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One-ride human powered vehicle

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SANTA CLARA UNIVERSITY
Department of Mechanical Engineering

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ENTITLED

One-Ride Human Powered Vehicle

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One-Ride Human Powered Vehicle

By

Alex Fisher, Alex Sahyoun, Geoffrey Schmelzer, Brendan Taylor and C.J. Toy

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Santa Clara Human Powered Vehicle 2014-2015

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Abstract

This document discusses the design, analysis, manufacturing and testing of the One-Ride human powered vehicle which was entered into the 2015 ASME West Coast HPVC Competition. The goal of the vehicle is to entice people to switch from gas powered vehicles to the One-Ride for trips of up to 20 miles round trip. The One-Ride design features fully adjustable seating and steering positions and was designed to fit anyone between the heights of 5’2” and 6’4” comfortably. The seat is adjusted using metal sliders, manufactured in the SCU machine shop, which fit into brackets attached to the frame. The bike features telescopic steering which is adjusted by the loosening and tightening of collar clamps. To increase the strength and safety of the frame, the welding and heat treatment were contracted to industry professionals. The frame was welded by Chavez Welding and heat treated by Byington Steel Treating. Deformation in the seat frame during heat treatment prevented full adjustability of the seat, however was secured in its middle position for testing. The wheelbase of the bike is 73.33 in and has an overall height of 50.77 in. . Slop in the steering caused instability at low speeds, which prevented the bike from being ridden in the ASME HPVC Competition. Design solutions to both of these problems have been identified. At the completion of senior design, the manufacturing is still ongoing.

Acknowledgements

The One-Ride human powered vehicle team would like to extend its gratitude and appreciation to all those who helped make this project possible. Starting with Santa Clara University and the Santa Clara University School of Engineering for their support throughout the entire process, and Dr. Drazen Fabris and Dr. Calvin Tszeng who served as advisors to the team and were extremely helpful and insightful to the team through each stage of the project. We would also like to acknowledge Dr. Timothy Hight and Dr. Scott Abrahamson who gave much of their time to helping identify and incorporate solutions to certain problems and customer needs into our design. The team would also like to thank Mr. Don MacCubbin, the Santa Clara University machine shop manager, and Chavez Welding who assisted the team in building and manufacturing the bicycle. Finally the team would like to thank the family and friends who have supported the members over the last four years at Santa Clara. Without their support this endeavor would not have been realized.

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1. Introduction

1.1: Background and Motivation

Team One-Ride consists of five senior mechanical engineering students who have the motivation to exercise their engineering knowledge and apply that knowledge to help combat rising greenhouse emissions and to lower the number of vehicles on the road. Currently, worldwide, there are a growing number of automotive vehicles being purchased. China and India have increased the number of vehicles being purchased in their respective countries, and these two countries combined have a population over 2.5 billion people. If the current rate of purchases continues, these countries will surpass the United States in the number of vehicles purchased annually. In 2013, Asia accounted for 30 percent of vehicles purchased[1]. Because of this increase, the amount of greenhouse gases released by these vehicles will also increase, contributing to the ever growing problem of climate change. The team would like to help diminish the number of vehicles purchased by providing an efficient, affordable, and environmentally friendly alternative in the form of an innovative Human Powered Vehicle. Our goal is to design an efficient, innovative, safe, and environmentally friendly bicycle that can be marketed to a global audience. It would serve as a replacement for automotive vehicles on trips that are twenty miles or less round trip.

Our design is based off the Groundhugger XR2[2], which is a two wheel recumbent bicycle with over-seat steering. With major focuses on speed, comfort, and safety, our bike features a protective roll bar, aerodynamic fairing, comfortable seating position and storage bins for everyday items such as groceries or backpacks. The bicycle is constructed out of Aluminum 6061 T6 due to its high strength to weight ratio and strong resistance to corrosion. A unique innovation in our design is a completely adjustable seat and steering column. When choosing to buy a bicycle, people are always trying different sizes to make sure their feet reach the pedals and their hands can reach the handle-bars. With our design, any sized person will be able to use our bike. By simply adjusting the seat and steering column, a rider will be able to customize his or her riding position to a comfortable setting. The design was entered into the ASME West

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1 Gomes, C., “Global Auto Report,” *Scotiabank*, May 7, 2015
http://www.scotiabank.com/gls/en/index.html#about

2 Riley, R., “Ground Hugger XR2,” *Robert Q. Riley Enterprises*, November 1, 2014

Coast HPV Competition where we competed against several other schools from all over the nation.

1.2 Review of Literature

Structure Properties of a Frame for Human Powered Vehicles

This journal is about frame design of a human powered vehicle[3]. The frame is the most important part of the HPV, therefore proper design and analysis is very crucial. This report goes over the research, design and analysis of a 3 wheel tricycle frame. While our design has 2 wheels, this journal was helpful in deciding what kind of analysis to perform on our frame. The analysis of different materials used in current bike frames was beneficial in our choosing of the frame material for the One-Ride design. This source was found through the library database.

Pegasus Human-Powered Vehicle

This is the design report of last year's Santa Clara HPVC team[4]. Everything from early design sketches to their final product is in this report. They built a three wheel tadpole style bike that had both Ackermann and tilt steering, and raced it in the ASME West Coast Competition we planned to do in April. Their report contains budget information, local welders who helped assemble their bike, as well as grants that they received to help fund their project. This source is very important to our team because it not only has local companies we can contact to get information and services from, but it allowed us to further improve our design this year. By studying their report and design we can see what the problems and failures their design encountered. When designing our prototype we have kept those problems in the back of our minds and made sure not to repeat them again this year. The report also helped in the early stages of the project by giving us a rough estimate of what the budget will be and how long it will take to complete the entire project. A copy of the report was obtained through the mechanical engineering office at Santa Clara University.

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[3] Alexandru, R., Maniu1, D., "Structure Properties Of A Frame For Human Powered Vehicles." Academic Journal Of Manufacturing Engineering 11.2 (2013): 12-17 .Applied Science & Technology Source. Web. 21 Oct. 2014

[4] Porter, D., Chester, P., Stephens, P., Flores, L., Jones, I., Nakamura, R., "Santa Clara University Human Powered Vehicle 2013-2014." Bachelor's Thesis, Santa Clara University, 2014.

On the Design of a Recumbent Bicycle with a Perspective on Handling Qualities

This journal article discusses different handling qualities of recumbent style bicycles[5]. The authors designed a new steering system and compared it with already proven handling methods for recumbent bicycles. They built a prototype with their new steering system and road tested it to see if their new handling system would be successful in real life situations. This article is important to our project because one of the main concerns with a two wheel recumbent bicycle is steering and handling. Being able to control our bike around tight turns and in between obstacles requires excellent steering and handling. Since this journal compares the new design created by the authors with already proven designs, we are able to use that information and decide on a steering system that we know will work well. This source was found on the ASME database.

A Study on the Efficiency of Bicycle Hub Gears

In this journal article the authors measured efficiency of several new generation bicycle hub gears[6]. They used a 1 HP motor to drive a crankshaft which was connected to a flywheel, and measured the torque and speed of the motor and flywheel. The authors plotted the efficiency with both power and speed, which allowed them to analyze the relationship between torque, speed, and efficiency. This article was useful to our research since we needed a gear train to power our bicycle. By studying the results in this article we decided on the gear train combination that has the greatest efficiency.

We can also compare the data in this analysis with any data that is obtained ourselves after the bike is rideable. This article was also found through the ASME database.

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[5] Schwab, A. L., Kooijman, J. D. G. and Nieuwendijk, J. "On the Design of a Recumbent Bicycle with a Perspective on Handling Qualities" *ASME 2012 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* 12 Aug 2012: 303-308

[6] Casteel, E. A., and Archibald, M., "A Study on the Efficiency of Bicycle Hub Gears." *ASME 2013 International Mechanical Engineering Congress and Exposition* 13. Transportation Systems (2013): n. pag. Web

Celeritas

This source is a design report for the HPV Celeritas[7] from Rose Hulman Institute of Technology. The main difference from Santa Clara's report is the type of human powered vehicle they designed. They designed a fully-faired semi recumbent bicycle. Similarly to Santa Clara's thesis, this report has all the calculations, budget, drawings and analysis that were used to design and manufacture their prototype. The reason this thesis was helpful is because their final design is similar to what our team produced. They have a two wheel recumbent style bike and while their design was fully faired, (ours is partially faired), their prototype is more similar to what we designed than Santa Clara's three wheel tadpole design. By studying their report our team gained more information on what makes a good two wheel recumbent bike. We also studied what went wrong with their design. Since we produced a similar style prototype, knowing what problems they encountered helped our team avoid similar mistakes. The report was found on the Rose Hulman HPV Team website.

1.3 Problem Statement

Greenhouse gas emissions and traffic congestion are two ongoing worldwide problems. The goal of our design is to help reduce carbon dioxide emissions and traffic congestion by providing a fast, safe, and aesthetically pleasing recumbent bicycle that can be used as a practical alternative to automobiles for short to mid-range trips (10-25 miles). It was desired to find ways to entice people to use human powered vehicles by concentrating on many of the popular features in cars, such as comfort, speed, and safety and incorporating these parameters in our design.

1.4 ASME HPV Competition Requirements

In order to gauge our vehicle's performance, we participated in the 2015 ASME West Coast Human Powered Vehicle Challenge. The team participated in the design innovation contest however, due to problems with the U-joint and low speed stability, we had to forfeit the speed and endurance competitions. The challenge took place from April 24, 2015 through April

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[7] Robertson, D., Woolfenden P., Coons, H., Burns, S., Skorina, M., *Celeritas*. Thesis. Rose Hulman Institute of Technology, 2013. N.p.: n.p., n.d. Print.

26, 2015 at Santa Clara University, the Hellyer Velodrome, and Santa Clara County Fairgrounds respectively and was split up into four specific sections:

<u>The Design Event</u>

-Design report detailing design, analysis, and testing submitted in advance of the competition

-Design presentation and safety and static presentation

<u>The Speed Event</u>

-Time trials were conducted at the Santa Clara velodrome

-A one lap run

<u>The Innovation Event</u>

-A presentation to the ASME judges that showcased our unique innovation incorporated into the design of the vehicle

<u>The Endurance Event</u>

-A two and a half-hour race with various obstacles in which we completed as many 1.3km laps as possible

<u>Mandatory Safety Requirements</u>

All quoted text in this section comes directly from the Rules for the 2014 Human Powered Vehicle Challenge (https://community.asme.org/hpvc/m/default.aspx).

General

- “The safety of participants, spectators, and the general public will override all other considerations during the competition.”

Performance Safety Requirements

- Vehicle “can come to a stop from a speed of 25 km/hr in a distance of 6.0 m.”
- Vehicle “can turn within an 8.0 m radius.”
- Vehicle “can demonstrate stability by traveling for 30 m in a straight line at a speed of 5 to 8 km/hr”

Rollover Protection System

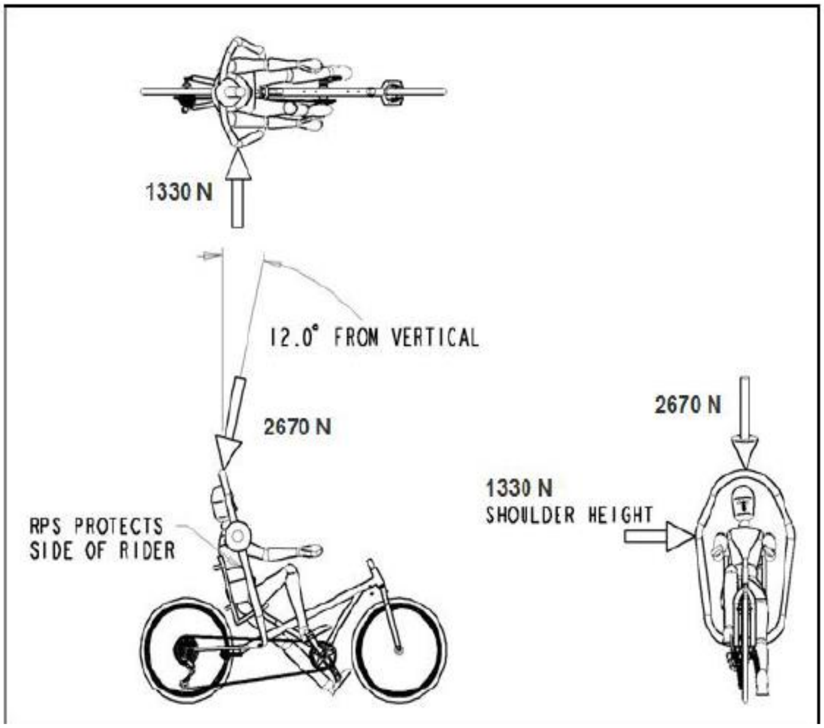

Figure 1.4.1 *ASME HPVC roll cage requirements for competing vehicles*[8]*-Reproduced with permission*

- "Top Load: A load of 2670 N per driver/stoker shall be applied to the top of the roll bar(s), directed downward and aft (towards the rear of the vehicle) at an angle of 12° from the vertical, and the reactant force must be applied to the roll bar attachment point and not the bottom of the roll bar (unless the bottom is the attachment point). Note that there may be one roll bar for the driver and another roll bar for the stoker which will result in each RPS having an applied load of 2670 N, or the driver and stoker can both be protected by a single roll bar which will result in the RPS having an applied load of 5340 N."
- "Side Load: A load of 1330 N per driver/stoker shall be applied horizontally to the side of the roll bar at shoulder height, and the reactant force must be applied to the roll bar attachment point and not the other side of the roll bar. Note that there may be one roll bar for the driver and another roll bar for the stoker which will result in each RPS having an applied load of 1330 N, or the driver and stoker.

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[8] Hilgenberg, W., "Rules for the 2015 Human Powered Vehicle Challenge". Rev 2. *ASME*. 2015. Print.

1.5 Bike Dimensions

Figure 1.5.1 shows the overall dimensions of the One-Ride bike design. The tallest and widest portion of the bike was the roll bar. The width is 27.5 in and the height is 50.77 in (measure from the ground to top of roll bar). The wheelbase is 73.33 in and the overall length of the bike is 96.58 in.

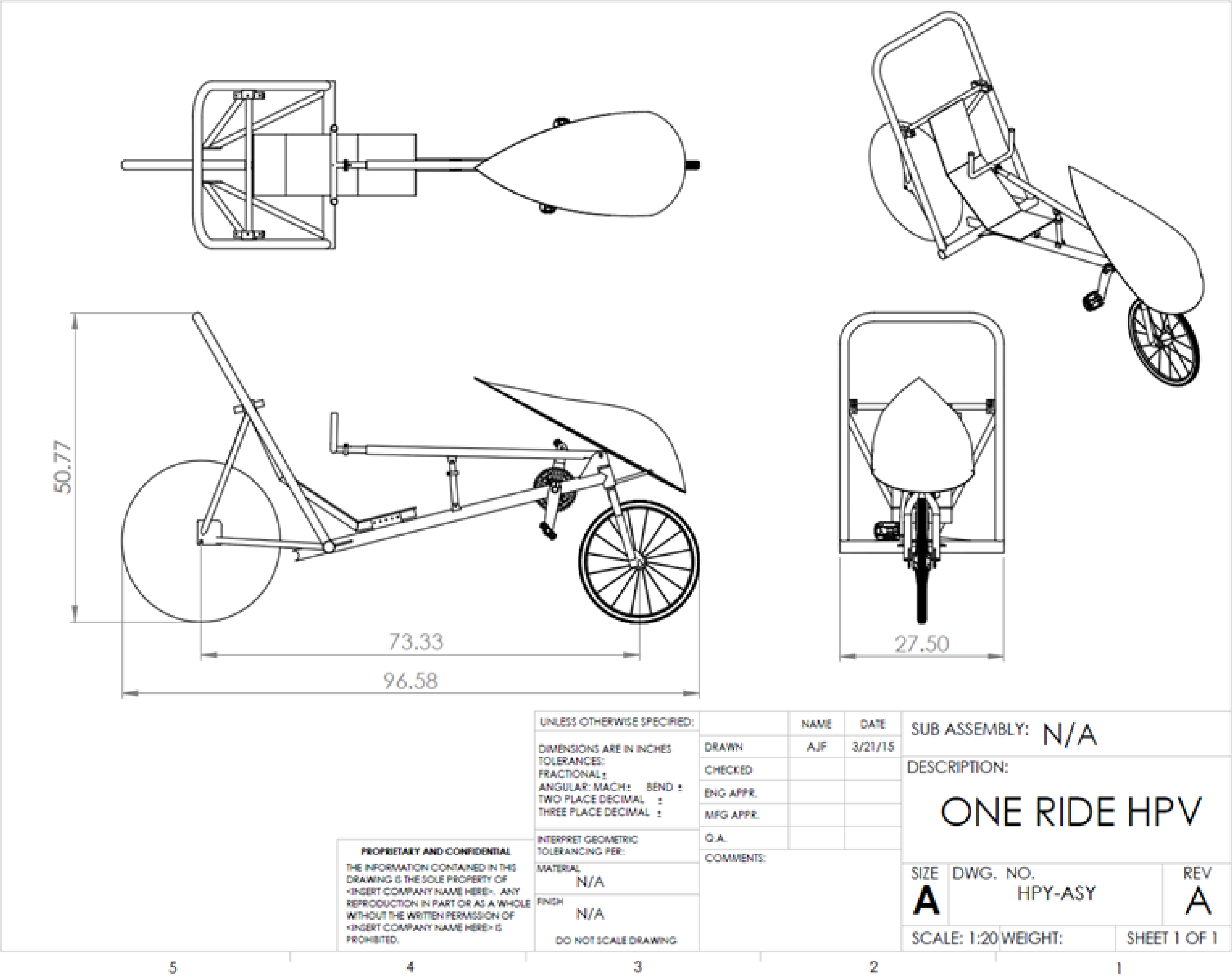


Figure 1.5.1 *Final Design of the One-Ride Human Powered Vehicle. Dimensions are given in inches.*

2. System Level Considerations

2.1 Requirements

In order for the HPV to be a successful commuter vehicle, there are certain requirements that the design needed to meet. These requirements were set by both the ASME HPVC judges as well as the One-Ride team based on goals the team wanted to accomplish.

Maximum Speed
  -Up to 35 mph on flat smooth ground
Allowable Rider Height
  -Any within the height range of 5’2” and 6’4” can fit and ride the bike comfortably
Roll bar Protection System
  -Can sustain a top load of 600 lbs and a side load of 300 lbs without failing or visible deformation
Additional Requirements
  -2 wheel recumbent style
  -Single Rider
  -Fully adjustable seating and steering position

2.2 Customer Interviews

To help determine what the team goals should be for the design, several interviews and surveys were conducted. The information gathered from these interviews and surveys not only showed us what people like in current bicycles already on the market, but also provided ideas that people have on ways in which current human powered vehicles can be improved.

2.2.1 Potential Customer Surveys

When identifying potential customers for the design, our team realized we are surrounded by a college campus filled with students who ride human powered vehicles such as scooters, bicycles, and longboards, etc., every day. Using surveymonkey.com, we created a questionnaire and posted it to social networking sites such as Facebook to gain feedback about student’s use of human powered vehicles. The survey, whose questions and responses can be found in Appendix C, yielded strong results with over 70 participants taking the survey.

2.2.2 Interviews

Along with the responses gathered from fellow students, we were able to get personal interviews with two individuals who have been around bikes for many years and who would be able to give us some good information from their many years experience in the bicycle world. The first was Santa Clara professor Scott Abrahamson. Prof. Abrahamson has been riding bikes for over 20 years and has had much experience with different kinds of bikes. He was able to give insight from a strictly customer point of view. From his interview we were able to gain insight into what a "hardcore" cyclist looks for in a bike and what aspects of our design will be most important to ensure it will be something a seasoned rider like Prof. Abrahamson would want to buy.

The second personal interview was with Joshua Muir, a long time bicycle manufacturer. Not only is Joshua a priority customer like Prof. Abrahamson, but he is also a professional in the bicycle frame business. Because of his profession, the interview with Joshua focused more on the manufacturing and actual designing of a bicycle. From his interview, we were able to find out, in detail, what companies do when designing a new product, and we were able to compare this side by side with what customers look for in a bike.

The questions and responses to each of the interviews can be found in Appendix C.

2.3 Customer Needs

Based off of the information gathered regarding customer needs from different age groups, it was clear that each age group has different preferences for their ideal human powered vehicle. Most users preferred a bike with some type of gear system for adjustable speed, regardless of their age. They typically use their human powered vehicle for short trips of less than 10 miles because of its speed limitations and safety concerns. Most user responses focused on the health and financial aspects of HPVs as a main motivation for their use. The low cost of maintenance compared to other forms of transportation is a key selling point for these vehicles.

Many customers found it essential to have an effective storage unit that accommodates all sizes of belongings ranging from cellphones, groceries, or other large items. In addition to storage needs, other main concerns included a theft protection and security system on the bike. While bicycle locks are available, wired locks can be easily broken and aren't as effective as traditional car theft systems. The main improvement that generally all consumers suggested was speed and ease of ride. For many, commuting to work or school with a human powered vehicle would take too long and therefore they choose either public transportation or an automobile to get to work. The public survey suggested that if these human powered vehicles had higher speed, longer ranges, and were easier to ride up hills, they would consider using this form of transportation more regularly. One of the biggest concerns with increasing the speed of the vehicle is safety. Crashing a human powered vehicle at near car speeds is much more dangerous than in a car, and thus an emphasis on safety would be essential for any high speed recumbent bicycle. The importance of customer needs in order of priority was safety, speed, ease of ride, storage capacity and theft protection

Users on the older end of the age bracket were also concerned with the comfort of the ride. Recumbents typically feature back support with a reclined seating position allowing for more area to support the rider's body weight. This allows for a less stressful seating position which is optimal for long distance rides. The seat also must be designed to accommodate all body shapes and sizes.

In conclusion, this small study determined that our human powered vehicle should be highly focused on speed, comfort of ride, and storage, while still maintaining safety. In order for this vehicle to be successful in the market, it must have a lower price that is affordable to the everyday non-enthusiast user. We believe that the practicality of existing HPVs must be improved to bring success in the market. These results allowed us to tailor our design goals and features to what the end user desires. With the survey and interview information we were able to prioritize and understand what features should be focused on for our design.

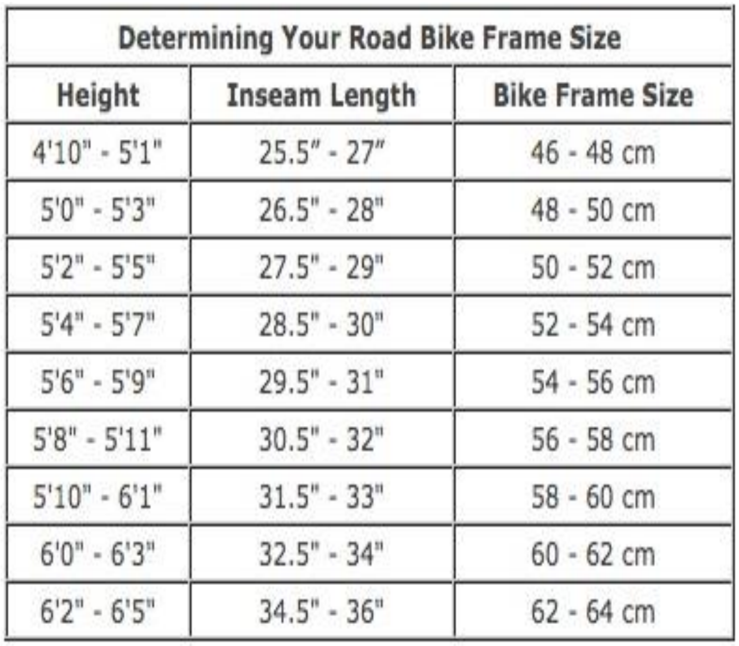
2.4 Engineering Standards and Ethical Constraints

2.4.1 Economical

Most recumbent bicycles on the market today cost between $200 and $10,000 depending on the quality of the bike. One goal of our team was to keep the cost of the bike low but still keep the quality of the bike high so that people would enjoy using it every day as they ride it to work, school, or the store.

While we are designing our bike to be at the lower end of this price range, a bike rider could still save over $5,000 dollars by switching to our design. The reason is the height range that our bike can support compared to the height range other bikes can. As seen from the chart below, current bikes can only support a 3in height range. Assuming a bike costs $1,000, an avid bike rider would spend $6,000 over the time he or she grew from 5’0” to 6’0”. The One-Ride bike is designed to support a rider for over a foot of growth. Even if the bike costs $1,000 dollars, the rider would save $5,000 because he or she would not have to purchase a new bike every time he or she grew 3 inches.

Table 2.4.1.1 *Height range of current bikes on the market*[9]



Determining Your Road Bike Frame Size		
Height	**Inseam Length**	**Bike Frame Size**
4'10" - 5'1"	25.5" - 27"	46 - 48 cm
5'0" - 5'3"	26.5" - 28"	48 - 50 cm
5'2" - 5'5"	27.5" - 29"	50 - 52 cm
5'4" - 5'7"	28.5" - 30"	52 - 54 cm
5'6" - 5'9"	29.5" - 31"	54 - 56 cm
5'8" - 5'11"	30.5" - 32"	56 - 58 cm
5'10" - 6'1"	31.5" - 33"	58 - 60 cm
6'0" - 6'3"	32.5" - 34"	60 - 62 cm
6'2" - 6'5"	34.5" - 36"	62 - 64 cm

The One-Ride design is also good for families. Instead of having to purchase several bikes for each member of the family because everyone needs a different size, they only need to purchase one or two bikes. By simply adjusting the seat and steering wheel to the desired position, an entire family only needs one bike for each of them to comfortably ride.

2.4.2 Environmental Impact

Human Powered Vehicles have the opportunity to greatly impact the environment. According to a census taken in 2012, only about 0.61% of the commuting public bike to work[10].

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[9] "Bike Shop | South Lake Tahoe | South Shore Bikes." *South Shore Bikes*. N.p., n.d. Web. 09 June 2015.

[10] “Commute Statistics,” *National Household Travel Survey, US Department of Transportation, Bureau of Transportation Statistics*, January 1st 2014, http://www.statisticbrain.com/commute-statistics/

While this number is climbing (only 0.56% commuted in 2011) it is still extremely small. By designing a bike that is comfortable and easy to ride, the One-Ride team hopes to increase this number, which would help reduce the amount of pollution left by cars, not only by driving them, but also from manufacturing them.

Automobile transportation is most inefficient when operated in congested areas with high traffic and frequent stops. Short trips are one of the biggest producers of greenhouse gasses because engines are constantly running at various rpms; thus consuming more gas. The One-Ride Human Powered Vehicle was designed so that it can be used in metropolitan areas for short to intermediate distances. A study by the National Geographic found that 80 percent of carbon monoxide emissions and up to 30 percent of U.S. carbon dioxide emissions are produced from automobiles. The same article found that individuals who biked 5 miles a day could reduce their household emissions by up to six percent[11]. While individually this number is somewhat insignificant, as a nation, over 900 million gallons of fuel could potentially be saved. This in turn would reduce carbon dioxide emissions between 6 million to 14.2 million tons per year.

2.4.3 Manufacturing Impact

Currently, bikes have a rider height range of about 3 inches. Once a rider grows out of this range it is recommended that he or she get a new bike with a bigger frame so he/she can continue to ride at the optimum position that produces the maximum power output with minimal energy input. For avid bike riders who continually buy new frames when they outgrow their current one, the cost can get extremely expensive. Manufacturing companies also spend a lot of money producing the frames as each size frame needs specific components to match the specific size. Ordering this wide range of parts and building jigs for welding and heat treating can raise manufacturing costs, which in turn raises the selling price.

The production of automobiles also creates subsequent consequences on infrastructure, waste, and manufacturing that can ultimately be limited with increased bicycle usage. Cars require sophisticated infrastructure ranging from parking spots, private roads, to public highways. However, if people begin to ride bicycles for short trips, maintenance costs for roadways will decrease. In fact, anywhere from 80 to 90 percent of the U.S. infrastructure can

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[11] "Buying Guide - Bike Environmental Impact - National Geographic's Green Guide." *National Geographic*. N.p., n.d. Web. 04 June 2015.

currently be used for bicycle routes. With the One-Ride HPV, one frame can accommodate over a foot height range of riders so that users will not have to replace the bicycle as frequently. In addition, the overall vehicle weight is roughly 30 pounds which requires significantly less material to produce than a car. Bicycles also are more reliable than cars because they require less maintenance due to fewer moving parts.

2.5 Functional Analysis

The One-Ride project has been broken into four major components:

-Steering
    •The vehicle has a unique steering system with a car-like steering wheel and steering column that interfaces the front fork
-Frame
    •The frame is built in a fashion that the rider is safely secured and the center of gravity is as low as possible in order to be stable.
-Drivetrain
    •The drivetrain is designed to maximize the speed of the vehicle
-Fairing
    •The fairing is built to minimize drag in order to increase the top speed of the vehicle and protect the rider from the elements

Each of the major subsystems can be broken down into smaller subsystems that were designed individually and then brought together into one whole system. During the research and design phase of the project, it was realized that the way a user controls and interacts with the vehicle is very important in the design of the four sub systems. The four main ways the user interacts with the vehicle can be seen in the input-output diagram in Figure 2.5.2 below.

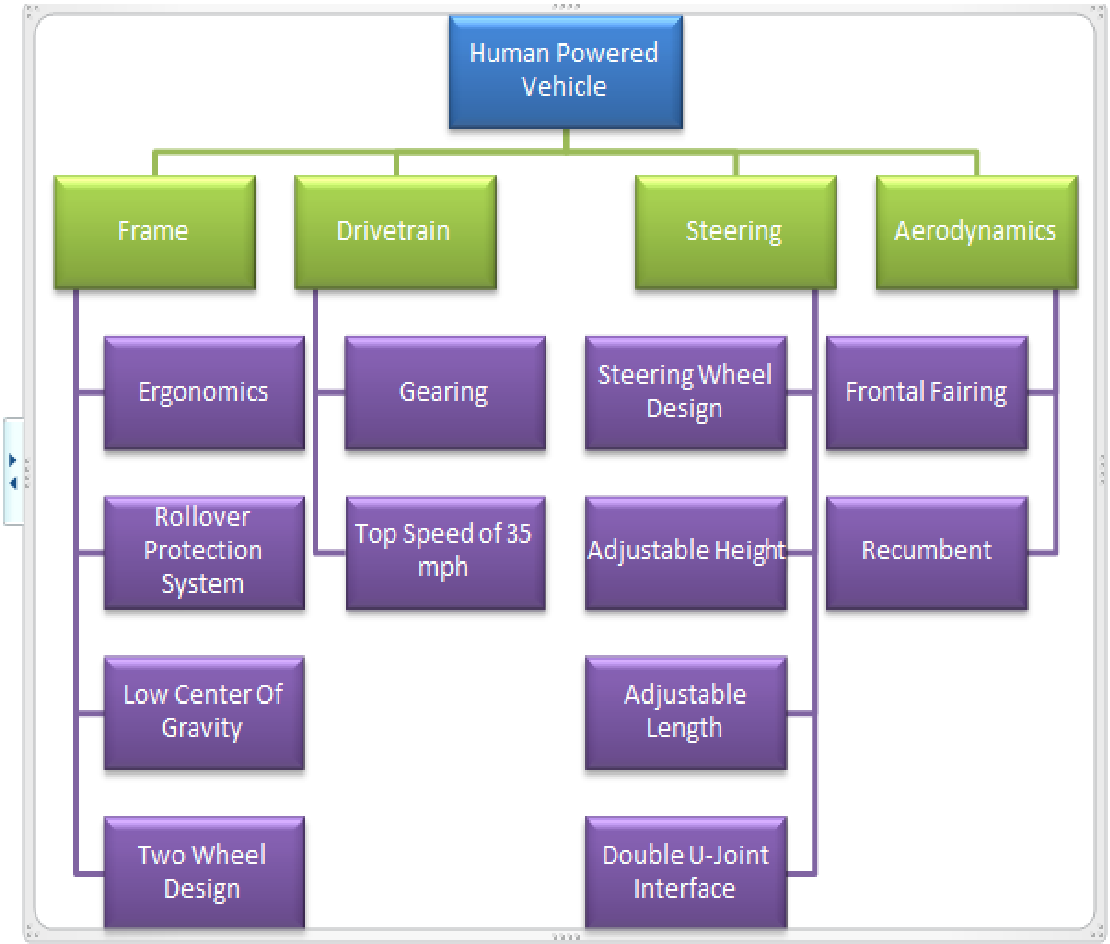

Figure 2.5.1: *Functional decomposition of all four major vehicle components*

The user interacts with the vehicle in a variety ways. One of the most important aspects of the design was the steering of the vehicle. Throughout the design process, the highest priority was placed on creating a vehicle that was simple to operate with responsive handling. The figure below shows how a user would interact with the vehicle and what output would result.

Input	System	Output
User presses on the brake handles	The brake cable is pulled, consequently the brake pads squeeze together on the brake disk	The wheel stops rotating which causes the vehicle to stop moving
User presses on the gear shifter	The derailleur changes gear to either a lower or higher gear	Vehicle RPM increases/decrease accordingly
User maneuvers steering wheel	Steering column translates motion through a double u-joint to the front fork, turning the vehicle	Vehicle moves in the desired direction
User presses feet against pedals in a circular motion	The chain transmits foot power to the rear wheel	Vehicle moves forward at a speed proportional to power input

Figure 2.5.2 *Input and output diagram of all major rider interfaces that the rider is capable of controlling. These features include steering, braking, shifting, and pedaling*

2.6 Design Sketch

When starting the initial design research of the vehicle, there was a wide variety of different frame styles to choose from. It was decided to go with a two wheeled recumbent style frame in order to achieve a high speed and stability at that high speed. A further explanation of the frame design and analysis can be found in Section 3. In order to satisfy the innovation part of the ASME competition, a lowering innovation for the bicycle was designed. The lowering innovation would lower the frame to the ground, allowing the user to park the vehicle in an upright position, making it easy to load and unload any cargo. This innovation would also provide added security to the vehicle by rendering the vehicle inoperable. This would prevent anyone from stealing the bike when it was lowered.

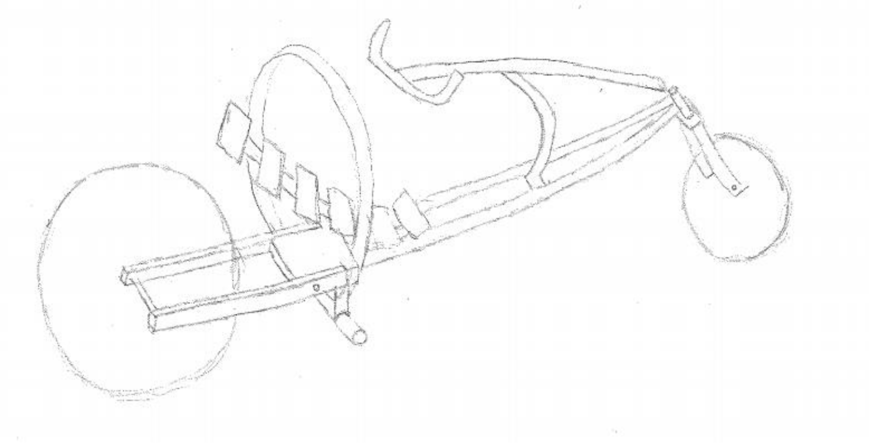

Figure 2.6.1: *Preliminary sketch of the Human Powered Vehicle. The bike was designed to lower just below the roll bar (function can be seen in Figure 2.6.2) for easy entry and exit as well as loading and unloading of cargo.*

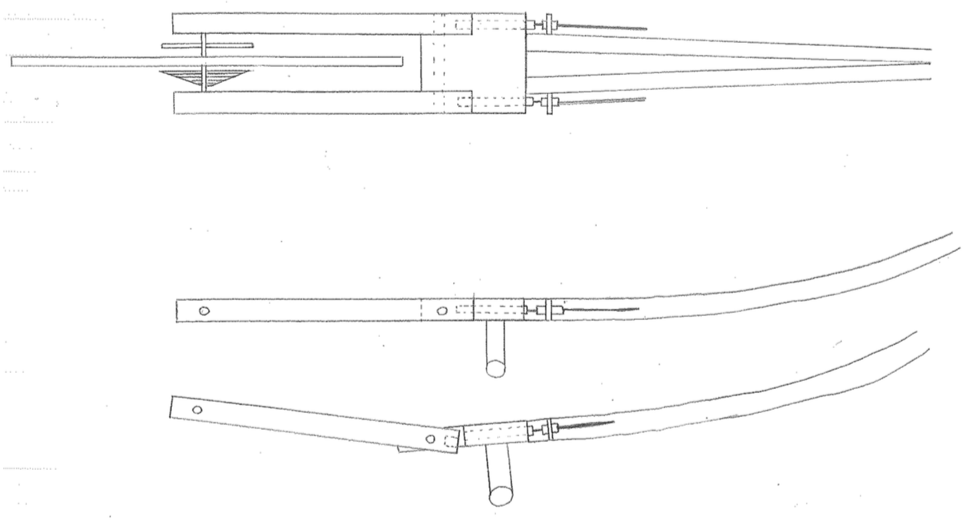

***Figure 2.6.2:** System sketch of the lowering mechanism part of the frame. The top sketch is a top view of the main section of the bike. The front wheel (not shown) would be on the right side of the page. The bottom two sketches show the two positions for the lowering innovation. The middle sketch is when the bike is in the riding position and the bottom sketch is when the bike is in the loading position.*

The lowering innovation would have been enabled by a pinned connection, that when opened would allow the rear wheel links to move freely of the main frame. Consequently, the frame would be able to move towards the ground and be parked in an upright position. The pins would have been spring loaded, to keep them set in the rear links at all times, until a cable would pull on them, actuated by the user, to allow the rear links to move freely. These pins would have had a lock on them, so that they could be locked in the lowered position, preventing them from going back into the riding position.

After a week of attempting to design the lowering innovation in Solidworks, it was determined that there would be too many moving parts to allow for a feasible, strong frame. The pins would have seen a significant amount of stress, and it was determined that the pinned connection would have encountered many problems with getting stuck in one position or the other. After much consideration, this lowering innovation idea was scrapped and an adjustable steering and seating system was designed.

An adjustable steering and seating system was designed to address the constraints of a normal bike frame. It was determined from various research that one bike frame can generally only accommodate a height range of about 3 inches for maximum comfort and power exertion. Meaning for one specific bicycle frame, it might only be recommended that users who are 5’-10” to 6’-1” should use that one frame. This is a rather limited range, so it was desired to create a frame that could accommodate a wider range of heights. The goal was to create a frame that would be comfortable for users who were 5’2” to 6’4” tall.

In order to accomplish this goal, an adjustable seat was designed to be able move forward and backward relative to the fixed pedals. In this fashion, the user could find the best seating position that would allow for maximum comfort and power exertion. Next, once the user was seated comfortably, he or she would be able to adjust a steering wheel, similar to a car’s, forward, backward, up and down. In this manner, the user’s legs and arms would be in the most comfortable position. A more in depth explanation of the innovation can be found in Section 3.2.

Another goal of the design was to achieve a top speed of 35 miles per hour. In order to achieve this goal, an aerodynamic fairing was added to the front of the vehicle. This fairing, in combination with the two wheeled designed, would cut down on aerodynamic drag, consequently allowing the user to reach a higher top speed. The overall design, including the adjustable seating, steering, and aerodynamic fairing, can be seen in the Figure 2.6.3 below.

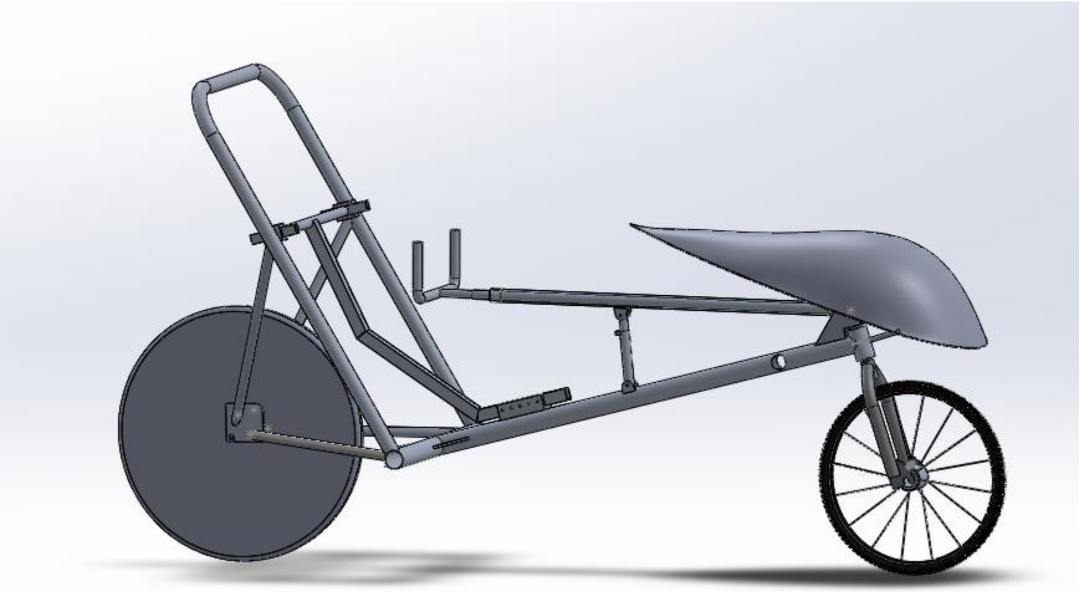

Figure 2.6.3: *3D Model of the whole vehicle*

2.7 Project Management

2.7.1 Timeline

Figure 2.7.1.1 shows a timeline of the One-Ride project. The project began in late September 2014 with research on current bikes and how these bikes are manufactured. The research included customer surveys and interviews as well as studying current bikes on the market and the bikes designed by previous HPVC teams at Santa Clara University. In late October the One-Ride team began drafting funding proposals in order to gain money for foreseeable bike costs, including things such as tires, gears, chains, materials, and welding. From these proposals we received over $4,000 from several groups, including the SCU engineering undergrad program, Roelandts family, and local ASME/IEEE/IEEE VTS chapters. In late November we focused more on the design of the bike. Using the Solidworks program, a 3-D model of the One-Ride design was created. Then using Abaqus, a finite element analysis program, the 3-D model was tested to ensure the design met the safety and strength constraints set by the team and ASME HPVC competition judges. The analysis was completed in late February, which allowed for manufacturing to start in early March.

Chavez welding and manufacturing, a local welding company, was contacted to produce to produce our frame. This portion of the project took longer than expected, which unfortunately resulted in the assembly and testing of the bike to begin in early April. During assembly and testing, the team discovered some major problems with the bike that were not found in the analysis. Due to these issues the bike was not ridable for the ASME HPVC design competition. The team has found solutions to these problems and moving forward will assist next year’s team in implementation if they wish to improve upon the One-Ride design.

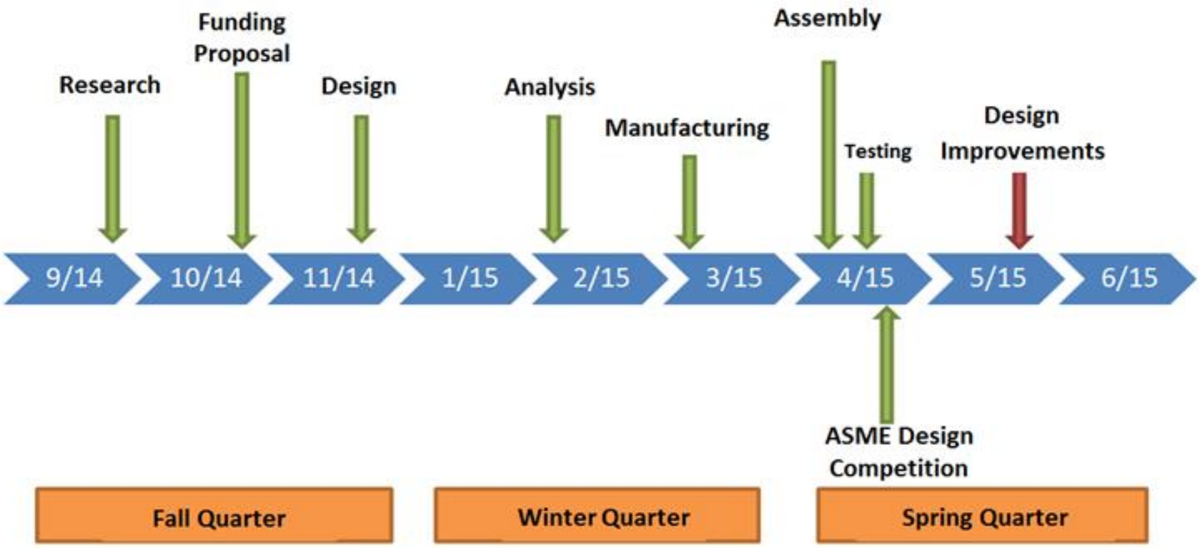

Figure 2.7.1.1 *Timeline of Project*

2.7.2 Cost and Budget

Recumbent bicycles that are currently on the market range anywhere from $1,500 to upwards of $10,000. This retail price however doesn't take into account all the design changes and excess money that was put into completing the final design. The One-Ride team began the year with funding proposals and strived to collect as much money as possible to allow for design modifications, outsource of labor, and for components. While some of the parts were machined in-house at the Santa Clara University Mechanical Engineering Shop, Chavez welding manufactured the majority of the Aluminum 6061 T6 frame. The total available budget was $4,460 and of this, $4,390 was used. Table 2.7.2 details the cost to design and produce (1) One-Ride vehicle.

Table 2.7.2.1 *Budget Breakdown*

Category	**Price**
Aluminum 6061 T6	$600
Chavez Welding	$1500
Heat Treatment	$325
ASME HPVC Registration	$450
Initial Design Documents	$100
Wheels/Tires	$250
Bolts/Nuts	$100
Testing Equipment	$65
Seating	$75
Helicoil Threading	$100
Gearing/Derailleur	$150
Gear Cassettes	$100
Steering Components	$350
Brakes	$75
Cables/Gear Shifters	$150
Total	**$4,390**

2.7.3 Team Management

The One-Ride team worked extremely well together. With a five member team it can often be difficult to get things done if different team members are on different pages. This was not the case with this year's team. Everyone had similar ideas and any conflicts were diffused quickly and easily with both parties agreeing with the solution. Having a larger team also made it easier to split up tasks and positions. Everyone on the team had particular skills that allowed him to take the lead on certain aspect of the projects. C.J. Toy was the team manager. He was in charge of setting meetings, turning in documents and making sure deadlines were met. Alex

Fisher was in charge of design. Coming into the project with the most experience working with Solidworks he was put in charge of final CAD designs and putting together the final model. Brendan Taylor was in charge of running the FEA once the final model was put together. Alex Sahyoun took the lead on the physical testing of the frame. He did the research on the best way to test the frame and made sure all the necessary equipment was around when it was time to test the frame. Geoff Schmelzer was in charge of the budget and finances. He monitored our budget, and made sure we had enough finances to complete the entire project within what was originally projected. He also performed a cost analysis of what it would cost if we took the bike into the market.

2.7.4 Risks and Mitigations

There is a large amount of risk that came along with designing the One-Ride human powered vehicle. The biggest risk is rider safety. As the designer of the bike, our team wanted to make sure that the rider was as safe as possible when seated in the bike. When looking at the design there are several areas where the bike could be considered a safety hazard. These areas and how they were addressed are described below.

Rotating Mechanical Parts

There are several rotating mechanical parts, such as the gears, steering wheel, and tires on the bicycle that have the possibility of pinching or catching the rider. In order to address these issues the position of the gear assemblies and chain were chosen for optimum bike performance while also keeping most of the assemblies and chain path a safe distance away from the rider.

The steering column of the bike is in a housing tube as well, protecting the rider from getting caught when turning the steering wheel. The wheels are located at the ends of the bicycle with the rider sitting in the middle. Therefore when the rider is operating the bicycle he is not at risk of getting caught in the spinning wheels.

Bike Tip-Over and Frame Strength

In order to keep the rider safe during a tip-over, a seatbelt and roll bar were installed on the bicycle. The seat belt is a 4 point harness that comes over the shoulders and wraps around the waist of the rider. The seat belt keeps the rider secured during a tip-over and prevents the bike from falling on top of them. The rider will also be wearing a helmet any time he or she is sitting on the bike.

The roll bar surrounds the rider on the sides and above the head and is made of 6061 T6 aluminum tubing. In order to make sure our roll bar would not fail during a tip-over, several tests were run in Abaqus to simulate different tip-over scenarios with varying loads on the roll-bar. Based on these results, the thickness of the aluminum tubing was adjusted to ensure there was a factor of safety of at least 2 for the roll bar.

Similar tests were performed for the entire frame of the bicycle to ensure the frame would support the weight of a rider without failing. Last year's model was also examined for weak points such as warped tubing or cracks in the welds. If problems were found we made sure our design was adjusted in similar areas to make the bike stronger. One example is the connection between the bottom tube and cross tube. Cracks in the weld were observed on last year's design so gussets were added this year to the same area to increase the strength and prevent cracking.

Physical tests were also performed on the final frame after it was heat treated. Using a come-along, straps and a tension gage the frame strength was tested to the required amount (600lb top load and 300lb side load) set by the ASME HPVC competition. More details about the experiment and the results of the test can be found in Chapter 3.5.3: Safety Analysis.

Bike Visibility

To address the hazard of low visibility, our design includes reflectors and flags that will increase the visibility during both day and night riding. Since the bike is very low to the ground the flags are tall enough where they will be in the line of sight of someone driving a car. The reflectors are placed on the front and rear of the bicycle to so any lights from a car or street lamp will reflect off and alert nearby vehicles of the rider's presence.

Testing Bike Rideability

To ensure all safety precautions were followed each time the bike was tested, a pre-ride checklist was gone through. The checklist is shown below.

- Advisor is present
- Riding area is safe (no threat of cars, pedestrians etc.)
- Campus Safety is notified and has approved riding area

- Bike is checked for any cracks in welding or bends in tubes
- Rider is equipped with helmet and proper attire (no baggy clothes, close-toed shoes)
- Seat Belt is fastened properly

2.8 Sustainability

A successful and conscious engineer must not only make a functional design, but must also consider its sustainability, or environmental impact. Since one of the main motivations of the One-Ride HPV was to help reduce emissions and lower fuel consumption used by commuters, it would have been pointless to create the One-Ride HPV if the design was not sustainable to manufacture. The One-Ride HPV design features materials that are not hazardous to the environment to manufacture. Not only is the One-Ride design environmentally friendly to manufacture, it could potentially play a huge role in reducing overall C02 emissions and fuel consumption from commuters. Since 68% of Americans commute 15 miles or less, an HPV would be a perfect alternative to many of those commuters since the commute is relatively short.

Since the One-Ride design solely relies on human power to propel itself the rider could be considered an engine. Like all other engines, efficiency is one of the top priorities. Efficiency was kept in mind throughout the entire One-Ride design and was one of the main reasons the design was made with only two wheels. This allows for a reduced frontal area and therefore reduced drag through the air. This allows for less energy to be used in order to maintain a certain speed meaning the rider can go that much further. The One-Ride design features a wide range of gear ratios allowing for minimal pedaling force at speed.

Another main objective of the One-Ride HPV design was to reduce the need for multiple sized bikes. Since the One-Ride features an innovative seat and steering adjustment, the frame can fit any rider between 5’2” and 6’4”. Since most bike frames only have a height range of about three inches, the One-Ride allows for the rider size adjustability of 6 bike frames in one. This means that the user does not have to constantly buy new bike frames to accommodate a rider size change such as a child slowly growing. This is another way in which the One-Ride HPV is designed to be environmentally friendly.

With environmental harm becoming an increasingly significant topic in today’s world, the One-Ride HPV offers a way for the individual to do his or her part in helping the world they live in. The One-Ride HPV causes no environmental harm to ride and virtually no harm to manufacture when compared to an automobile.

2.9 Ethical Impact

Engineers are constantly faced with challenges that they must overcome. Some of these challenges are easier than others while some require more thought and perseverance. We also have a duty to make sure that what we make is safe and reliable which provides the most challenge when faced with a project. When human safety is added to the goals, the project becomes much harder to achieve through normal means. Instead of having to only worry about the integrity of the project, we must also be concerned about the safety of the user. As we worked on the HPV, we realized that compromises had to be made in the performance part of our project to ensure that safety was also covered. However, these sacrifices were necessary as they are an integral part of what it means to be an ethical engineer. There are many other factors that we must consider, including sustainability, cost, and societal impact. Health and safety is paramount for being an ethical engineer and is a consideration that should not be overlooked when designing any project.

Health and Safety

Since our project involves individuals directly using our product we had to make sure that if any accidents occurred that the person would be safe and remain unharmed. Part of the ASME Ethical code requires us to act in manner that is conducive to the health and safety of the public. If we were to not hold that ethical standard to the highest degree then we would have failed as engineers. That is why when building the HPV we placed restrictions for what we considered acceptable as well as the restrictions that ASME had placed for us. In our design to ensure that the rider was safe and not in any danger during an accident a minimum factor of safety of 2 was used. This factor of safety ensured that if any extra force was experienced the frame would not fail. We also implemented a roll bar protection system as required by the ASME design competition. This part of the requirements had set guidelines requiring a 600 lb force to act upon the top of the roll bar and a 300 lb force to act on the sides of the roll bar. During these loads the frame was not allowed to deform no more than 2 inches on the top and 1.5 inches on the sides. This guideline influenced us to change part of our design by strengthening the main tube of the frame. Over all the ASME ethical code as well as the stringent design requirement inevitably altered our design.

Sustainability

Another area of focus was how sustainable our HPV would be as environmental impact due to manufacturing is a growing concern for companies today. Our frame, while not biodegradable or made from recycled materials, is made of aluminum which can be recycled. This part of the project has some flexibility, but ultimately due to aluminum's strength to weight ratio it was selected as the primary part of our frame. Our design also pushes to cut down on the number of bicycles needed in a household due to the innovative adjustable seating and steering that we designed. A typical bicycle has about a 3 inch growth limit, such that when a rider purchases a bicycle he has about 3 inches of growth that can occur before a new bicycle is needed. With our HPV, design a foot of growth can be accommodated, thus allowing for less bicycles being purchased and less material being used.

Environmental, Public Health and Cost

Today fossil fuels are still the main source of energy that people use for transportation. Whether it is a car or public transportation, some form of fossil fuel is being burned. This does not benefit the planet or the public health at large as carbon dioxide emissions continue to rise. With our HPV we hope to push people into using a HPV so that they not only can save money on gas but help by taking vehicles off the road and reducing emissions as well. Another benefit of using a HPV is the health improvement of the user. Since we, as engineers, have to use our skills for the betterment of society, pushing people to not only save the planet but also improve their own health provides a positive goal for both the user and the user's environment. Ideally this would push people to use their HPV for short distance trips rather than using a car and, if at all possible, eliminate purchasing a car altogether. Current Green technologies are accelerating even faster, but are hampered by one aspect, the technology is expensive. Currently the most popular electric vehicle on the market is the Tesla Model S. The Tesla Model S has a MSRP of 70,000 dollars, not an insignificant amount of money for someone to consider without a long term budget. Battery technology is only getting better, but until it becomes cheaper those type of options are available only to financially secure individuals. By using the HPV model a person could afford to not only benefit the planet, but benefit from cutting the cost of having a car altogether. We planned on making an affordable HPV that was in the price range of about 1000 to 2000 dollars. We determined that this was a competitive range when compared to current HPV on the market.

Impact

With these design considerations in mind we made various improvements on our design. As mentioned earlier, the main frame was bumped from 1/8 inch wall thickness to 3/16 inch. This was to ensure that the frame would not bend during operation and would provide a solid base for the rest of the HPV to build upon. In the roll bar testing we found that the roll bar only deflected no more than 1 mm when under the 600 lb load and only 2 mm when under the 300 lb side load. Those tests will be discussed later on in section 3.1.2 in a little more detail. As for the look and feel of the bike since our bicycle was to have a roll bar system and we moved to a recumbent style frame the roll bar was placed such that the rider would have good overhead protection and was seated under the roll bar in all seating positions. Since we were mainly focused on the safety of the rider most of the frame is centered on the user as a whole. Our innovation, as well, was to increase the overall comfort of the rider. By improving the comfort we can improve the travel distance as the rider will have more back support allowing for stronger pedaling power.

2.10 Health and Safety

During the design of the One-Ride HPV there were many safety concerns that needed to be addressed by both the ASME competition standards and for general safety of the rider. Since the goal is to provide a healthy alternative for short distance travel, the design must also ensure that the trip is not a dangerous one for the rider.

Design Safety

The safety goals of this project were clear, design a HPV that would protect the rider from rollovers as well as be safe to operate. Much of the design was based around the ASME HPV standards such that a roll bar was integrated into the frame of the HPV to provide excellent protection should the rider experience a roll over. The main focus was the limits set by the

ASME rules which required a roll bar to withstand a 600 lb load acting 12 degrees from the top without deforming more than 2 inches, and a side load of 300 lbs without deforming more than 1.5 inches. These considerations formed the backbone of our safety concerns as well as ensuring a minimum Factor of Safety of 2 on all parts of the frame.

Material Selection

There were many considerations for the material that was to be used to make the frame. Since safety was a major concern a stronger material was favored, however weight was also an issue as we desired a lighter frame for speed in the competition. This led us to consider three options carbon fiber, steel or aluminum. In the end we decided to use Aluminum 6061-T6 as it has both the strength and the weight that we desired. This type of aluminum is also widely used in the commercial bike market, thus confirming a decision to move forward with the design. There were issues with this material that we later discovered, but that will be covered later on.

Manufacturing

All parts of the frame were checked beforehand by a machinist to ensure that the parts could be made not only successfully but safely as well. Parts of the frame also needed to be welded as well which was done by an industry professional to ensure that it was done correctly and safely. For in house manufacturing, all parts were made under the supervision of a machine shop manager and were made by experienced members of the team.

3 Detailed Design and Analysis

When designing the HPV, priority was placed on implementing an innovative steering system, a protective roll cage, an efficient drivetrain system, and an aerodynamic fairing. It was decided to fabricate the frame from Aluminum 6061 T6, because it would reduce the weight of the frame when compared to high strength steel. The design featured an adjustable steering system with a steering wheel interfaced to the front fork with a double u-joint. The vehicle utilized 2 sets of gear and 2 derailleurs to create 14 possible gearing combinations. A standard rim brake was used for the front wheel, while a disc brake was used for the rear wheel. It was planned to use the aerodynamic fairing from the previous year's design, but due to unforeseen design issues, the fairing could not be mounted. The seat was fabricated from plywood with foam cushioning and storage compartments were located in the rear of the frame.

3.1 Frame

3.1.1 Background

In a recumbent-style vehicle, the rider can operate the vehicle at a reclined angle which allows the center of gravity to be closer to the surface of the ground and creates a more comfortable riding position when compared to a traditional bicycle. When starting the initial design process for the frame, two different type of frame designs were considered. The first was a three wheel tadpole design and the second was a two wheeled design based off the groundhugger frame[12]. It was decided to go with the two wheeled design because a high top speed was desired. The two wheeled design offers great stability at high speeds, although it does sacrifice stability at low speeds. The three wheeled design is quite stable at low speeds, but at high speeds, this stability is sacrificed. This stability is sacrificed because at high speeds, the user cannot properly during, allowing the possibility for a roll over. See the decision matrix in Appendix D for more information. The goal was to design a lightweight (under 10 lb) frame that could hold the weight of the rider plus cargo (~250 lbs) while maintaining stiffness so that the majority of the pedal force is transferred into linear motion. The design of our vehicle is detailed below.

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[12] Robert Riley "Ground Hugger XR2," *Robert Q. Riley Enterprises*, November 1, 2014

3.1.2 Frame Design

The center of gravity of the vehicle was designed to be as low as possible in order to increase stability and decrease the aerodynamic drag. Reducing aerodynamic drag is key for the vehicle to be able to achieve a top speed of 35mph. When testing last year's design, it was noticed that the seating position was not comfortable for all of the team members. The issue was addressed by creating a more upright, adjustable seating position that will be later explained. With a more upright seating position, the cross-sectional area of the user and vehicle is increased, consequently increasing aerodynamic drag. This posed a problem because it was desired to cut down the aerodynamic drag. It was decided for this reason, and others, to go with the two wheel design because it would cut down the cross sectional area of the vehicle in front by almost half. After this decision, the next step in the process was determining the proper size of the frame based of the various sizes of our group members. A seat mockup with pedals was created and tested out by all of the group members, upon which measurements were made for each member. A picture of the mockup with and without a user can be seen in Figure 3.1.2.1.

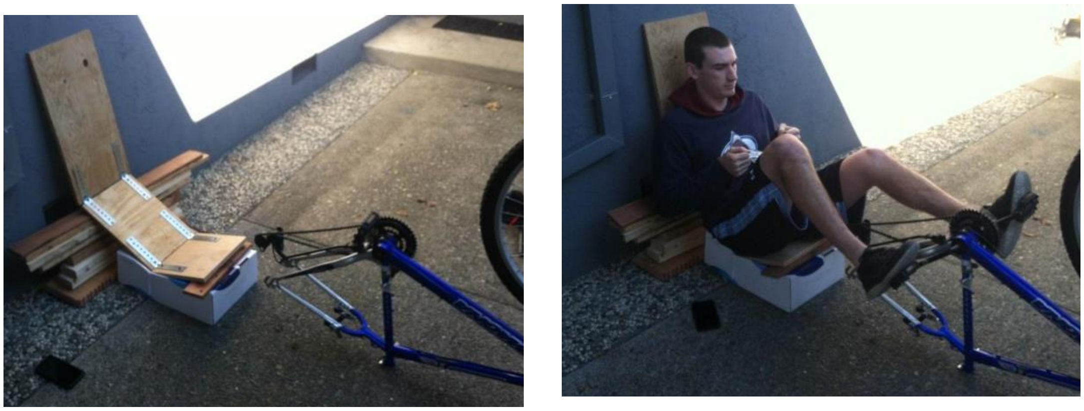

Figure 3.1.2.1 *Seat Mockup with and without user*

Once the measurements of the various team members were taken, a frame was designed in Solidworks that could accommodate the range of users with a roll bar. This roll bar was made big enough so that even the largest rider's head would be covered and protected in the event of a roll over.

The frame design has two framestays and two wheelstays extending down from the roll bar to the rear axle of the wheel. This creates a triangulated geometry that keeps the rear wheel rigid. Stiffness in the frame is key when designing a performance vehicle, because sway in the vehicle arrests forwards motion. A 3D view of the frame CAD model is shown below in Figure 3.1.2.2.

***Figure 3.1.2.2** CAD rendering of the main vehicle frame*

Material Choice

While the shape and geometry is critical for the performance of the vehicle, it is also extremely important to choose the appropriate material. When deciding on what material to use to manufacture the vehicle, there were four criteria: strength to weight ratio, cost, manufacturability, and repairability (in order of importance). Next, research on various materials including carbon steel, aluminum, titanium, and carbon fiber was carried out.

Chromoly steel is one of the most common materials bicycles are manufactured from because it is cheap, has a good strength to weight ratio, and is easy to manufacture. On the opposite end of the spectrum, titanium has a fantastic strength to weight ratio, is very expensive, and difficult to manufacture. Carbon fiber also has a great strength to weight ratio, but is extremely difficult to manufacture, and very hard to repair. This was ruled out because of the manufacturing difficulties. Finally, there is aluminum which has a great strength to weight ratio, is easy to manufacture, and is reasonably priced.

Upon further research, it was determined that Aluminum 6061-T6 would be the best material to meet the needs of design. It is lightweight and strong, with properties that allow it to be easily TIG welded unlike some different aluminum alloys. Table 3.1.1 compares the various properties of the different metals considered in the design process.

Table 3.1.2.1 *Material properties for commonly used frame design materials*[13]

Material	Elastic Modulus (ksi)	Yield Stress (psi)	Density (lb/in3)
Aluminum 6061 T6	10,000	40,000	0.0975
Chromoly 4130 Steel	29,700	63,100	0.284
Titanium Ti-6Al-4V (Grade 5)	15,000	128,000	0.16

Even though the aluminum has the lowest yield stress and elastic modulus, it is also the lightest out of all the metals. This allows the aluminum to be made into larger diameter and thicker tubes (which increases stiffness) while maintaining a lower weight than steel and much less cost than titanium.

3.1.3 Frame Analysis

As mentioned earlier the frame needed to be able to hold the weight of the rider and we also wanted to make sure that the frame would perform well while under an overstress situation. The material properties of Aluminum 6061-T6 are seen here in Table 3.1.3.1.

Table 3.1.3.1 *Material Properties of 6061 T-6 Aluminum*

Yield Strength	40000 psi
Poisson’s Ratio	0.33
Modulus of Elasticity	10000 ksi
Density	0.0975 lb/in^3

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[13] "ASM." *ASM*. N.p., n.d. Web. 30 May 2015. <http://asm.matweb.com/>.

Using ABAQUS CAE to run finite element analysis, and Solidworks to generate the, model the frame was generated and put under the various loads that we believed the HPV would experience as well as the ASME design requirements for the roll bar testing.
Some parameters that were used to generate the finite element model were as follows:

Overall Parameters

- Sections were solid and homogenous throughout
- The tetrahedral mesh algorithm
- All parts are mated such that welds are not included in analysis
- All parts are the same material
- Point loads were made rather than surface loads
- Holes and mounting points were included in the analysis
- Some parts were over stressed to ensure a good factor safety

Some parts of the frame were overstressed, by factor of three, from what we believed to be the normal operating range as an assurance that the frame would be able to withstand the regular loading of the frame.

Static Load Testing

For the first set of tests the full frame was placed into the Abaqus program and subjected to a 600 lb load acting on the seat position of the bicycle. This can be seen in Figure 3.1.3.3.
For this test we assumed the following:

Complete Frame Parameters

- Frame was completely static (fixed in x,y,z)
- Frame was subjected to a total force of 600 lbs. across the seat
- Overstress was used to ensure factor of safety

From our results we concluded that the frame would have the max point of stress on the underside of the frame, which was to be expected. The frame also had a high factor safety, but due to either modeling errors or program behavior this factor of safety could not be counted on to be true. This was due to the fact that the program was giving a fact or safety of 4000. To ensure that the frame was still viable, the parts were tested individually.

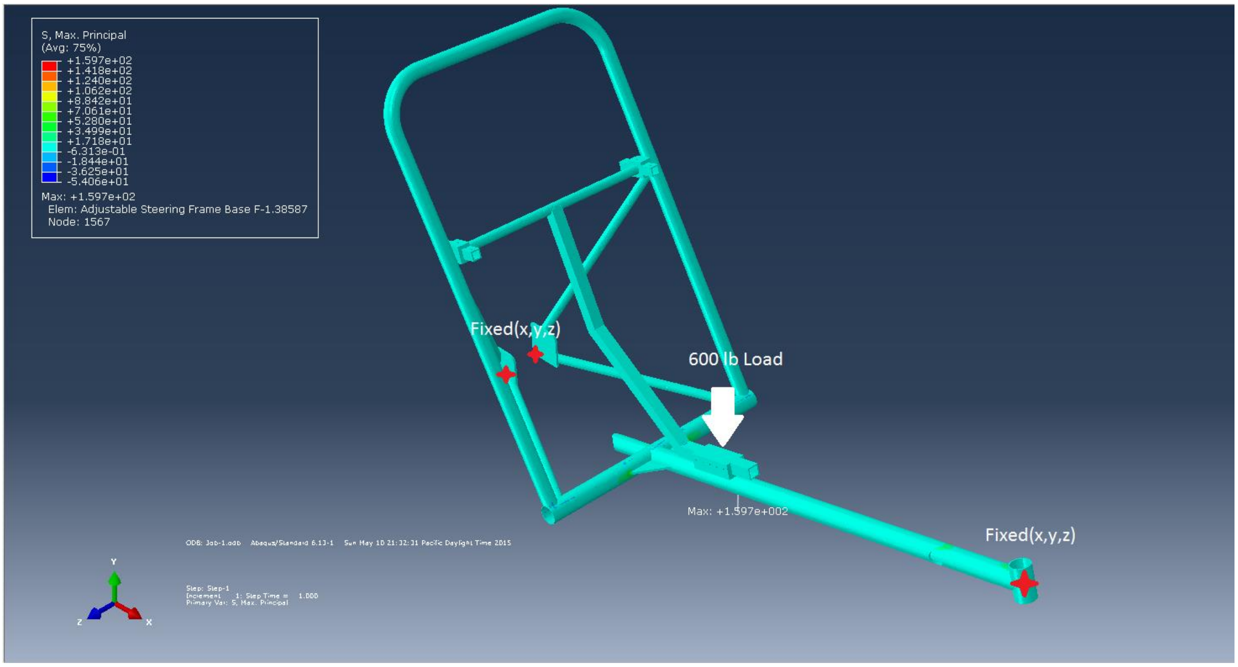


Figure 3.1.3.3 *FEA of 600lb load acting on the seat position. The color table shows the stress levels which range from 54.06 psi (blue) to 159.7 psi (red). The maximum stress, which occurs at the triangular gussets was 159.7 psi. The red crosses represent the areas where the bike model was fixed. In this simulation the fixed points are where the frame meets the tires.*

The main tube was tested to ensure that the heart of the frame could withstand the load of the rider. The main tube was made to 3/16 inch, wall thickness, aluminum tubing.

The assumptions for this part of the frame were as follows:

Main Tube Parameters

- Tube was fixed at both ends to simulate being welded to the frame
- Load of 250 lbs. was applied to the seat position on the main tube

The max stress was found to be once again on the underside of the tube and the max stress was calculated to be 10208 psi (see Figure 3.1.3.4). The yield strength of the material is 40000 psi. This effectively gave a factor of safety of 3.89 and minimal deformation, about .00135 inches. This fell well within our goal of a factor of safety of 2 and demonstrated an excellent base frame strength. There was concern over stress concentrations near the opening for the pedals, but this test demonstrates that it would not compromise the frame integrity.

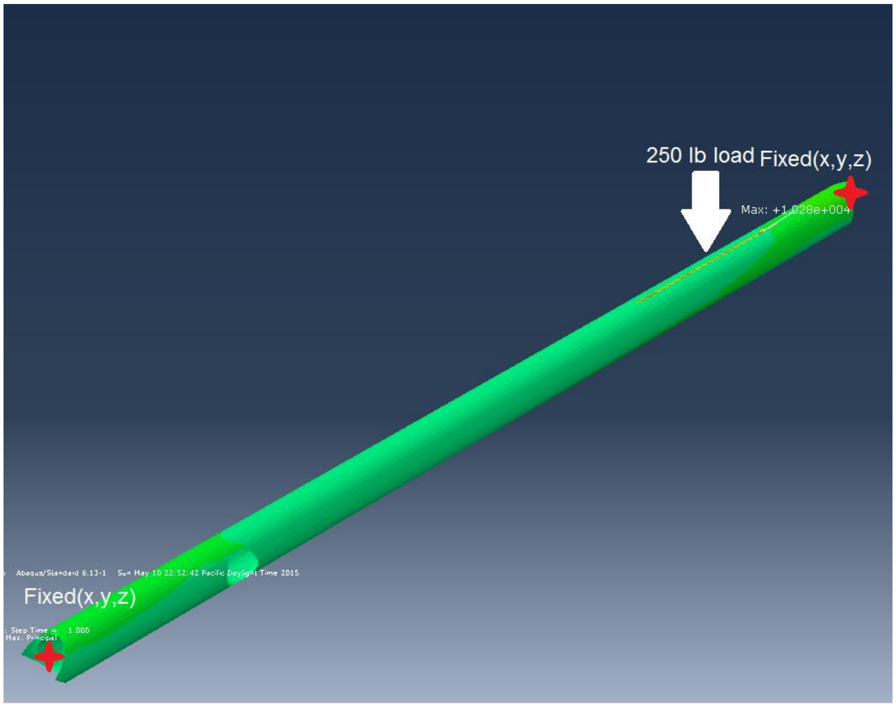


Figure 3.1.3.4 *FEA of main tube 250 lb load. The red crosses represent the fixed points of the beam. The results can be seen results Table 3.1.3.2*

Table 3.1.3.2 *Main Tube Finite Element Analysis results*

Max Stress	Factor Safety	Max Deformation
10208 psi	3.89	.00135 in

The roll bars were a primary focus of design as they had strict regulation that had to be adhered to in order for the HPV to be enterable in the design competition. Part of the ASME standards requires that the roll bar system must experience not more than 2 inches of deformation from a top load of 600 lbs and no more than 1.5 inches of deformation on the sides from a 300 lb load. These parameters were the driving factor in our roll bar design and testing. For the top load test (Figure 3.1.3.5) the roll bar was under these constraints:

Roll Bar Parameters

- Fixed at the bottom to simulate a weld to the frame
- Subjected to a 600 lb point load on the top of the roll bar

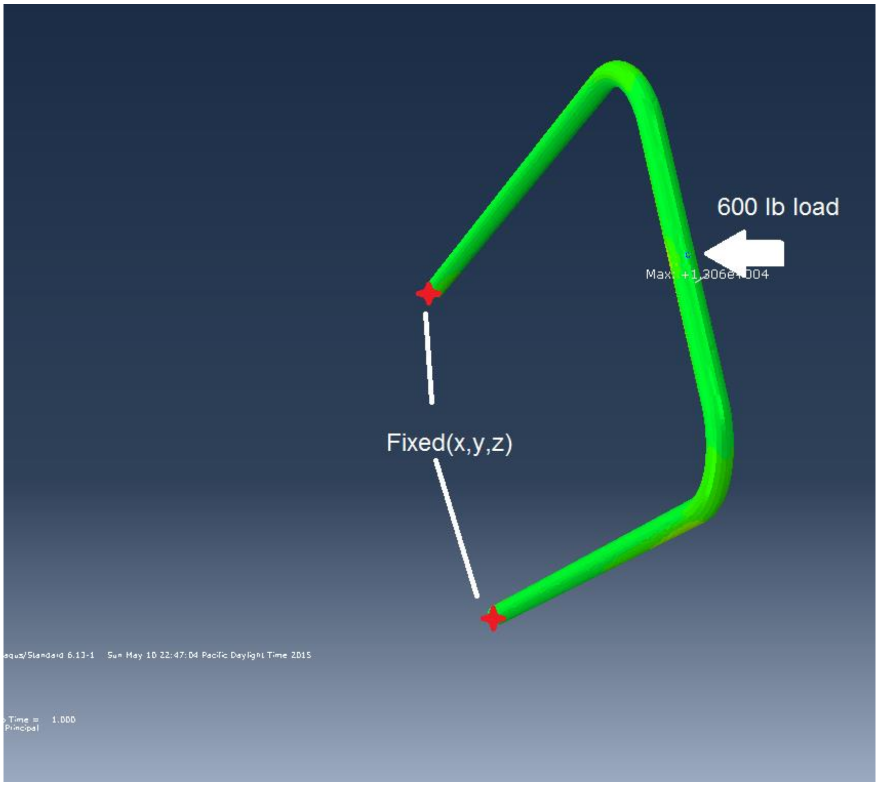


Figure 3.1.3.5 *FEA of 600 lb top load on rollbar. The red crosses represent the fixed portions of the roll bar. The results can be seen in Table 3.1.3.3*

The roll bar performed beyond the requirements having a max stress of 13060 psi and a resulting factor of safety of 3.06 (Table 3.1.3.3). The frame was also predicted to deform .0093 inches, which was far below the ASME allowed limit.

Table 3.1.3.3 *Rollbar top load Finite Element Analysis Results*

Max Stress	Factor Safety	Max Deformation
13060 psi	3.06	.0093 in

The side loading was subjected to the same parameters albeit with only 300 lb side load and being fixed on the side to simulate a rollover (Figure 3.1.3.6). The side frame analysis also included the cross bar as it too would provide strength to the roll bar.

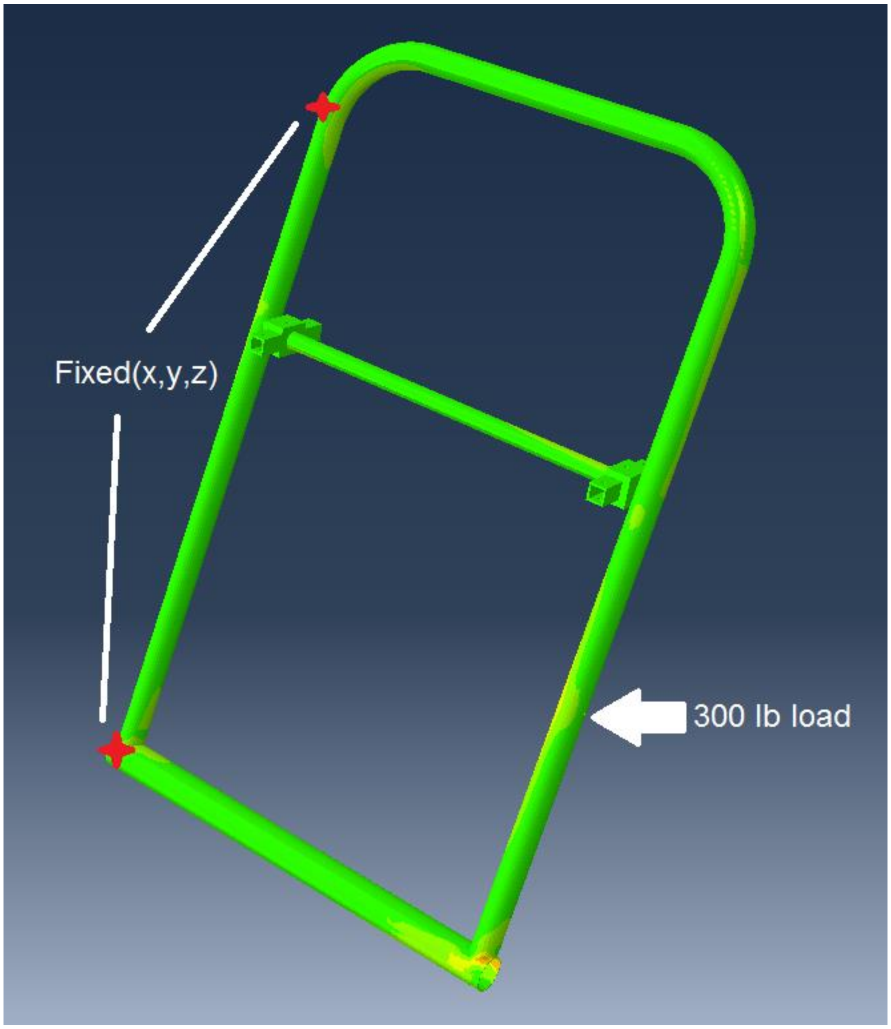


Figure 3.1.3.6 *FEA of 300lb side load on rollbar. The red crosses represent where the model was fixed. The results can be seen in figure 3.1.3.4.*

The side load test performed with in the design constraints giving a max stress of 9110 psi and a factor of safety of 4.39 and a predicted deformation of close to zero, 2.944E-4 inches. With these test completed we felt that the design was sufficient enough to begin manufacturing the frame.

Table 3.1.3.4 *Rollbar Side load Finite Element Analysis Results*

Max Stress	Factor Safety	Max Deformation
9110 psi	4.39	2.944E-4 in

3.1.4 Frame Manufacturing

Once everything was theoretically tested in ABAQUS CAE, the CAD model of the frame was sent off to Chavez Welding to be manufactured. The manufacturing was done off site, rather than on campus, because Santa Clara University did not have the proper welding equipment to do aluminum TIG welding. As previously mentioned, the time it took to manufacture the frame took much more time than expected and delayed assembly. In order to manufacture the frame, Chavez Welding used a CNC machine to manufacture some of the more complicated parts and a tube bending to create the shape of the roll ball. A picture of the fully welded frame after being manufactured can be seen below in Figure 3.1.4.1.

Figure 3.1.4.1 *Fully welded frame from Chavez Welding*

Everything went according to plan except for some issues with the seat innovation, which will be explained in the Challenges, Problems, and Solutions section of this thesis. These problems arose from the heat treating process in order to regain the strength lost in the welding process.

3.2 Innovation

3.2.1 Innovation Background

As previously stated, to satisfy the innovation requirement of the HPV competition, it was decided to create an adjustable seating and steering system to accommodate various sized riders. This innovation would decrease theoretical manufacturing costs of the vehicle because one bicycle would work for a large population of people, eliminating the need to create various sized frames to fit a range of different sized people. Additionally, the system utilizes a steering wheel that is operated much the same as a car's steering wheel. It allows the user to be comfortable while riding the vehicle by allowing them to place their arms in an ideal driving position.

3.2.2 Innovation Design

The first part of the innovation is the adjustable seating position. Since the pedals are in a fixed position, an adjustable seat was designed to allow people with various sized legs to all reach the pedals. There are five different seating positions, each one inch apart from one another. As seen in Figure 3.2.2.1 below, the arrows indicate the direction in which the seat can move forward and backward within the mounts on the frame. The other part of the innovation is the adjustable position of the steering wheel.

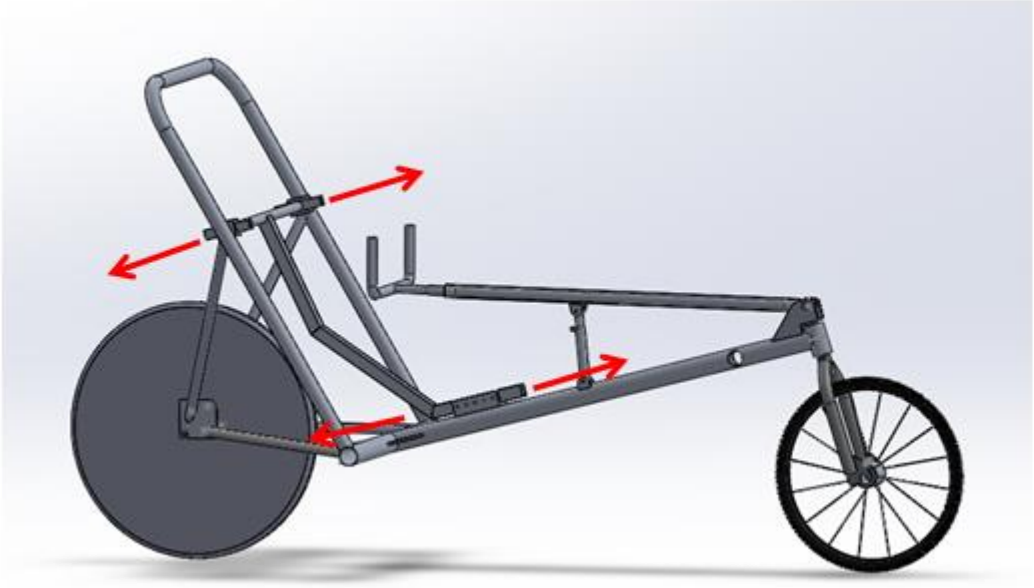


Figure 3.2.2.1 *Movement of Seat. The frame can move both forwards and backwards and indicated by the arrows to adjust for different size riders.*

The adjustable steering wheel can move both vertically and horizontally to accommodate various size riders and works in tandem with the adjustable seat positions. The steering wheel can be adjusted within the steering column to allow for horizontal positioning. A collar clamp around the steering column creates compression around the moving tube to create enough friction to prevent movement of the steering wheel, once the ideal position has been found. The same adjustment system is used for adjusting the height of the steering wheel. To ensure that rotational motion always was transferred to the steering column a safety pin was placed through both the steering column and steering wheel. The movement in the vertical and horizontal position can be seen in Figure 3.2.2.2 below.

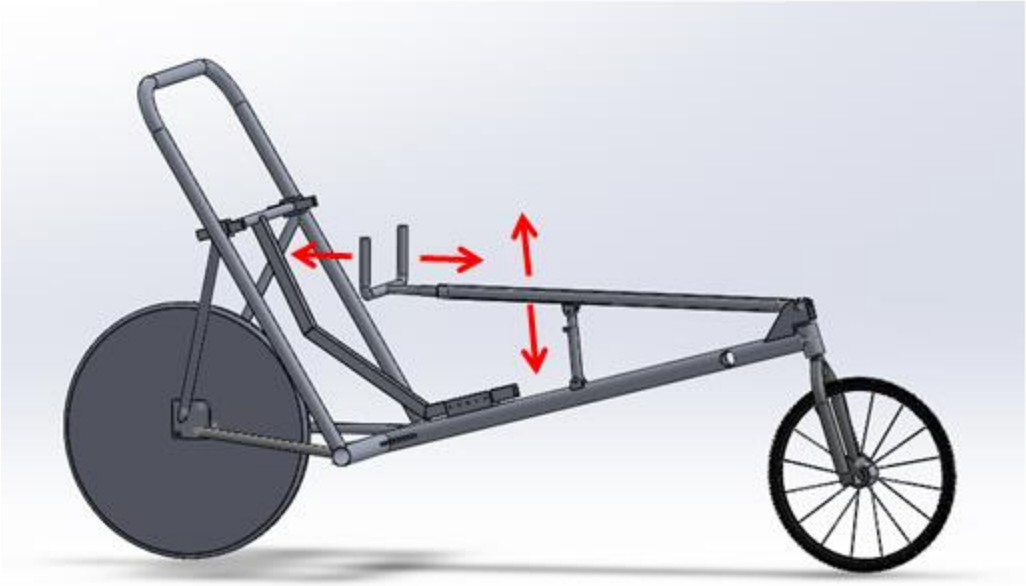


***Figure 3.2.2.2** Movement of Steering Wheel. The telescopic steering wheel can be moved closer or farther away from the rider based on his or her desired position. It can also be moved up or down based on rider height..*

The adjustability is made possible by a slit in the steering column and the collar clamp that creates the clamping forces necessary to transfer steering forces. The steering column is housed in a tube that allows for the adjustment of height and also provides protection from rotating parts. The steering column is able to move within this housing tube because of nylon bushings between the two parts. The collar clamp and bushing can be seen in Figure 3.2.2.3 below.

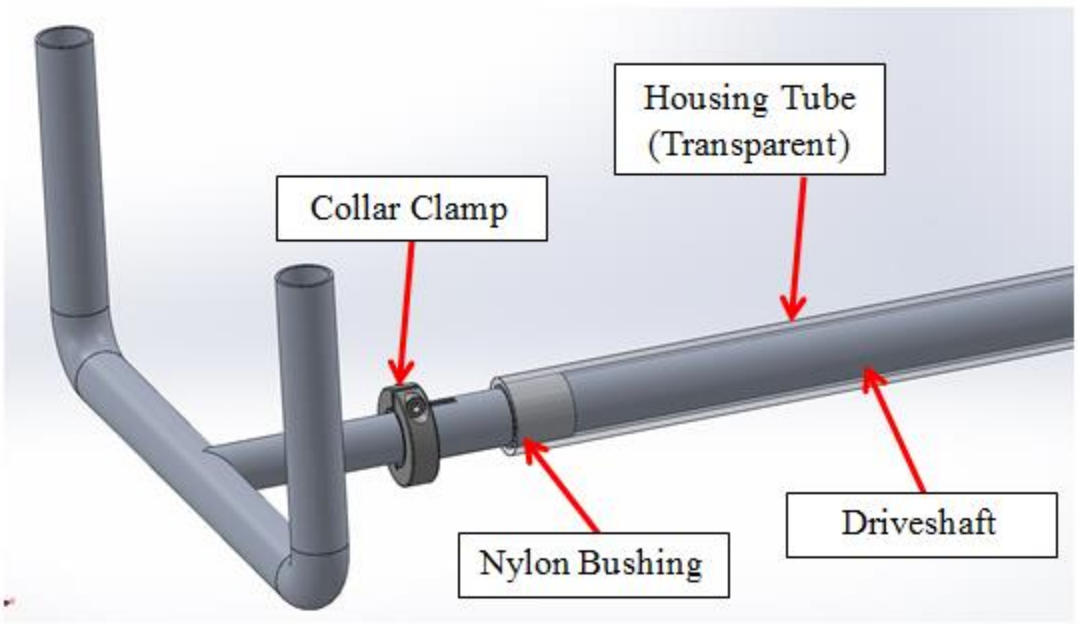


Figure 3.2.2.3 *Steering Wheel and Collar Clam. By loosening and tightening the collar clamp the steering wheel can be adjusted in and out based on the riders preferred position.*

In order to transfer the steering motion from the steering wheel down to the front wheel, the steering wheel is attached to a steering column, which is welded to a u-joint, which is welded to the front fork. This u-joint not only transfers the steering forces, but it also allows for the various height positions of the steering wheel. With all of the various adjustments of the seat and the steering column, a wide range of users will be able to ride the vehicle comfortably. This u-joint assembly can be seen in Figure 3.2.2.4

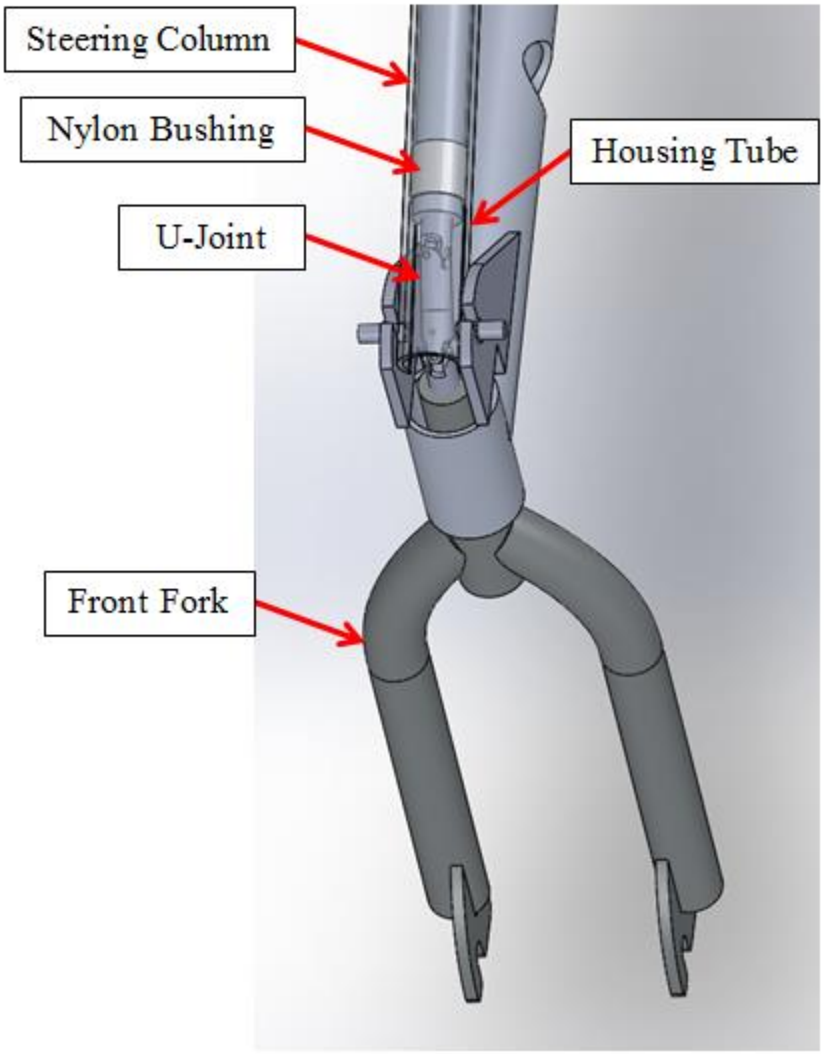


Figure 3.2.2.4 *Steering Column with U-Joint Assembly. The U-joint connects the front fork to the steering column which is connected to the steering wheel (not shown).*

The assembly above shows how the steering column operates with the front fork. The housing tube not only acts as the tube to guide the steering column, it also provides some safety for the rider. The housing tube extends over the u-joint to prevent anything from getting caught in the rotating u-joint. In order to mount this housing tube to the main tube, a mounting bracket was needed.

The mounting bracket was designed so that the housing tube could adjust for the various heights and be removable to easily service the bike. The bracket can be seen below with an innovative locking system to prevent the column from accidentally dislodging itself.

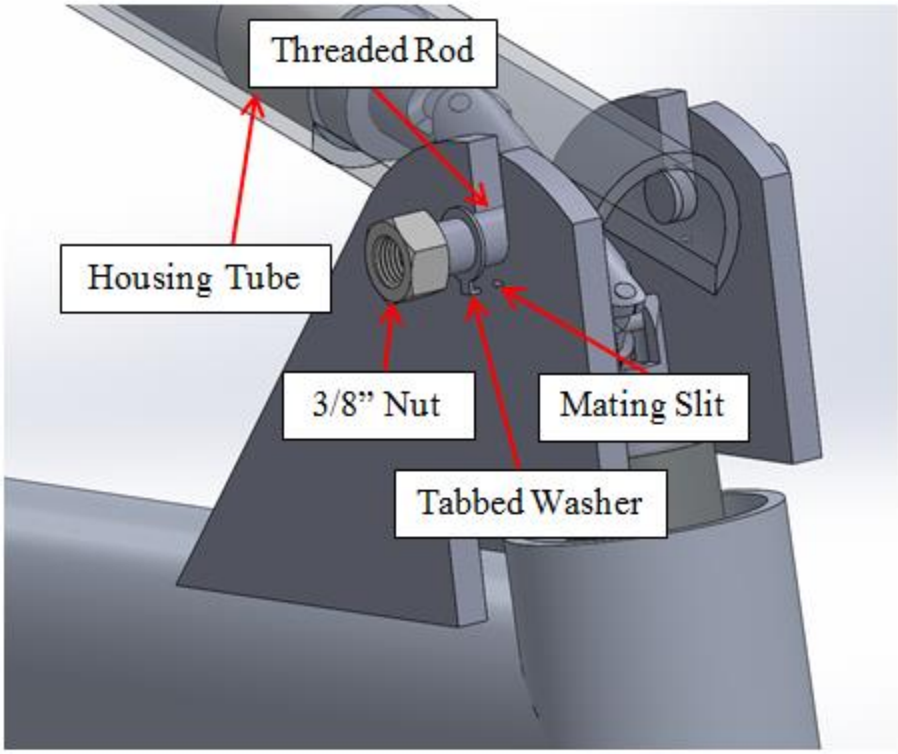


Figure 3.2.2.5 *Housing tube mounting bracket*

In the figure above, it can be seen that there are threaded rods welded to the housing tube, which can move in and out of the cut outs in the mounting bracket. In order to ensure that the housing tube would not accidentally dislodge from the cut outs, a locking feature was designed using a tabbed washer, mating slit in the bracket, and a nut. The mating slit in the bracket matches the size of the tab on the washer so that when it is assembled, the tab fits securely in the slit, preventing the housing tube from rising out of the cut out.

3.2.3 Innovation Manufacturing

After finishing the overall design and Finite Element Analysis, it was time to start building the HPV. The One-Ride design involves multiple moving parts to allow for user adjustability.

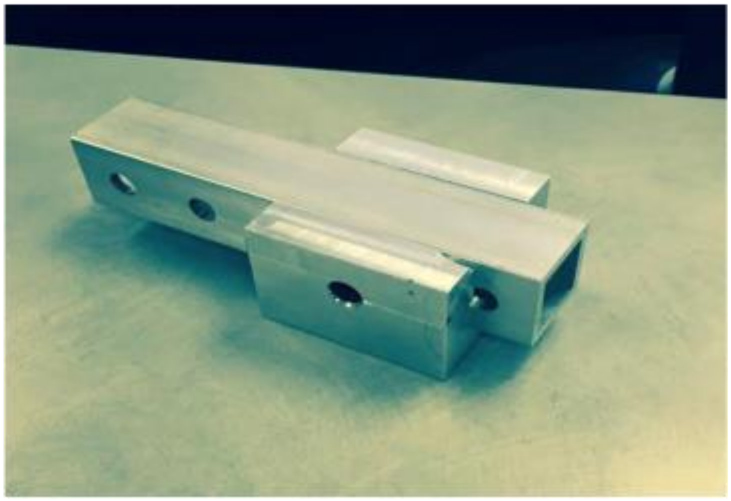


Figure 3.2.3.1 *Right side seat adjustment rail system. These parts were manufactured at Santa Clara University and sent to Chavez welding to be welded to the rest of the frame*

To prevent the added adjustability from creating play in the seating, a precise fit was required, so the three seat adjustment rails were machined using a mill. All three rail systems were made of the same aluminum 6061-T6 alloy used in the rest of the frame. After machining of the rails was completed, each of the individual adjustment holes were tested with the pin to ensure fitment for all rail positions. The rail system shown in figure 3.2.3.1 is for the two top mount seat adjustment rails, figure 3.2.3.2, shown below, shows the assembled and pinned top rail seat adjustment.

A similar system to the one above was used for the lower seat adjustment rail positioned under the seat. The length of the lower slider rail was increased to ensure safety and rigidity since it is experiencing much more of the rider's weight. The lower slider rail can be seen in figure 3.2.3.3.

After completing the manufacturing for the seat adjustment system, the drive shaft and housing tube were then machined for our steering system. The housing tube was made with the same aluminum 6061-T6 alloy used in the rest of the frame, and featured a cutout for the double u-joint to pass through to insure clearance for any amount of turning. This cutout was done using the mill, along with the mounting hole located just over the cutout. The assembled housing tube showing the cutaway and mounting hole can be seen in the figure below.

Figure 3.2.3.2 *Pinned right seating bracket*

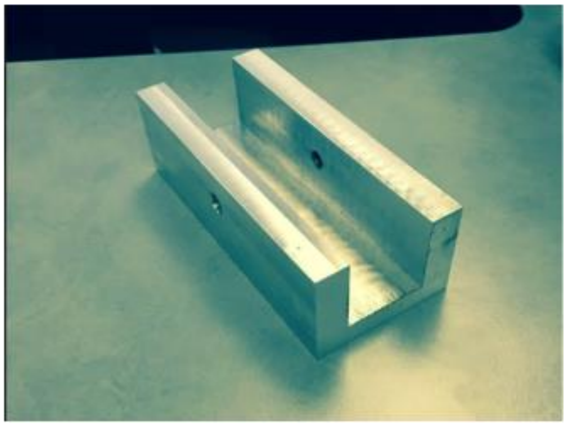


Figure 3.2.3.3 *Seat slider rail for seat position adjustment. This piece was manufactured at Santa Clara University and sent to Chavez welding to be welded to the rest of the frame*

Figure 3.2.3.4 *Housing tube and u-joint connection*

After manufacturing the housing tube there was a large gap between the mounting bracket and the housing tube. In order to fill this gap, 6 washers were used that prevented virtually any steering play once compressed by the two brackets during assembly. After completing the manufacturing of the housing tube, manufacturing began for the steering drive shaft. Instead of the typical aluminum 6061-T6 alloy used throughout the rest of the bike, Chromoly 4130 steel was used instead to ensure weldability to the u-joint connection. The drive shaft featured four slits cut using a vertical band saw to allow for the drive shaft to crush around the steering tube using a collar clamp. The drive shaft connection to the steering tube can be seen below.

The collar clamp alone did not provide enough clamping force to fully translate the steering motion from the steering wheel to the drive shaft. In order to remedy this issue a hole was milled through the drive shaft and inner steering tube to allow for a pin to be fitted (Figure 3.2.3.5). This added safety pin allowed for virtually no play to be seen between the steering inputs to the drive shaft.

Figure 3.2.3.5 *Drive shaft to steering tube collar clamp and pin connection*

After completing as much of the in-house manufacturing as possible the rest of the frame and adjustment parts we had made were welded by Chavez Welding. After receiving the welded frame it was already known that much of the strength had been lost due to the loss or lowering of the temper rating. In order to regain this lost strength the frame was sent to Byington Steel Treating. Due to time and budget constraints a full jig could not be made to prevent warping of the frame. This warping led to numerous problems, which is discussed in Section 3.6 Challenges, Problems, and Solutions of the thesis.

3.3 Drivetrain

3.3.1 Drivetrain Background

One of the three main goals of the One-Ride team was speed. In order to achieve high top speeds, the drivetrain design was crucial. Even though it is very important to the team's design goals, the drivetrain design was one of the last systems developed because other subsystems, such as the frame and steering system, had larger impacts on the bicycle's overall functionability. It was determined early that a multiple gearing system would be needed to achieve higher rpm at the rear wheel. To do this, the rider would transfer mechanical energy through a large front gear and this would be transferred to a smaller second gear. This smaller second gear would be connected to a larger gear located on the opposite side of the frame through a bottom bracket. From the bottom bracket, the gearing would reach a seven speed cassette that would transfer the remaining power to the rear wheel. Since a two-wheeled design is subject to tipping when starting from rest, it was imperative that the drivetrain allowed for an easy transition from rest. It was desired to achieve a high top speed of 35mph which meant that friction and drag needed to be mitigated.

3.3.2 Drivetrain Analysis

In order to calculate the optimal gearing for the One-Ride HPV, several assumptions needed to be made. It was assumed that an average rider pedals at a speed of 80 RPM at the crank with a 150 pound force. Microsoft Excel was used to find the optimal gearing ratios by calculating the revolutions per minute of the rear wheel. From here, the revolutions per minute of the rear wheel was converted into miles per hour. For all cases, an 80 RPM speed at the crank was assumed. All of the detailed calculations can be seen in Appendix A.

We achieved the highest rpm when using a 54 tooth front gear. This gear was then connected to a 32 tooth bracket gear, which in turn was connected to a 54 tooth gear via a bottom bracket. To achieve a high top speed, the chain would need to be connected to a small tooth gear at the cassette so that angular momentum is conserved. To achieve a high top speed, the rider would need to have the bicycle on an eleven tooth gear located on the cassette. Through the calculations, the bicycle rear wheel would reach a speed of 51.25 mph. Even though this well exceeds our 35 mph goal, it doesn't take into account the losses due to the weight of the bicycle, rolling resistance of the tires, and aerodynamic drag.

3.3.3 Drivetrain Design

Once the proper gearing setup was determined through basic analysis, the gear train was implemented on the bicycle. The basic setup of the gear train can be seen in the picture below, where the pedaling gears move back to a set of gears that increases the gear ratio, which ultimately moves back to the rear wheel. In the gear train, there is also a follower that was implemented to increase the tension in the lower part of the chain. This was necessary to prevent the chain from catching on something and also to give better pedal feel for the user.

Figure 3.3.3.1 Front portion of gears in the gear train

This extra set of gears was implemented into the system to reach a much higher top speed. A more detailed view of this part of the gear train, where it transition through the bottom bracket, to the other side of the bicycle, back to the rear wheel can be seen below.

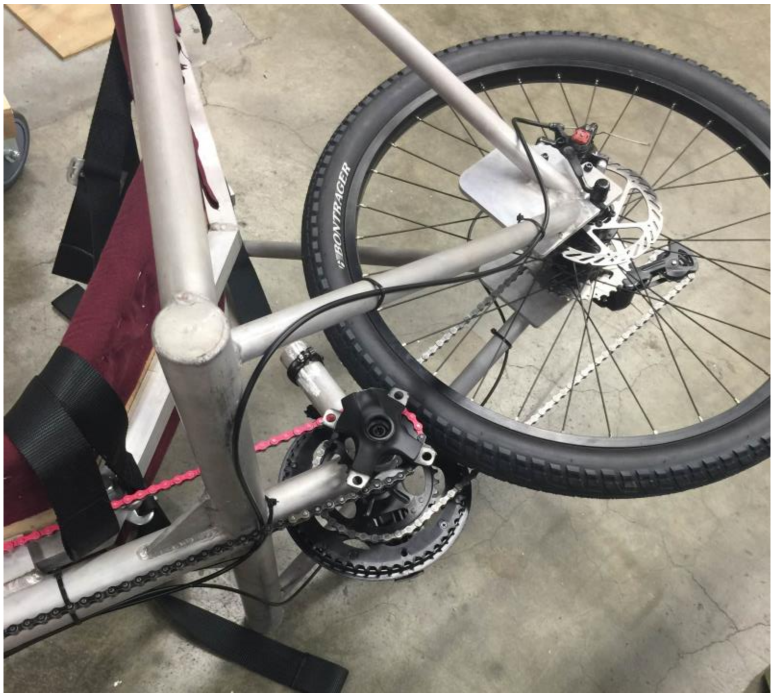


Figure 3.3.3.2 Rear gear train setup

On the other side of the bike, with the larger gear, a derailleur was set up so that the user could choose gears at the position of the bike as well as at the rear wheel. A custom mount was fabricated to hold the derailleur in place and can be seen in Figure 3.3.3.3.

3.4 Aerodynamic Design

In order to decrease the drag of the One-Ride design the team decided to attach a fairing to the front end of the bicycle. This would reduce wind resistance and the overall drag coefficient. After looking at the fairing used in the 2014 HPV Team, Pegasus HPV, it was determined that the same fairing could be used in the One-Ride design.

3.4.1 Aerodynamic Background

The fairing was designed to be used as a both a shield for wind and to improve the overall aerodynamics of the HPV. The faring used this year was a recycle of the previous year’s faring. All of the analysis was done using the previous year’s faring.

Figure 3.3.3.3 *Rear Derailleur*

3.4.2 Aerodynamic Design

The design was focused on reducing the drag on the HPV which in turn would allow for higher top speed which was a focus of our design. The fairing that was used was from the previous year's HPV as such many of the dimensions and shape were the same as last years design. One hope was to incorporate a full fairing, but due to budget constraints and time this was not achievable. The faring used for the design was a LEXAN polycarbonate faring that had the dimensions of 17 inches wide by 40 inches long with a depth of blow of 9 inches.

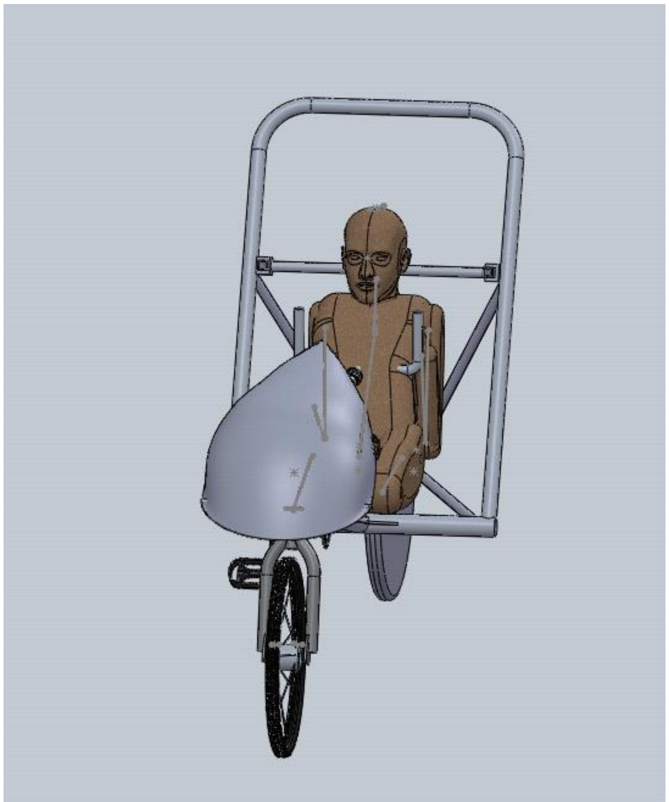


Figure 3.4.2.1 *CAD model of person riding One-Ride design with fairing attached*

3.4.3 Aerodynamic Analysis

For the testing of the fairings we used a CFD program known as STAR CCM+ which gave the fluid flow lines used for analysis. The first fairing test was a general model modeled in Solidworks to get a general idea of the how the air will flow over the fairing at 30 mph.

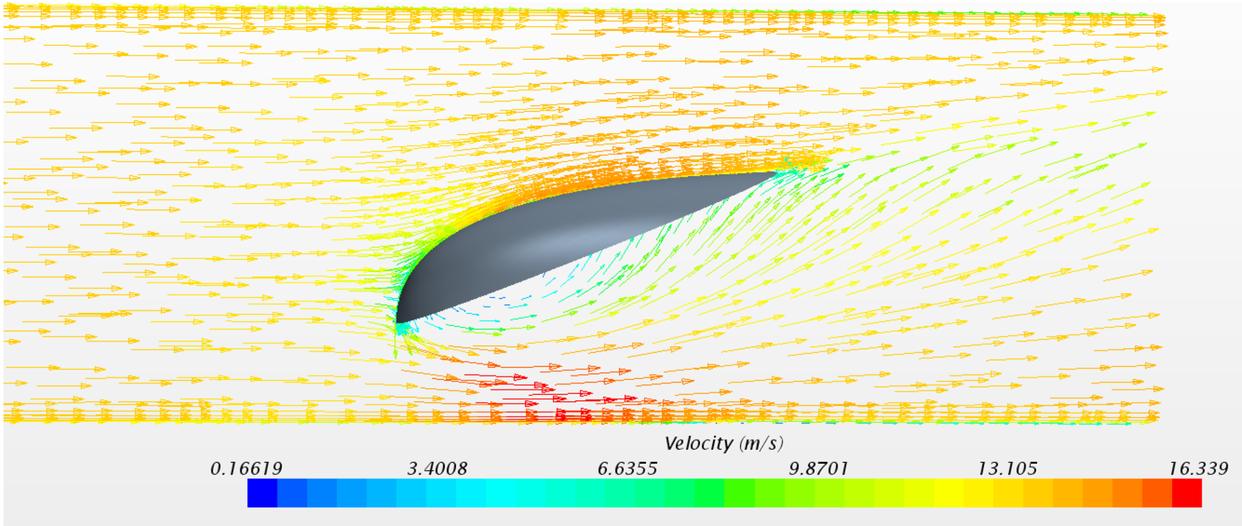


Figure 3.4.3.1 *Analysis of a generic fairing using Star CCM+ Program. The velocity ranges from 0.1662 m/s (blue arrows) to 16.34 m/s (red arrows).*

For these tests the fairings were subjected to a 30 mph wind speed coming head on to the fairing. The next faring was the previous year faring.

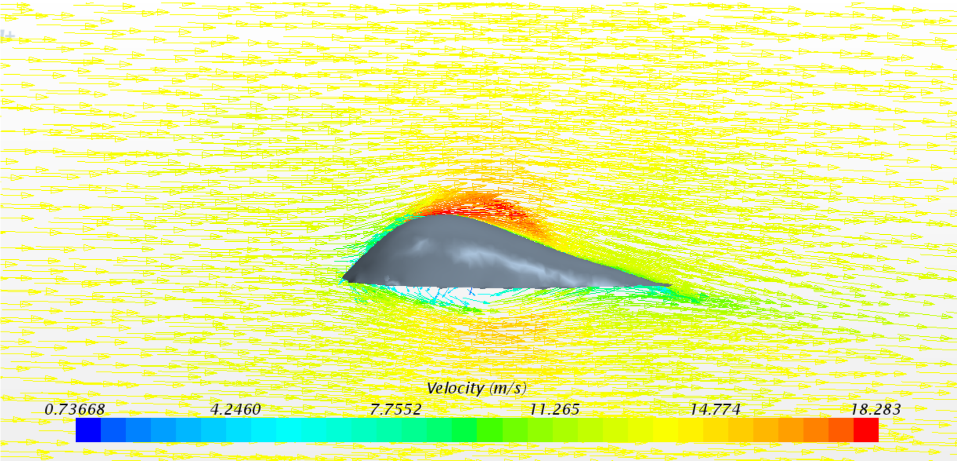


Figure 3.4.3.2 *Analysis of fairing used by 2013 SCU HPV Team. The range goes from 07.367 m/s (blue arrows) to 18.283 m/s (red arrows).*

These tests were conducted to see how the fairings would behave in the expected wind conditions. This orientation was chosen to simulate a head wind of 30 mph. These tests did not yield values for the coefficient of drag and thus the only known value were the previous year's data points. The main reason no values were found was due to inexperience with the Star CCM+ software, because of this no data points could be found

The next test demonstrated the fairing while it was attached to the frame. Here is the fluid flow when the fairing is attached the frame (Figure 3.4.3.3). Due to time constraints the fairing was not attached to the frame on the actual bike. For the aerodynamic analysis the following steps were taken to solve for the drag coefficient. Using Star CCM+ the model was imported from Solidworks. From there a box was created to represent the wind tunnel that the model would be placed into for analysis.

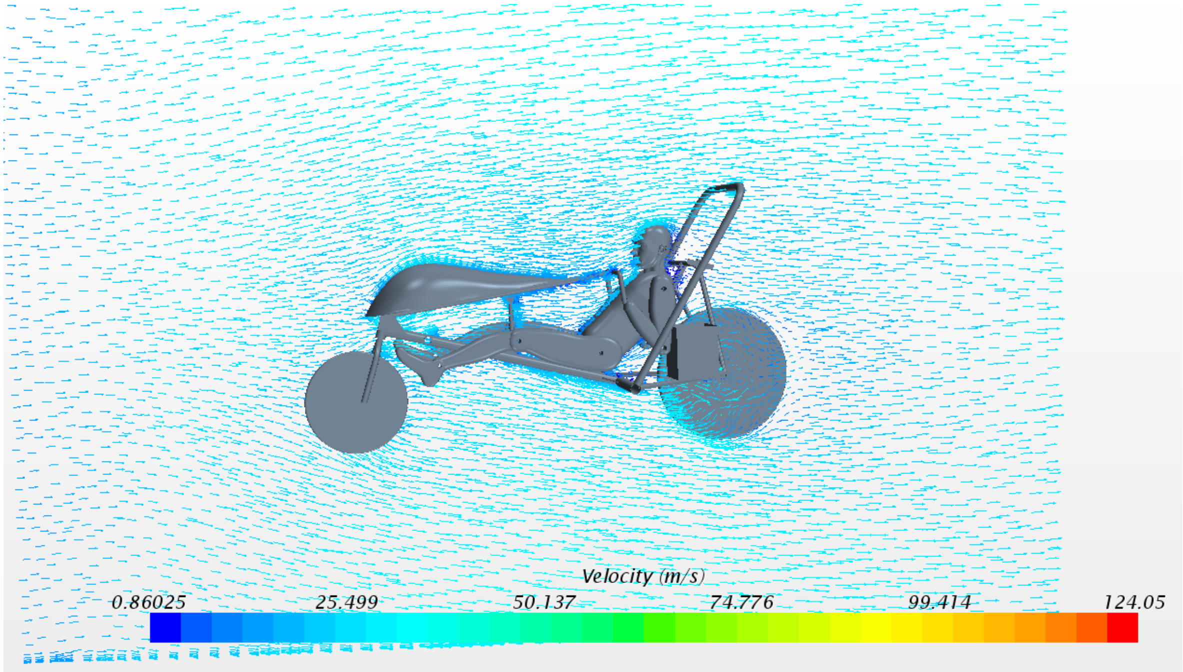


Figure 3.4.3.3 *Star CCM+ analysis of rider and frame. The range of wind speed goes from 0.86025 m/s (blue arrows) to 124.05 (red arrows).*

The box was then split up by different parts making the front and rear of the box to make the inlet and outlet of the tunnel. Form here the model was meshed by using the in program meshing tools. The mesh continua system was set up like so: Surface Wrapper, Prism Layer Mesher, Polyhedral Mesher and Surface Remesher. This was used to create the physical model to represent the physical system. The physics continua was set like so: Laminar Flow, Coupled Energy, Ideal Gas, Coupled Flow, Steady, Gas, Gradients and Three Dimension. With the physics system in place this established the parameters for the model. The wind velocity used was 30 mph to simulate the HPV moving through the air. The system was designed to stop after 100 iterations and give a force coefficient report from the surface of the fairing. Unfortunately due to lack of experience with Star CCM+, no force coefficients could be found. Due to an error in the program, the drag coefficient could not be calculated accurately. As a result it was considered to use last year data.

3.5 Safety

3.5.1 Safety Background

Safety is one of the main goals of the One-Ride team. We want the users of our bike to feel and be as safe as possible while they are riding a One-Ride bicycle. To make the bike as safe as possible it was fitted with a roll bar and 4 point safety harness. The roll bar encloses the rider on the sides and above his or her head.

3.5.2 Safety Design

The roll bar, which is made of a 6061-T6 aluminum with an outer diameter of 1.5 in is ⅛ in thick and is designed to support a top load of 600 lbs and a side load of 150 lbs. The height of the rollbar is 42in tall and it 24.5in wide. These dimensions were chosen based on what the expected height of the tallest rider would be. Since the bike is designed to allow someone who is 6’4” to fit comfortably the rollbar was designed to be taller than that in order for the user’s head to fit underneath the roll bar while they are wearing a helmet. The loads were set by the ASME HPVC competition and also required that the top deflection be less than 2 in and the side deflection be less than 1.5 in when the loads are applied.

3.5.3 Safety Analysis

To ensure that the roll bar design was up to the ASME HPVC competition standards the design was tested in the finite element program Abaqus. In table 3.5.1 are the results of finite element analysis. As seen in the table, the roll bar passed the tests and was strong enough to support the loads required by the competition. With a factor of safety of over 3.0 the maximum deflection that was observed to be less than 0.01 for both the top and side loads. The test results for the finite element analysis can be found in Appendix A**.**

Table 3.5.3.1 *Rollbar Finite Element Analysis Results*

	Load Amount (lbs)	**Max Stress (psi)**	**Max Deformation (in)**	**Factor of Safety**
Top Load	600	13060	0.0093	3.06
Side Load	300	9110	2.944*10-4	4.39

After it was determined through the finite element analysis that our roll bar was strong enough to support the required loads given by the ASME HPVC competition, the designs were sent to be manufactured and heat treated off site. When the frame was completed and returned, the roll bar was tested to ensure the FEA results were accurate and that actual frame was as strong as originally anticipated.

In order to test the frame strength, straps were attached in tandem with a come-along and tension gauge and the entire assembly was wrapped around the frame as seen in Figure 3.5.3.1.

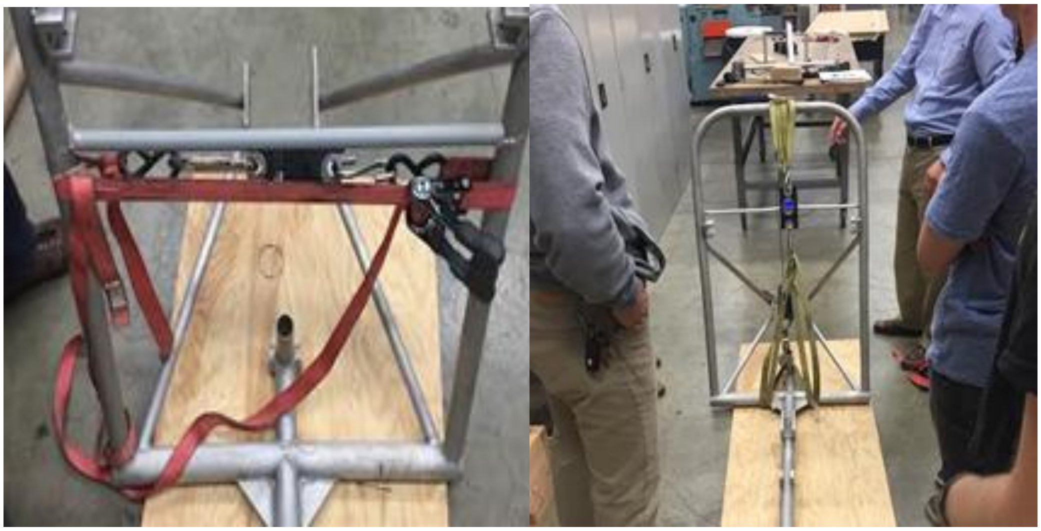
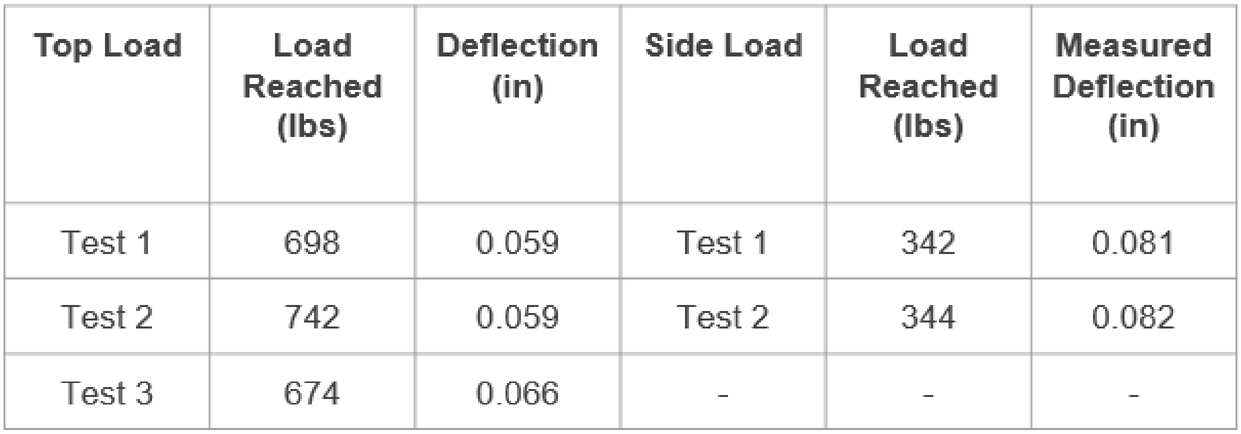


Figure 3.5.3.1 *Rollbar testing set up for side load (left) and top load (right)*

The come-along was then tightened until the readout on the tension gauge was at the desired load. Once the desired load was reached, a PVC pipe was fit snug between the frame. The load was then released and the deflection was measured based on the difference between the PVC pipe and the unloaded frame. Table 3.5.3.2 shows the results from the frame tests.

***Table 3.5.3.2** Rollbar strength test results*



Top Load	Load Reached (lbs)	Deflection (in)	Side Load	Load Reached (lbs)	Measured Deflection (in)
Test 1	698	0.059	Test 1	342	0.081
Test 2	742	0.059	Test 2	344	0.082
Test 3	674	0.066	-	-	-

The physical testing proved that the frame was strong enough to hold the required loads set by the ASME HPVC competition. In each test the load was well over the minimum amount required and the deflection never exceeded 0.09 in.

3.6 Challenges, Problems, and Solutions

The One Ride team faced most of its challenges during the assembly and testing stage of the project. The first set of problems arose when the frame was heat treated. After the frame was welded the strength of the aluminum was severely diminished, dropping the hardness from T-6 to T-1. To return the aluminum to its T-6 status the frame was heat treated. During the heat treating, the seat frame was warped and bent. This caused the sliders to become non-parallel (Figure 3.6.1). This prevented them from moving to the maximum and minimum positions that the seat was designed to move to. In order to test the design, the sliders were secured into the middle position (where they were when the frame was heat treated) and not moved for the rest of testing.

The bending of the frame could have been avoided by manufacturing a steel jig that the frame could have been placed in immediately following the heat treatment process. This would have removed any deformities that would occur and kept the sliders parallel, which would have allowed the seat frame to reach its maximum and minimum positions. However, due to time and budget constraints, a jig was not manufactured for this project.

Figure 3.6.1 *Bending of Seat Frame after heating treating. The bend prevented full adjustability in the seat. For the rest of testing and assembly the seat was fixed in its middle position.*

Another problem that occurred because of heating treating was misalignment of the rear axle of the bike. As seen in figure 3.6.2, the rear wheel was pointing 3 degrees off the centerline of the bike. When riding, this would have caused balance and control issues as the rear wheel would naturally want to pull the bike to the right.

This issue was solved by filing back the hole on the left rear axle mount ½ in (Figure 3.6.3). Filing the axle mount re-aligned the rear wheel and allowed it to point in the same direction as the rest of the bike.

Another problem that was discovered during the testing of the bike was that there was a significant amount of free play or slop in the u-joint that was chosen to connect the driveshaft to the front fork of the bicycle. Because of the slop there was ±5 degrees of freedom in the front wheel while steering wheel was not phased. This made the bike difficult to ride because, when the test rider was shifting his weight to stay balanced, the front wheel would constantly be moving back and forth uncontrollably.

Figure 3.6.2 *Misalignment of the rear wheel due to axle warping. The wheel was pointing about 3 degrees off center as shown by the red lines. The line on the right shows the original direction of the wheel and the left shows the direction the wheel needed to point.*

Figure 3.6.3 *The rear axle mount was filed backwards ½ in. This allowed the rear wheel to point in the same direction as the rest of the bike.*

In order to fix this problem, a new “no slop” u-joint had to be ordered. By replacing the current u-joint with the new one, the play in the front wheel will no longer occur and the rider will be able to have a much easier time remaining in control of the bike and the front wheel.

Another major problem with the bike was stability at low speeds. During ride testing it was impossible to get up to a ridable speed without someone else pushing the bike. This is a problem with any two wheel bicycle, however due to the reclined rider position and u-joint slop, it made the One-Ride bike impossible to ride.

To address the low speed stability issue, a balance wheel has been designed to act as support when the bike is at lower speeds. The balance wheel is a beach cruiser bike kickstand with a wheel attached to the end of it and will be attached to the bottom of the cross bar of the frame (Figure 3.6.4). A handlebar that will be designed later will allow for the rider to lift the balance wheel and make it parallel with the bike. By moving the wheel into the lifted position, the bike still retains the ability to lean when it goes around turns. Once the rider begins to slow the bike down, he can use the handlebar to move the wheel back into the down position so he can balance at the lower speeds. There will be two balance wheels, one on each side of the bike, so if the user over adjusts on one side he will be supported by the second wheel.

Figure 3.6.4 *Balance wheel design (left) and expected placement(right). The wheel is only shown on one side but after tests are done on wheel strength, another wheel will be added to the other side to prevent over adjustment and tip over.*

4 System Integration

4.1 System Integration and Test

Since many parts of the One-Ride design involved complex motion or tight clearances many subsystems had to be tested prior to assembly or manufacturing. One of these subsystems was the steering to fork connection involving the u-joint. By using PVC piping, plywood, and mounting hardware, a mockup of the steering shaft to u-joint connection was made. A ½ in swivel from a toolbox was used to simulate the u-joint. The mock-up yielded excellent results and confirmed that the One-Ride steering and adjustable height would indeed work.

The next mockup was made to determine seating angles and distance of components relative to the rider. This was accomplished by having multiple potential users sit with their back to the wall and their feet elevated on a ladder, all of which was adjusted until the user felt most comfortable. Different sized people were used to determine the optimal distance and angle ranges to maximize comfort.

4.2 Experimental Protocol and Results

Table 4.2.1 shows experiments and the expected results for top speed, acceleration, endurance and deceleration. Because of the problems with the u-joint and balance at low speeds the tests have not been performed yet.

Table 4.2.1 *Experimental Protocol and Expected Results*

Acceleration	25 ft in 10 sec
Top Speed	35 mph
Endurance	25 miles in 2.5 hr
Deceleration	15 to 0 mph in 8 ft

Each of these tests can be done on the Santa Clara campus using only cones and a stop watch. Some tests such, as top speed and endurance were planned to be tested in the ASME HPVC competition. However, because the bike was not ridable during the time of the competition, the tests were not able to be completed. Once the new u-joint and balance wheel are installed and the bike is ridable, the tests will be performed to see if our desired results can be reached. To test the top speed, two cones will be set up 15 ft away each other. After gaining maximum speed, the rider will pass through the cones. A timer will start when the front tire passes the first cone and will stop once the front tire passes the second cone. Using the equation

$$Speed = \frac{Distance}{Time} \tag{1}$$

the top speed of the bike can be determined.

To test the acceleration the cones will be placed 25 ft apart. Starting from the first cone at 0 mph a timer will begin and the rider will accelerate through the second cone. With the equation

$$Acceleration = 2 * \frac{Distance}{Time^2} \tag{2}$$

The acceleration of the bike can be calculated.

To test the braking force, two cones will be set up 8 ft apart. The rider will get the bike up to 15 mph using a speedometer and drive by the cones. When the first wheel passes the first cone the rider will apply the brakes. If the bike fully stops before the front tire passes the second cone the bike has the required stopping force. If not, then the brakes must be adjusted and the test will be redone until it stops within the cones.

5 Cost Analysis and Business Plan

5.1 Cost Analysis

Engineering projects are limited by the amount of money that is available. Whether it is the design of a bicycle or the design of an aircraft, we live in a world that is dictated by money. For our project, the team received roughly $4,500 dollars from the Santa Clara University Undergraduate Engineering Grant, the Roelandts Grant, and ASME IEEE/IEEE VTS. When designing any product, more funds are needed to allow for all of the design modifications and changes that go into producing a full prototype.

The cost to produce a One-Ride bicycle was broken down into subcategories, which included raw materials, manufacturing, competition fees, and change orders. Chavez Welding purchased and welded all of the Aluminum 6061-T6 material for a total of $2,100. While the seating brackets and mounting brackets were manufactured in-house, we contracted Chavez Welding to manufacture the majority of the frame due to limited shop capabilities. The aerodynamic fairing was reused and mounted from the 2013-2014 HPV Pegasus team which saved upwards of $500. All other components such as bolts, washers, wheels, tires, ect., were purchased for roughly $1,350. We also purchased initial design documents supplied by the Groundhugger XR2 for $100 to begin our preliminary design of the One-Ride. A second, larger U-Joint was purchased for an additional $150 which is an example of one of the many change orders we incurred. In total, the team used all of the funding available and also invested a small amount of personal money.

5.2 Business Plan

The business plan is a simulation of the One-Ride Team's proposal to investors if we were to start a company that built and sold One-Ride HPVs. The business plan contains background information on the design, initial startup costs for machines, rental space etc., everyday costs such as bike components, and salaries, final sale price of one bike, and a ten year plan that shows the profit the company would make.

Abstract

Through research from customer interviews and surveys, five mechanical engineers developed a two-wheeled recumbent bicycle that incorporates customer preferences in a human powered vehicle. Amongst these are a fully adjustable seating and steering system that allows riders from 5’2” to 6’4” to commute to destinations of under 20 miles in a safe, comfortable, and fast manner. With a retail price of $2,644, this proposed business plan details the strategy to bring this recumbent bicycle to market in a time when traffic congestion and carbon dioxide emissions are at an all-time high.

Introduction

As more and more recumbent bicycles enter the market, it becomes increasingly difficult for consumers to choose one bicycle over another. It is difficult to distinguish one company over another unless there are distinct differences between bicycles that the rider notices and prefers. The goal of the One-Ride HPV team was to find a way to entice potential clients into choosing our design. Through an innovative adjustable seating and steering system that provides comfort and adaptability between riders, we aim to satisfy customers by providing a durable and long-lasting bicycle that can replace short to medium range trips that are less than 20 miles. Through customer interviews, we have narrowed customer’s interests into three main categories. Through speed, safety, and comfort designs, we have successfully completed the design of an aesthetically pleasing and safe bicycle that will hopefully draw the attention of consumers. By creating a thorough and detailed business plan, we can market the bicycle to the public in an efficient way so that it will eventually reduce greenhouse gas emissions, traffic congestion, and will provide added health benefits to a growing population.

Goals

- Sell one bicycle per day
- Manufacture 7 bicycles/week
- 10 year investment
- Reach a market share of 5% in the recumbent market
- Reach a 50% return on investment

Objectives

- Expand manufacturing through capital investments and detailed marketing plans
- Optimize the marginal product of labor of One-Ride employees

- Provide high quality bicycles and high customer satisfaction

Product Description

The One-Ride HPV is a practical alternative to a car by providing many of the customer preferences of an automobile and incorporating these preferences in our two-wheeled recumbent bicycle. Through customer research, the One-Ride team found that there were three main features in automobiles that they preferred. Amongst these were speed, safety, and comfort. The One-Ride HPV features a two-wheeled design to achieve high top speeds by decreasing frontal area and allowing for improved handling compared to most current three-wheeled designs. An adjustable seating and steering system addresses one of the main customer complaints about bicycles, comfort. Through a protective roll cage bar and a four-point harness safety belt, our design has proven to be safe with minimal deflection when external loads are applied.

By implementing a one-size fits all bicycle that allows for riders from 5’2” to 6’4” to operate the vehicle, manufacturing costs will be reduced since less frames will have to be produced. It will allow riders to commute comfortably 20 miles round trip/day and with the increasing population, our product could potentially grow worldwide. The company will start as a small-scale manufacturer due to limitations in finances and limited market power. As popularity of One-Ride vehicles increases, we will be able to expand our factory to produce more bicycles and potentially sell these vehicles worldwide. While there are several other recumbent bicycle companies in the market, our primary competitors will be those who also produce two-wheeled recumbents. Amongst these are companies such as EasyRacers and SunsBicycles. Both companies have multiple two-wheeled recumbent models and One-Ride will need to offer similar options in order to stay competitive with the market. Low end models start anywhere from $1,500 and go to upwards of $7,000. In order to entice consumers to purchase our product, we must be somewhere within this range.

Currently, 2% of all bicycles are recumbent style. There were 18.7 million bicycles sold in 2012, which means that 374,000 were recumbent.[14] In order to achieve a 5% market share of recumbent bicycles, One-Ride would have to sell 18,700 bicycles/year. If one bicycle is sold per

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[14] "Industry Overview 2013." - National Bicycle Dealers Association. Web. 25 May 2015. <http://nbda.com/articles/industry-overview-2013-pg34.htm>.

day, we will achieve .1% of the market share in the first year, and will have to expand our manufacturing to achieve a 5% market share.

Potential Markets

When designing the One-Ride HPV, the target audience was originally intended for families with different sized members, some of which would still be growing. The One-Ride HPV allows for these families to have one bicycle that both a child and an adult can ride by simply adjusting the seat and steering positions. As the design process continued, the One-Ride HPV became much more feasible as a daily commuter.

Sales and Marketing Strategies

In order to have a successful business, a company must have a strong sales and marketing team. Consumers will only buy a One-Ride bicycle if there is awareness and publicity around our product. In order for consumers to learn about the benefits of a One-Ride vehicle, advertising tools such as websites and brand recognition must be created. The first step in a marketing strategy is to get our product online. Upon completion of our website, we will consult with large search engines such as Google and Yahoo so that when people type in specific keywords related to our bicycle, they will see our website through the search engine they are using. While we will have to pay for these features, it is necessary to do so because the Internet is one of the best ways to spread awareness quickly. In addition, we will use other advertising techniques to draw attention to our bicycle through postings in local newspaper ads and magazines.

Our company will be called One-Ride because the name is simple and short, but also because it conveys our intended message. By having a one-size fits all frame that is comfortable, safe and fast, families of all different sizes can share the same bicycle. There will be no need to own multiple sized frames unless the family intends on going on family bike rides.

Manufacturing Plans

In order to produce 7 bicycles per workweek, the One-Ride team would have to open a small scale manufacturing shop locally in Santa Clara, California. One of the largest investments will be the capital investment of a CNC, lathe, heat-treating equipment and additional tools. We have estimated the total sunk cost to be $500,000 in equipment. In addition, we face other fixed costs such as a shop lease, insurance and taxes. The table below represents the initial start-up cost breakdown.

Table 5.2.1 *Initial Start-Up Costs*

Category	**Price ($)**
Capital Investment	500,000
Lease/Yr	25,000
Wages/Yr	235,000
Insurance and Taxes/Yr	25,000
Inflation/Yr	1,260

We have broken the labor down into six main groups, manufacturing of parts, welding and heat annealing, product assembly, testing, sales and advertising, and finance. In order to fulfill these labor needs, six machinists will be hired at $20/hour according to research found through the Bureau of Labor Statistics.[15] Two workers will manufacture parts using a CNC, Lathe, and other tools. Two workers will weld and heat-anneal the bicycles and the final two workers will assemble. The five design engineers will do all testing, sales, marketing, and finance to ensure build quality and company success. The longest areas of the manufacturing process will be manufacturing of parts and the welding process; however, the assembly process should go relatively quickly assuming all of the parts have the correct tolerances. By having an assembly-line manufacturing shop, we aim to produce at least one bicycle/day.

Product Cost and Price

Table 2 shows the breakdown for the raw materials needed to produce (1) One-Ride vehicle. These prices were the costs we endured to build our bicycle, however, once we expand we will be able to get some of the parts for cheaper through wholesale distributors.

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[15] "51-4041 Machinists." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics. Web. 25 May 2015. <http://www.bls.gov/oes/current/oes514041.htm>.

***Table 5.2.2** Raw Material costs to Produce one Bike*

Category	**Price ($)**
Aluminum 6061-T6	600
Wheels/Tires	200
Brakes	100
Bolts	100
Seating	100
Gearing	250
Fairing	150

The total cost in raw materials was roughly $1,500. The overhead costs includes the wages of our six machinist, utilities, lease, insurance and taxes, and the cost of five design engineers. As will be discussed in the financial plan, $600,000 will be borrowed in bank loans to pay for the capital investment and some of the start-up costs. Table 3 details the total costs we will endure over a 10-year period and accounts for inflation at a yearly rate of 0.84%.

Table 5.2.3 *Total Cost For 10 Years*

Year	Material Cost Per Frame ($)	Material Cost/Yr ($)	Overhead/Yr ($)	Loan Payments/Yr ($)
1	1,500	540,000	300,000	79,935
2	1,513	544,594	302,520	79,935
3	1,526	549,187	305,040	79,935
4	1,538	553,781	307,560	79,935
5	1,551	558,374	310,080	79,935
6	1,564	562,968	312,600	79,935
7	1,577	567,562	315,120	79,935
8	1,589	572,155	317,640	79,935
9	1,602	576,749	320,160	79,935
10	1,615	581,342	322,680	79,935
		5,606,712	3,113,400	799,348
				9,519,460

In order to earn zero accounting profit, the profit not taking into account implicit costs, a One-Ride HPV must retail for $2,644. If the five design engineers each earn a salary of $100,000, the bicycle must retail for $4,033. However, the product price could decrease if we are able to expand and sell more than one bicycle/day by using Internet advertising. The cost to produce (1) One-Ride HPV of $2,644 doesn't take into account paying any wages to the five design engineers. Other two-wheeled recumbent bicycles, such as those featured on easyracers.com, retail for anywhere from $1,995 to $6,595. We are well within an acceptable price range for current recumbent bicycles that are on the market and we believe by having a fully adjustable design that features comfort and speed, it can be considered a top of the line recumbent bicycle.

Warranties and Service

Both customer satisfaction and build quality are paramount to the One-Ride team. Warranties regarding the bicycle would extend to the entire bike, except normal wear parts such as brakes, tires, etc. The rest of the warranties would be categorized by part. For example, the frame would be warranted for 8 years unless damaged by abuse or abnormal use. The One-Ride team wants to ensure the ultimate build quality, especially in regards to the frame. If the frame fails due to poor workmanship or materials, the frame will be replaced under warranty. Buyers would also have the option of purchasing a lifetime warranty plan for the frame covering the whole lifespan of the original buyer.

The mechanical components of the bike such as the brake system, derailleur, wheels, head tube, chain, and other mechanical components would be warranted for 1 year. Warranty times are subject to change when the HPV is used for commercial use. In this case the frame is only warranted for 2 years and the mechanical components would only be warranted for 120 days from the date of purchase. The limited warranty would not cover cosmetic blemishes, improper maintenance or assembly, and damage caused by misuse or an accident.

In terms of bicycle service, the One-Ride team would pay for shipping and repairs if the component that failed is covered under warranty. Larger components such as the frame would require a third party to inspect the frame in case the One-Ride team could not inspect the frame in person. If the frame is irreparable and is still warranted, the One-Ride team would pay for shipping and replace the customer’s frame free of cost. The use of a third party would allow for the One-Ride team to be able to issue repairs for a customer that is too far for shipping to be a cost-effective solution.

Financial Plan

Due to the large capital investment of the CNC, lathe, and heat-treating equipment, we have decided to take out a $600,000 bank loan at an interest rate of 6%. We have estimated that the start-up equipment is roughly $500,000. The total cost to sell roughly 3,600 bicycles over a

10-year period is $9,519,460. In order to break even, a One-Ride HPV must retail for $2,644. To achieve a 50% return on investment, the retail price is $3,966.44, which is well within an acceptable price. While it may take a little time to get advertising and our business up to speed, the extra $100,000 in the bank loan will cover wages and other expenses until we are able to begin selling our product. It is estimated that after a couple months of production, we will have enough inventory to begin selling bicycles online and through various advertisements. If sales exceed expectations, then we will move equipment and personnel to a larger factory where more bicycles can be manufactured and then sold.

6 Arts

As part of satisfying the SCU Core Arts & Humanities requirements, members of this team have all contributed original drawings, sketches, and/or CAD models and drawings to this project. Below are listed a sampling of at least one such artifact, and a reference to it, for each of the team members

Table 6.1 *Reference of drawings done by each team member*

Team Member	**Description**	**Location**
Alex Fisher	Preliminary sketch of human powered vehicle	Figure 2.6.1
Alex Sahyoun	CAD Model	Dwg Fr-08, pg 106
Geoff Schmelzer	CAD Model	Dwg ST-07, pg 91
Brendan Taylor	FEA of Frame	Appendix A
C.J. Toy	CAD Model	Dwg SE-01, pg 96

7 Conclusion

The goal of the One-Ride human powered vehicle team was to create a human powered vehicle that would entice people to switch from cars to bicycles for round trips of 20 miles or less. With the switch from cars to human powered vehicles there would be a drastic decrease of greenhouse emissions and other pollutions. After surveys and interviews to gain a better understanding of what customers look for in a bicycle, the goals of safety, speed, and comfort were found to be most important for the design. In order to satisfy these goals, the team designed a two wheel recumbent style bicycle that has fully adjustable seating and steering positions. Using the computer programs Solidworks and Abaqus, along with the help of local welders and heat treating companies, the bike was designed, tested and assembled. In order to validate the design it was planned to be entered into the ASME HPVC West Coast Competition. However during assembly and testing it was discovered that there were two major problems with the design that prevented the team from entering the design in the competition. The first problem was slop in the u-joint. The front wheel would turn about 3 degrees and this motion would not be felt in the steering wheel. This made it extremely difficult to balance on the bike and made it very unstable at higher speeds. The second problem was balance at low speeds. The user had trouble getting up to a balanceable speed without assistance from another person holding the bike. Solutions to both of these problems have been found and are currently being worked on and added to the bike. To fix the slop in the u-joint a new no slop u-joint will replace the current one. To solve the balance issue, a balance wheel was designed to prevent the bike from tipping over at low speeds. This wheel will be able to be rotated to parallel with the bike so that, at higher speeds, the bike still has the ability to lean. Once the solutions are fully designed and implemented the bike will be re-tested and evaluated for rideability.

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Appendices

Appendix A: Finite Element Analysis Figures

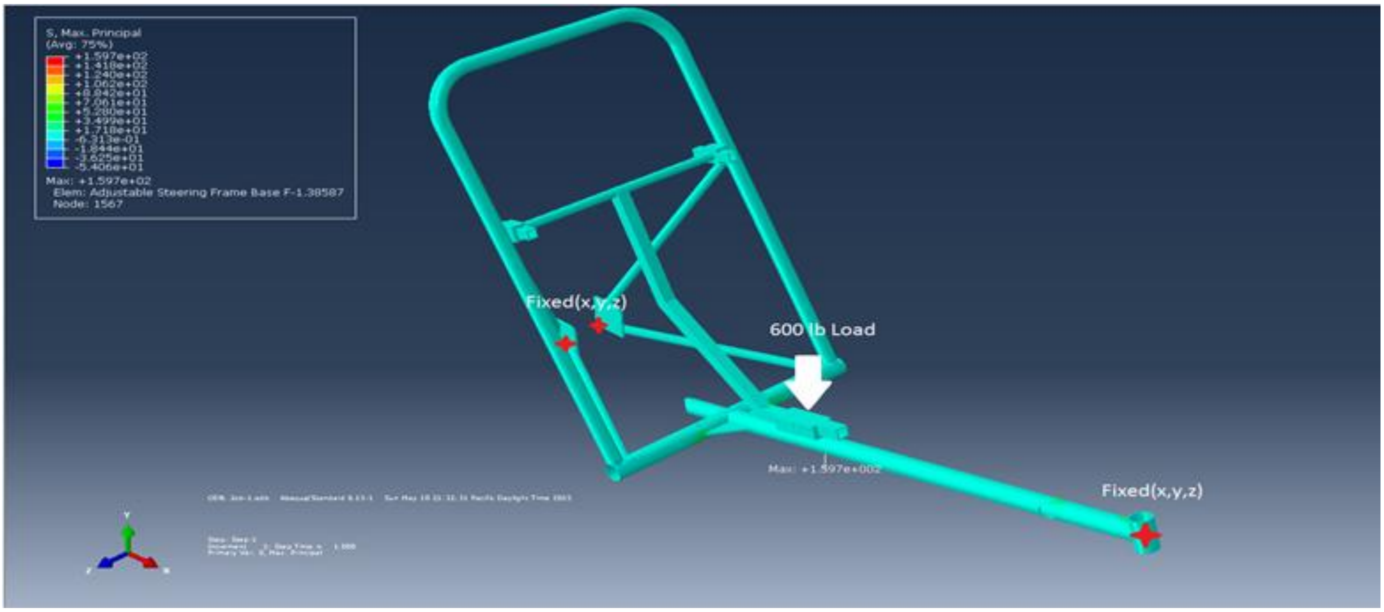
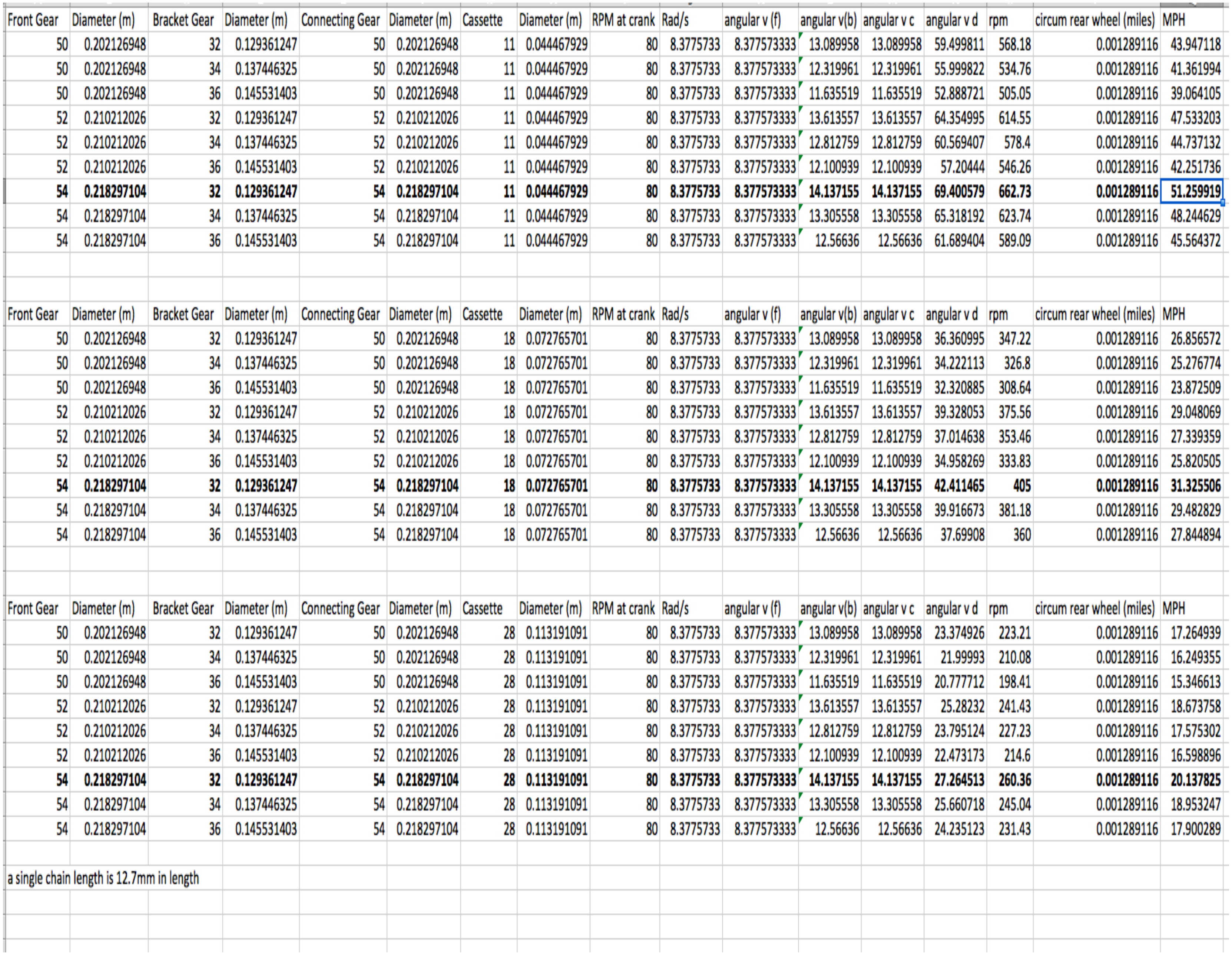


Figure A.1 *Analysis of entire frame with 600 lb load on seat*

Appendix B: Detailed Calculations

The drive train calculations were done by assuming constant angular momentum with no energy losses. The diameters of different sized tooth gears was found so that the radius could be used in the relation wr=constant. An Excel spreadsheet was used to vary the combinations of gear sizes, and the angular momentum of the front gear was found by assuming the rider pedals with a 150 pound force at a speed of 80 revolutions per minute. The revolutions per minute of the rear wheel was then found and converted to miles per hour.



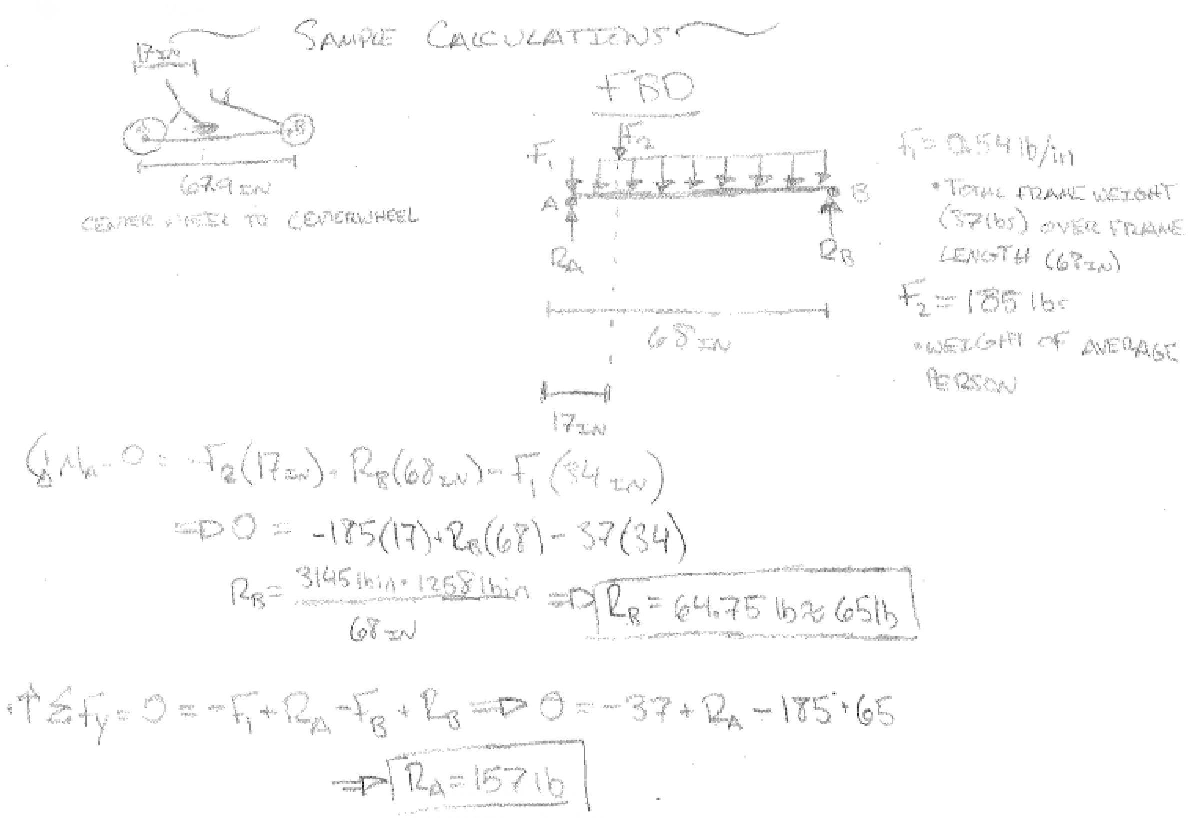
Front Gear	Diameter (m)	Bracket Gear	Diameter (m)	Connecting Gear	Diameter (m)	Cassette	Diameter (m)	RPM at crank	Rad/s	angular v (f)	angular v(b)	angular v c	angular v d	rpm	circum rear wheel (miles)	MPH
50	0.202126948	32	0.129361247	50	0.202126948	11	0.044467929	80	8.3775733	8.377573333	13.089958	13.089958	59.499811	568.18	0.001289116	43.947118
50	0.202126948	34	0.137446325	50	0.202126948	11	0.044467929	80	8.3775733	8.377573333	12.319961	12.319961	55.999822	534.76	0.001289116	41.361994
50	0.202126948	36	0.145531403	50	0.202126948	11	0.044467929	80	8.3775733	8.377573333	11.635519	11.635519	52.888721	505.05	0.001289116	39.064105
52	0.210212026	32	0.129361247	52	0.210212026	11	0.044467929	80	8.3775733	8.377573333	13.613557	13.613557	64.354995	614.55	0.001289116	47.533203
52	0.210212026	34	0.137446325	52	0.210212026	11	0.044467929	80	8.3775733	8.377573333	12.812759	12.812759	60.569407	578.4	0.001289116	44.737132
52	0.210212026	36	0.145531403	52	0.210212026	11	0.044467929	80	8.3775733	8.377573333	12.100939	12.100939	57.20444	546.26	0.001289116	42.251736
54	**0.218297104**	**32**	**0.129361247**	**54**	**0.218297104**	**11**	**0.044467929**	**80**	**8.3775733**	**8.377573333**	**14.137155**	**14.137155**	**69.400579**	**662.73**	**0.001289116**	**51.259919**
54	0.218297104	34	0.137446325	54	0.218297104	11	0.044467929	80	8.3775733	8.377573333	13.305558	13.305558	65.318192	623.74	0.001289116	48.244629
54	0.218297104	36	0.145531403	54	0.218297104	11	0.044467929	80	8.3775733	8.377573333	12.56636	12.56636	61.689404	589.09	0.001289116	45.564372

Front Gear	Diameter (m)	Bracket Gear	Diameter (m)	Connecting Gear	Diameter (m)	Cassette	Diameter (m)	RPM at crank	Rad/s	angular v (f)	angular v(b)	angular v c	angular v d	rpm	circum rear wheel (miles)	MPH
50	0.202126948	32	0.129361247	50	0.202126948	18	0.072765701	80	8.3775733	8.377573333	13.089958	13.089958	36.360995	347.22	0.001289116	26.856572
50	0.202126948	34	0.137446325	50	0.202126948	18	0.072765701	80	8.3775733	8.377573333	12.319961	12.319961	34.222113	326.8	0.001289116	25.276774
50	0.202126948	36	0.145531403	50	0.202126948	18	0.072765701	80	8.3775733	8.377573333	11.635519	11.635519	32.320885	308.64	0.001289116	23.872509
52	0.210212026	32	0.129361247	52	0.210212026	18	0.072765701	80	8.3775733	8.377573333	13.613557	13.613557	39.328053	375.56	0.001289116	29.048069
52	0.210212026	34	0.137446325	52	0.210212026	18	0.072765701	80	8.3775733	8.377573333	12.812759	12.812759	37.014638	353.46	0.001289116	27.339359
52	0.210212026	36	0.145531403	52	0.210212026	18	0.072765701	80	8.3775733	8.377573333	12.100939	12.100939	34.958269	333.83	0.001289116	25.820505
54	**0.218297104**	**32**	**0.129361247**	**54**	**0.218297104**	**18**	**0.072765701**	**80**	**8.3775733**	**8.377573333**	**14.137155**	**14.137155**	**42.411465**	**405**	**0.001289116**	**31.325506**
54	0.218297104	34	0.137446325	54	0.218297104	18	0.072765701	80	8.3775733	8.377573333	13.305558	13.305558	39.916673	381.18	0.001289116	29.482829
54	0.218297104	36	0.145531403	54	0.218297104	18	0.072765701	80	8.3775733	8.377573333	12.56636	12.56636	37.69908	360	0.001289116	27.844894

Front Gear	Diameter (m)	Bracket Gear	Diameter (m)	Connecting Gear	Diameter (m)	Cassette	Diameter (m)	RPM at crank	Rad/s	angular v (f)	angular v(b)	angular v c	angular v d	rpm	circum rear wheel (miles)	MPH
50	0.202126948	32	0.129361247	50	0.202126948	28	0.113191091	80	8.3775733	8.377573333	13.089958	13.089958	23.374926	223.21	0.001289116	17.264939
50	0.202126948	34	0.137446325	50	0.202126948	28	0.113191091	80	8.3775733	8.377573333	12.319961	12.319961	21.99993	210.08	0.001289116	16.249355
50	0.202126948	36	0.145531403	50	0.202126948	28	0.113191091	80	8.3775733	8.377573333	11.635519	11.635519	20.777712	198.41	0.001289116	15.346613
52	0.210212026	32	0.129361247	52	0.210212026	28	0.113191091	80	8.3775733	8.377573333	13.613557	13.613557	25.28232	241.43	0.001289116	18.673758
52	0.210212026	34	0.137446325	52	0.210212026	28	0.113191091	80	8.3775733	8.377573333	12.812759	12.812759	23.795124	227.23	0.001289116	17.575302
52	0.210212026	36	0.145531403	52	0.210212026	28	0.113191091	80	8.3775733	8.377573333	12.100939	12.100939	22.473173	214.6	0.001289116	16.598896
54	**0.218297104**	**32**	**0.129361247**	**54**	**0.218297104**	**28**	**0.113191091**	**80**	**8.3775733**	**8.377573333**	**14.137155**	**14.137155**	**27.264513**	**260.36**	**0.001289116**	**20.137825**
54	0.218297104	34	0.137446325	54	0.218297104	28	0.113191091	80	8.3775733	8.377573333	13.305558	13.305558	25.660718	245.04	0.001289116	18.953247
54	0.218297104	36	0.145531403	54	0.218297104	28	0.113191091	80	8.3775733	8.377573333	12.56636	12.56636	24.235123	231.43	0.001289116	17.900289

a single chain length is 12.7mm in length

Figure B.1 *Drivetrain Calculations*



SAMPLE CALCULATIONS

$f_1 = 0.54$ lb/in

- TOTAL FRAME WEIGHT (37lbs) OVER FRAME LENGTH (68 IN)

$F_2 = 185$ lbs

- WEIGHT OF AVERAGE PERSON

$$\circlearrowleft + \sum M_A = 0 = -F_2(17_{IN}) + R_B(68_{IN}) - F_1(34_{IN})$$

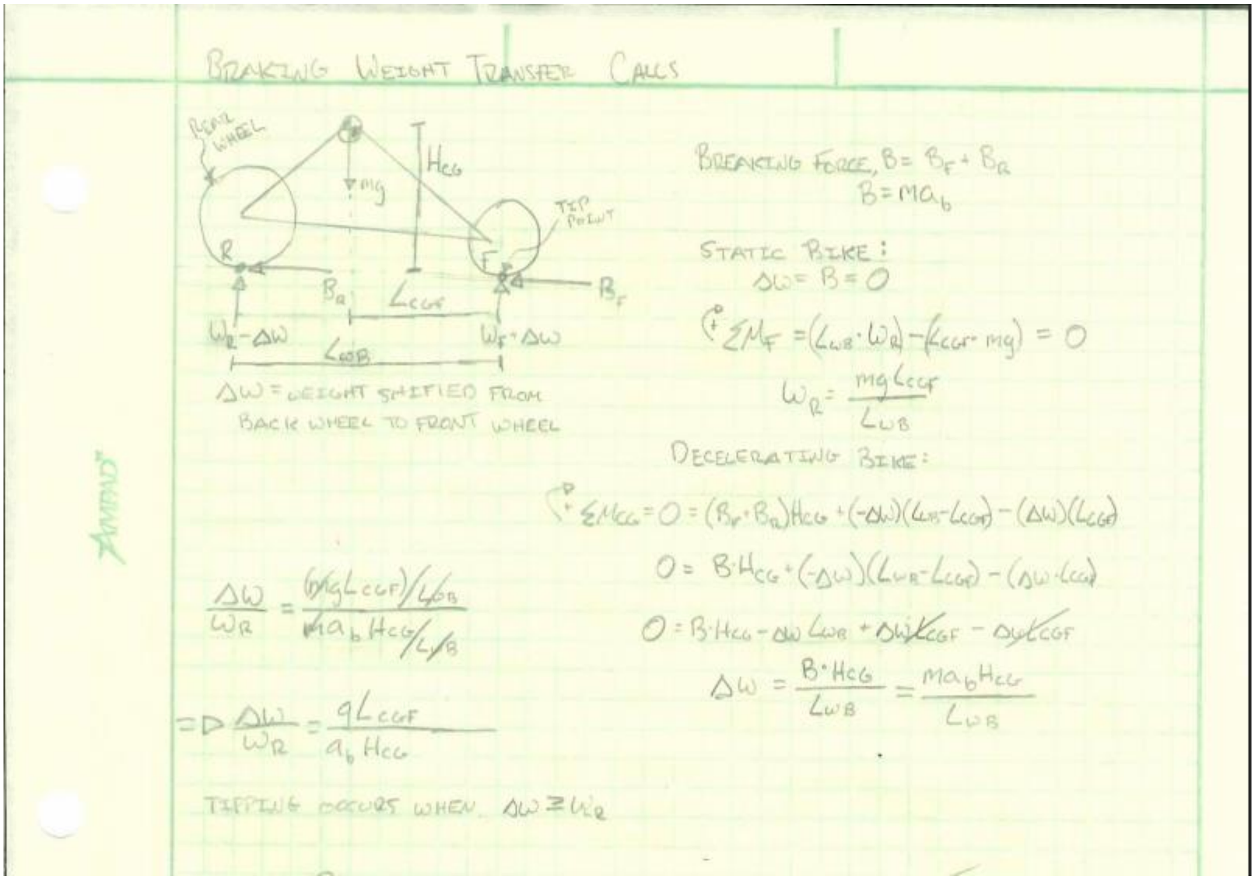
$$\Rightarrow 0 = -185(17) + R_B(68) - 37(34)$$

$$R_B = \frac{3145\,\text{lbin} + 1258\,\text{lbin}}{68_{IN}} \Rightarrow \boxed{R_B = 64.75\text{ lb} \approx 65\text{ lb}}$$

$$+\uparrow \sum F_y = 0 = -F_1 + R_A - F_B + R_B \Rightarrow 0 = -37 + R_A - 185 + 65$$

$$\Rightarrow \boxed{R_A = 157\text{ lb}}$$

Figure B.2 *Reaction Forces at wheel locations*



BRAKING WEIGHT TRANSFER CALCS

ΔW = WEIGHT SHIFTED FROM BACK WHEEL TO FRONT WHEEL

BREAKING FORCE, $B = B_F + B_R$

$B = ma_b$

STATIC BIKE:

$\Delta W = B = 0$

$$\circlearrowleft^{+} \sum M_F = (L_{WB}\cdot W_R) - (L_{CGF}\cdot mg) = 0$$

$$W_R = \frac{mgL_{CGF}}{L_{WB}}$$

DECELERATING BIKE:

$$\circlearrowleft^{+} \sum M_{CG} = 0 = (B_F + B_R)H_{CG} + (-\Delta W)(L_{WB} - L_{CGF}) - (\Delta W)(L_{CGF})$$

$$0 = B\cdot H_{CG} + (-\Delta W)(L_{WB} - L_{CGF}) - (\Delta W \cdot L_{CGF})$$

$$0 = B\cdot H_{CG} - \Delta W L_{WB} + \cancel{\Delta W L_{CGF}} - \cancel{\Delta W L_{CGF}}$$

$$\Delta W = \frac{B\cdot H_{CG}}{L_{WB}} = \frac{ma_bH_{CG}}{L_{WB}}$$

$$\frac{\Delta W}{W_R} = \frac{(\cancel{m}gL_{CGF})/\cancel{L_{WB}}}{\cancel{m}a_bH_{CG}/\cancel{L_{WB}}}$$

$$\Rightarrow \frac{\Delta W}{W_R} = \frac{gL_{CGF}}{a_bH_{CG}}$$

TIPPING OCCURS WHEN $\Delta W \geq W_R$

Figure B.3 *Braking and Weight Transfer Calculations*

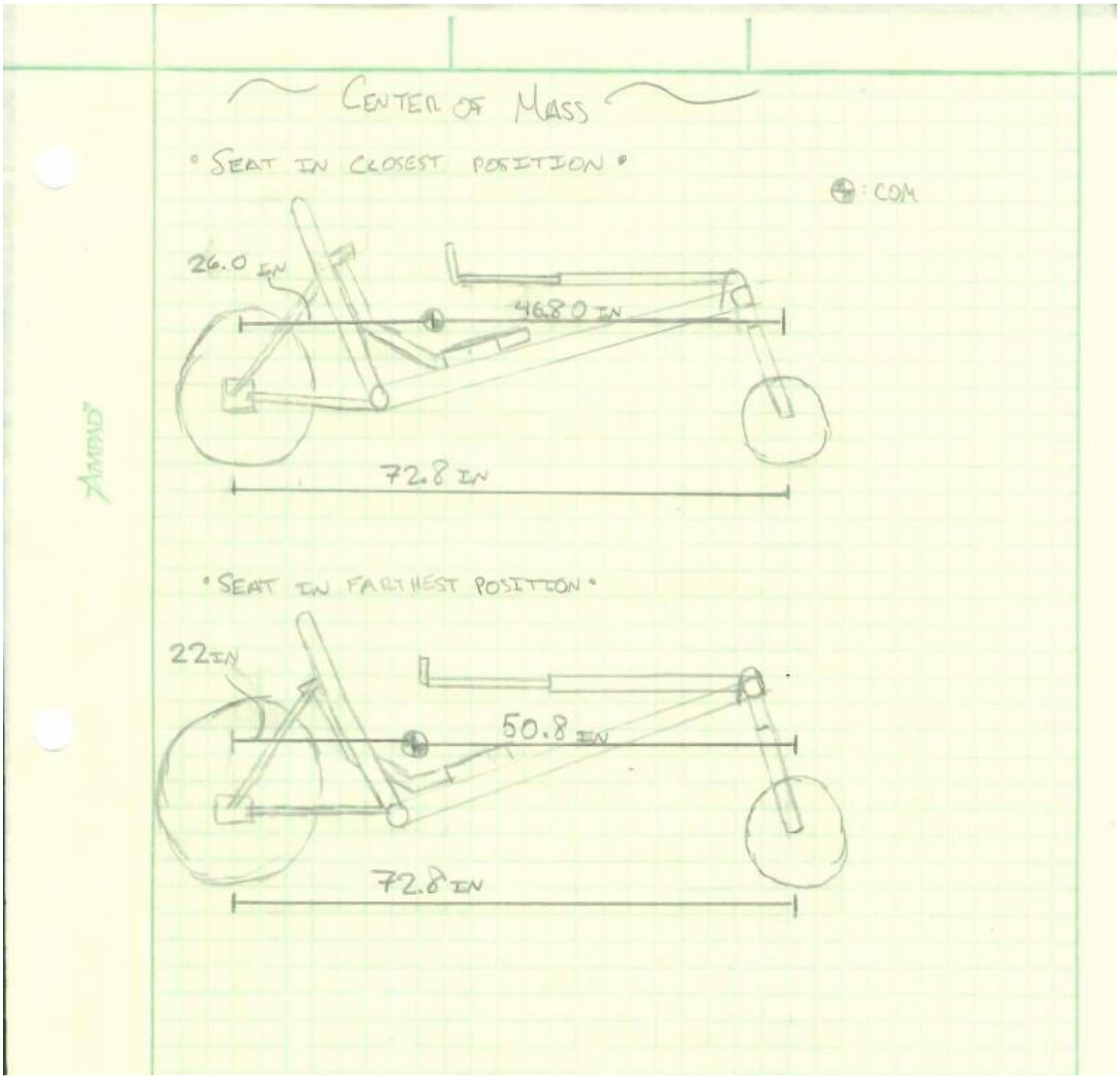


Figure B.4 *Center of mass position for nearest and farthest seat positions*

Appendix C: Responses to Customer Survey and Individual Interviews

Online Survey Questions and Responses

Customer: General Public Survey Type: Online Questionnaire
Survey Dates: Oct. 23, 2014-Oct. 26, 2014

Question 1: What is your age?
Of the 75 people surveyed, 44 were 18-21 years of age, 18 were 22-27, 3 were 28-31, 4 were 32-40, and only 6 were over 40.

Question 2: Male or female?
62 people or 79.49% of the total people surveyed were male, where as just 20.51% or 16 people were female

Question 3: Which human powered vehicles do you use?

Answer Choices		Responses	
Bike		64.10%	50
Scooter		10.26%	8
Skateboard/Longboard		33.33%	26
Rollerblades		12.82%	10
I do not use any human powered vehicles		20.51%	16
Other (please specify)	Responses	12.82%	10
Total Respondents: 78			

Figure C.1*: Response from survey on various human powered vehicles used*

Question 4 (Open ended responses): Where do you take your human powered vehicle?

This was an opened ended question and therefore received a wide array of answers. The most common responses were to work, school, the store, and on bike trails. More specifically users in large cities typically used HPVs.

Question 5 (Open ended responses): How far do you ride your human powered vehicle?

Most people who responded to this question said they take their HPV for trips between 0 and 5 miles typically to school or to the grocery store. The next most common answer was between 10 and 20 miles.

Question 6: Why do you use your HPV
Around 10% used HPVs since they dont have a car, less than 5% used HPVs to better the environment, around 35% used HPVs for their convenience and the remainder chose "Other". Responses in the "Other" category included, to save money on gas, and for recreational use or exercise.

Question 7 (Open ended responses): What items do you have with you when you ride your HPV?

The responses to this question were all fairly similar. cell phones, laptops, groceries, and backpacks were amongst the most popular answers.

Question 8 (Open ended responses): What do you like most about your HPV?

Convenient to ride, good exercise, and fun to do were amongst the most popular answers. Some mentioned the non-existent cost of gas and relatively low maintenance cost compared to a car. Responses stated that the increased sense of speed make the ride more engaging and entertaining.

Question 9 (Open ended responses): What would you change about your human powered vehicle?

This question received a wide variety of responses. Some examples are theft protection, extra power when climbing hills, rider comfort, speed, want it to be multi-terrain and also want it to have some sort of a human-hybrid electric power. Some responses mentioned that they wanted something to set their HPV apart from the others.

Table C.1*: Customer Needs based on age groups*

Age Bracket	**Customer Needs**
18-25	The younger audiences portrayed a desire to have a faster and lighter HPV. They generally enjoyed the existing sense of speed of HPVs but wanted them to be more capable. Many wanted some sort of motorized hybrid included in the HPV design. Portability and ease of storage was also a desirable addition to HPVs since many users were using them to get to class or work.
25-30	The 25-30 bracket, like the 18-25 bracket, also wanted some sort of motorized hybrid to be incorporated into HPV design. However this age group had more desire to be able to overcome more types of terrain and obstacles with HPVs. Some customer requests were also focused on providing a more comfortable ride for the user.
>30	Like the 25-30 bracket, the >30 bracket also called for a more comfortable and effortless ride. This bracket, unlike the others, also requested an improvement in existing HPV safety and durability.

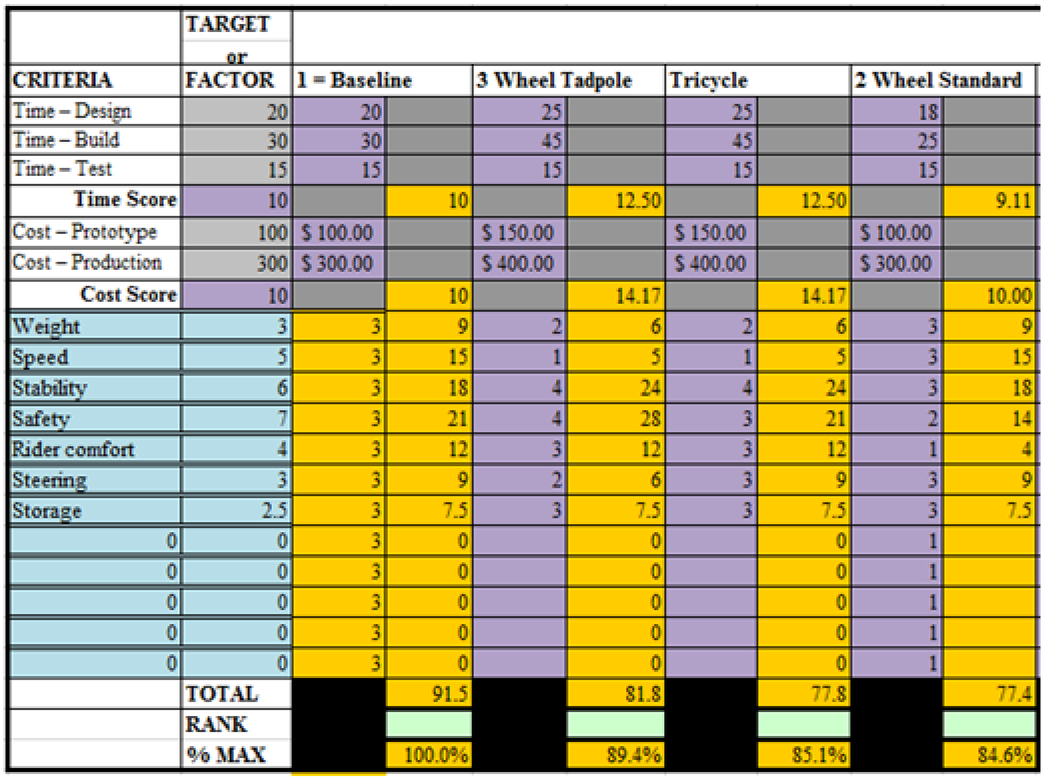
Table C.2: *Question and Answer from Prof. Scott Abrahamson*

Question/Prompt	**Customer Answer**	**Interpreted Need**
How often and where do you ride	-I ride for pleasure now. It started by riding to work with a coworker for health then turned into a passion -I was riding about 3000 miles per year -At the peak of my riding career I was riding up to 7500 miles per year	-User has fun while riding bike -Frame still in rideable shape after several thousand miles of use
Items brought along while riding	-I rode with a laptop, change of clothes, lunch	-The bike can store numerous items of different size
Sought out qualities when buying a bike	-The frame should be light but stiff. -It should be stable without being sluggish -It should have lots of trail	-Bike frame is made of a light but strong material -Tire placed in correct position in relation to rest of frame
Thoughts on a recumbent style bike	-It has low visibility in traffic -Can be hard to get power when climbing hills. -Cars have to see them on the road	-Rider is positioned in bike for maximum visibility -Drive train has maximum efficiency, especially in low gear -Contains bright colored flags and lights, mirrors
Additional Thoughts	-A rider has lots of things to pay attention to, debris, both parked and moving cars, other cyclists etc. so good handling, visibility and stability are key.	-Easy to maneuver through turns and obstacles on roads -Simple overall use so rider is not distracted and can stay focused on the road

Table C.3: *Question and Answer from Joshua Muir, a professional bike frame builder*

Question/Prompt	**Customer Answer**	**Interpreted Need**
What is the average price of a custom bicycle?	For a custom frame and full assembly, it generally costs around 5000 dollars.	The design of the bike needs to be much cheaper than 5000 dollars in order that it is accessible for any person to buy
What material do you use to build frame?	Steel, because it is cheap and easy to use. It is better for small scale designs. Larger companies use aluminum because custom extrusions can be made and it is lighter.	Determine whether to use aluminum, steel, or other material, based on cost, strength, and weight.
What is the most common change/upgrade to a bike?	People often want to change the size of tire they have on their wheel for different terrains. Often the clearance is not there for people to change to the appropriate tire.	Clearance for a variety of tire sizes in the frame design.
When building a custom frame, do you consider the possible aerodynamic effects it might have?	No, I do not, because I build normal bike frames, but if I were building a recumbent bike, I would really consider the effects of a fairing at low and high speeds.	Need a low profile design that a fairing could be used on to decrease aerodynamic drag.
When building a complete bike, what is your main concern?	Integration of all components, including cargo areas, lights, gearing, and brakes, so that it all performs well together.	Need to integrate a useful cargo area and all other necessary components in a efficient and useful manner.

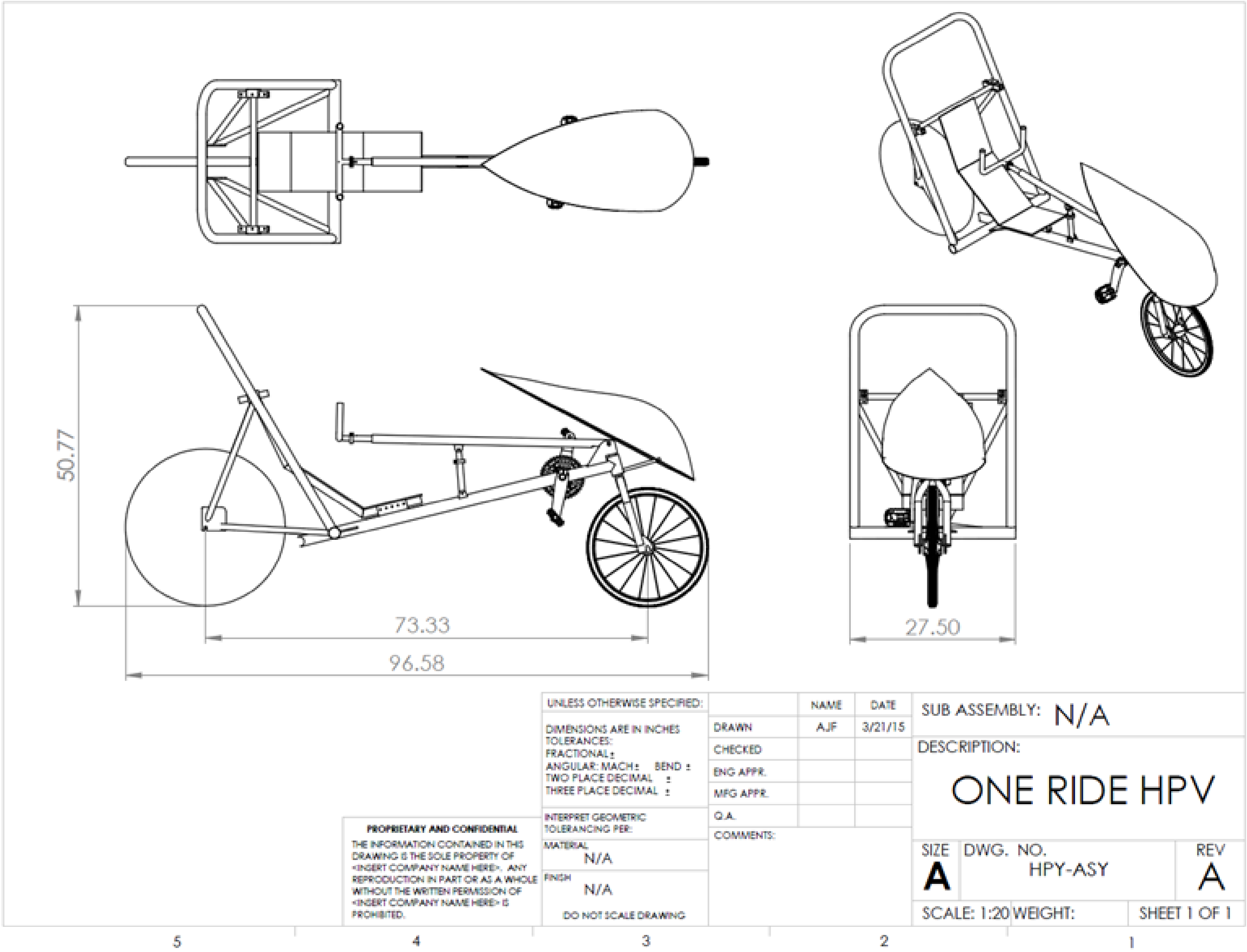
Appendix D: Decision Matrix



CRITERIA	TARGET or FACTOR	1 = Baseline		3 Wheel Tadpole		Tricycle		2 Wheel Standard	
Time – Design	20	20		25		25		18	
Time – Build	30	30		45		45		25	
Time – Test	15	15		15		15		15	
Time Score	10		10		12.50		12.50		9.11
Cost – Prototype	100	$ 100.00		$ 150.00		$ 150.00		$ 100.00	
Cost – Production	300	$ 300.00		$ 400.00		$ 400.00		$ 300.00	
Cost Score	10		10		14.17		14.17		10.00
Weight	3	3	9	2	6	2	6	3	9
Speed	5	3	15	1	5	1	5	3	15
Stability	6	3	18	4	24	4	24	3	18
Safety	7	3	21	4	28	3	21	2	14
Rider comfort	4	3	12	3	12	3	12	1	4
Steering	3	3	9	2	6	3	9	3	9
Storage	2.5	3	7.5	3	7.5	3	7.5	3	7.5
0	0	3	0		0		0	1	
0	0	3	0		0		0	1	
0	0	3	0		0		0	1	
0	0	3	0		0		0	1	
0	0	3	0		0		0	1	
	TOTAL		91.5		81.8		77.8		77.4
	RANK								
	% MAX		100.0%		89.4%		85.1%		84.6%

Figure D.1: *Selection Matrix for different bike designs. Baseline is two wheel recumbent style*

Appendix E: Hardware Drawings



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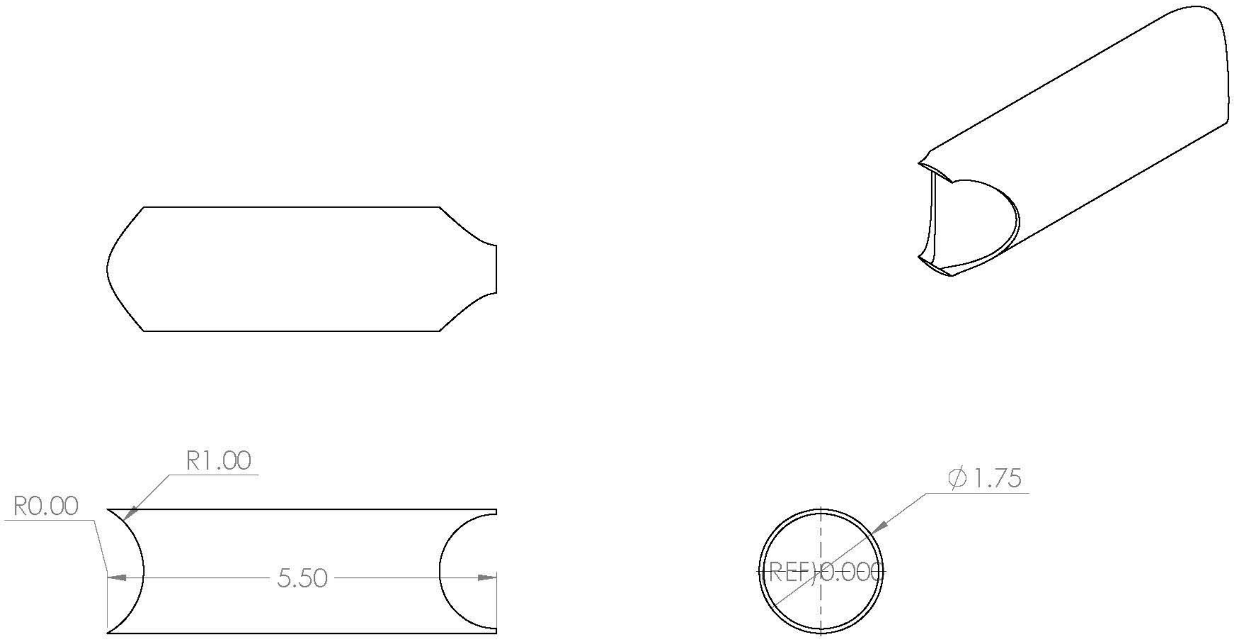

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ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

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CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
FRAME

DESCRIPTION:
BOTTOM BRACKET INTERFACE

SIZE	PART NO.	REV
A	FR-06	A

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

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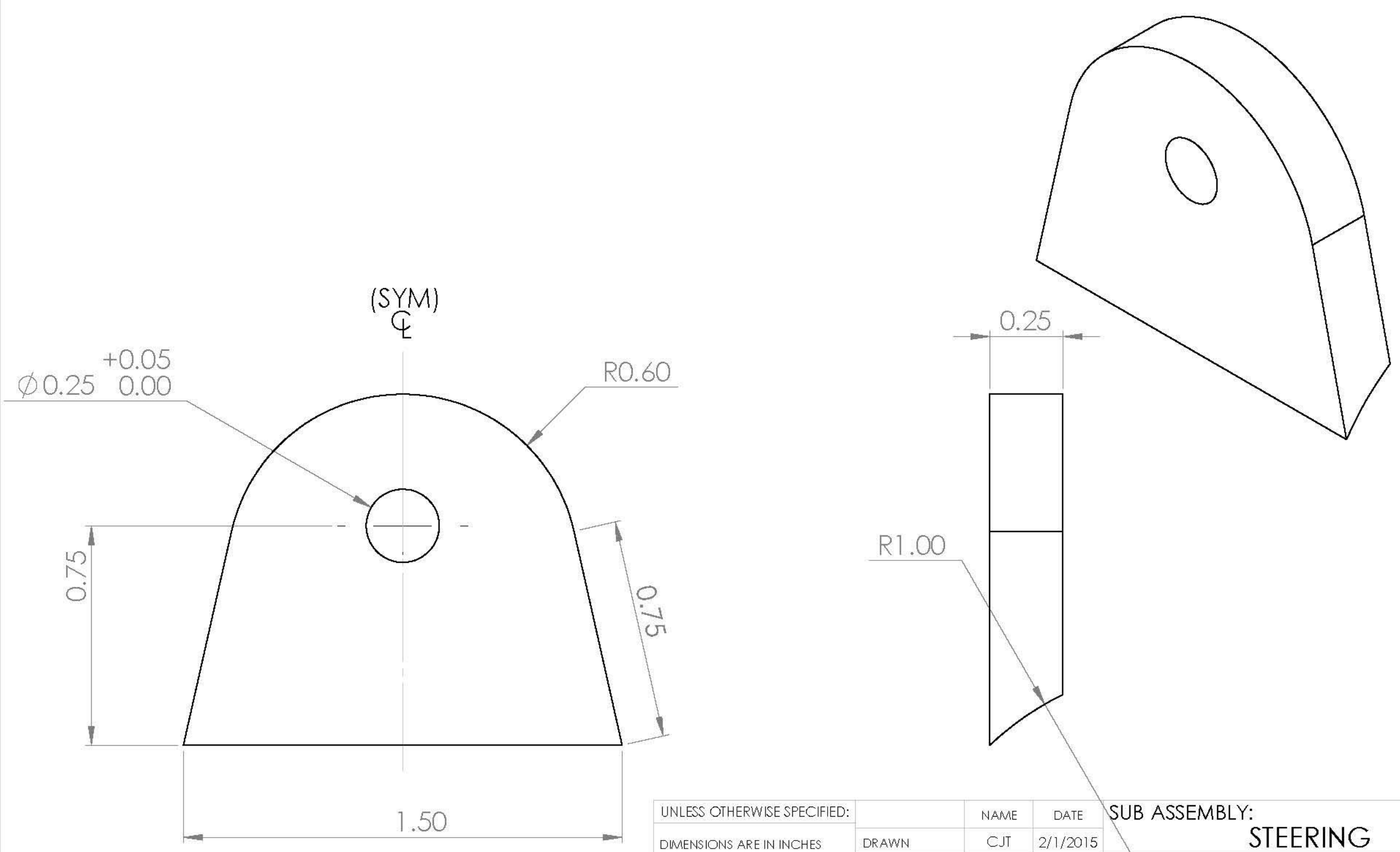

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	CHECKED			
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL 6061-T6 (SS)	COMMENTS:			SIZE A · PART NO. · REV
FINISH NA				
DO NOT SCALE DRAWING				SCALE: 2:1 · WEIGHT: · SHEET 1 OF 1

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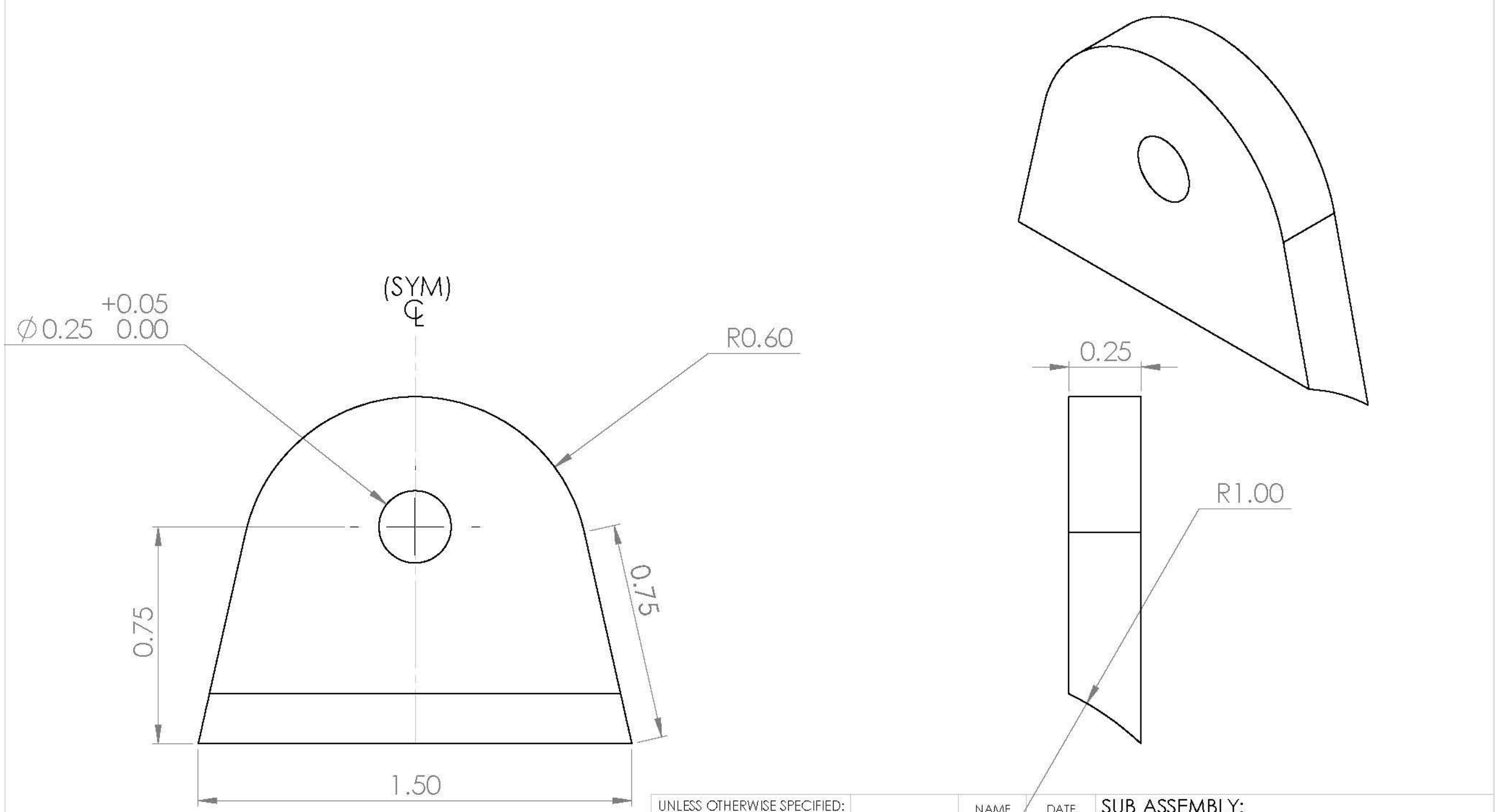

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FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

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TOLERANCING PER:

MATERIAL
6061-T6 (SS)

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CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
STEERING

DESCRIPTION:

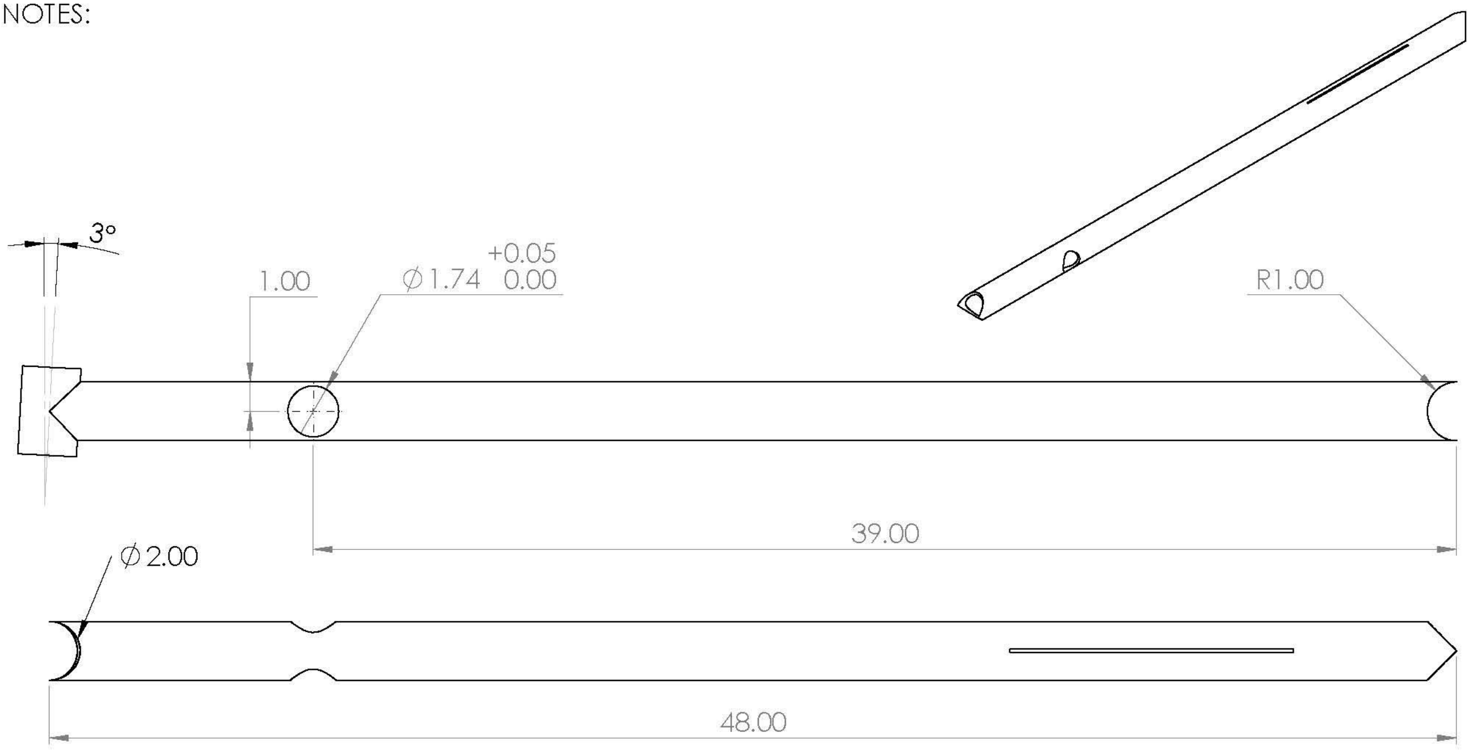
UPPER MOUNTING TAB LEFT

SIZE **A**
PART NO.
REV A

SCALE: 2:1
WEIGHT:
SHEET 1 OF 1

5 4 3 2 1

NOTES:



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	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061-T6 (SS)	COMMENTS:		
FINISH N/A			
DO NOT SCALE DRAWING			

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SUB ASSEMBLY:
FRAME

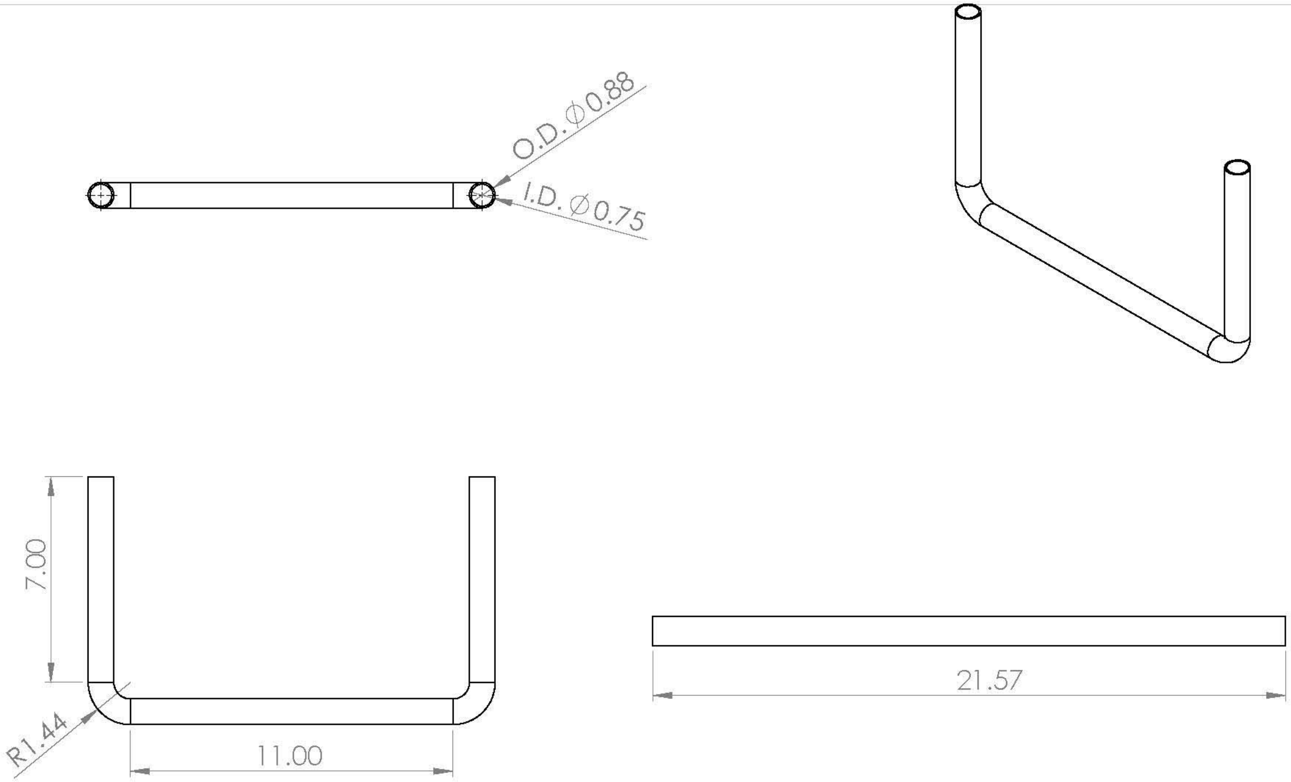
DESCRIPTION:
MAIN FRAME TUBE

SIZE	PART NO.	REV
A	FR-01	A

SCALE: 1:5 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:



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TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL 6061-T6 (SS)

FINISH N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	GCS	1/31/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
STEERING

DESCRIPTION:

STEERING WHEEL

SIZE A
PART NO.
REV A

SCALE: 1:5 WEIGHT: SHEET 1 OF 1

PROPRIETARY AND CONFIDENTIAL

5 4 3 2 1

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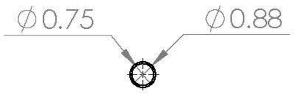

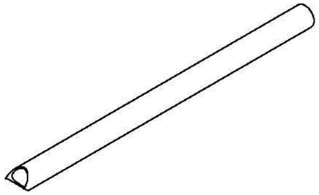

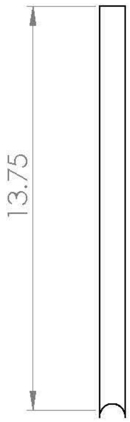

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TOLERANCES:
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ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

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DRAWN	GCS	2/1/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
STEERING

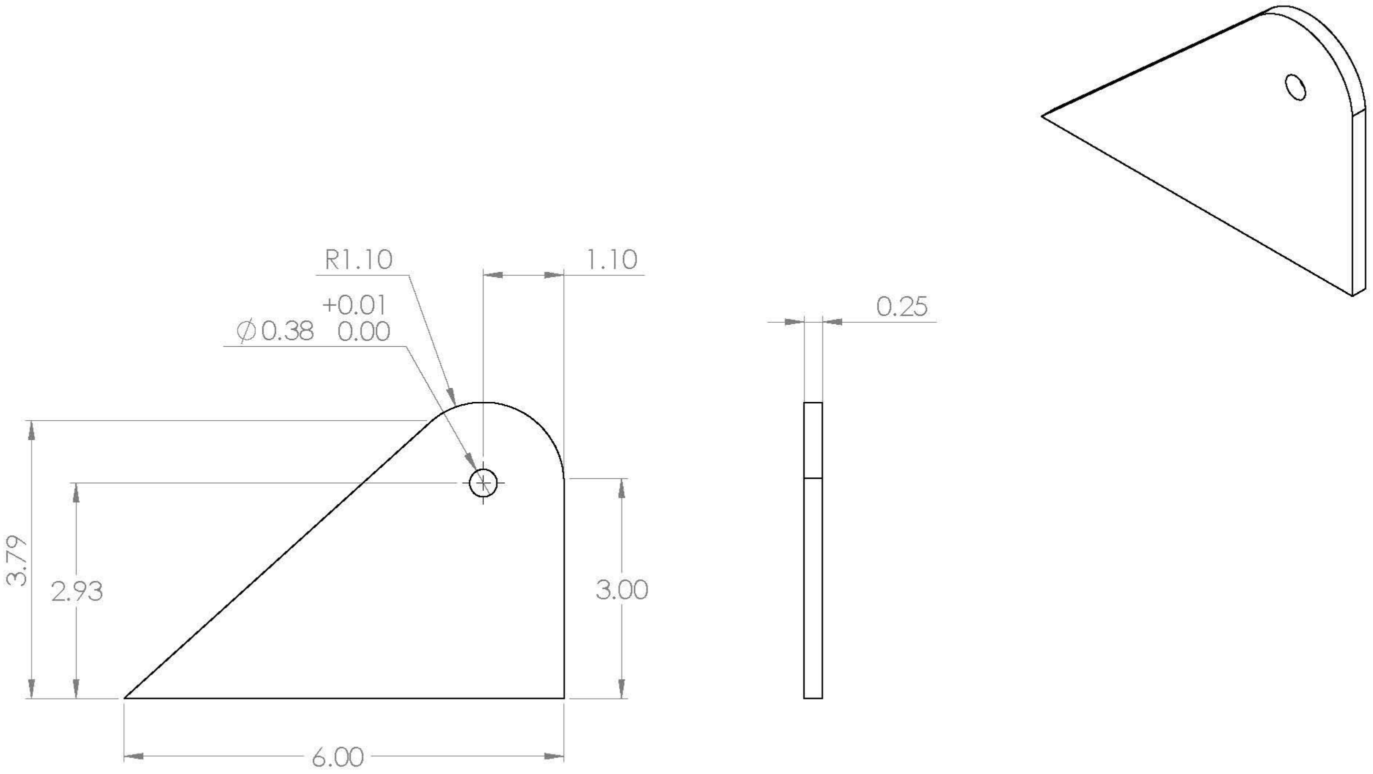
DESCRIPTION:
STEERING COLUMN INNER SHAFT

SIZE	PART NO.	REV
A	ST-07	A

SCALE: 1:5 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:



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TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	AJF	2/1/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
FRAME

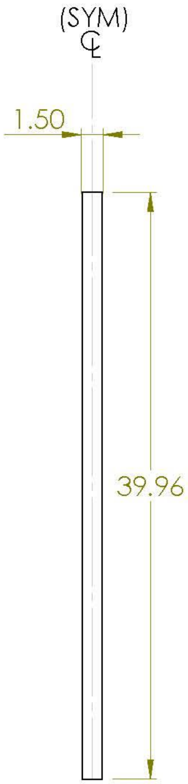
DESCRIPTION:
STEERING MOUNTING BRACKET

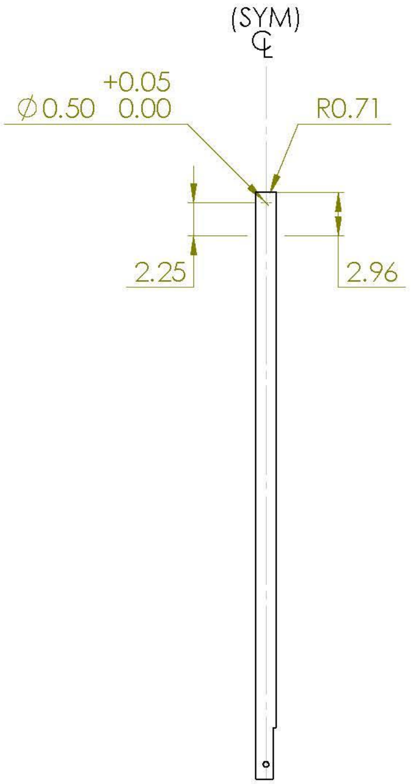
SIZE	PART NO.	REV
A	FR-05	A

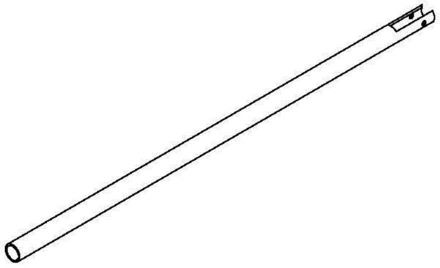
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:







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FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	GCS	1/31/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
STEERING

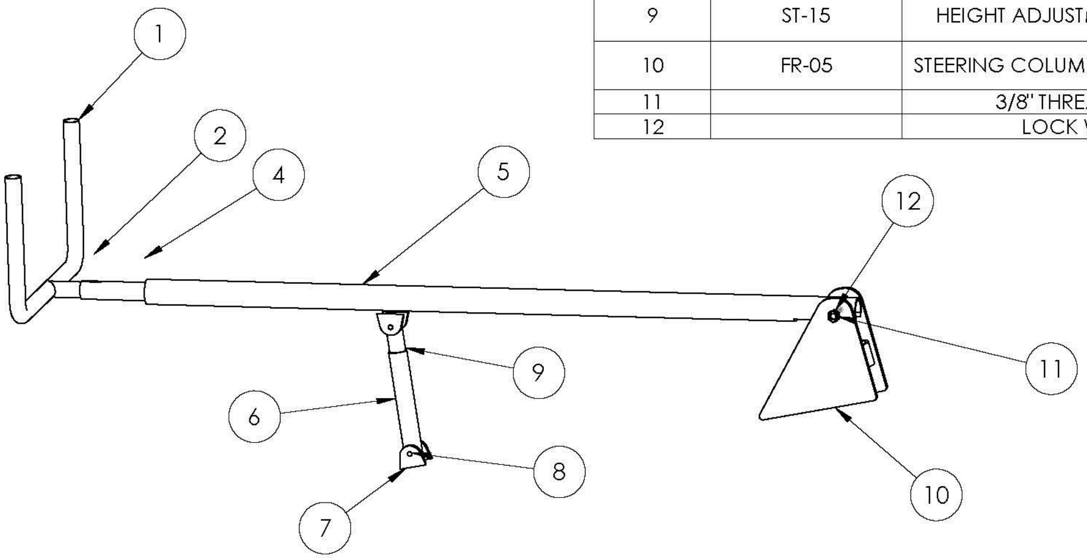
DESCRIPTION:
STEERING COLUMN HOUSING SHAFT

SIZE A
PART NO. ST-08
REV A

SCALE: 1:10 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ST-01	STEERING WHEEL	1
2	ST-07	STEERING COLUMN INNER SHAFT	1
3		COLLAR CLAMP	2
4	ST-09	STEERING COLUMN SHAFT	1
5	ST-08	STEERING COLUMN HOUSING SHAFT	1
6	ST-14	HEIGHT ADJUSTMENT OUTER TUBE	1
7	ST-10	MOUNTING TAB	4
8		1/4" PIN	2
9	ST-15	HEIGHT ADJUSTMENT INNER TUBE	1
10	FR-05	STEERING COLUMN MOUNT BRACKET	2
11		3/8" THREADED ROD	2
12		LOCK WASHER	2



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
N/A

FINISH
N/A

DO NOT SCALE DRAWING

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	NAME	DATE
DRAWN	AJF	3/19/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY: STEERING

DESCRIPTION:

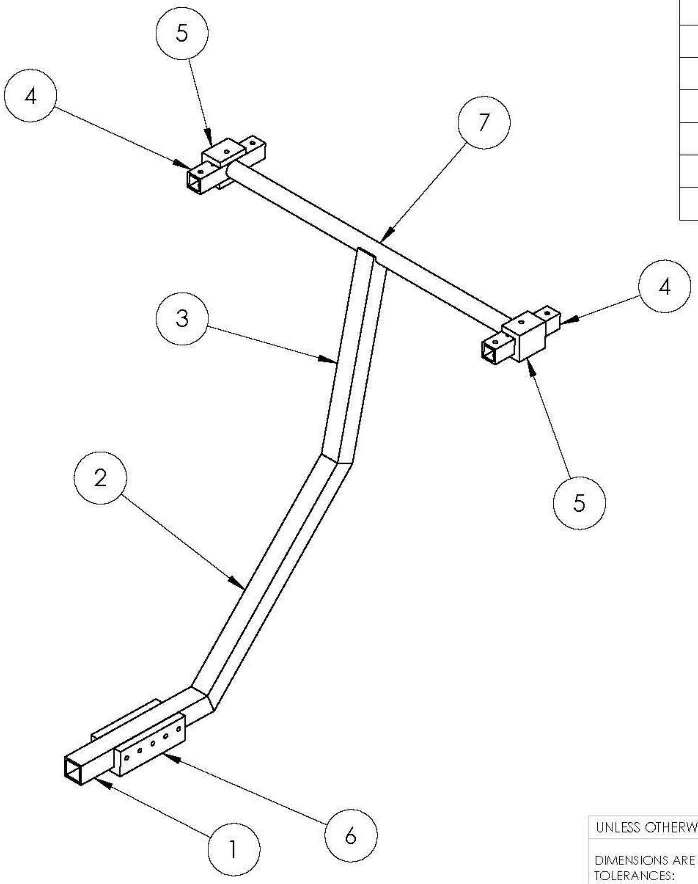
STEERING ASSEMBLY

SIZE A
DWG. NO. ST-ASY
REV A

SCALE: 1:8
WEIGHT:
SHEET 1 OF 1

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	SE-01-B	BOTTOM BEAM	1
2	SE-01-M	MIDDLE BEAM	1
3	SE-01-T	TOP BEAM	1
4	SE-06	SLIDER BAR	2
5	SE-05	SHOULDER BRACKET	2
6	SE-04	BOTTOM BRACKET	1
7	SE-07	CROSS BAR	1



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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 AL

FINISH
RED PAINT

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	AJF	3/19/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY: SEAT

DESCRIPTION:

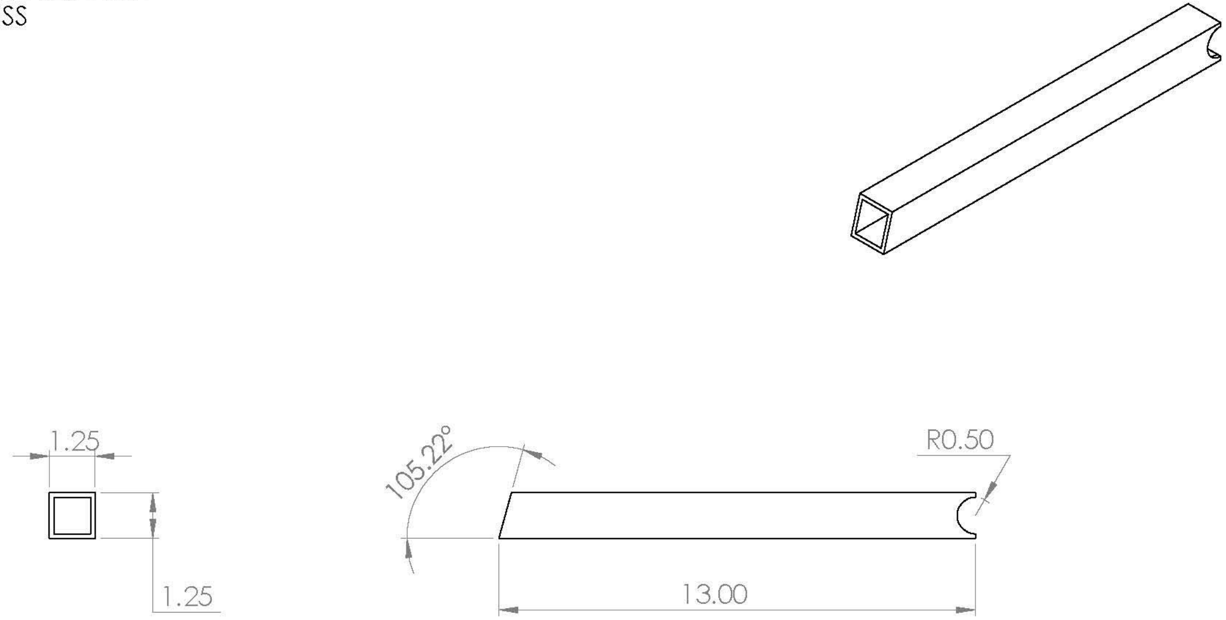
SEAT ASSEMBLY

SIZE	DWG. NO.	REV
A	SE-ASY	A

SCALE: 1:8 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES: BEAM IS 1.25INCH
SQUARE WITH A .125 INCH
WALL THICKNESS



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC
TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	CJT	2/1/2015
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

PROPRIETARY AND CONFIDENTIAL

SUB ASSEMBLY:
SEAT MOUNT

DESCRIPTION:

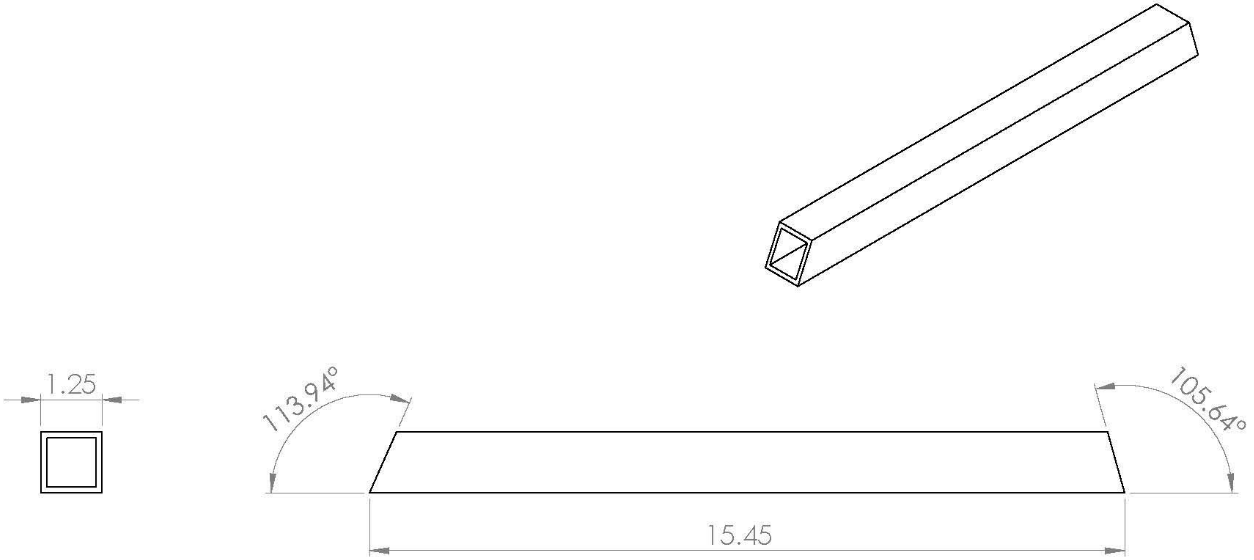
TOP BEAM

SIZE A
PART NO. SE-01-T
REV A

SCALE: 1:4 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES: BEAM IS 1.25INCH
SQUARE WITH A .125 INCH
WALL THICKNESS



PROPRIETARY AND CONFIDENTIAL

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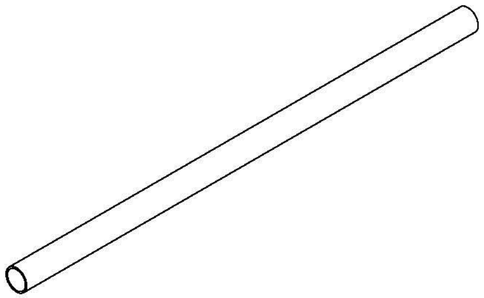
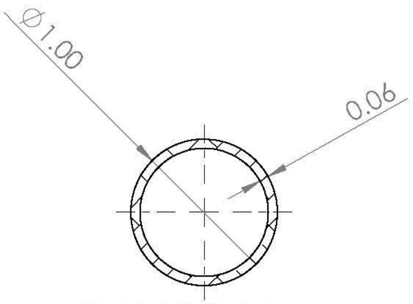
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	SUB ASSEMBLY: SEAT MOUNT
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL±.01 ANGULAR: MACH±.1 BEND ±.01 TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	CJT	2/1/2015	DESCRIPTION: MIDDLE BEAM
	CHECKED			
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL 6061-T6 (SS)	COMMENTS:			SIZE A · PART NO. SE-01-M · REV A
FINISH N/A				
DO NOT SCALE DRAWING				SCALE: 1:3 · WEIGHT: · SHEET 1 OF 1

5 4 3 2 1

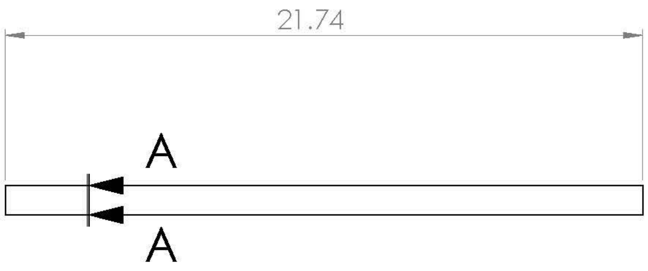
NOTES:





SECTION A-A

SCALE 1 : 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	SUB ASSEMBLY: SEAT MOUNT
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL±.01 ANGULAR: MACH±.1 BEND ±.01 TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	CJT	2/1/2015	DESCRIPTION:
	CHECKED			
	ENG APPR.			CROSS BAR
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL 6061-T6 (SS)	COMMENTS:			SIZE A · PART NO. SE-07 · REV A
FINISH N/A				
DO NOT SCALE DRAWING				SCALE: 1:5 · WEIGHT: · SHEET 1 OF 1

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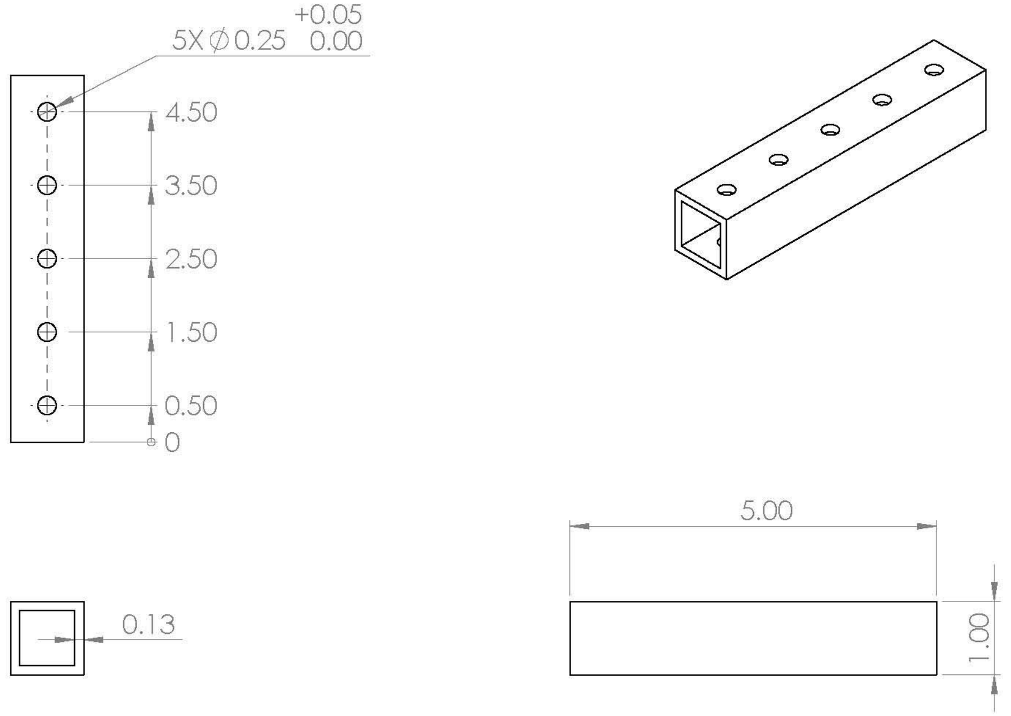
5 4 3 2 1

NOTES: BEAM IS SQUARE WITH
1/8IN THICKNESS AND OUTER
WALL LENGTH OF 1.00IN



PROPRIETARY AND CONFIDENTIAL

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UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	CJT	2/1/2015
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
SEAT MOUNT

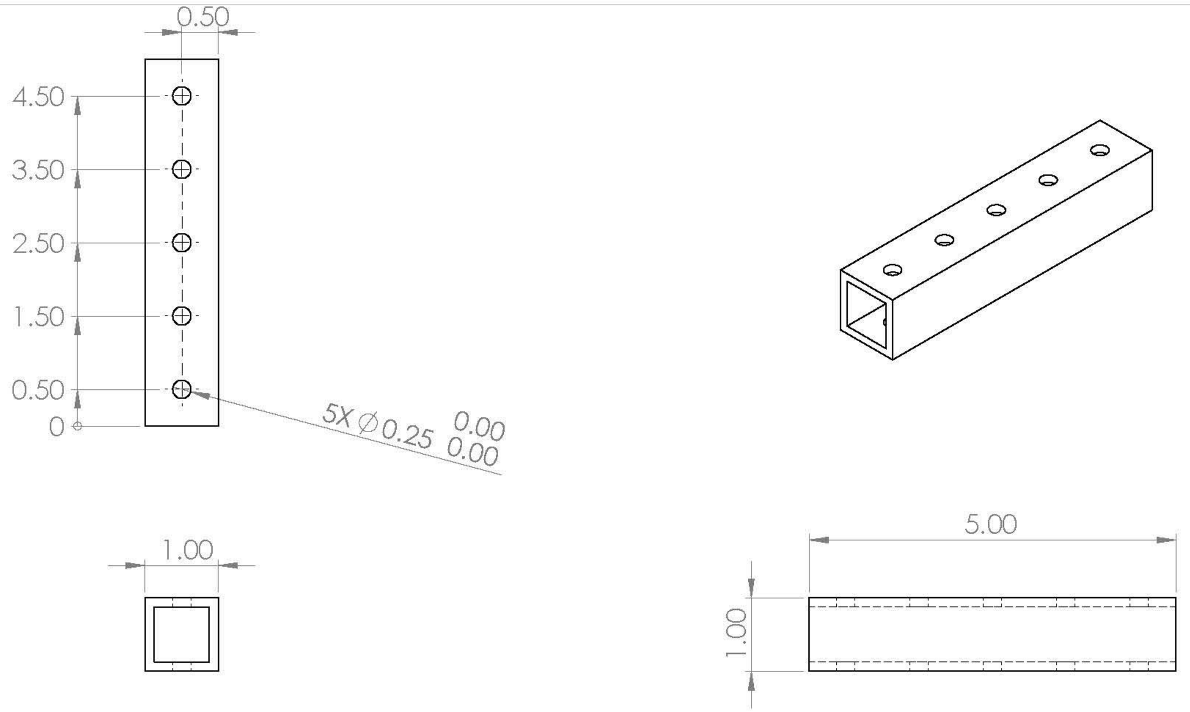
DESCRIPTION:

SLIDER

SIZE A
PART NO. SE-05
REV A

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC
TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	C. Toy	1/31/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

NEXT ASSY	USED ON
APPLICATION	

PROPRIETARY AND CONFIDENTIAL

Seat Mount

Part

SLIDER

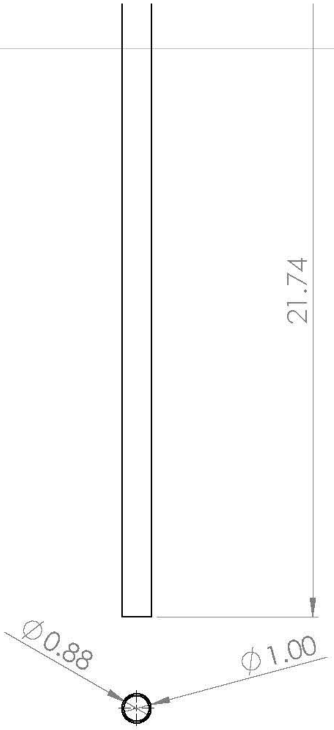
SIZE
A

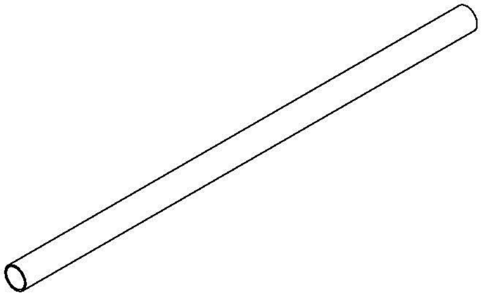
Part Number
SE06

REV
1

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1





NEXT ASSY	USED ON
APPLICATION	

PROPRIETARY AND CONFIDENTIAL

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	C. Toy	1/31/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

Seat Mount

TITLE:

Crossbar

SIZE
A

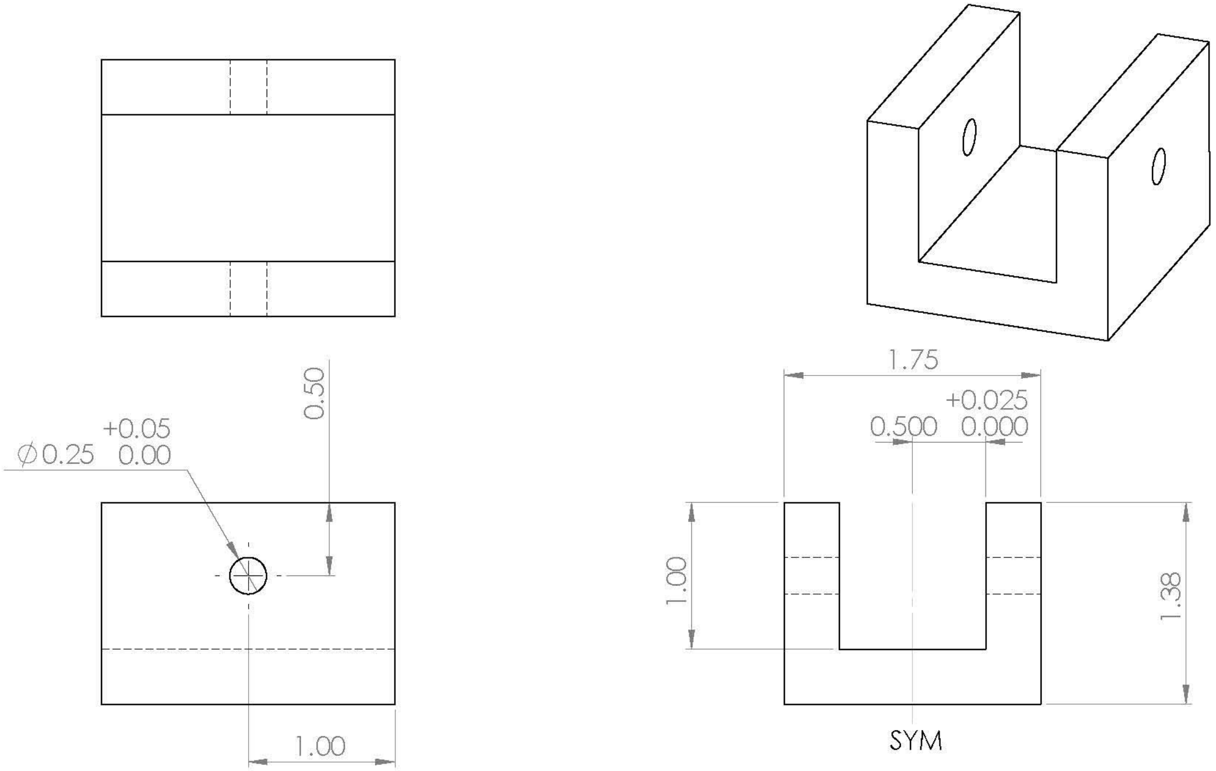
Part Number
SE07

REV
1

SCALE: 1:5 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL±.01 ANGULAR: MACH±.1 BEND ±.01 TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	CJT	2/1/2015
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061-T6 (SS)	COMMENTS:		
FINISH N/A			
DO NOT SCALE DRAWING			

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SUB ASSEMBLY:
SEAT MOUNT

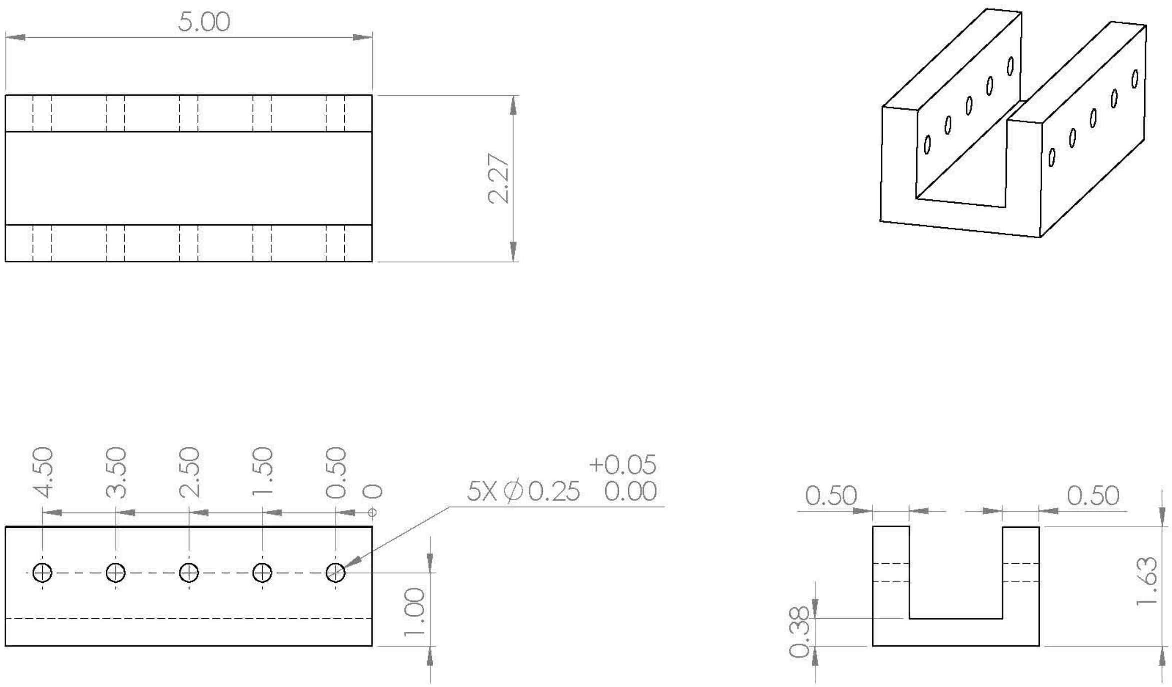
DESCRIPTION:

SHOULDER BRACKET

SIZE **A**	PART NO. SE-05	REV A
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1

NOTES:



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	CJT	2/1/2015
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
SEAT MOUNT

DESCRIPTION:

BOTTOM BRACKET

SIZE A
PART NO. SE-04
REV A

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

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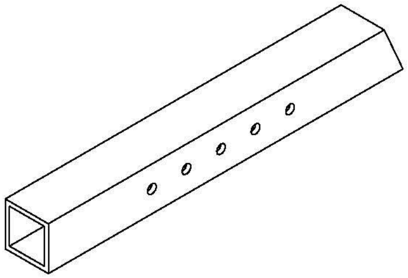
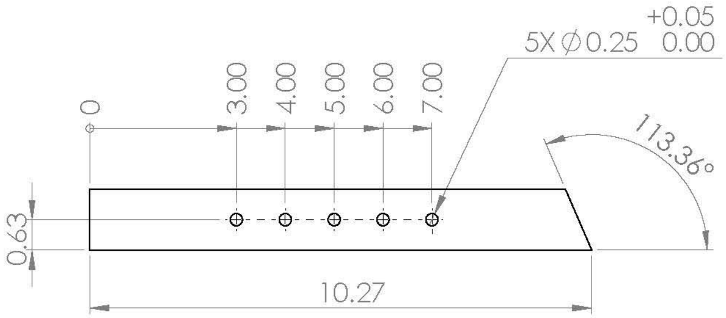
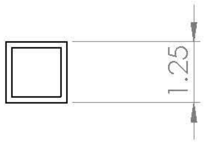
5 4 3 2 1

NOTES: BEAM IS SQUARE WITH
1/8IN THICKNESS AND OUTER
WALL LENGTH OF 1.25IN







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UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	CJT	2/1/2015
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
SEAT MOUNT

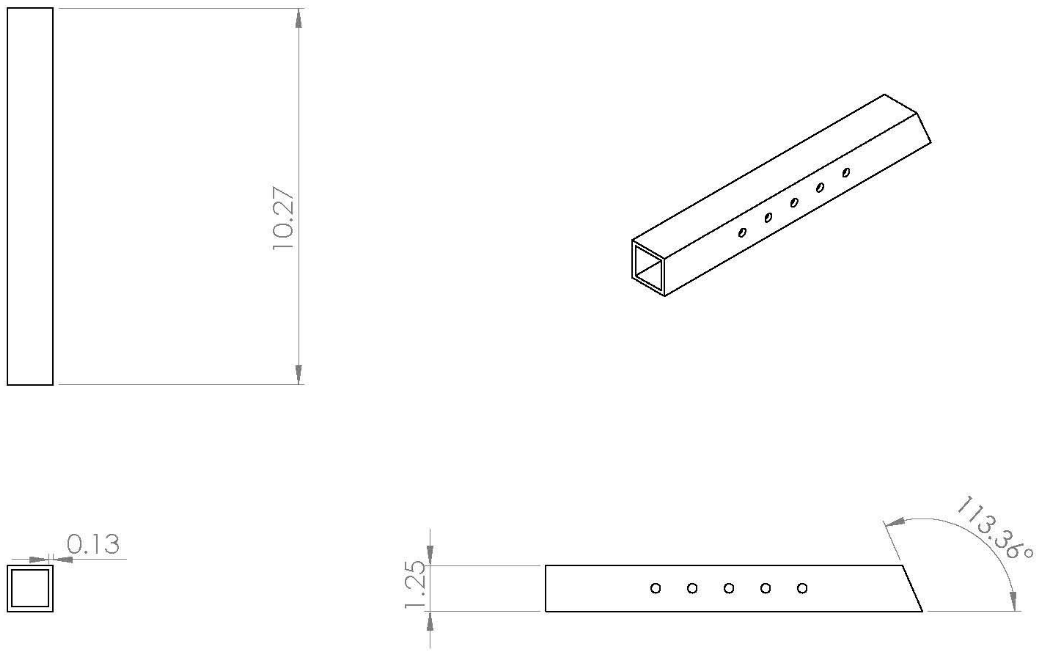
DESCRIPTION:

BOTTOM BEAM

SIZE	PART NO.	REV
A	SE-01-B	A

SCALE: 1:3 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



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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 6061-T6 (SS)

FINISH N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	C. Toy	1/31/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

Seat Mount

TITLE:

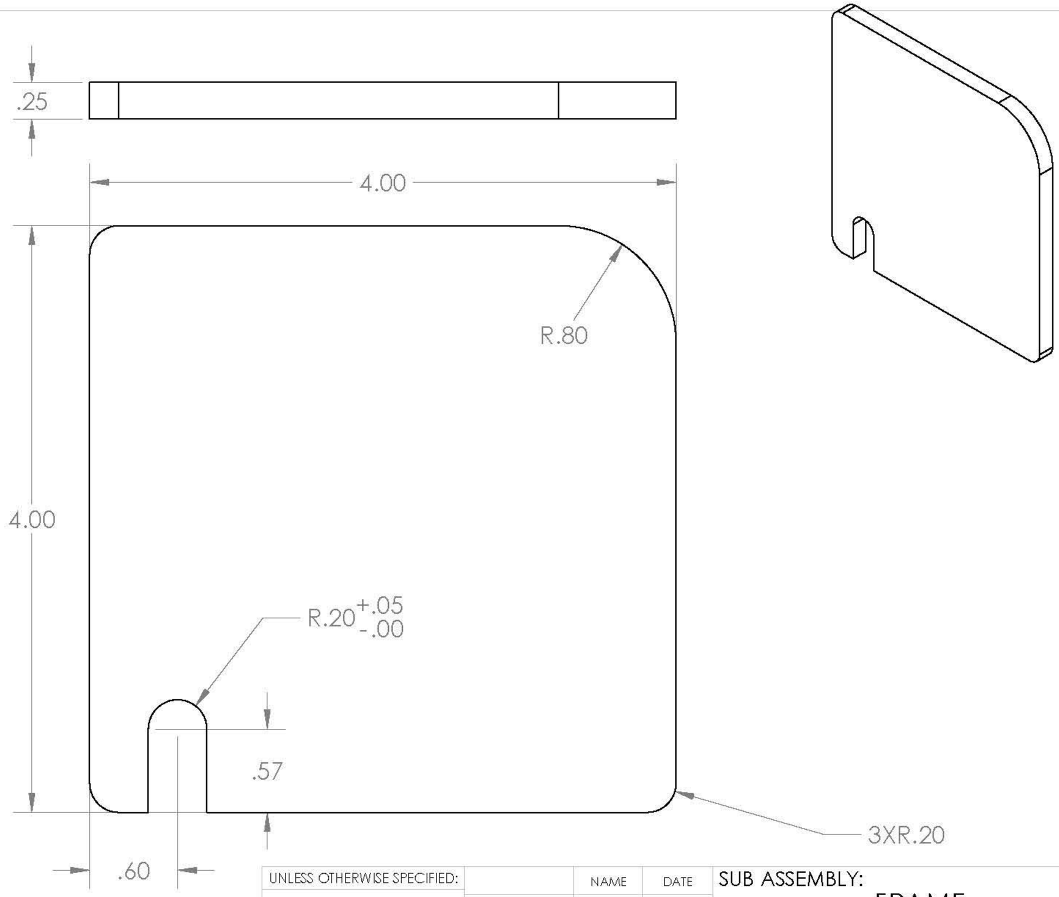
Bottom Beam

SIZE	DWG. NO.	REV
A	SE01-B	1

SCALE: 1:4 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL±.01 ANGULAR: MACH±.1 BEND ±.01 TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	AHS	2/1/15
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061-T6 (SS)	COMMENTS:		
FINISH N/A			
DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

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SUB ASSEMBLY:
FRAME

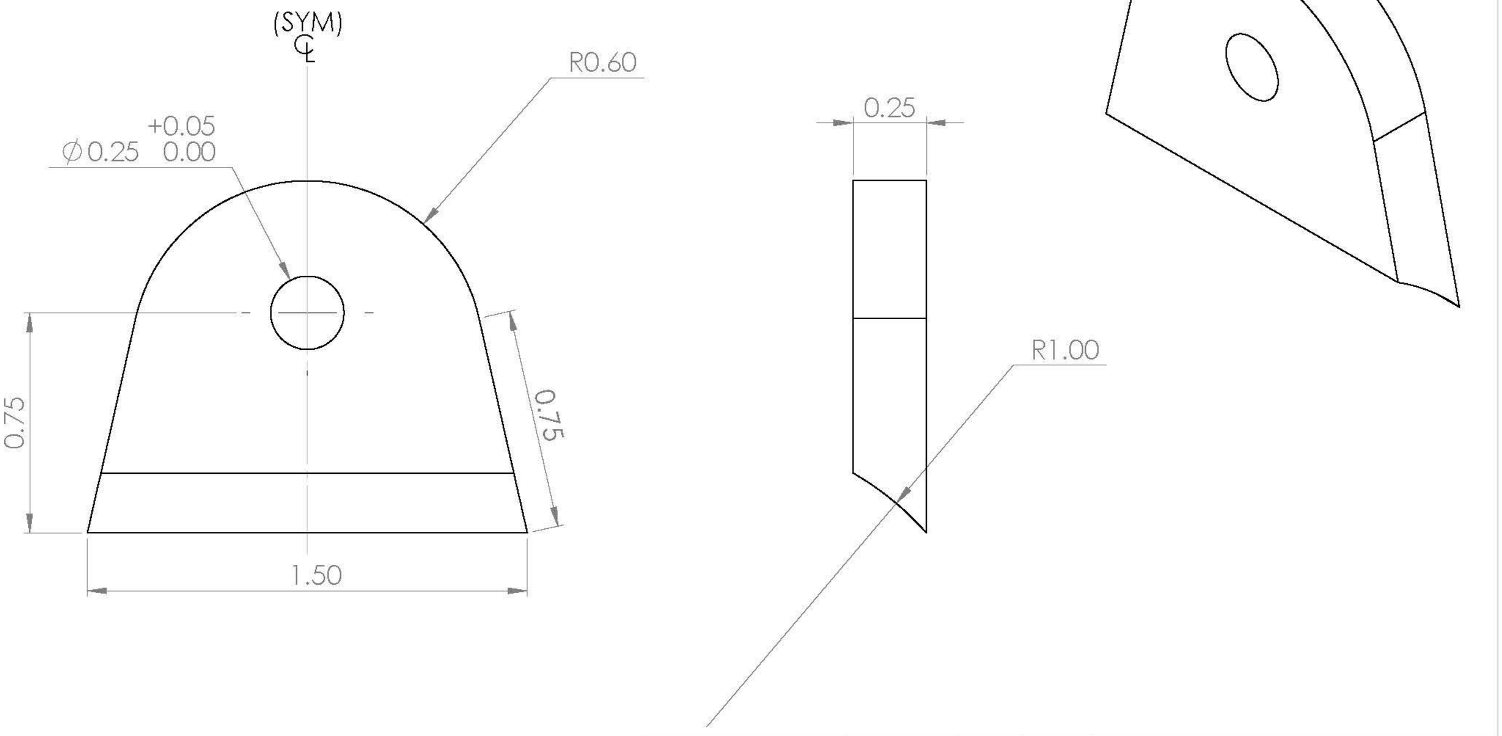
DESCRIPTION:
REAR DROPOUTS

SIZE	PART NO.	REV
A	FR-08	A

SCALE: 1:1	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1

NOTES:



PROPRIETARY AND CONFIDENTIAL

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UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
NA

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	CJT	2/1/2015
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
STEERING

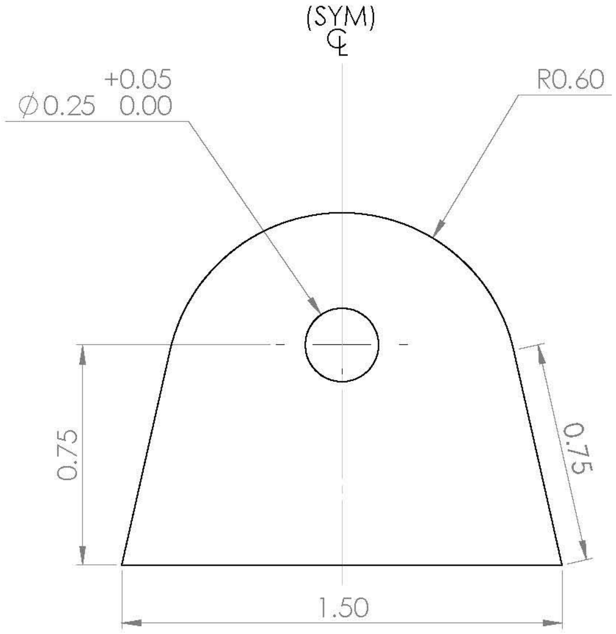
DESCRIPTION:
LOWER MOUNTING TAB RIGHT

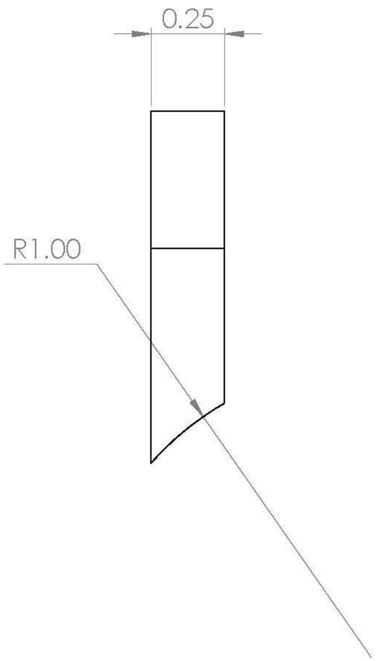
SIZE	PART NO.	REV
A	ST-13	A

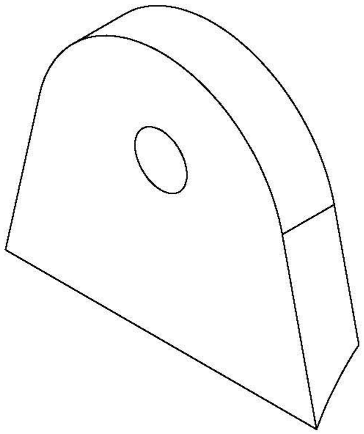
SCALE: 2:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:







UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL±.01 ANGULAR: MACH±.1 BEND ±.01 TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	CJT	2/1/2015
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061-T6 (SS)	COMMENTS:		
FINISH NA			
DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

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SUB ASSEMBLY:
STEERING

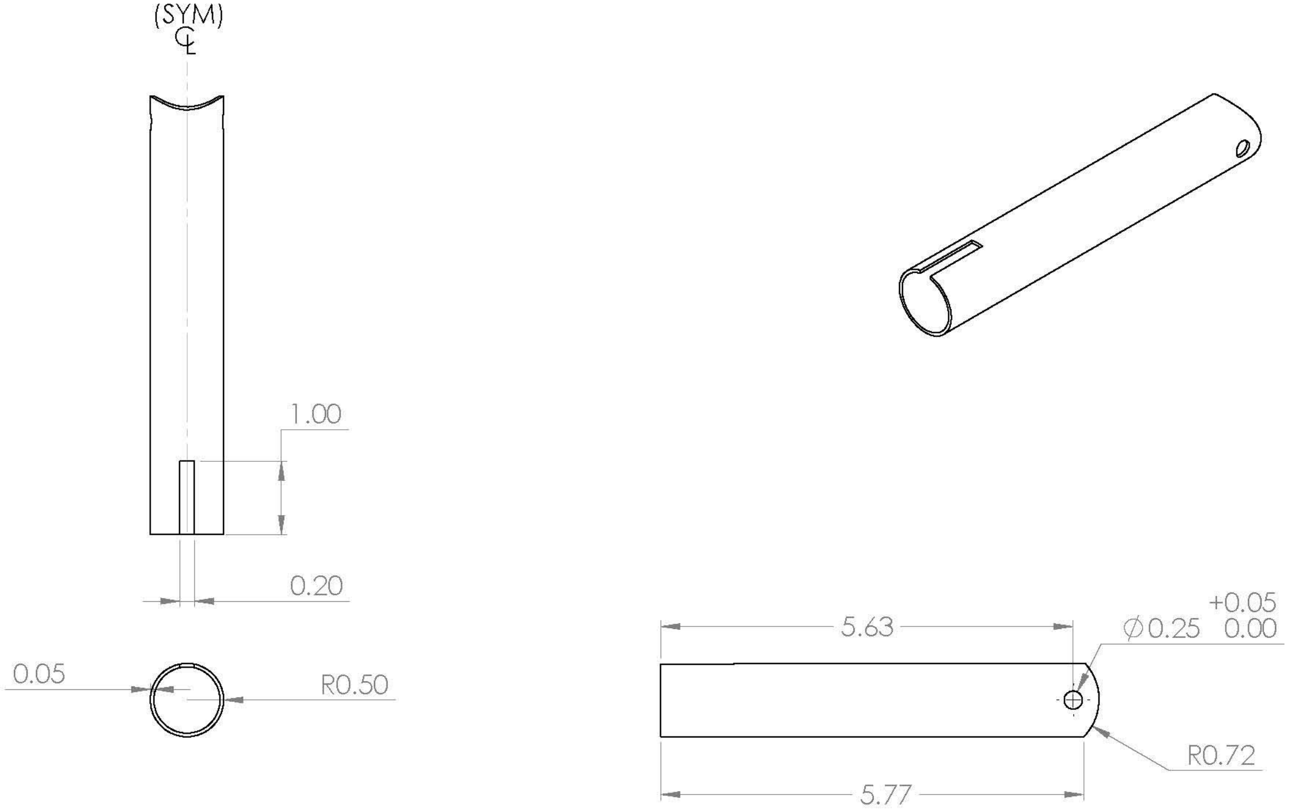
DESCRIPTION:
LOWER MOUNTING TAB LEFT

SIZE	PART NO.	REV
A	ST-12	A

SCALE: 2:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL±.01 ANGULAR: MACH±.1 BEND ±.01 TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	CJT	2/1/2015
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061-T6 (SS)	COMMENTS:		
FINISH N/A			
DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

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SUB ASSEMBLY:
STEERING

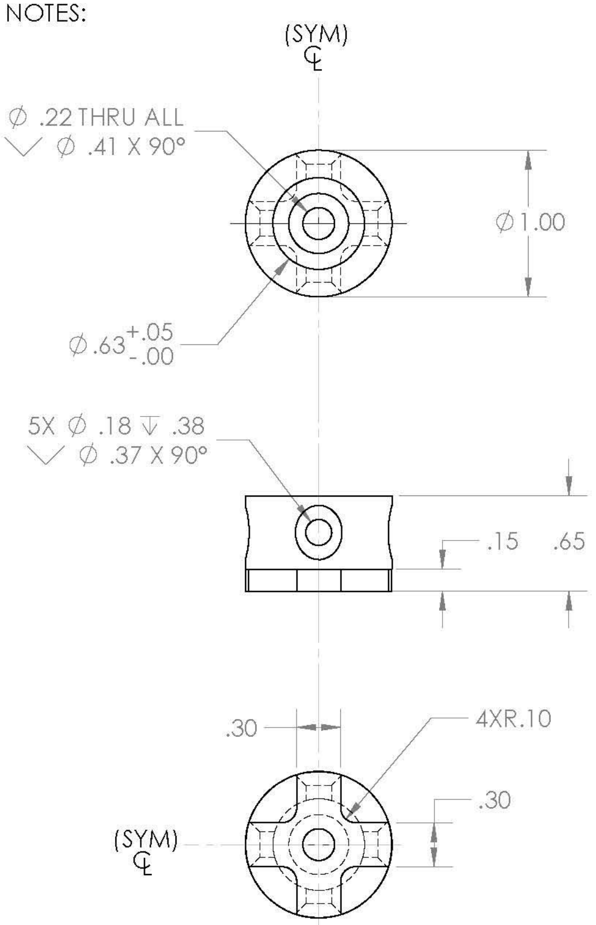
DESCRIPTION: HEIGHT ADJUSTMENT OUTER TUBE

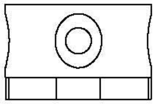
SIZE	PART NO.	REV
A	ST-14	A

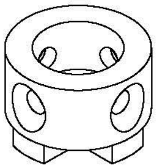
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:







UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	AJF	2/2/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

PROPRIETARY AND CONFIDENTIAL

SUB ASSEMBLY:
STEERING

DESCRIPTION:

HEAD TUBE CAP

SIZE
A

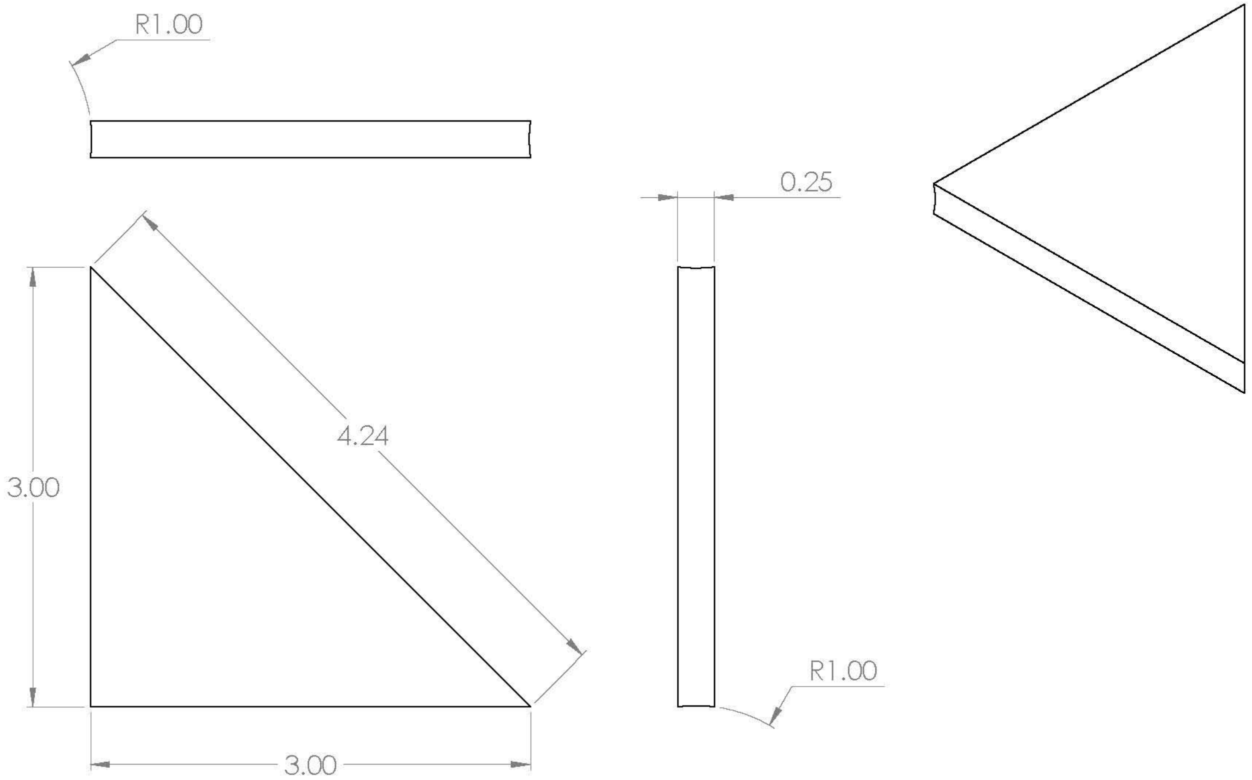
PART NO.
ST-18

REV
A

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:



PROPRIETARY AND CONFIDENTIAL

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UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	AJF	2/1/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
FRAME

DESCRIPTION:

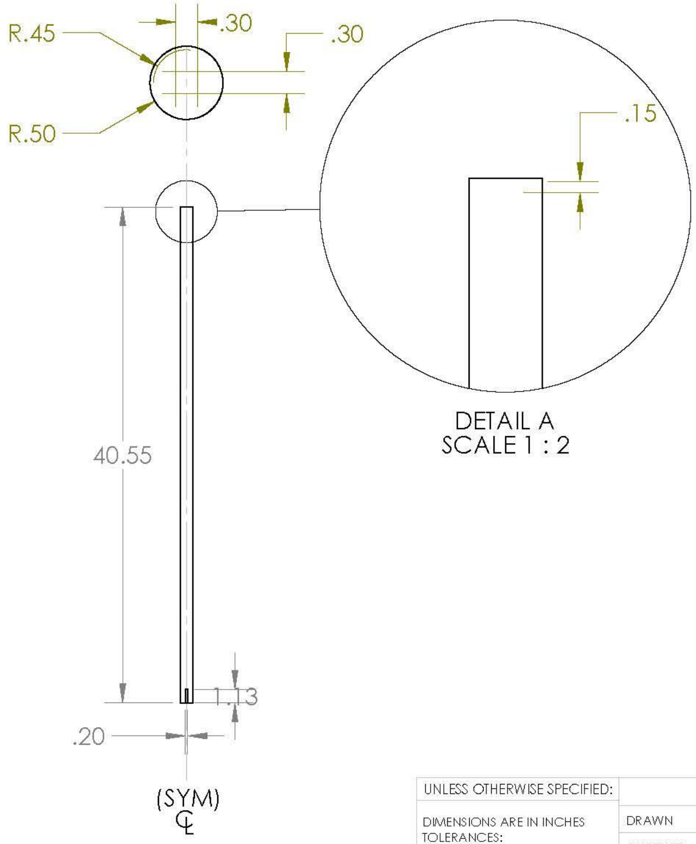
FRAME GUSSET

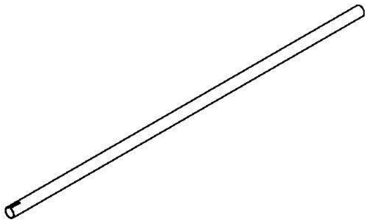
SIZE	PART NO.	REV
A	FR-09	A

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:





UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	AHS	2/2/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
STEERING

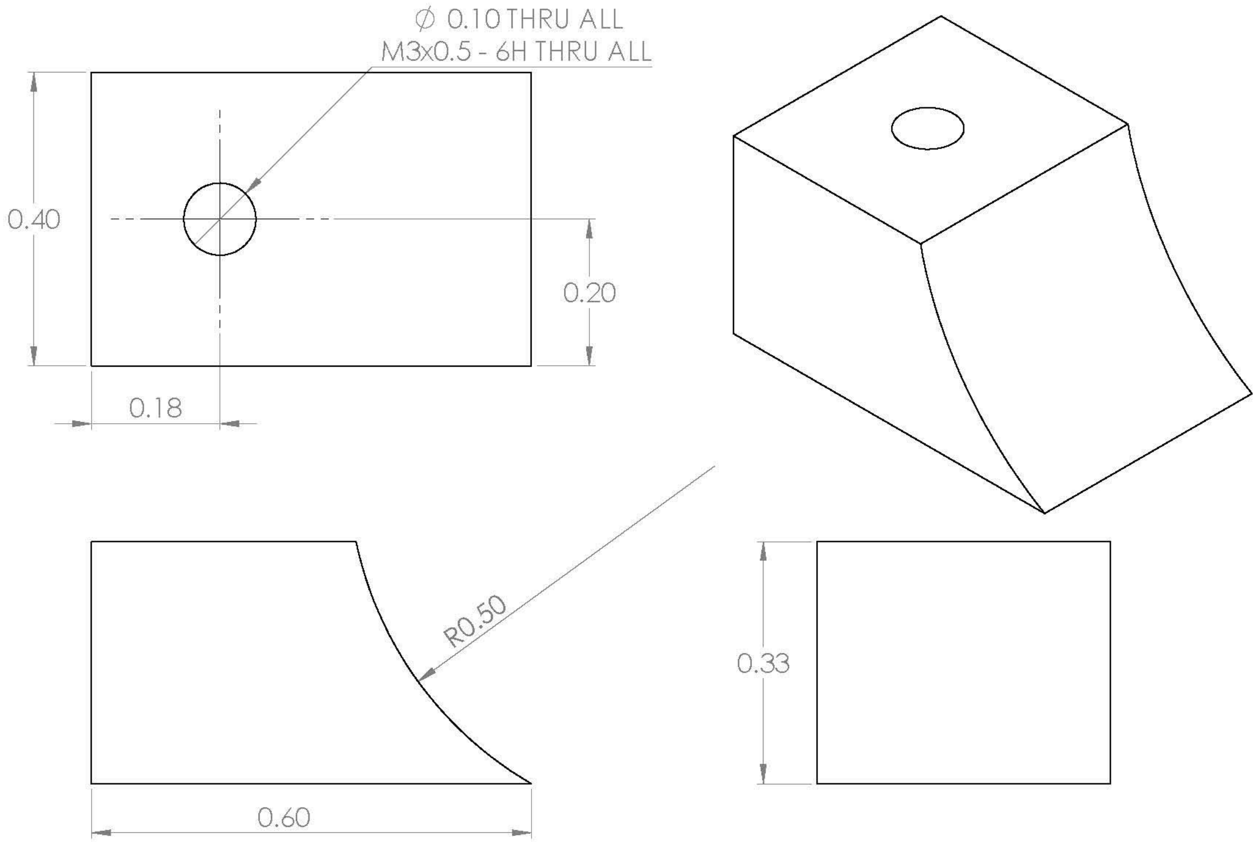
DESCRIPTION:
STEERING COLUMN SHAFT

SIZE A
PART NO. ST-09
REV A

SCALE: 1:12 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:



PROPRIETARY AND CONFIDENTIAL

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UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	GCS	1/31/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
STEERING

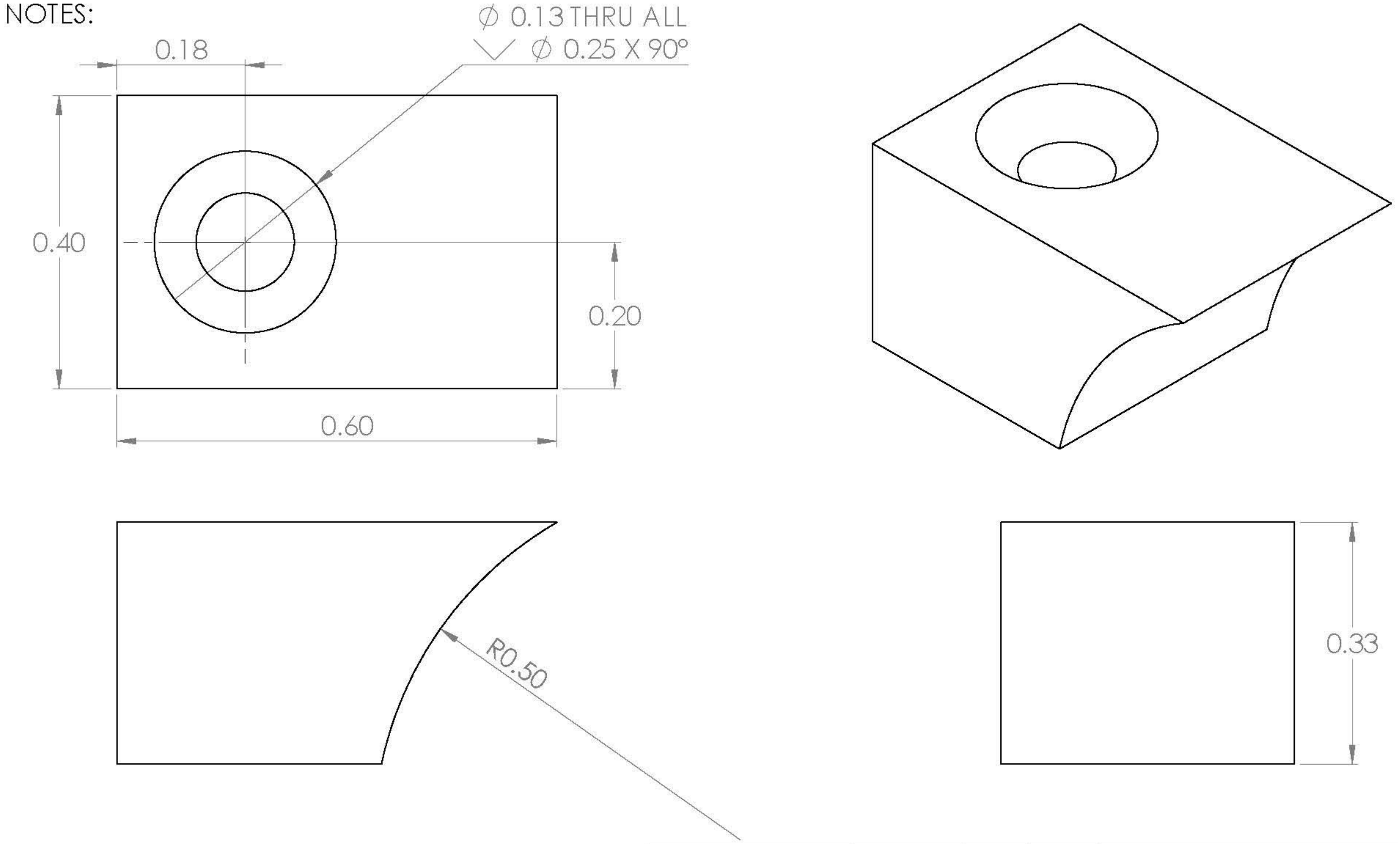
DESCRIPTION:
CRUSH SLEEVE RIGHT

SIZE	PART NO.	REV
A	ST-17	A

SCALE: 5:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

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	NAME	DATE
DRAWN	GCS	1/31/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

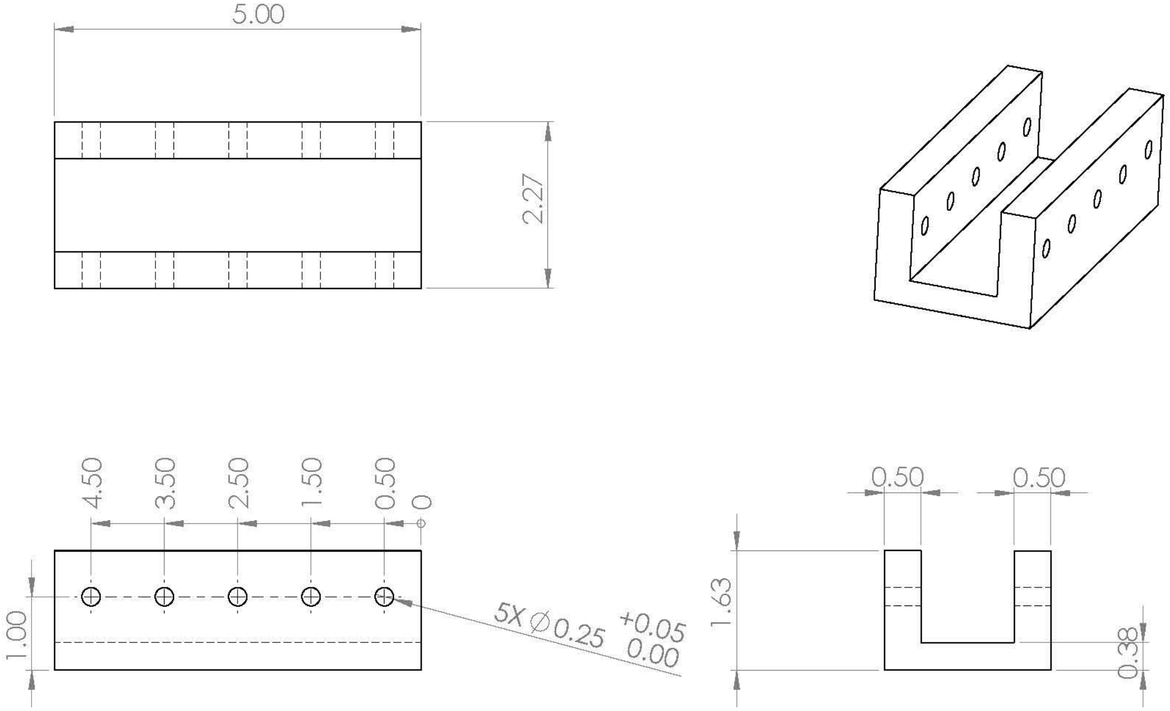
SUB ASSEMBLY:
STEERING

DESCRIPTION:
CRUSH SLEEVE
LEFT

SIZE A
PART NO. ST-16
REV A

SCALE: 5:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	C. Toy	1/31/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

NEXT ASSY USED ON
APPLICATION

PROPRIETARY AND CONFIDENTIAL

Seat Mount

TITLE:

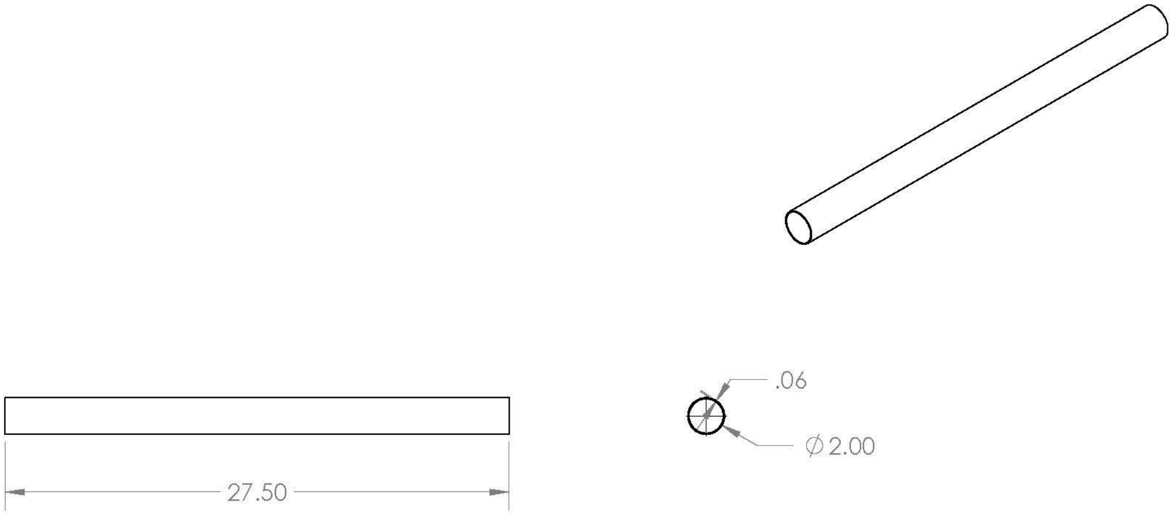
Lower Bracket

SIZE A
Part Number SE04
REV 1

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

NOTES:



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	SUB ASSEMBLY: FRAME
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL±.01 ANGULAR: MACH±.1 BEND ±.01 TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	AJF	2/2/15	DESCRIPTION: BOTTOM ROLL BAR TUBE
	CHECKED			
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL 6061-T6 (SS)	COMMENTS:			SIZE A · PART NO. FR-04 · REV A
FINISH N/A				
DO NOT SCALE DRAWING				SCALE: 1:8 · WEIGHT: · SHEET 1 OF 1

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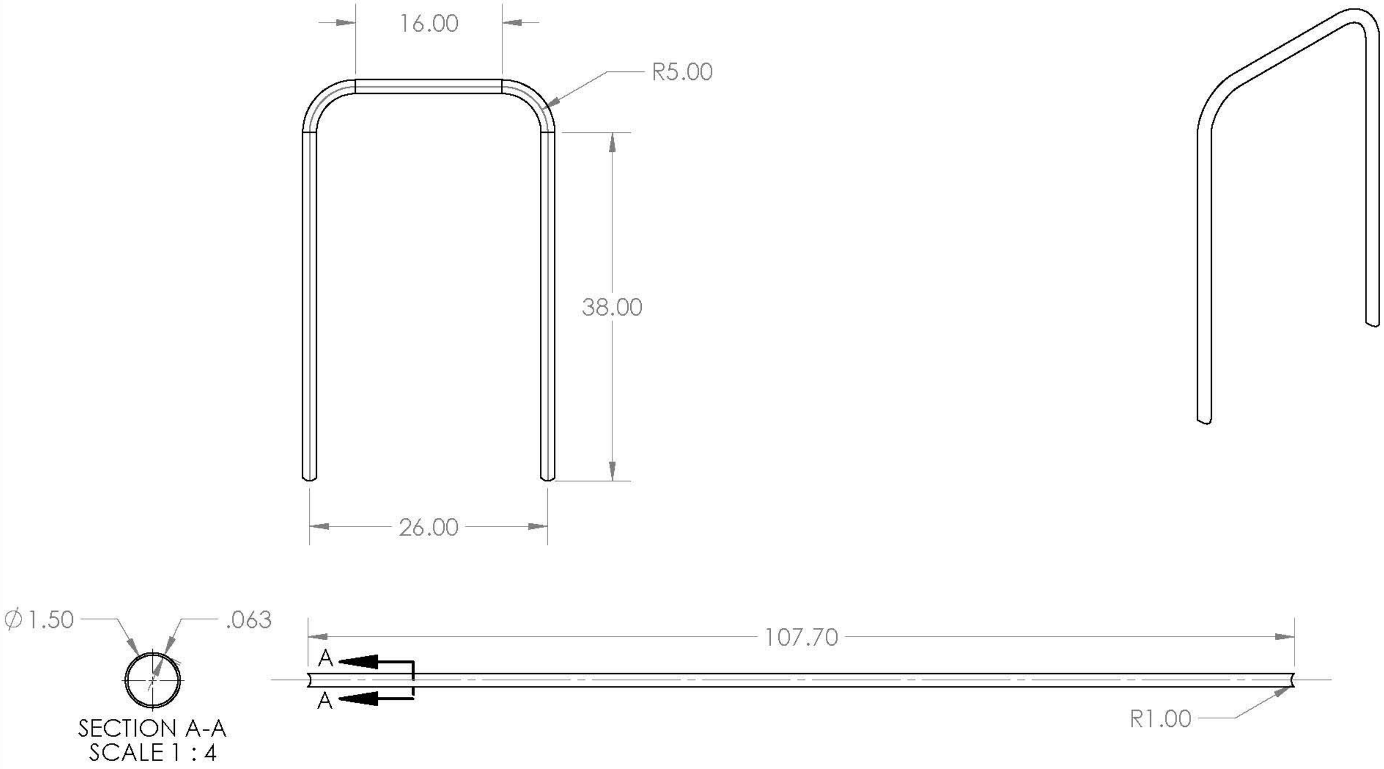
5 4 3 2 1

NOTES:



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±.01
ANGULAR: MACH±.1 BEND ±.01
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061-T6 (SS)

FINISH
N/A

DO NOT SCALE DRAWING

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	NAME	DATE
DRAWN	AJF	2/2/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SUB ASSEMBLY:
FRAME

DESCRIPTION:

UPPER ROLL BAR

SIZE
A

PART NO.
FR-03

REV
A

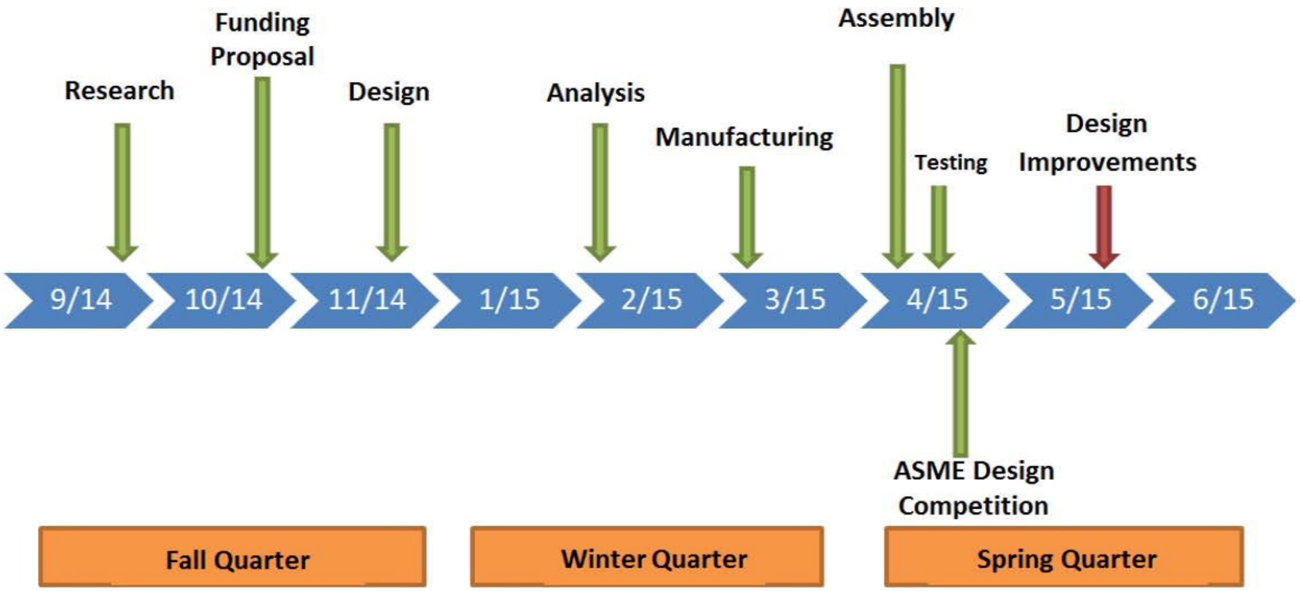
SCALE: 1:16 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

Outline

- -Background
- -Design Overview
- -Stress Analysis
- -Safety Testing
- -Problems and Solutions
- -Business Plan
- -Conclusion

Timeline



Research

Funding Proposal

Design

Analysis

Manufacturing

Assembly

Testing

Design Improvements

9/14 10/14 11/14 1/15 2/15 3/15 4/15 5/15 6/15

ASME Design Competition

Fall Quarter

Winter Quarter

Spring Quarter

Purpose and Impacts

Purpose

Design and build human powered vehicle to transport people in safe and efficient manner

Economic Impact

- Current bikes cost between $500-$2000
- Height range of bike is 3 in
- Families often own several different sized bikes

Social Impact

Environmental Impact

- 68% of Americans commute 15 miles or less to work
- 30% of CO2 emissions come from cars
- Using HPV would reduce household emissions by 6%
- Save up to 700 million gallons of fuel

http://environment.nationalgeographic.com/ http://www.adventurecycling.org/

Health and Safety Impact

- 17% of all bike injuries occur because user fell off bike
- Increase cardiovascular health by 3-7%
- Increased lifespan

Design Motivation

Customer Surveys
- Sent out to general public

Interviews
- Potential customer and professional in bike industry

ASME HPVC Competition Rules
- Design, Innovation, Speed, and Endurance

Main Design Goals

Safety

Speed

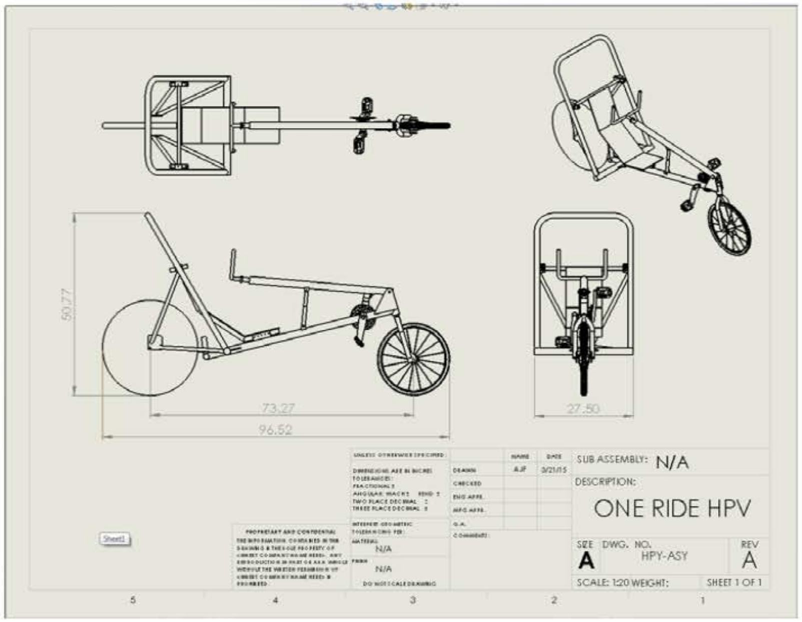
Comfort

Design Overview

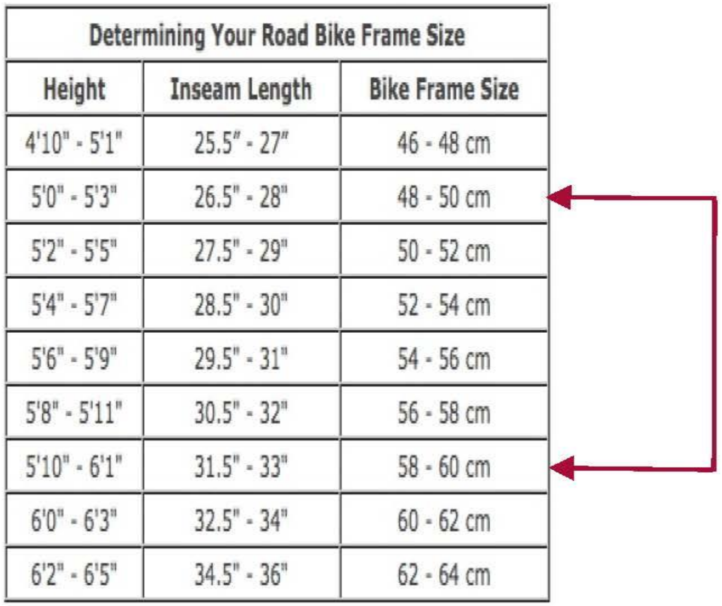
-2 Wheel Recumbent Design

-Fully Adjustable Seating

-Fully Adjustable Steering
    Steering Wheel
    U-Joint Connection
-Safety
        Roll Bar
    4 Point Harness
-Speed
        Desired for up to 35 mph
-Comfort
    Recumbent position with padded seat



Motivation for Innovation



Determining Your Road Bike Frame Size		
Height	Inseam Length	Bike Frame Size
4'10" - 5'1"	25.5" - 27"	46 - 48 cm
5'0" - 5'3"	26.5" - 28"	48 - 50 cm
5'2" - 5'5"	27.5" - 29"	50 - 52 cm
5'4" - 5'7"	28.5" - 30"	52 - 54 cm
5'6" - 5'9"	29.5" - 31"	54 - 56 cm
5'8" - 5'11"	30.5" - 32"	56 - 58 cm
5'10" - 6'1"	31.5" - 33"	58 - 60 cm
6'0" - 6'3"	32.5" - 34"	60 - 62 cm
6'2" - 6'5"	34.5" - 36"	62 - 64 cm

Current Bikes

-Only 3in height range before new frame is needed

-Increase manufacturing cost

-Decrease life of bike with owner

One Ride Design

-Lower manufacturing cost

-Longer life span of bike with owner

Design Overview

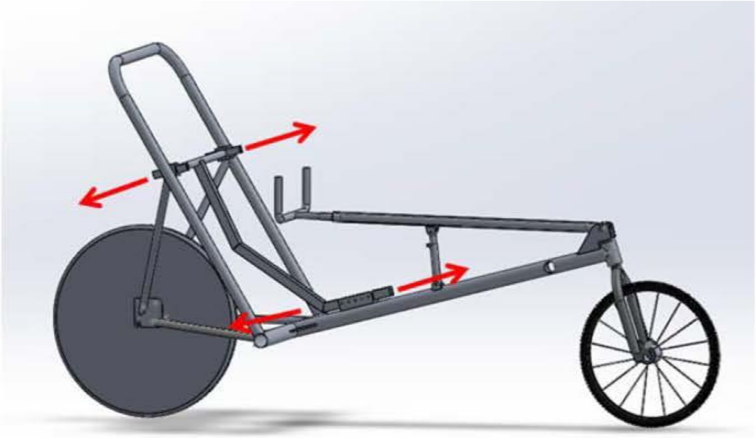
Design Overview

U-Joint Connection

Adjustable Steering

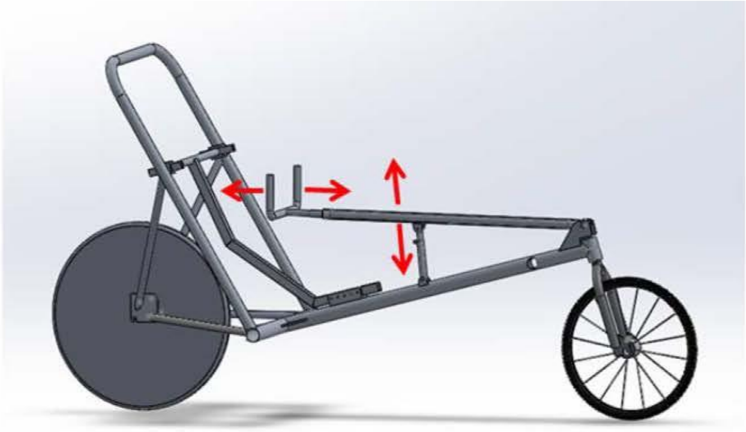
Adjustable Seating

Innovation Explanation



Seat Adjustment Along Frame Main Tube

Allows rider to adjust for pedaling comfort



Steering Wheel Adjustment

Allows rider to steer from a comfortable position

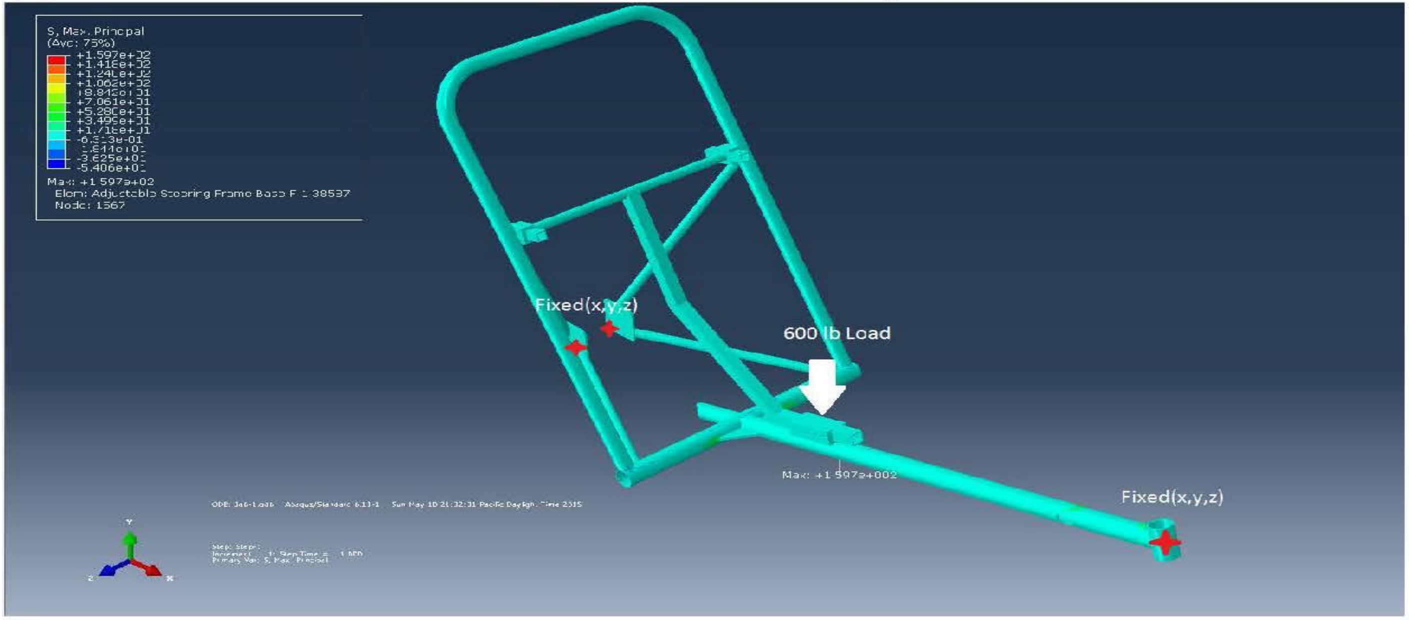
Innovation Explanation

-Two Riders: 5’5” and 6’0”
-Adjusted seating and steering to their own comfort positions

Product Design Specifications

Requirements	Units	Datum (Pegasus HPV)	Target Range
Top Speed	MPH	21.5	35
Turning Radius	ft	7.7	7
Deceleration	Feet from 15 MPH	8	8
Total Bike Weight	lbs	52	<45
Rider Height Range	ft and in	5’6”-6’0”	5’2”-6’4”
Rollover Protection Top Load	lbs	610	620
Rollover Protection Side Load	lbs	320	320

Finite Element Analysis

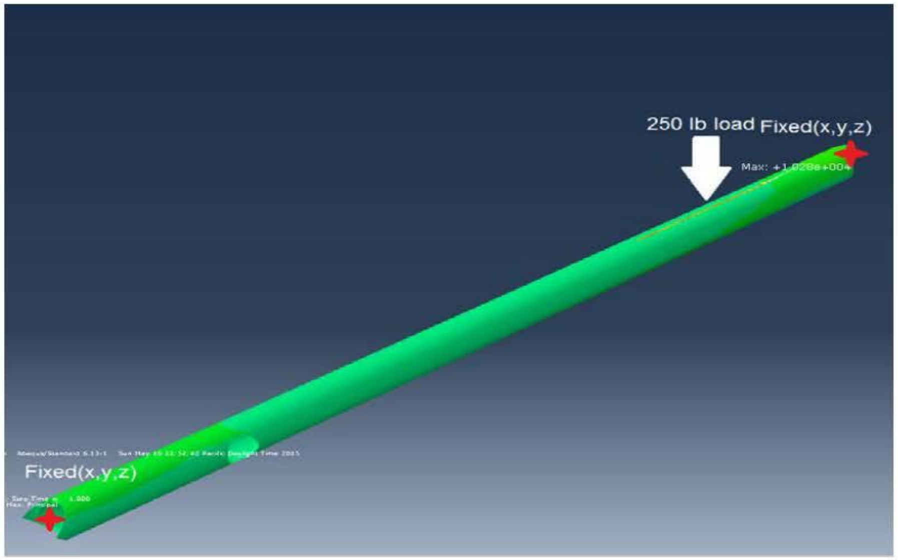


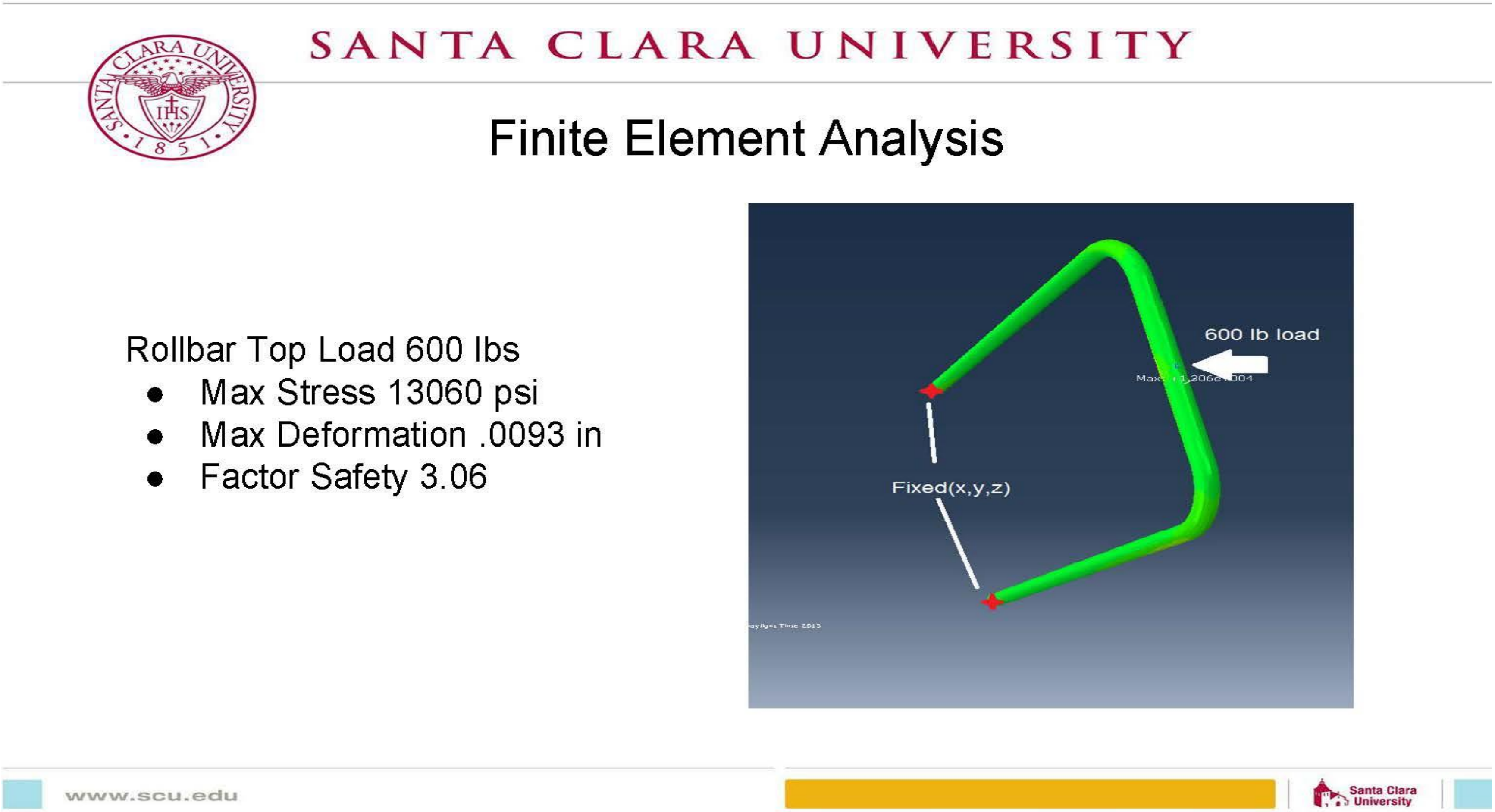
Full Frame Analysis 600 lb Load

Finite Element Analysis

Main Tube Loading of 250 lbs

- Max Stress 10208 Psi
- Max Deformation .00135 in
- Factor Safety 3.89





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Finite Element Analysis

Rollbar Top Load 600 lbs
- Max Stress 13060 psi
- Max Deformation .0093 in
- Factor Safety 3.06

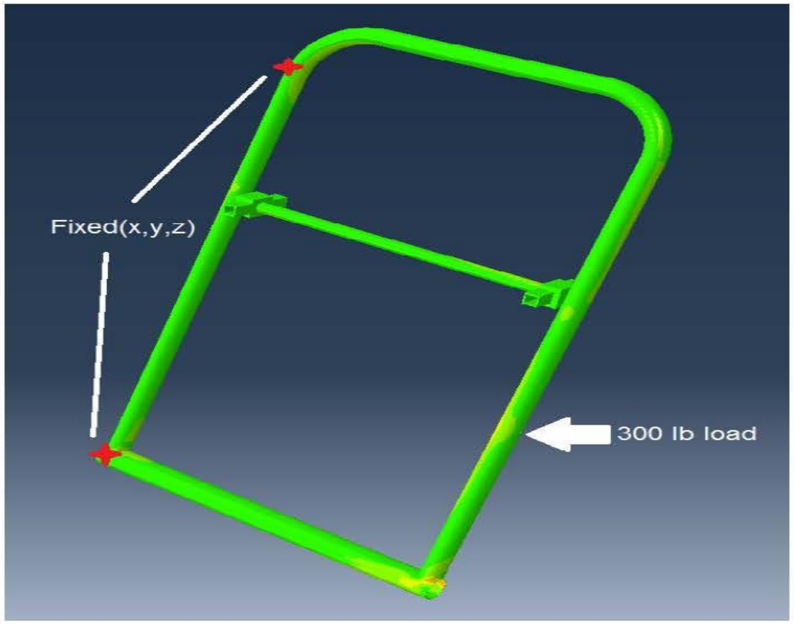
www.scu.edu

Santa Clara University

Finite Element Analysis

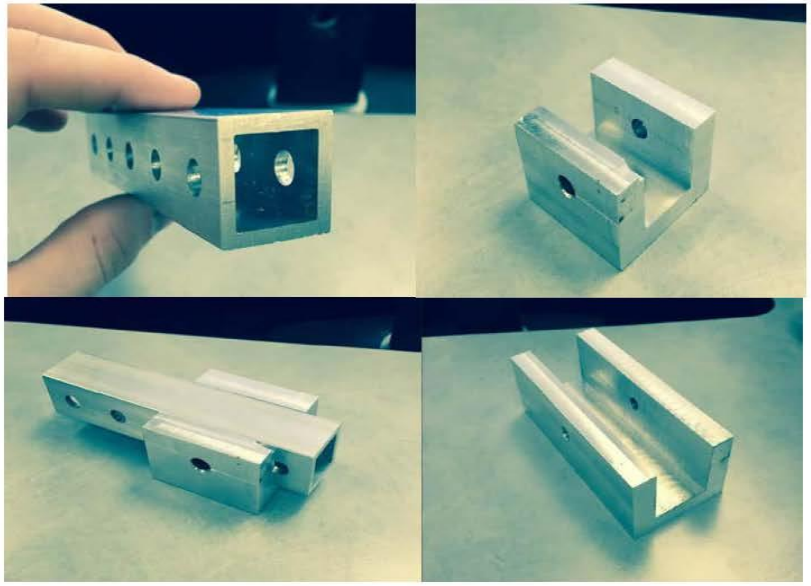
Rollbar Side Load 300lbs

- Max Stress 9110 Psi
- Max Deformation 2.944E-4 in
- Factor Safety 4.39



Manufacturing

- Parts machined in house
  - -Sliders
  - -Mounting Brackets
  - -Housing Tube
  - -Drive Shaft
- Parts were sent to welder once completed to be added to overall frame
- After welding, the entire frame was heat treated



Safety Testing

-**Tools Used:**Come-along, Tension Gauge (hanging scale), and straps.

-**Method:** Wrapped strap around roll bar with scale and come-along attached. Increased strap tension via come-along until desired load was reached.

Safety Testing Results

-Loads well over ASME required 600 lb top load and 300 lb side load.

-Deflections far less than ASME requirement of 3.8 cm side and 5.1 cm top.

Top Load	Load Reached (lbs)	Deflection (mm)	Side Load	Load Reached (lbs)	Measured Deflection (mm)
Test 1	698	1.5	Test 1	342	2.06
Test 2	742	1.5	Test 2	344	2.08
Test 3	674	1.7	-	-	-

Problems and Solutions

Frame Bending

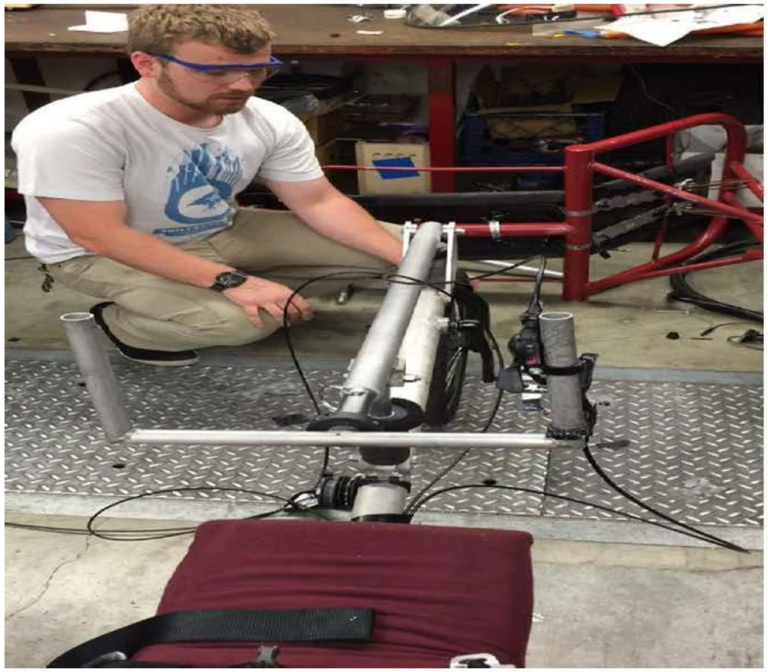
-Frame experienced warping during heat treatment.
-Misalignment of bracket seat adjuster
-Solution would consist of a jig or different material altogether.

Problems and Solutions

Axle Alignment

-Warping also caused rear axle misalignment.
-Solution was to redrill mounting hole further back.

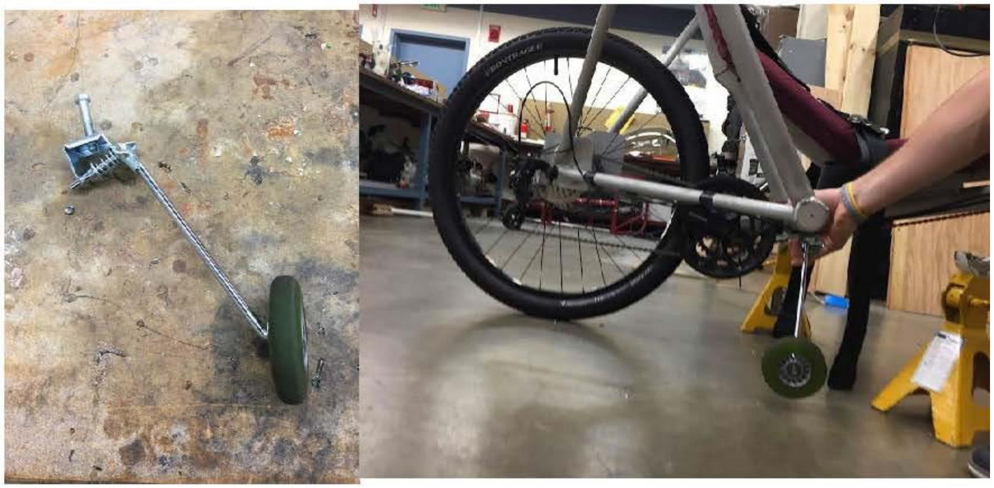
U-Joint Problems



Improvements/Modifications

No slop U-Joint to replace current one
    Connect with set screws for easier access for repairs/further improvements

Balance Wheel to be used at low speeds
    Can be rotated up so bike can get full lean when going around turns



Funding

Source	Amount
Undergraduate	$2,500
Roelandts Grant	$1,500
ASME/IEEE/IEEE VTS	$460
	$4,460

Budget

Category	Price
Aluminum Welded Frame	$2,100
Components	$1,500
Heat Treatment	$350
Competition Fee	$460
	$4,410

Cost Analysis

Category	Expenditures
Capital Investment: CNC, Lathe, Heat Treating Equipment, Tools	$500,000
Shop Lease	$25,000/yr
Utilities	$15,000/yr
Wages (2 full-time)	$83,200/yr
Insurance/Taxes	$25,000/yr
Total Material Cost Per Bike	$1,500

Assumptions:

- 10 year investment
- 2 full-time machinist
- 30 bicycles/month
- $600,000 Bank Loan
- 6% Interest Rate
- Inflation Rate Constant at .84%/yr

Cost Analysis

Year	Material Cost	Material Cost/Yr	Overhead/Yr	Loan/Yr
1	1500	540000	148200	79935
2	1513	544594	149460	79935
3	1526	549187	150720	79935
4	1538	553781	151980	79935
5	1551	558374	153240	79935
6	1564	562968	154500	79935
7	1577	567562	155760	79935
8	1589	572155	157020	79935
9	1602	576749	158280	79935
10	1615	581342	159540	79935
		5606712	1538700	799348
			Total:	7944760
			Price/Bike	2207

Conclusion

Two-wheeled recumbent designed for speed, safety and comfort

Fully adjustable seating and steering
- accommodates riders 5’2”-6’4”

Safety test showed minimal roll bar deflection

Retail Price is at a competitive market price ($2,200)

Sponsors & Donations from:

BYINGTON STEEL TREATING

SUMMIT BICYCLES

Chavez Welding & Machining

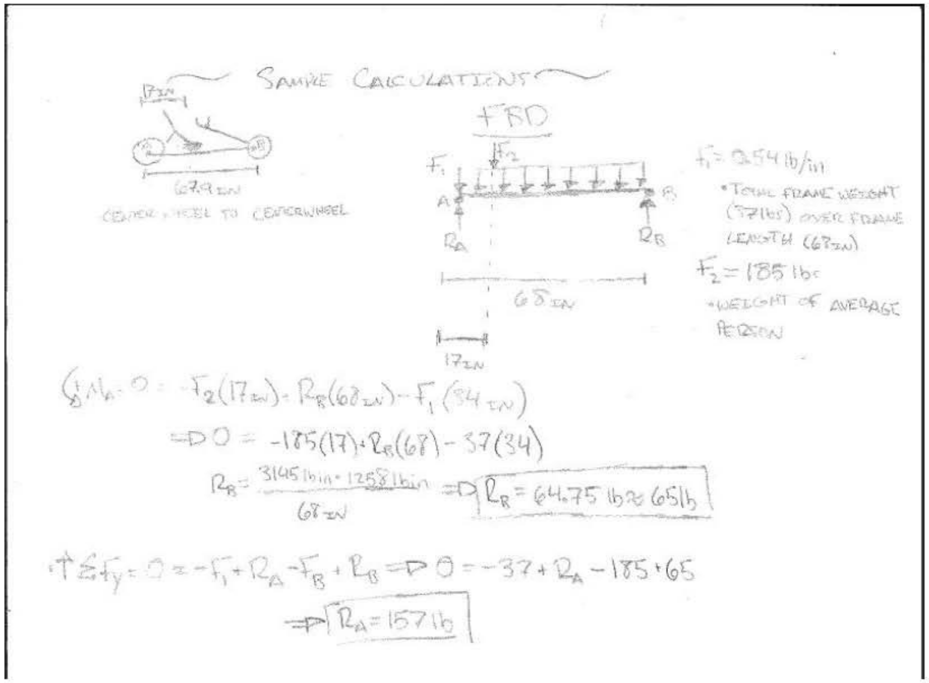
Acknowledgments

Santa Clara University, School of Engineering
-Dr. Drazen Fabris
-Dr. T. Calvin Tszeng
-Don MacCubbin
-Dr. Timothy Hight
-Dr. Scott Abrahamson
-Calvin Sellers

SCU Center for Science, Technology, & Society
-Roelandts Family
-Santa Clara Valley ASME/IEEE/IEEE VTS

Appendix Slides

Load Distribution Calculations



SAMPLE CALCULATIONS

$F_1 = .54$ lb/in

- TOTAL FRAME WEIGHT (37lbs) OVER FRAME LENGTH (68IN)

$F_2 = 185$ lbs

- WEIGHT OF AVERAGE PERSON

$$\circlearrowleft^{+} \sum M_A = 0 = -F_2(17_{IN}) + R_B(68_{IN}) - F_1(34_{IN})$$

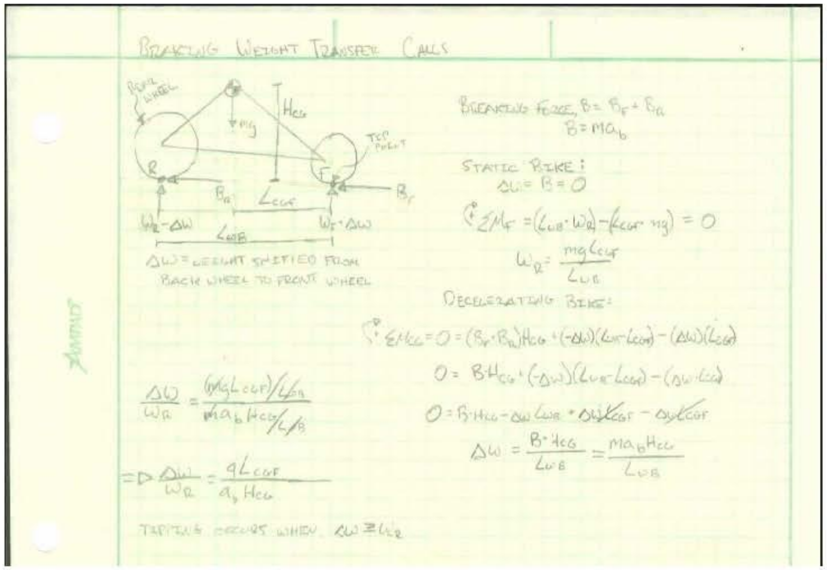
$$\Rightarrow 0 = -185(17) + R_B(68) - 37(34)$$

$$R_B = \frac{3145\,\text{lbin} + 1258\,\text{lbin}}{68_{IN}} \Rightarrow \boxed{R_B = 64.75\,\text{lb} \approx 65\,\text{lb}}$$

$$+\uparrow \sum F_y = 0 = -F_1 + R_A - F_B + R_B \Rightarrow 0 = -37 + R_A - 185 + 65$$

$$\Rightarrow \boxed{R_A = 157\,\text{lb}}$$

Braking Weight Transfer Calculations



BRAKING WEIGHT TRANSFER CALCS

ΔW = WEIGHT SHIFTED FROM BACK WHEEL TO FRONT WHEEL

BREAKING FORCE, $B = B_F + B_R$

$B = ma_b$

STATIC BIKE:

$\Delta W = B = 0$

$\circlearrowleft^{+} \Sigma M_F = (L_{WB} \cdot W_R) - (L_{CGF} \cdot mg) = 0$

$$W_R = \frac{mgL_{CGF}}{L_{WB}}$$

DECELERATING BIKE:

$\circlearrowleft^{+} \Sigma M_{CG} = 0 = (B_F + B_R)H_{CG} + (-\Delta W)(L_{WB} - L_{CGF}) - (\Delta W)(L_{CGF})$

$0 = B \cdot H_{CG} + (-\Delta W)(L_{WB} - L_{CGF}) - (\Delta W \cdot L_{CGF})$

$0 = B \cdot H_{CG} - \Delta W L_{WB} + \cancel{\Delta W L_{CGF}} - \cancel{\Delta W L_{CGF}}$

$$\Delta W = \frac{B \cdot H_{CG}}{L_{WB}} = \frac{ma_b H_{CG}}{L_{WB}}$$

$$\frac{\Delta W}{W_R} = \frac{(\cancel{m}gL_{CGF})/\cancel{L_{WB}}}{\cancel{m}a_b H_{CG}/\cancel{L_{WB}}}$$

$$\Rightarrow \frac{\Delta W}{W_R} = \frac{gL_{CGF}}{a_b H_{CG}}$$

TIPPING OCCURS WHEN $\Delta W \geqq W_R$

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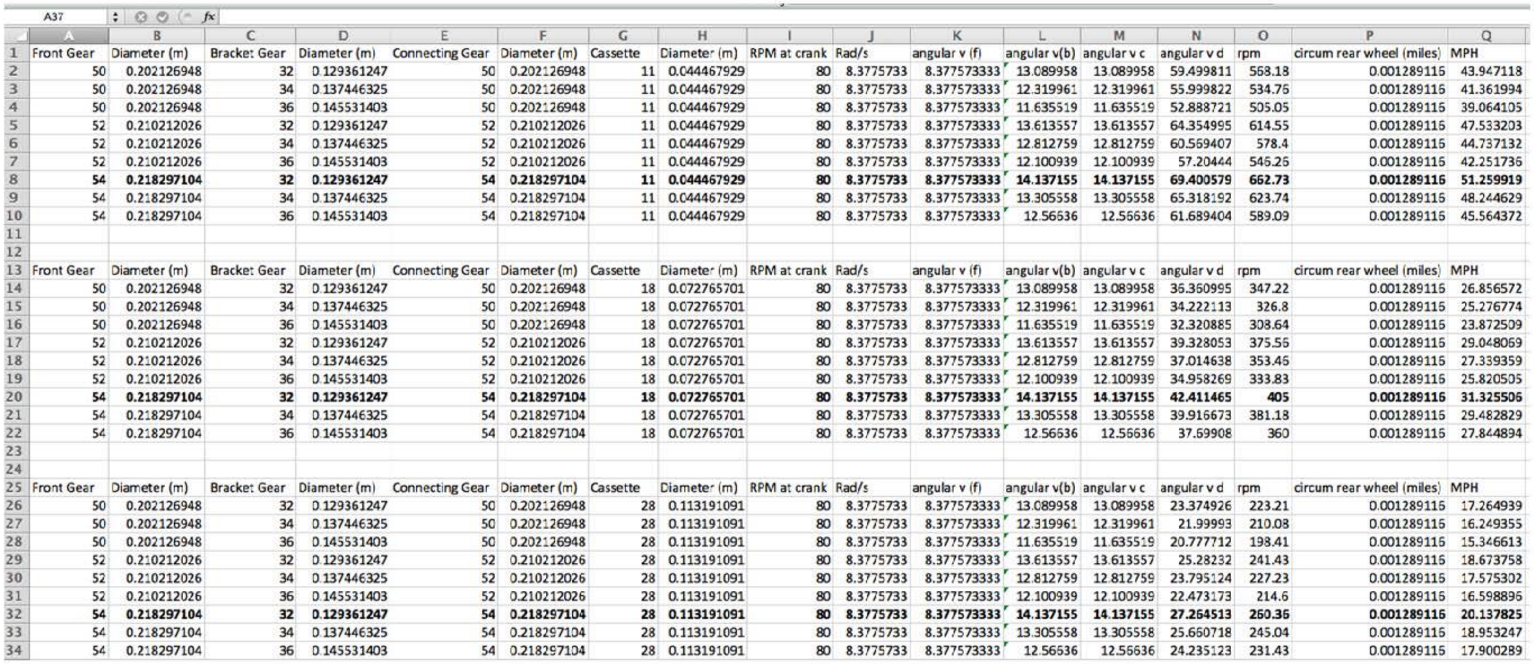
Gearing/Speed Calculations

WILL MAKE CLEARER



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Front Gear	Diameter (m)	Bracket Gear	Diameter (m)	Connecting Gear	Diameter (m)	Cassette	Diameter (m)	RPM at crank	Rad/s	angular v (f)	angular v(b)	angular v c	angular v d	rpm	circum rear wheel (miles)	MPH
2	50	0.202126948	32	0.129361247	50	0.202126948	11	0.044467929	80	8.3775733	8.377573333	13.089958	13.089958	59.499811	568.18	0.001289116	43.947118
3	50	0.202126948	34	0.137446325	50	0.202126948	11	0.044467929	80	8.3775733	8.377573333	12.319961	12.319961	55.999822	534.76	0.001289116	41.361994
4	50	0.202126948	36	0.145531403	50	0.202126948	11	0.044467929	80	8.3775733	8.377573333	11.635519	11.635519	52.888721	505.05	0.001289116	39.064105
5	52	0.210212026	32	0.129361247	52	0.210212026	11	0.044467929	80	8.3775733	8.377573333	13.613557	13.613557	64.354995	614.55	0.001289116	47.533203
6	52	0.210212026	34	0.137446325	52	0.210212026	11	0.044467929	80	8.3775733	8.377573333	12.812759	12.812759	60.569407	578.4	0.001289116	44.737132
7	52	0.210212026	36	0.145531403	52	0.210212026	11	0.044467929	80	8.3775733	8.377573333	12.100939	12.100939	57.20444	546.26	0.001289116	42.251736
8	**54**	**0.218297104**	**32**	**0.129361247**	**54**	**0.218297104**	**11**	**0.044467929**	**80**	**8.3775733**	**8.377573333**	**14.137155**	**14.137155**	**69.400579**	**662.73**	**0.001289116**	**51.259919**
9	54	0.218297104	34	0.137446325	54	0.218297104	11	0.044467929	80	8.3775733	8.377573333	13.305558	13.305558	65.318192	623.74	0.001289116	48.244629
10	54	0.218297104	36	0.145531403	54	0.218297104	11	0.044467929	80	8.3775733	8.377573333	12.56636	12.56636	61.689404	589.09	0.001289116	45.564372
11																	
12																	
13	Front Gear	Diameter (m)	Bracket Gear	Diameter (m)	Connecting Gear	Diameter (m)	Cassette	Diameter (m)	RPM at crank	Rad/s	angular v (f)	angular v(b)	angular v c	angular v d	rpm	circum rear wheel (miles)	MPH
14	50	0.202126948	32	0.129361247	50	0.202126948	18	0.072765701	80	8.3775733	8.377573333	13.089958	13.089958	36.360995	347.22	0.001289116	26.856572
15	50	0.202126948	34	0.137446325	50	0.202126948	18	0.072765701	80	8.3775733	8.377573333	12.319961	12.319961	34.222113	326.8	0.001289116	25.276774
16	50	0.202126948	36	0.145531403	50	0.202126948	18	0.072765701	80	8.3775733	8.377573333	11.635519	11.635519	32.320885	308.64	0.001289116	23.872509
17	52	0.210212026	32	0.129361247	52	0.210212026	18	0.072765701	80	8.3775733	8.377573333	13.613557	13.613557	39.328053	375.56	0.001289116	29.048069
18	52	0.210212026	34	0.137446325	52	0.210212026	18	0.072765701	80	8.3775733	8.377573333	12.812759	12.812759	37.014638	353.46	0.001289116	27.339359
19	52	0.210212026	36	0.145531403	52	0.210212026	18	0.072765701	80	8.3775733	8.377573333	12.100939	12.100939	34.958269	333.83	0.001289116	25.820505
20	**54**	**0.218297104**	**32**	**0.129361247**	**54**	**0.218297104**	**18**	**0.072765701**	**80**	**8.3775733**	**8.377573333**	**14.137155**	**14.137155**	**42.411465**	**405**	**0.001289116**	**31.325506**
21	54	0.218297104	34	0.137446325	54	0.218297104	18	0.072765701	80	8.3775733	8.377573333	13.305558	13.305558	39.916673	381.18	0.001289116	29.482829
22	54	0.218297104	36	0.145531403	54	0.218297104	18	0.072765701	80	8.3775733	8.377573333	12.56636	12.56636	37.69908	360	0.001289116	27.844894
23																	
24																	
25	Front Gear	Diameter (m)	Bracket Gear	Diameter (m)	Connecting Gear	Diameter (m)	Cassette	Diameter (m)	RPM at crank	Rad/s	angular v (f)	angular v(b)	angular v c	angular v d	rpm	circum rear wheel (miles)	MPH
26	50	0.202126948	32	0.129361247	50	0.202126948	28	0.113191091	80	8.3775733	8.377573333	13.089958	13.089958	23.374926	223.21	0.001289116	17.264939
27	50	0.202126948	34	0.137446325	50	0.202126948	28	0.113191091	80	8.3775733	8.377573333	12.319961	12.319961	21.99993	210.08	0.001289116	16.249355
28	50	0.202126948	36	0.145531403	50	0.202126948	28	0.113191091	80	8.3775733	8.377573333	11.635519	11.635519	20.777712	198.41	0.001289116	15.346613
29	52	0.210212026	32	0.129361247	52	0.210212026	28	0.113191091	80	8.3775733	8.377573333	13.613557	13.613557	25.28232	241.43	0.001289116	18.673758
30	52	0.210212026	34	0.137446325	52	0.210212026	28	0.113191091	80	8.3775733	8.377573333	12.812759	12.812759	23.795124	227.23	0.001289116	17.575302
31	52	0.210212026	36	0.145531403	52	0.210212026	28	0.113191091	80	8.3775733	8.377573333	12.100939	12.100939	22.473173	214.6	0.001289116	16.598896
32	**54**	**0.218297104**	**32**	**0.129361247**	**54**	**0.218297104**	**28**	**0.113191091**	**80**	**8.3775733**	**8.377573333**	**14.137155**	**14.137155**	**27.264513**	**260.36**	**0.001289116**	**20.137825**
33	54	0.218297104	34	0.137446325	54	0.218297104	28	0.113191091	80	8.3775733	8.377573333	13.305558	13.305558	25.660718	245.04	0.001289116	18.953247
34	54	0.218297104	36	0.145531403	54	0.218297104	28	0.113191091	80	8.3775733	8.377573333	12.56636	12.56636	24.235123	231.43	0.001289116	17.900289

Stress Calculations

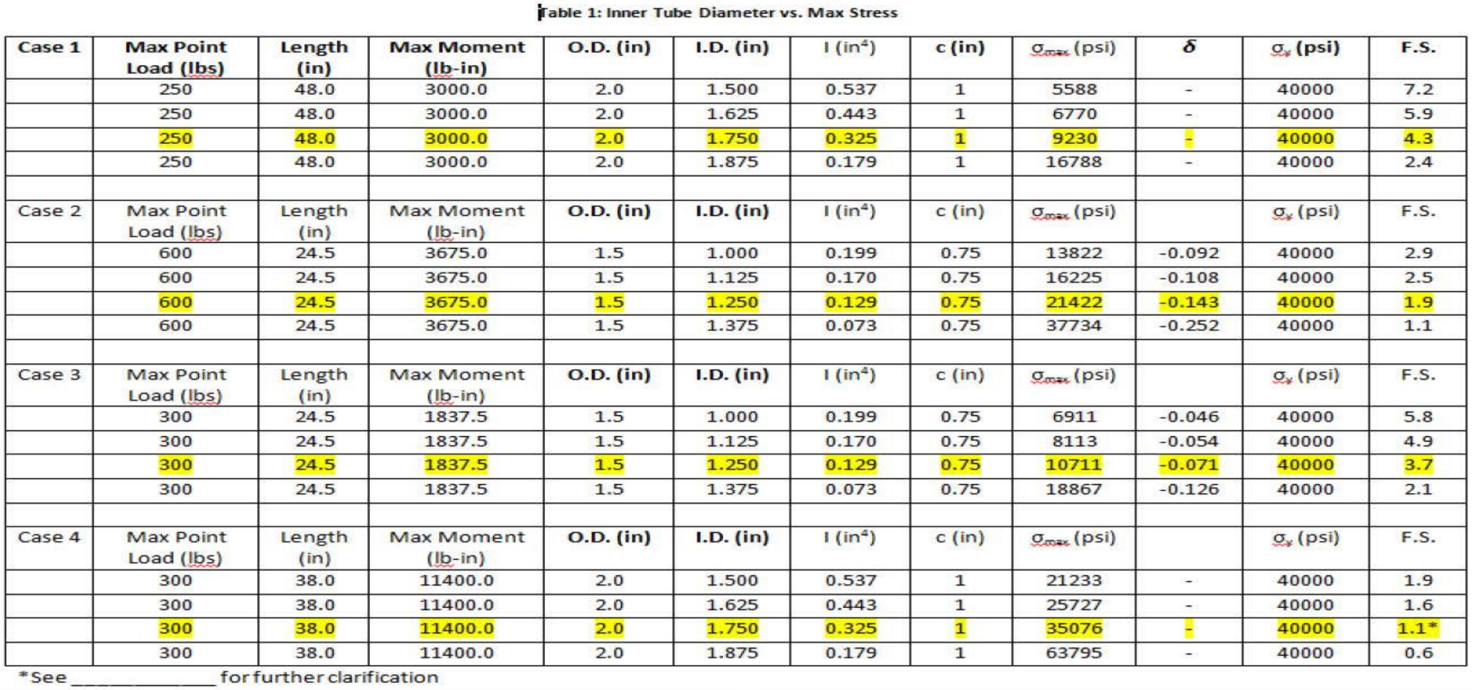


Table 1: Inner Tube Diameter vs. Max Stress

Case 1	**Max Point Load (lbs)**	**Length (in)**	**Max Moment (lb-in)**	**O.D. (in)**	**I.D. (in)**	I (in^4)	**c (in)**	σ_{max} (psi)	**δ**	**σ_y (psi)**	**F.S.**
	250	48.0	3000.0	2.0	1.500	0.537	1	5588	-	40000	7.2
	250	48.0	3000.0	2.0	1.625	0.443	1	6770	-	40000	5.9
	250	48.0	3000.0	2.0	1.750	0.325	1	9230	-	40000	4.3
	250	48.0	3000.0	2.0	1.875	0.179	1	16788	-	40000	2.4
Case 2	Max Point Load (lbs)	Length (in)	Max Moment (lb-in)	**O.D. (in)**	**I.D. (in)**	I (in^4)	c (in)	σ_{max} (psi)		σ_y (psi)	F.S.
	600	24.5	3675.0	1.5	1.000	0.199	0.75	13822	-0.092	40000	2.9
	600	24.5	3675.0	1.5	1.125	0.170	0.75	16225	-0.108	40000	2.5
	600	24.5	3675.0	1.5	1.250	0.129	0.75	21422	-0.143	40000	1.9
	600	24.5	3675.0	1.5	1.375	0.073	0.75	37734	-0.252	40000	1.1
Case 3	Max Point Load (lbs)	Length (in)	Max Moment (lb-in)	**O.D. (in)**	**I.D. (in)**	I (in^4)	c (in)	σ_{max} (psi)		σ_y (psi)	F.S.
	300	24.5	1837.5	1.5	1.000	0.199	0.75	6911	-0.046	40000	5.8
	300	24.5	1837.5	1.5	1.125	0.170	0.75	8113	-0.054	40000	4.9
	300	24.5	1837.5	1.5	1.250	0.129	0.75	10711	-0.071	40000	3.7
	300	24.5	1837.5	1.5	1.375	0.073	0.75	18867	-0.126	40000	2.1
Case 4	Max Point Load (lbs)	Length (in)	Max Moment (lb-in)	**O.D. (in)**	**I.D. (in)**	I (in^4)	c (in)	σ_{max} (psi)		σ_y (psi)	F.S.
	300	38.0	11400.0	2.0	1.500	0.537	1	21233	-	40000	1.9
	300	38.0	11400.0	2.0	1.625	0.443	1	25727	-	40000	1.6
	300	38.0	11400.0	2.0	1.750	0.325	1	35076	-	40000	1.1*
	300	38.0	11400.0	2.0	1.875	0.179	1	63795	-	40000	0.6

*See _____________ for further clarification

Frame Material Tradeoffs

AISI 4130 Steel

-Strong (670 MPa)
-Easy to manufacture with
-Heavy (7.85g/cc)
-Failure very unlikely to happen

6061-T6 Aluminum

-Weaker (310 MPa)
-Not as easy to work with
-Light (2.7g/cc)
-Desirable failure characteristics

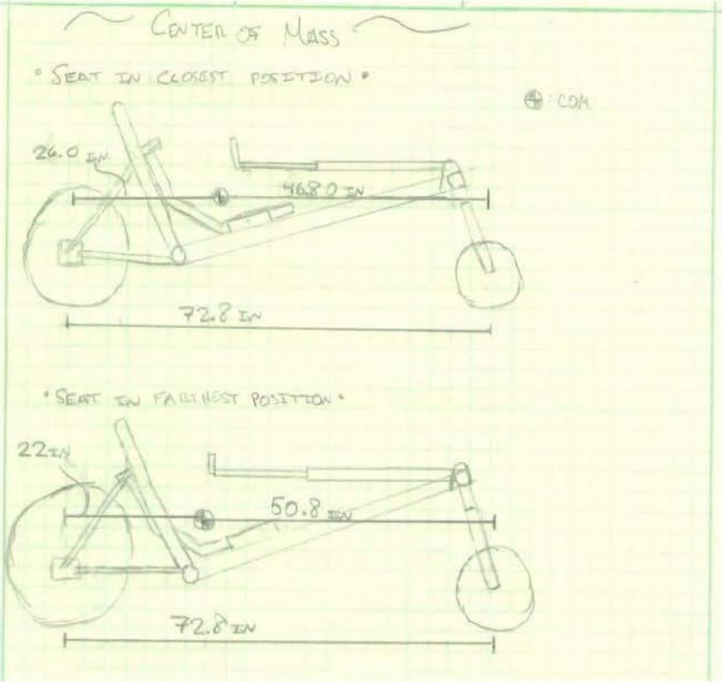
Carbon Fiber

-Similar Strength properties to steel
-High skill level required for manufacturing (expensive manufacturing)
-Lightest option
-Failure is critical

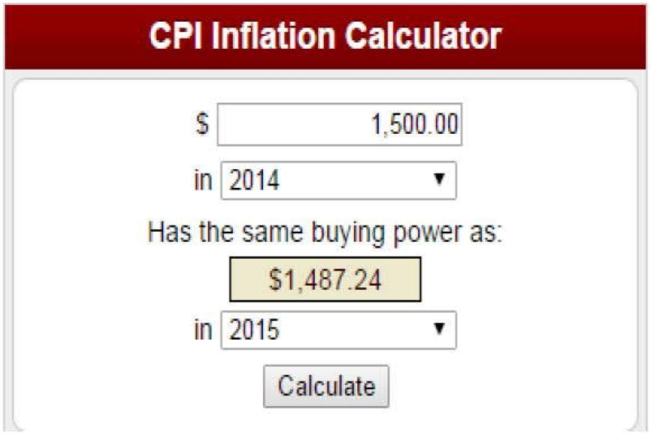
Benefits of Heat Treating

Material	Ultimate Tensile Strength (psi)	Yield Strength (psi)	Top Load Factor of Safety (based on y.s)	Side Load Factor of Safety (based on y.s.)
6061-T6	45000	40000	2.0	3.7
6061-T4	35000	21000	0.9	1.9
6061-T1	29000	16000	0.7	1.4

Center of Mass Comparisons



Aluminum 6061-T6	$600
Wheels/Tires	$200
Brakes	$100
Bolts	$100
Seating	$100
Gearing	$250
Fairing	$150
Total	$1,500
Inflation/Yr	$12.60



CPI Inflation Calculator

$ 1,500.00

in 2014

Has the same buying power as:

$1,487.24

in 2015