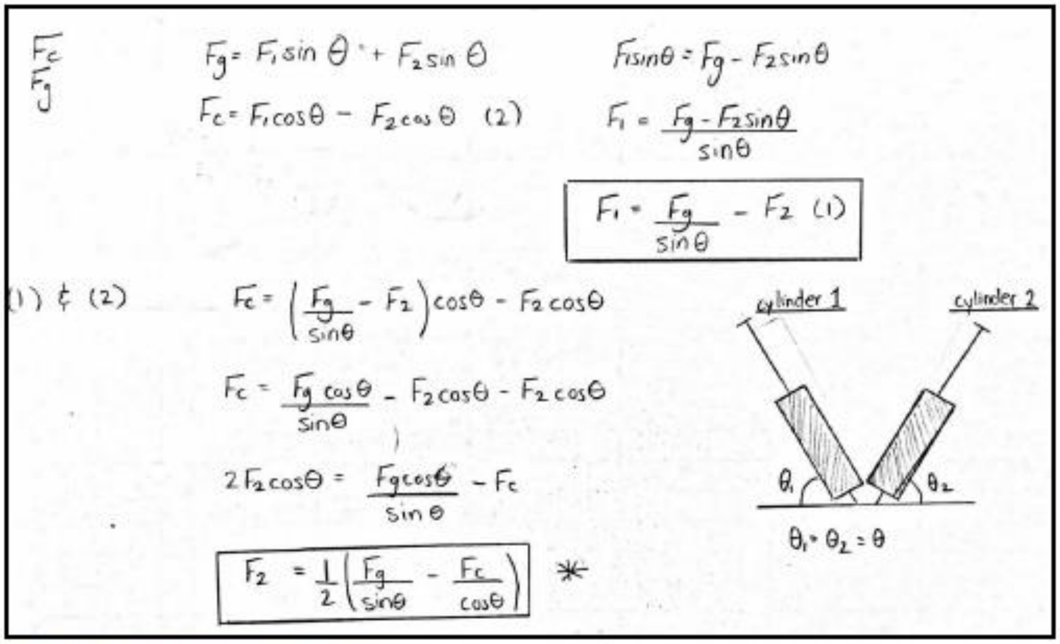


Figure 11: Cylinder Orientation Derivation

Radius of Curvature	F centrifugal(N)	Resultant (N)	F Cyl 1 (N)	F Cyl 2 (N)	P Cyl 1 (psi)	P Cyl 2 (psi)
20	41	884	499	411	66	54
19	43	884	501	407	66	54
18	45	884	503	404	66	53
17	48	884	505	400	67	53
16	51	884	507	396	67	52
15	54	885	509	391	67	52
14	58	885	512	385	68	51
13	62	885	515	379	68	50
12	68	885	519	371	69	49
11	74	886	524	362	69	48
10	81	887	529	351	70	46
9	90	887	536	338	71	45
8	101	889	544	322	72	43
7	116	890	554	301	73	40
6	135	893	568	272	75	36
5	162	898	588	233	78	31
4	203	906	618	174	82	23
3	270	923	667	75	88	10

Figure 12: Cylinder Orientation Calculation

m	90	kgs
g	9.81	m/s^2
v	3	m/s
Fg	882.9	Newtons
Angle	70	Degrees
Angle	1.221730476	Rads
Bimba Powerfactor	1.7	

Figure 13: Fixed Parameters for Calculation

3.0 Electrical Designs/Controls

The electrical components are required to control pressure, measure deck tilt and truck rotation. An op amp circuit was required to use the analog output of our data collection device while getting the full range of pressures from the pressure regulators.

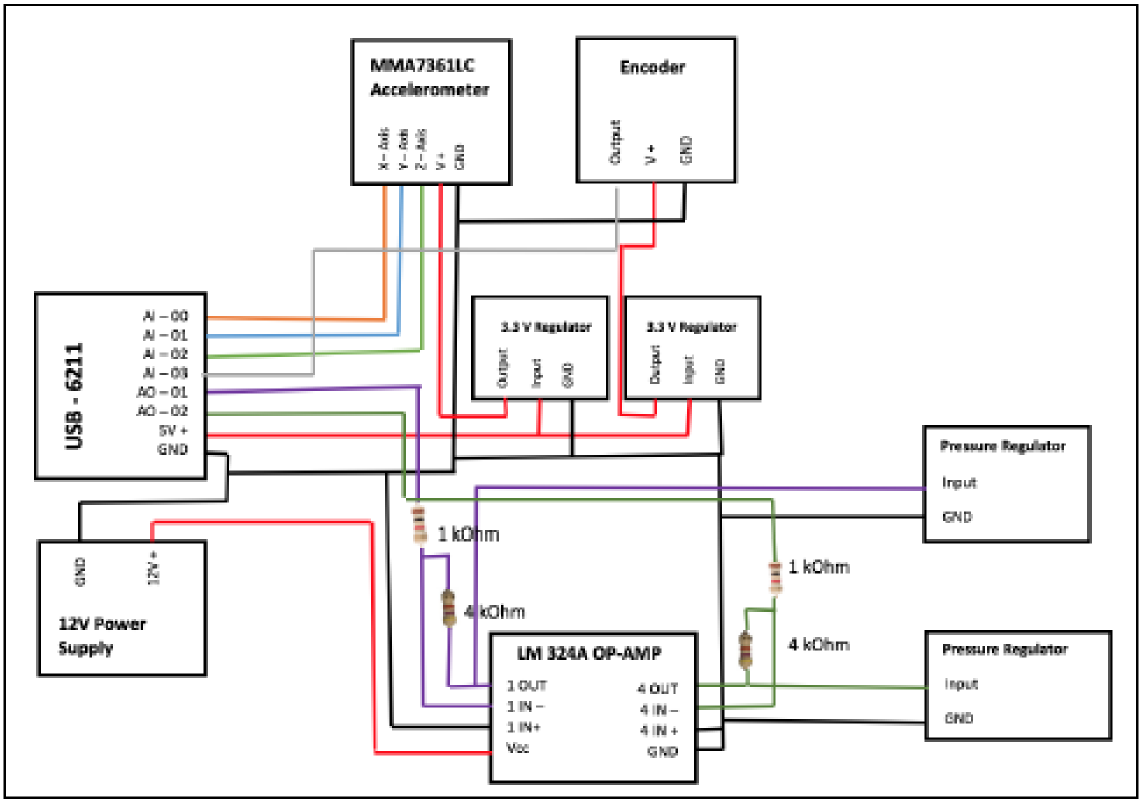


Figure 14: Electrical Circuit Diagram

Power Supply

Since the truck testing device requires an outside source of air pressure (a compressor) and a laptop, which will both require 110V power from a wall, the decision was made to use a direct power source from a wall outlet for the circuit above as well. The charger on the right is being implemented as it provides the necessary voltage and ample current.


Figure 15: Power Supply

Data Acquisition Device (USB 6211)

To collect the required data and accurately control the outputs, while being easily integrated with a user-friendly software such as MatLab, it was determined to use a USB-6211. This will allow for the easy user input to control the system and allow for the operator to get the results easily.

Figure 16: USB 6211

4.0 Current Product Development Specifications

There are many product development specifications for this device. Currently the device requires power input electrically and pneumatically, where the latter needs to be controlled. There are adaptability and range of motion requirements which are dependent on the truck. The test requires measurements of key characteristics using instrumentation. These instrumentation devices should be within a certain accuracy to produce reliable data. The device also needs to be safe to operate.

Category	Specification	Comment
Force	150 lbs	Analysis of half of maximum rider weight on one truck
Accuracy	± 1 PSI	Components used for measurements must be this accurate
	± 1 degree	
Range of Motion	Max. Deck Tilt Angle: ± 20°	Specifications are results from previous group
	Max. Turning Angle: ± 15°	
Adaptability	Max. Truck Width: 10"	Trucks must complete full range of motion before cylinders bottom out or else data will be invalid after that point
	Max. Riser Pad Angle: 20°	Changing riser angle will introduce added vertical height
	Added Height from Riser Pad: Min. 1"	
Sufficient Power Supply	Min. Pressure Input: 130 PSI	Both are specified by pressure transducer
	Min. Voltage: 10 V	
Key Measurements Required	Deck Tilt	
	Turning Angle	
	Force / Pressure	
Intrumentation	Laptop/Desktop with Matlab	
	Data acquisition device	
	Measurement devices for key measurements	
Controlled Variables	Pressure into cylinders	
Safety	Framing that withstands min. 400 lbs	Each cylinder outputs max. 200 lbs
	Emergency shut down	

Table 1: Current Product Development Specifications

5.0 Competitive Analysis of Existing Products

Currently there is only one device available on the market for performing quantitative tests on skateboards: the ONAN Electric Skateboard Driving Simulation Testing Device (seen below). This device is used to measure top speed, while simulating load and road pressure as well as monitoring the battery temperature.

Figure 17: The ONAN Electric Skateboard Driving Simulation Device

Similarities	Differences
Performs quantitative tests on skateboards	Requires electric skateboards only
Simulates load	Can't measure turning angle or deck tilt
Creates data report of results	Measures top speed
	Simulates road pressure
	Monitors motor/battery temperature
	Simulated load is max. 100 kg
	Requires motion for tests

Table 2: Comparison of the Two Devices

Other than this device, there is no other device available on the market that tests the handle and the feel of a skateboard truck. This means that currently our device will not have any competition on the market. If our device was to be sold as a product, most of the buyers would be both domestic and international skateboard truck manufacturers, since using this device for a skateboard truck is one method of measuring if the skateboard truck is manufactured properly.

6.0 Cost Status and Projections

Below is a table detailing the current cost status of the project. The current budget set aside for this project includes any additional material and components that must be bought or manufactured and integrated to the current device prototype. Currently, the team has spent roughly 130.00 USD.

ITEM DESCRIPTION	QUANTITY	TOTAL PRICE (USD)
Solder-in Breadboard	1	4.10
4.02 KΩ Resistor	4	0.56
1.0 KΩ Resistor	4	0.40
Power Switch	1	4.56
Breadboard	1	6.60
5V Regulator	4	0.78
Adjustable Handle	4	27.80
Spring Table End-Feed Fastener	12	16.80
Adjustable Handle (stud end)	4	16.80
Spiral Bundling Wrap	1	5.77
Electronics Enclosure	1	26.81
Power Source (12V)	1	11.18
Emergency Stop	1	11.16
TOTAL		133.32

Table 3: Current Order List

The most time restrictive task is the design and concept generation process. Manufacturing will not take a significant amount of time as our project already has a prototype. The projected cost for all the parts potentially required for the project are shown below in Table 4. The total maximum budget required to complete the rest of the project is 302.00 CAD.

Components Required	Projected Time Required (Weeks)	Qty	Projected Budget Required (CAD)
Rod-End Plates	1	4	25.00
Bottom-End Bushing Plates	1	4	25.00
L-Angles	1	2	12.00
Pressure Sensors	2	2	80.00
Pressure Manifold	2	1	40.00
Load Cells	2	2	120.00
TOTAL			302.00

Table 4: Truck Testing Device Projected Costs and Time

7.0 Project Risk Analysis

The team has analyzed the current and potential risks of the device and the project in general, which can be seen in the table below. Since a prototype already exists, there were inherent risks present in the previous design. These risks have been either been completely eliminated or reduced to a reasonable level. See below for the risks present in the current prototype.

Potential Risks	Risk Ranking (1-5)
Software won't integrate with DAQ	1
Frame/connections won't withstand applied forces	1
Manufacturing costs too high	2
Lack of desire from customers	2
Device not adjustable to every truck size	2
Pneumatics won't represent the force vector required	3
Tests will not be repeatable	3
Component costs too high	3
Total cost of device too high	3
Project not completed by expected date	3
Too much effort adjusting and/or changing truck	4
Data won't be accurate and/or representative enough	4

Figure 18: Project Risk Analysis