Joseph's Jogger

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Statement of Disclaimer

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Executive Summary

The goal of our project was to construct a new jogger for a young man name Joseph Cornelius with spastic quadriplegia. Joseph enjoys participating in marathons on his jogger and has been an inspiration to many. However, his jogger has been worn down with the foot rests breaking often due to the immense force he exerts on them. The old jogger itself did little to provide comfort to Joseph as he would experience the bumps on the road which was issue especially as his right femur is dislocated from his hip making his right hip sensitive.

With comfort as key in our design, we decided to make a new frame from scratch. The components of the new jogger were divide into parts with Luke Kraemer in charge of the frame, Robert Trujillo in charge of the seat, Carolina Reyes in charge of the harness, and Josh Egli in charge of the sunshade canopy and finances.

Some issues in our process were that we had expected to finish constructing the jogger a month earlier and spend the remaining time testing the jogger. However due to an error in our measurements on our frame design, the jogger frame and seat had to be redesign. Fortunately, this error was seen when we built a prototype prior to the final design. Another cause of delay was the upholster for the seat and the manufacturer for the wheels took more longer then estimated. If done again we would be more cautious of complications that we may face and not be too confident that everything will work out, but make preparations in case something doesn't.

After months of designing, ordering, prototyping, building, and testing we were finally able to construct a new jogger that met the most essential needs of Joseph. The new jogger is able to provide a comfortable ride for Joseph as it is layered with a foam seat as well as having a headrest and cushions on his side that will secure Joseph in place without feeling restraining. The jogger also rides smoothly with it being made of a single unit rather than being collapsible, feeling much sturdier. In addition, it has custom quick release pneumatic wheels that can be easily removed when loading and unloading into a van.

This report details the steps we took in designing and constructing the new Jogger that Joseph will be using for years to come.

1.0 Introduction

This section gives information about Joseph and his jogger and the technical challenges of making a new jogger. In addition, it will define the problem and highlight the customer requirements and engineering specification of the new jogger as well as explaining the role each team member will play in the process of creating a new jogger

1.1 Information on Joseph

Joseph Cornelius is a 22-year-old man with spastic quadriplegia, a form of cerebral palsy. Cerebral palsy is a condition that results from brain damage while the baby is still in their mother's womb. The brain damage affects muscle control and functioning. Spastic quadriplegia is a severe form of cerebral palsy in which limited muscle function has rendered all four limbs of the person to be very stiff. This stiffness is due to high muscle tone because the muscles are constantly engaged under tension. People with spastic quadriplegia usually have difficulty speaking, are unable to walk, and are intellectually impaired [1]. Consistent with these characteristics, Joseph is nonverbal, unable to walk, and has an intellectual impairment. Additionally, due to the high stress generated by the high muscle tone, his right femur is displaced from the acetabular socket of his hip joint. This results in his right leg being roughly two inches shorter than his left leg. Due to the hip dysplasia, his hip joint is very sensitive and can cause him discomfort. Although his limbs are very stiff and he is unable walk, Joseph is very strong. When he was younger, he exerted enough force in his leg to break his right femur which further intensified the hip dysplasia. This strength is present in all of his muscles and therefore, when unsettled, Joseph's movements can become quick and powerful. Joseph is five feet tall, and fluctuates between 70 and 80 pounds in weight. He is not expected to get any bigger. Joseph is in his most calm and happy state when he is in motion. His father, John, enjoys running with him in a specialty adult jogging stroller. Together they participate in triathlons using the stroller along with specialty swimming and biking devices. Competing under the name "Team Joseph," they have created a tightly knit community of friends and family who all participate in helping Joseph complete triathlons. When speaking with John, it is easy to see that Joseph is the most important part of his life. "He is my world" is one of the phrases he repeatedly uses. He passionately described how when they are in motion on runs, Joseph is in a pure state of happiness and exerts a type of positive energy that all around can feel. The existing stroller that Joseph uses is getting old and worn out with more than 7,000 miles on it. It has been welded for repairs numerous times and signs of wear such as broken rivets are present. Joseph needs a new safe, comfortable, and quality stroller to allow him to continue experiencing the thrill of motion.

1.2 Technical Challenges

There are some technical challenges when choosing a stroller for Joseph. Due to his strong muscles, he can exert a lot of force on a stroller. On his current stroller, he has damaged the foot supports and the crotch support when he pushes against them. Additionally, due his hip dysplasia, special care must be taken to ensure that this area of his body is properly protected and that the shorter length of his right leg is taken into account. We have designed Joseph's jogger to fit inside John's minivan. We came to the conclusion that making the jogger collapsible was not crucial. However, the lack of collapsibility meant that we needed to focus on a compact jogger design.

The current jogging stroller market is dominated by strollers for infants and small children. Understandably the market for adult strollers is much smaller and is geared toward people with some sort of disability. Although they do not satisfy our customer's because Joseph is too tall for them, there are some well-designed baby joggers that are helpful to look at. The joggers for people with disabilities are also well-designed and accommodate adult heights. Joseph currently uses one such jogger, the Adaptive Star which has functioned well for him throughout the years.

1.3 Customer Requirements

We started our process by carefully observing John and Joseph in motion while interviewing John and Michael. The following are requirements that we developed for this project after meeting with our sponsor.
The device should…

- **1:** safely secure Joseph and provide crotch support.
- **2:** be transportable inside a standard-sized minivan.
- **3:** be lightweight in order to push easily.
- **4:** accommodate Joseph's size and weight.
- **5:** protect and align Joseph's body—specifically at the hips.
- **6:** position Joseph in a relatively upright position.
- **7:** have a quality braking system.
- **8:** provide a smooth ride--dampen impacts.
- **9:** require minimum maintenance, including at footrest.
- **10:** have an adjustable handlebar to suit different size drivers.
- **11:** protect Joseph from the sun and rain.
- **12:** be weatherproof.
- **13:** allow Joseph a clear view of the road.
- **14:** be in Team Joseph colors.

1.4 Problem Statement

Joseph is a young man with spastic quadriplegia who loves the experience of being in triathlons. He actively participates in triathlons in which he is pushed in a jogger. His current jogger is becoming worn out and does not dampen road impacts which cause Joseph discomfort. Thus, Joseph is in need of a new stroller in which he can be pushed efficiently for long distances and that dampens road impacts in order to allow Joseph to continue enjoying triathlons.

1.5 Engineering Specifications

We developed a set of engineering specifications that guided us through our design phase. This specification table can be seen in Appendix B. The specification table details our examination of customer requirements. Each customer requirement was given a target that our team concluded as attainable as well as an improvement to competing devices. In addition, each requirement was ranked according to our judgment of difficulty to achieve (*low risk (L), medium risk (M), high risk (H))*. Thus, we only classified the distribution of load on the footrest as high. We predict this need to be challenging because Joseph has managed to break his existing jogger numerous times due to his strength. Thus, we are fairly concerned with this requirement.

In addition, each requirement will be examined as described below. Certain needs will be analyzed through calculations, while others will be tested, inspected, or compared to a similar existing device.

- Analysis/Calculations (A)
- Test (T)
- Similarity to Existing Device (S)
- Inspection/Visually (I)

As shown in the specification table, most specifications will be tested. In testing the device, we will measure its parameters as well as Joseph's anatomy. Other specifications will require analysis using numerical techniques, while the remaining will be inspected or compared to existing products. Our team decided to limit our design to a total weight of 40lbs, length of 60in, width of 36in, and height of 52in. These parameters were developed by researching adult-size joggers and simultaneously aiming to improve the dimensions of existing joggers. We established our user's limitations based on Joseph's anatomical measurements and advise from his doctor on his predicted growth. Moreover, we chose a maximum of zero pinch-points because it is of high importance that we put Joseph's safety first. Thus, wherever his safety is concerned, we cannot make any negotiations with our design. In addition, the production cost we concluded rooted from the prices of existing products as well as from our budget. We also made it a target to have 75% of the components to be off the shelf. This is because we do not want John to have any problems with replacing components, if necessary. The most challenging specification we decided on was the load that will be distributed on the footrest. We are still unsure of our 100lbs minimum limit. Thus, we are aware that it must resist a large force over continuous use; however, we are not clear on Joseph's strength yet. We will be designing this jogger for a long life by using good materials and manufacturing processes.

Table 1.5.1 Engineering Specifications for Joseph's Jogger

Spec #	Specification Description	Target (Units)	Tolerance	Risk	Compliance
1	Weight of Device	35lbs.	Max	M	T
2	Length of Device	60 in.	Max	M	T
3	Width of Device	36 in.	Max	M	T
4	Adjustable Handlebar Height	52 in.	± 3 in.	L	I
5	Payload	100 lbs.	± 5 lbs.	L	T
6	User Width	15 in.	± 3 in.	L	T
7	User Height	60 in	± 3 in.	L	T
8	Pinch Points	0	Max.	M	I
9	Distributed Load on Foot Platform	100lbs.	Min.	H	A,T
10	Production Cost	$2500	Max.	M	A, S
11	Off the Shelf Components	75% of cost	Min.	M	S, I

1.6 Management/Teamwork

With every group, there is a need for accountability between group members. Hence, each of our group members have been assigned areas of the project that we will be held accountable for. Through our management plan, we hope to create an environment that will promote communication, ideation, and overall success of this project. This management plan acknowledges the growth and expansion of these areas of accountability, and allows for positions to be created and modified by group consensus as the project advances.

Manufacturing Lead - Luke Kraemer
Luke will be responsible for the pre-welding work necessary on the frame. As he was the lead designer on the frame, he will be the most knowledgeable in the necessary steps to prepare the frame for welding. This includes instructing team members in cutting and mitering steel for the frame. While also possibly leading the creation and construction of a jig to hold the frame while it is being welded.

Treasurer - Josh Egli
Josh will be responsible for maintaining and controlling the team's budget. He will be in charge of applying for grants, fundraising, and discovering other ways to supplement the projects funding. Josh will be in charge of purchasing all items deemed necessary by group consensus. He will also be in charge of documenting the team's purchases through an expense report. He will also be responsible for ordering parts at the correct times.

Secretary - Robert Trujillo
Robert will be responsible for recording conversations with our sponsor and advisor. He will be responsible for recording team discussions, and summarizing the main points of group meetings. Robert will also be in charge of maintaining the team calendar and creating team deadlines. Robert will also be the main point of contact with Mitch's Stitches.

Communications - Carolina Reyes
Carol will be responsible for all communication between the group and Michael, John, Joseph, and Sarah. She will be responsible for setting up and maintaining team meetings. Carol will be the source of contact for the team, and will be handling all phone calls / emails on the group's behalf.

2.0 Background

This section covers the research and assessment of existing products on the market.

2.1 Existing Products

Figure 2.1.1: Picture of Joseph in his Adaptive Star Endeavor Jogger

Adaptive Star Endeavour
Pros:
-Foldable
-Weather Shield
-Front Brake and Emergency Brake
-Foot support and 5-point harness
-Lightweight (30lbs)
-Weight Capacity (100 lbs.)
-Adjustable back seat angle (10-30 degrees)
-Available in different models for different heights and weights

Cons:
-Expensive ($1500)
-Weak Foot Supports
-Lots of play in folding connections
-Doesn't keep Joe's body in line
-Little padding for bumps

Figure 2.1.2: Joseph's current jogger

Figure 2.1.3: Repair Weld on Joseph's jogger

Figure 2.1.1 shows Joseph Cornelius on his daily run in a state of pure bliss. While jogging, he will stay in this position, without moving, and loving every second. It is an experience that both he and his father treasure immensely. The jogger shown in use is an Adaptive Star Endeavour (*Figure 2.1.2)*. This jogger is available in four models, each having the same design but differing in cargo and height capacity. The cargo capacity ranges from 100 to 250 lbs., and the seat height changes accordingly. However, as capacity increases, so does the price: rising to almost $2,500 at the 250 lbs. capacity jogger. More on the adaptive star jogger can be found in reference [2]. As you can see from the picture above, Joseph's current jogger does not have sufficient restrains or padding to keep his upper body in line. Additionally, when we went and experimented with his jogger, we felt a lot of play in the handlebar and flex in the jogger frame when pushing down on the handlebar to turn it. Numerous repairs have been made to Joseph's jogger, one of which is shown in *Figure 2.1.3* which shows a spot where the jogger frame broke and was welded. Padding could be added to this jogger in order to improve Joseph's body posture. Overall, the Adaptive Star Endeavour is an adequate jogger, but there is a lot of room for improvement on the design.

Figure 2.1.4: BOB Revolution Jogging Stroller

BOB Revolution
Pros:
-Foldable
-Weather Shield
-Front Brake and E-Brake
-Suspension for bumps
-5-point harness
-Rotating front wheel for turning
-Front wheel also locks forward
-Lightweight (25 lbs.)
-Low Cost ($460)
-Seat can recline to 70 degrees past vertical

Cons:
-Max weight 70 lbs.
-Max height 44 inches
-Not suitable for adults

The BOB Revolution stroller [3] shown here is unique due to its sophisticated folding and suspension system. This is one of the more popular high end infant jogging strollers on the market due to its high performance and smooth ride. It has thicker gauge tubing in its frame than other strollers in the same product class which makes it more rigid and has less play. While the suspension does dampen road impacts, it also affects how the stroller turns. With the front wheel set to pivot mode, the stroller can rotate without having to lift up the front wheel. However, in jogging mode the front wheel is locked straight for added stability. This mode required that the front wheel be lifted up to turn and this is done by pushing down on the handlebars. However, when the handlebars are pushed down, part of this force goes into compressing the suspension which is inefficient and feels spongy instead of rigid. This stroller folds simply by pulling a lever and a strap, no pins or components need to be removed. It is compact and sturdy. If it were made with a larger capacity, it would be a good fit for Joseph assuming we could modify the suspension to not feel spongy when turning.

Figure 2.1.5: Hoyt Blade Running Chair

Pros:
-Very fast and efficient
-Collapsible
-Customizable for different heights and weights

Cons:
-Heavy (44 lbs.)
-Very long and difficult to turn
-Expensive ($4000)
-Little padding to keep Joseph's body in line
-Seat angle too reclined

Figure 2.1.5 shows the high-performance Hoyt Blade running chair [4]. This is the official chair of Team Hoyt, a father/son team where father Dick Hoyt has pushed his son Rick (who has cerebral palsy) in over 1,000 endurance events. This chair is designed for speed and performance. Therefore, large bicycle wheels are used, and the seat is reclined in order to keep the center of gravity low. The chair does collapse, but it does not fold. Instead, pieces of the frame are removable to make it more compact. There is not sufficient padding on the Hoyt to keep Joseph's body aligned which was a point that John brought to our attention. We discussed the Hoyt Blade with John and he told us that he knew Team Hoyt personally and had even tried out their running chairs. He described how they were incredibly well built and fast, but did not turn well due to the long wheelbase. He also pointed out that these chairs were for performance and racing exclusively. Team Joseph is looking for a chair that is functional both in races and for everyday jogs around the neighborhood.

Figure 2.1.6: Ottobock Kimba Cross Jogging Stroller

Pros:
-Collapsible
-Max weight, 110 lbs.
-Well designed seat that keeps upper body in line
-5-point harness

Cons:
-Max height, 47 inches
-No weather guard
-High Cost $2300

Figure 2.1.6 shows the Kimba Cross jogging stroller [5]. While this stroller wouldn't work for Joseph because of the height capacity, it does offer a good option for seating. With the lateral supports present in this design and the 5-point harness, Joseph would be restrained from moving his upper body left and right. There would be a concern over whether sufficient padding and space would be provided for his right displaced hip. Additionally, we would have to ensure that his arms are restrained inside so that he is not in danger of getting his body caught on any pinch points on the stroller.

Tadpole Adaptive Wheelchair Style Jogger

Pros:
-Wheel chair design is familiar and comfortable for Joseph

Cons:
-High center of gravity
-low performance, unstable

Figure 2.1.7: Tadpole Adaptive wheelchair style jogger

The jogger shown in *Figure 2.1.7* is an example of a wheelchair style jogger [5]. John has told us that Joseph is very comfortable in his wheelchair and that it would be nice if a stroller could put him in a similar position. Due to the short wheelbase and high center of gravity, this would be an unsafe and unstable jogger at high speeds. For these reasons, it would not work for us. However, with this design, it appears that if the wheelbase was extended, the seat could be dropped down; thus, lowering the center of gravity. The seat design in this stroller could have worked for our project if more padding was added and a sturdy restraint system was implemented.

Figure 2.1.8: Wike Bike Trailer

Pictured in *Figure 2.1.8* is Joseph's bike trailer. His father is very happy with how this trailer performs, especially when it comes to the seat. This trailer has a five-point harness and adequate padding that helps Joseph maintain a desired body posture when in motion. His feet are not pushing against any footrests and instead are allowed to float around in the stroller's platform. Since this platform is sunken down, his feet will not fall out. Additionally, because there is nothing for Joseph to push his feet against, damage to the device is low. Aspects of this bike trailer, specifically those pertaining to the seat, were used in the designing of Joseph's new jogger.

2.2 Quality Function Deployment

We used a Quality Function Deployment (QFD), Appendix A, tool in order to weigh each requirement and measurement. This QFD allowed us to numerically identify each specification, compare competing devices, and develop a priority list. As seen in Appendix A, this tool neatly organizes the needs, specifications, competitors, and results. From this tool, we learned that the production cost, product lifetime, and low maintenance are highly affected by the customer's requirements. We concluded the preceding through identifying any correlation between the requirements and specifications based on the division below:

9 – Strong Correlation
3 – Moderate Correlation
1 – Small Correlation
0 – No Correlation

The QFD is organized as follows:

- **Area 1 (What?):** The "what" area, on the left, of our QFD lists the customer requirements provided by John and Michael.

- **Area 2 (Who?):** The “who” area, on the top left, identifies the customer; hence, Joseph Cornelius and Team Joseph.
- **Area 3 (Who vs What):** The “who vs what” area, next to the “what”, weighs each customer requirement per Joseph’s perspective—how important is the requirement to Joseph.
- **Area 4 (How?):** The “how” area, on the center top, lists the engineering specifications for the device.
- **Area 5 (What vs How):** The “what vs how” area, on the center, shows the correlation, if any, between the customer requirements and engineering specifications as described above (i.e. 9,3,1,0).
- **Area 6 (Now):** The “now” area, on the top right, lists the existing competing devices.
- **Area 7 (Now vs What):** The “now vs what” area, on the right, scores the existing devices based on the customer requirements.
- **Area 8 (How Much?):** The “how much” area, on the bottom, center, identifies the targets of our ideal device.

In addition, we surveyed five competitors (Hoyt, Wike, Adaptive Star, Ottobock, Bob) in order to understand the strengths and weaknesses of each. Hence, we distinguished the Ottobock Kimba stroller as a favorite, and the Hoyt as the least suitable for Joseph. The Ottobock Kimba showed to satisfy over 70% of the customer requirements with a score of three or better. On the other hand, the Hoyt only satisfied 50% of the customer requirements using the same grading rubric. Thus, when designing we paid close attention to the Ottobock, as we knew it had a lot to offer. Although, the Ottobock scored the highest, the goal was to adopt the best features from all competitors and design a device that obtains a combination of all.

2.3 Summary of Research

Thanks to our time spent with Joseph and his father, we were able to get a clear idea of what they specifically wanted: a stroller focused on safety, comfort, and performance. Through our research on existing products, it appears that there are no strollers on the market that perfectly fit our customers’ requirements. However, during our design phase, we paid close attention to existing designs and adopted features that we found useful according to our customer’s needs. Some of the joggers could possibly be modified in order to fit all of Joseph’s specific needs but we would need to see the strollers in person to make sure. We are confident that with our abilities, this project will produce a jogging stroller for Joseph that suits his needs better than any other products on the market.

3.0 Design Development

This section of the report will discuss the steps our team followed in order to develop two full system concepts for Joseph's Jogger.

3.1 Concept Generation

After researching the needs and requirements for Joseph's new jogger, we took the key features of existing products to generate potential solutions. Before conceptualizing ideas for the jogger, the project was first divided into five subsystems: frame, seat, harness, footrests, and wheels. Mainly for the frame and seat subcomponents, we used SCAMPER (Substitute, Combine, Adapt, Modify, Put to other uses, Eliminate, Rearrange or Reverse features from the existing products and some of our other ideas). Note that when coming up with the final design idea, some ideas from each subsystem are not compatible with each other.

3.1.1 Frame

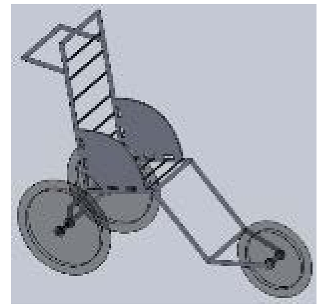
The frame needs to meet the customer's requirements. Thus, it must be easily transportable, lightweight, easy to push, safe, and require low maintenance. In addition, it must also have a low center of gravity, the correct body posture, and high strength. Building on these requirements we generated four different frame designs:

Design 1
Similar to the current jogger, the seat would be hanging from the frame rails with an aluminum bar underneath his footrest to add support. The difference in the bar's length is due to Joseph's leg difference.

Design 2
The main difference from Design 1, is that it eliminates the footrest support and has more of a wheelchair approach where the user would be at a more upright position.

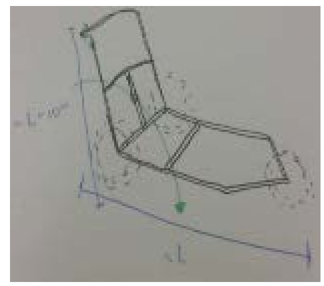
Design 3

This is inspired by the Hoyt running chair as described in the background. Instead of hanging from the frame as Design 1, the seat would overlay on top of heavy duty quick-release straps so that Joseph would experience minimal vibration and shock. On the sides of the frame are welded plates that would prevent Joseph's arms from hanging out of the seat while adding support to the frame.



Design 4

Adapting from the Ottobock Kimba Cross Jogging Stroller, the frame would be able to collapse to conserve space and can easily be converted into a bike trailer.

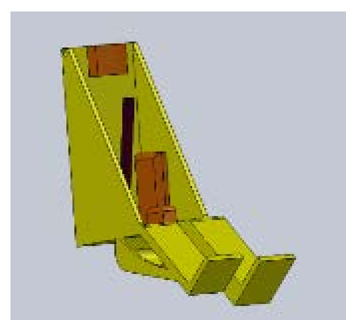


3.1.2 Seat

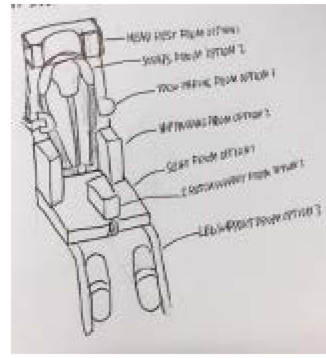
The seat must comfortably support Joseph's legs, crotch and torso in order to position his body correctly. It must also be weatherproof, easy to manufacture, and require low maintenance. Applying these requirements, we generated three types of seats:

Design 1

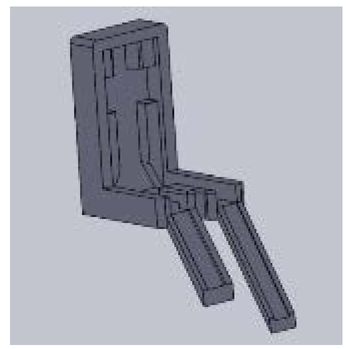
The seat would be made of memory foam layered between weatherproof fabric which would hang from the rails of the frame. The headrest is inspired from the headrest of the bike trailer which would prevent the head from slouching while providing comfort. It also has side bolsters to provide additional comfort to the arms, and an abductor post for crotch support. The legs of the seat are of different size and thickness to accommodate Joseph's different leg sizes.



Design 2
Similar to Design 1, it has all the features with the inclusion of a restraint system and pads on the sides of his torso to maintain his body in the correct posture. Joseph's legs would also be supported on pads; however, it does not include any foot support.



Design 3
Similar to Design 1, the seat uses padding that would support the torso with the legs again at different lengths to accommodate Joseph's different leg lengths. However, this seat is too difficult to manufacture and the outline is not ergonomic.



3.1.3 Harness

To prevent Joseph from slouching, it is necessary that his jogger has a harness. When designing a harness restraint, it must restrain his torso and reinforce crotch support. It must also be easy to buckle, comfortable, and avoid Joseph's bard button which is where he is fed from. Thus, our harness options are as follows:

Design 1
The harness is a four-point system that would provide minimal support; however, it does not reinforce the crotch support and avoid the barb button.

Design 2

This harness uses a five-point design that provides additional support for the user, reinforcing the crotch support, and has padded straps that makes it comfortable.

Design 3

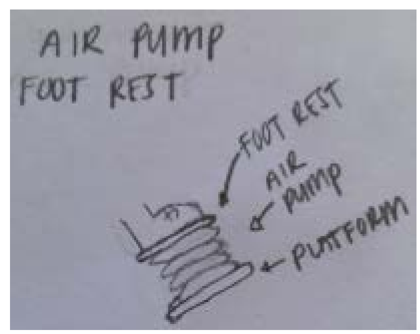
Similar to Design 2, the harness adds additional restraint for Joseph; however, it would be less comfortable because Joseph has a dislocated leg joint on his waist that is sensitive and the additional straps may disturb his waist.

3.1.4 Footrest

The purpose of the footrest is to prevent Joseph's feet from dangling from the frame and onto the ground or front wheel as well as reduce force against his crotch and abductor post when he extends. The footrest must be adjustable and have zero pinch points. durable, weatherproof, easy to manufacture, and require low maintenance.

Design 1

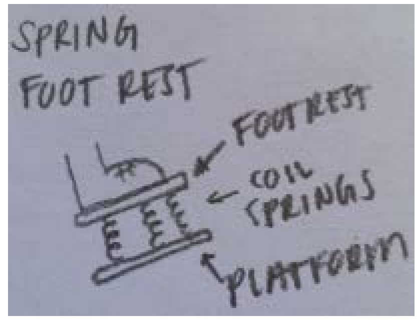
In order to reduce the force against the footrest, an air pump design was developed that would push air out of the pump whenever he applies force and inflate again by itself once it does not experience any forces.



Design 2

Using foam material, the foam would absorb the force against the footrest and regain its shape once the force is not applied.

Design 3
Using springs, the springs would absorb the force against the footrest and regain shape afterwards however would apply also a force on Joseph's feet greater than the previous designs.

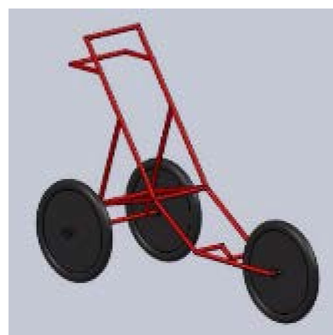


3.1.5 Wheels

When designing the jogger, it was important to recognize what wheel arrangement would be use which would dictate the frame, speed, cost amongst others.

Design 1
Like the current jogger and most other joggers, the front wheel will be stationary the front wheel smaller than the back wheels. The back wheels will also be in the same axial.

Design 2
Similar to Design 1, the only difference is that the wheels are the same size.



Design 3
Like in other strollers, there are four wheels where the back wheels are in the same axial while the front wheels are in different axials.

3.2 Idea Selection

We used Pugh matrices in order to select our best subsystems for Joseph's jogger. Pugh matrix is a tool that allowed us to weigh each subsystem based on a criterion rooted from the customer requirements. Because the Pugh matrix allows us to weigh each requirement based on priority, and use Joseph's existing jogger as the reference design, we were able to compare each design and calculate a numerical result. The design with the highest score proved to be the most convenient and is implemented on our final concepts. We identified the most critical features that make up the jogger; thus, we constructed a Pugh matrix for the frame, seat, harness, footrest, and wheels. We concluded that these were the top five components that need the most attention based on our observations and interviews with John, Michael, and Joseph. Other features such as the braking system and handle are still in need of designing; however, our engineering intuition tells us that these features will be very similar to the existing. Hence, they will be decided with a simple group consensus.

3.2.1 Frame

Appendix A, Figure A.2 shows the complete Pugh matrix for the frame. Design 1 scored the highest with a total score of 33. Design 1 has a similar geometry to Joseph's existing jogger, but our goal is to optimize it in order to make it lighter in weight while keeping its strength. His current jogger weighs 40 lbs., and our goal is to make it at least 5 lbs. lighter. Unlike his current jogger, Design 1 is wider in order to hold a seat with more padding that will maintain Joseph in the correct body posture. In addition, Design 4 was the second top choice and because it scored relatively high, as a group we decided to consider it as a final concept as well. Design 4 is highly influenced by the Hoyt Jogger and allows the seat to overlay instead of suspend from the frame as Design 1. Due to their different arrangements, Designs 1 and 4 will determine the way our final seat attaches. Hence, from the frame matrix, we concluded that Design 1 and Design 4 are both worth further analysis.

3.2.2 Seat

Appendix A, Figure A.3 shows that Design 1 and Design 2 resulted as equally competitive by providing our customers with the upmost of each requirement with the exception of collapsibility. Both concepts were designed with keeping two things in mind: safety and body posture. Thus, our top two designs revolve around the idea of keeping Joseph safely aligned as he is in motion. Subcomponents such as the head, lateral, and crotch support are to guide Joseph's body into a fixed position. Moreover, the knee placement and leg support are intended to suit Joseph's 2in. difference in leg length that results from his right leg not connecting with his right hip. In addition, padding at the sides were included in order to keep Joseph from leaning to one side and placing too much pressure on his right hip as is the situation with his current jogger. Design 1 compliments frame Design 1 as it is designed to suspend from the frame; while, Design 2 is compatible with frame Design 4 as it overlays on the frame. Both Designs 1 and 2 will be further analyzed in order to conclude our final seat concept.

3.2.3 Harness

Appendix A, Figure A.4 concludes Design 2 as the most appropriate harness design based on our customer's requirements. Design 2 is a combination of the advantages of Designs 1 and 3 since it provides a reliable restraint on the torso, but is also easy to buckle. It is also very similar to Joseph's existing jogger, but shows to be more firm due to its thicker padded straps. In addition, it includes crotch reinforcement which will decrease Joseph's tendency to slide off as he often does in his current jogger. This concept will contribute to keeping Joseph comfortably aligned and prevent him from pushing forward when riding downhill. Most importantly, it should not obstruct Joseph's bard button which is where his gastronomy tube connects. Design 2 proves to keep Joseph safe and protected; therefore, it is the chosen design for Joseph's jogger.

3.2.4 Footrest

Appendix A, Figure A.5 shows Design 2 as the most convenient footrest arrangement. Design 2 integrates foam between the footrest and the jogger's platform. When Joseph is uncomfortable in his jogger, he stretches his body and places a large amount of force on the footrest requiring John to make repairs. Consequently, we plan to build a footrest that will tolerate a minimum of 100lbs. of distributed load. Thus, foam seems to be appropriate because it will absorb the energy exerted by Joseph and prevent the platform from fracturing. It is also easy to obtain. Moving forward, we will inquiry the type of foam and fabric that will work best with the weather as this is our only concern.

3.2.5 Wheels

Appendix A, Figure A.6 shows Design 1 as the best wheel combination. When deciding on the wheel arrangement for Joseph's jogger, our criteria included important requirements such as balance, performance, and low maintenance. Design 1 scored the highest and proved to be slightly better than Joseph's existing jogger. Design 1 entails the rear wheels to be 20in in diameter, while the front wheel is 16in. in diameter. This pattern will provide the jogger with stability. In addition, as requested by our customers, John and Michael, the front wheel will be stationary. The tires will also be pneumatic in order to help dampen the impacts from the road. Hence, Design 1 is our chosen arrangement for the wheels on Joseph's jogger.

3.2.6 Summary

Using Pugh matrices, we have concluded that Joseph's jogger will include a five-point harness (Harness Design 2), foam at the footrest (Footrest Design 2), and a three pneumatic wheel arrangement with two 20in. rear wheels and one 16in. stationary front wheel (Wheel Design 1). However, from the Pugh matrices we were left deciding between Frame Designs 1 and 4, and Seat Designs 1 and 2. In order to build the best jogger for Joseph, we discussed our concepts with Michael and John. They were worried that Frame Design 4 would not be able to provide sufficient side protection. Thus, their feedback resulted in the combination of Frame Design 1 and Seat Design 1 as our final arrangement.

3.3 Full system Concepts

Two full system concepts were chosen based off of the highest scoring subsystem ideas from our Pugh matrices. These two concepts are shown below in *Figure 3.3.1 and Figure 3.3.2.* The following section will discuss the technical feasibility of our two proposed system concepts. The frame, seat, wheels, harness, foot platform, and brakes will be discussed in detail.

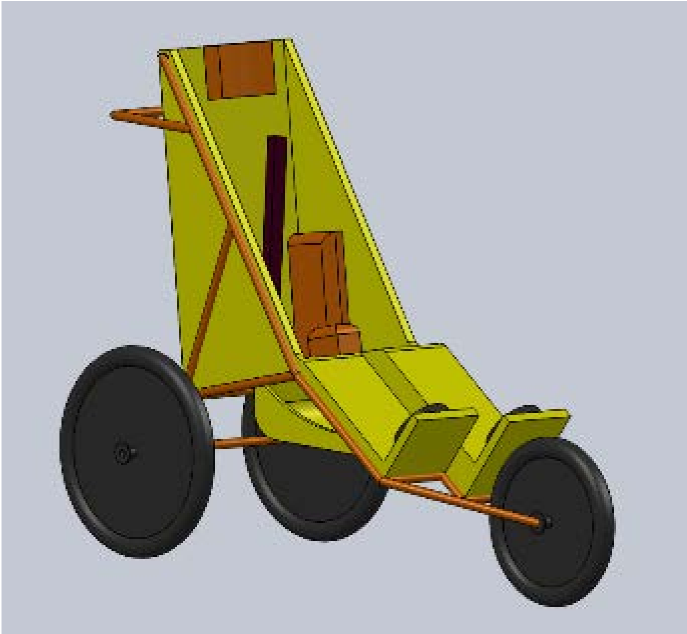


Figure 3.3.1: System Concept 1

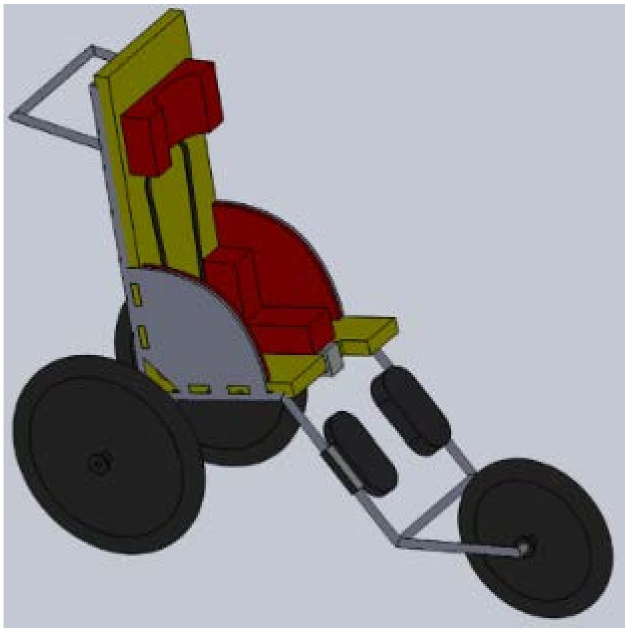


Figure 3.3.2: System Concept 2

3.3.1 Frame

The proposed frame for both concepts is an exoskeleton design that surrounds and protects the occupant. The seat will be hung/supported by the frame and attached at specified locations to give it a defined and permanent shape. In order to make the frame lightweight, strong, and corrosion resistant, we propose to use 6061 aluminum tubing. The current CAD models of the stroller and the subsequent stress analysis studies are all modeled using 6061 Aluminum tubing with the following dimensions:

Outer Diameter = .84” Inner Diameter = .62” Wall Thickness = .11”

Two FEA (finite element analysis) studies were conducted for each of our top frame concepts in order to estimate the stress distribution under prescribed loading conditions, and to predict whether the frames would fail. The first simulation modeled Joseph as a 100-pound person sitting stationary in the jogger. As seen in *Figures 3.3.1.1 and 3.3.1.3*, the stress never reaches the yield stress, it is actually lower by an order of magnitude. Therefore, the jogger does not yield or fail. The second simulation modeled the jogger being in motion and the operator pushing down on the handlebars in order to execute a turn. As is seen in *Figures 3.3.1.2 and 3.3.1.4*, the jogger is once again in a safe stress zone and does not yield. From these two simulations we concluded that both frame designs are realistic options that will be able to handle the expected loads. We were also able to see where the stress concentrations would be on the designs as demonstrated in *Figure 3.3.1.5*. This allowed us to foresee areas the frame that might need to be overbuilt. In terms of manufacturability, these frames should not offer any challenges to an experienced welder. The majority of the tubes are straight and there are no tight joints that are too small for a welding torch. The most difficult tube to manufacture and join will be the long tube that runs from the handlebars to the front wheel (denoted by the blue arrow in *Figure 3.3.1.5*). Ideally this tube would run straight to the front wheel with minimal bends and welds for maximum strength. However, for Frame Design 1, two bends or two welds are necessary. We need to further investigate whether it is stronger to have one long tube with two bends, or a long tube composed of three welded segments to accommodate the geometry. Currently the frame is modeled with the latter.

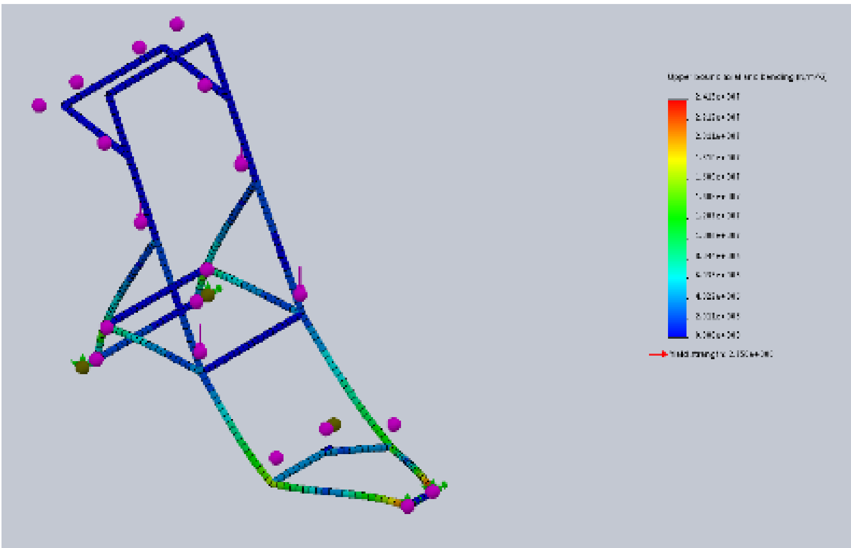


Figure 3.3.1.1: FEA model of Joseph sitting in frame #1 without any other forces acting on jogger. Joseph is modeled as being 100 pounds and the jogger does not yield.

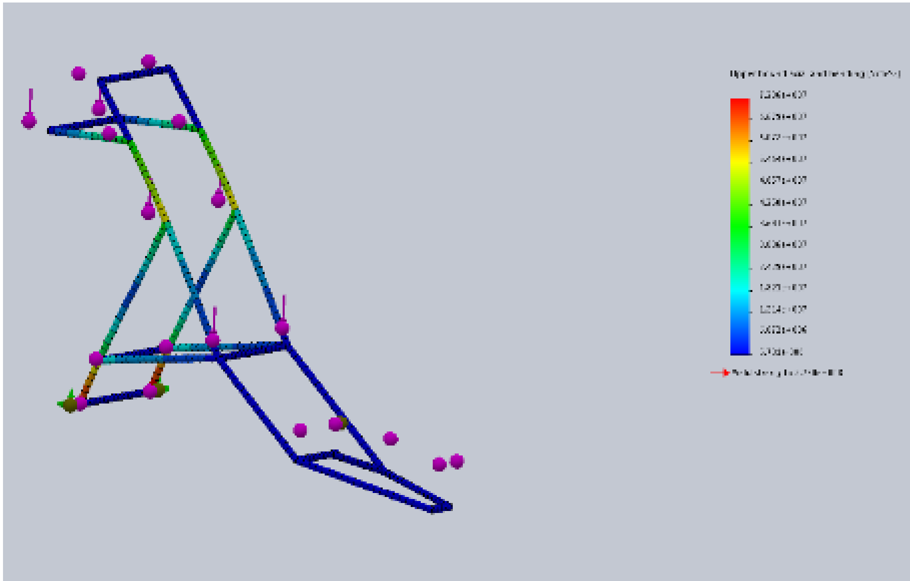


Figure 3.3.1.2: FEA model of frame #1 under the scenario of executing a moving turn. The operator pushes down on the handlebars with Josephs 100-pound load still present. The jogger does not yield.

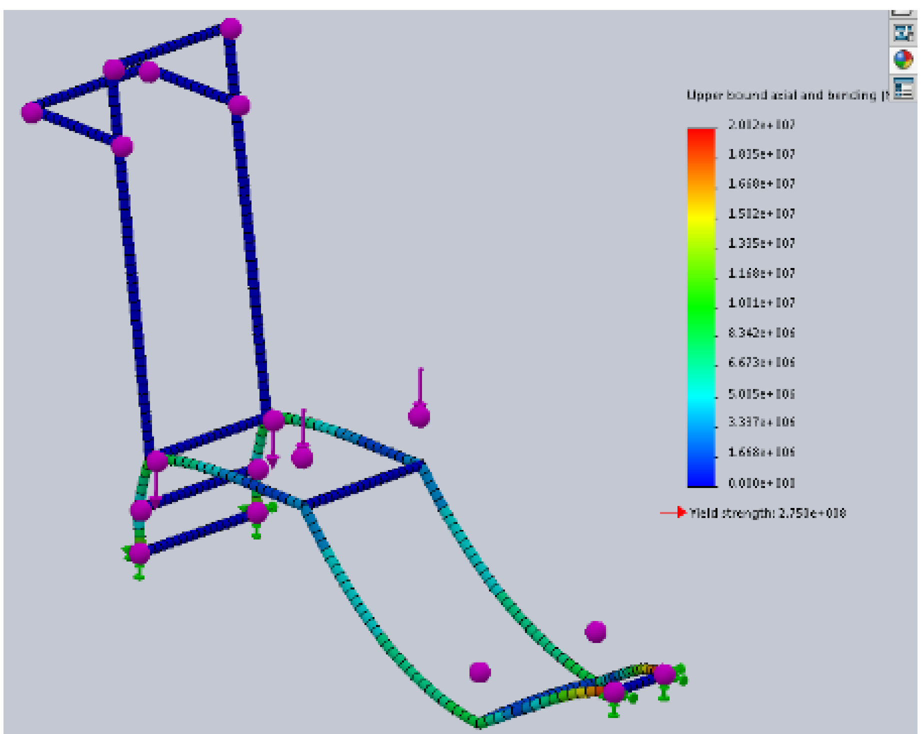


Figure 3.3.1.3: FEA model of Joseph sitting in frame #2 without any other forces acting on jogger. Joseph is modeled as being 100 pounds and the jogger does not yield.

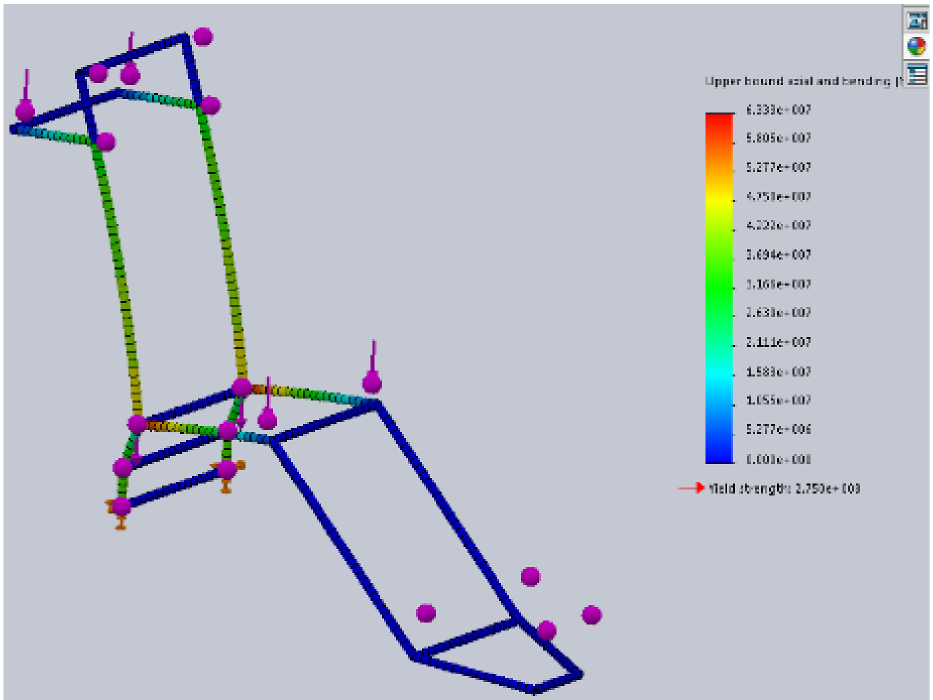


Figure 3.3.1.4: FEA model of frame #2 under the scenario of executing a moving turn. The operator pushes down on the handlebars with Joseph's 100-pound load still present. The jogger does not yield.

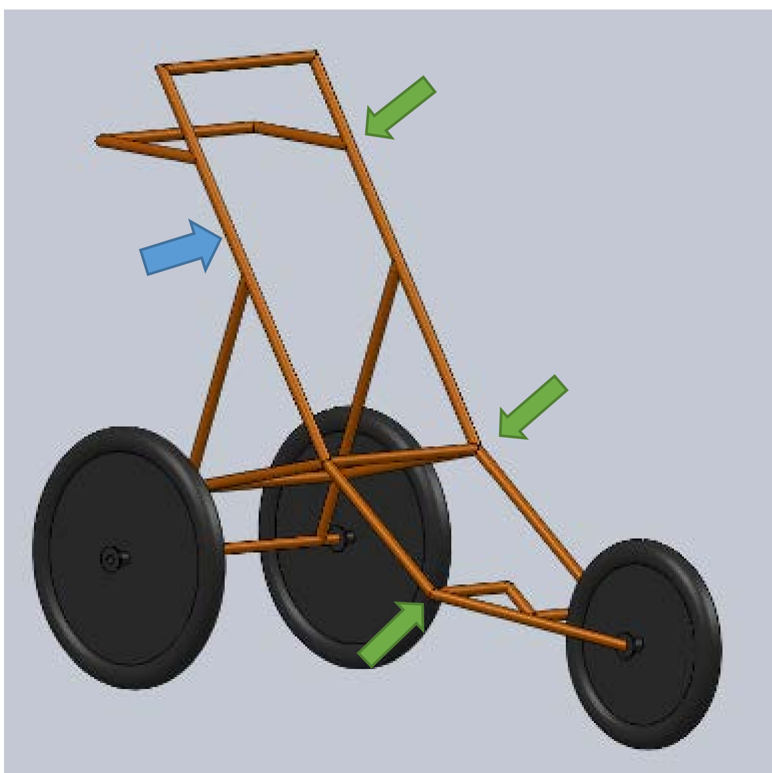


Figure 3.3.1.5: Proposed frame #1 for Joseph's Jogger with green arrows denoting areas of stress concentration.

3.3.2 Seat

Both of our proposed systems use a fabric seat suspended from the frame rails and attached at the lowermost corners to anchors on the frame in order to give it shape. The seat will attach to the frame rails in the manner shown in *Figure 3.3.2.1*. This method of mounting the seat is used on strollers such as the highly rated BOB stroller. For the seat construction, a layer of foam padding will be sandwiched between two sheets of weatherproof fabric. This type of seat is used by the Hoyt Running Chair so we know that it is a feasible option. Additionally, many car upholstery shops are capable of making seats like the one we propose. One such shop, Mitch's Stitches, has been recommended to us by our advisor after having helped sew a seat for a previous Cal Poly senior project. Thus, we have met with Mitch and consulted both seat designs. He informed us that neither seat should be disregarded due to fabrication purposes, for both are feasible.

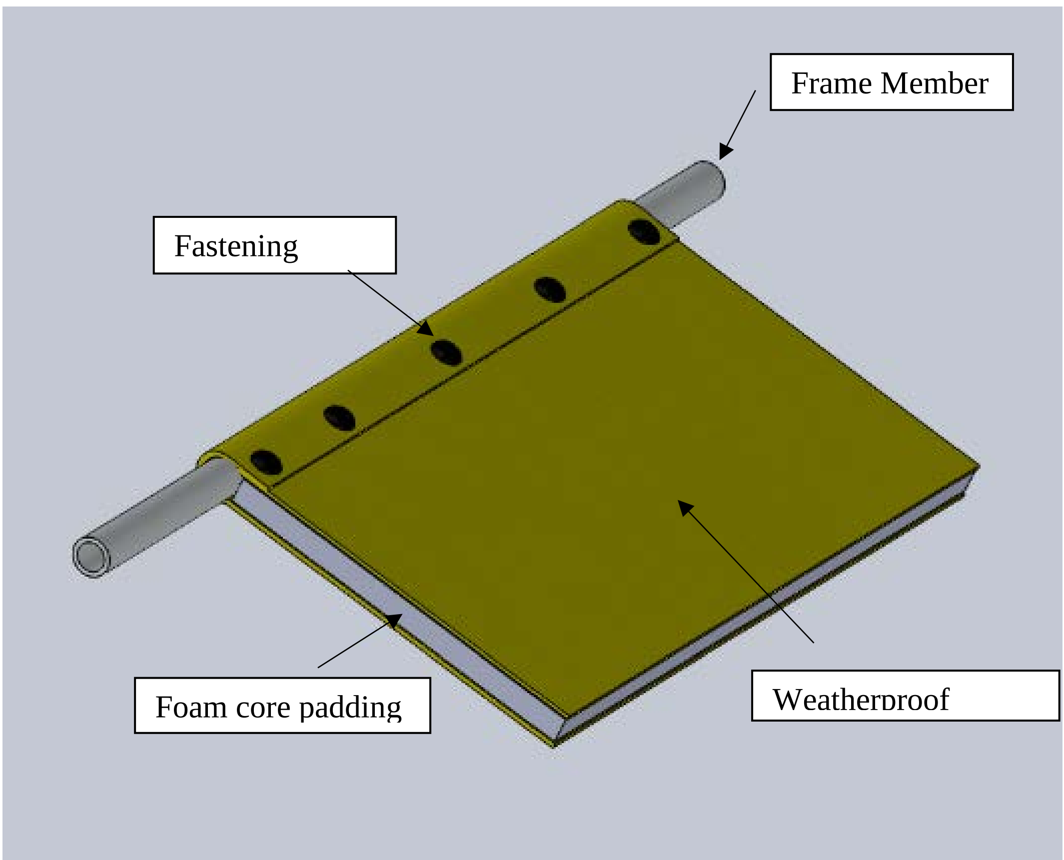


Figure 3.3.2.1: Attaching seat to the frame rails

3.3.3 Harness

The chosen harness is installed by sewing part of it to the seat, and by interlacing the other part to the frame. The sewing will once again be done by Mitch's Stitches and should be a simple job. The part that attaches to the frame will be interlaced through the Velcro straps that attach the seat to the frame.

3.3.4 Foot Platforms

A high risk location on this stroller for failure is at the foot platforms. Due to his high muscle tone, when in an unsettled state Joseph exerts a substantial amount of force with his legs which is then translated to his feet. It is not an option to let his feet float freely because he needs them to be supported for comfort and safety. In place of a rigid foot platform, we have inquired a low modulus padded platform that will support his feet when he is calm, and then deform to absorb energy when he extends his legs. Different foam materials are readily available and can be molded and covered in weatherproof material by upholstery shops to meet our needs. Selecting the right foam for the padding was very important. The ideal foam would have the same feel of a tractor or car seat. Apart from selecting the correct foam for the job, no technical challenges were encountered for the foot platforms.

3.3.5 Wheels and Braking

The proposed jogger designs will use three wheels in delta configuration. The rear wheels will be 20 inches in diameter, and the front wheel will be 16 inches in diameter. All three wheels will have pneumatic tires in order to dampen road impacts for a smoother ride. The jogger will also have a disc brake system mounted on the front wheel. This requires an aftermarket front wheel because currently there are not disc brake ready 16” rims on the market. This challenge is easily overcome with the help of a wheel builder. A disc brake compatible bike hub can be purchased, and built up with a 16” rim to accommodate our needs. The caliper would connect with a mount off the frame rail. The 20 inch wheels could be built up with high quality bicycle components if the budget permits. If the budget is low though, there are existing 20” wheels made by Burley that can be purchased cheaply. The front wheel can be mounted with standard bicycle dropouts which are easily welded on to the front frame members. The back wheels are slightly trickier to attach because they mount to the outside of the frame. Therefore, a removable thru axle system will be used that extends thru the wheel hub and into the cylindrical frame tubing. Custom made thru axles will need to be made that are easily removable in order to take off the rear wheels quickly for transport. The design of this thru axle will require some more thought but we do not expect it to very hard. If the budget is low and we choose to go with the Burley wheels, the company actually offers a thru axle that is compatible with the wheels.

4.0 Final Design

This section covers details of each component of our final design as well as the manufacturing plan in order for our designs to take shape.

4.1 Frame

In our PDR report, we stated that we would be using high strength 6061 Aluminum tubing for the frame. Preliminary FEA analysis showed promising factors of safety under different loading conditions which led us to believe that this would be a good material to use. However, upon consulting various metal fabricators, we learned that aluminum welded joints are very weak unless they are heat treated. The strength of a welded aluminum joint is about 50% that of the actual structural material because the strength of the weld is governed by the strength of the filler material. In order to prove this, we tested the strength of a weld that had not been heat treated. The results are shown below in *Figure 4.1.1*.

Figure 4.1.1: Demonstration on how the strength of an aluminum weld is governed by the filler material.

By heat treating the entire aluminum frame, it is possible to reduce the effects of the heat affected area and bring the strength back up to the T6 rating. However, heat treating the entire frame would be a complicated process because it consequently results in warpage. In order to control this warpage, a jig would have to be made and would result in increased cost and labor. Many of the fabricators we talked to suggested that we use steel, more specifically 4130 Chromoly Steel. 4130 Chromoly Steel is commonly used in bicycle frames where max strength and low weight is required. This material actual results in lightweight frames because its high strength allows thin walled tubing to be used. Although it is much more dense than aluminum, the thinner walled tubing results in lower overall volume which yields a frame of comparable weight. The biggest benefit of using Chromoly over Aluminum is that there is no significant decrease in strength after welding, thus no heat treatment is required. By experimenting with different size Chromoly tubing, we were able to exceed the strength of the previous frame iteration while at the same time maintaining the same overall design. The final frame design is shown below in *Figure 4.1.2*.

Figure 4.1.2: Final frame design made with high strength 4130 Chromoly steel tubing.

The frame largely determines how the jogger will perform and feel. From talking to John, we discovered that he liked how the existing jogger performed. By making certain measurements on our jogger match up with those on Joseph's Axiom Star, we can assure that it will perform to John's liking. *Table 4.1.1* and *Figure 5.1.3* highlight a few of these key measurements. The most noticeable difference between our jogger and the existing jogger is that the wheelbase and track width are 3 inches and 6 inches wider/longer respectively. This will result in a more stable, and safe jogger. It will not make the jogger harder to turn. The ease of turning is related to the horizontal distance of the center of gravity from the rear axle. The Center of gravity of the stroller-occupant interaction is determined by the location of the “L” of the seat which positions the occupant’s body. By keeping the “L” of the seat the same horizontal distance from the rear axle and by maintaining similar handlebar geometry, we can mimic the required force to turn the stroller.

Table 4.1.1: Comparison of Joggers

*With wheels On	**Adaptive Star** (Inches)	**Trek Jogger** (Inches)
Max Width	27	30
Max Length	55	61
Max Height	52	44
Highest Handlebar	45	45
Lowest Handlebar	35	35
Back Axle to Front Axle	33.5	40
height of Seat L from Ground	20.5	16
Back Axle to Handle Pivot	12.75	13
Handle Bar Radius	6.5	6
Weight (Pounds)	32	33

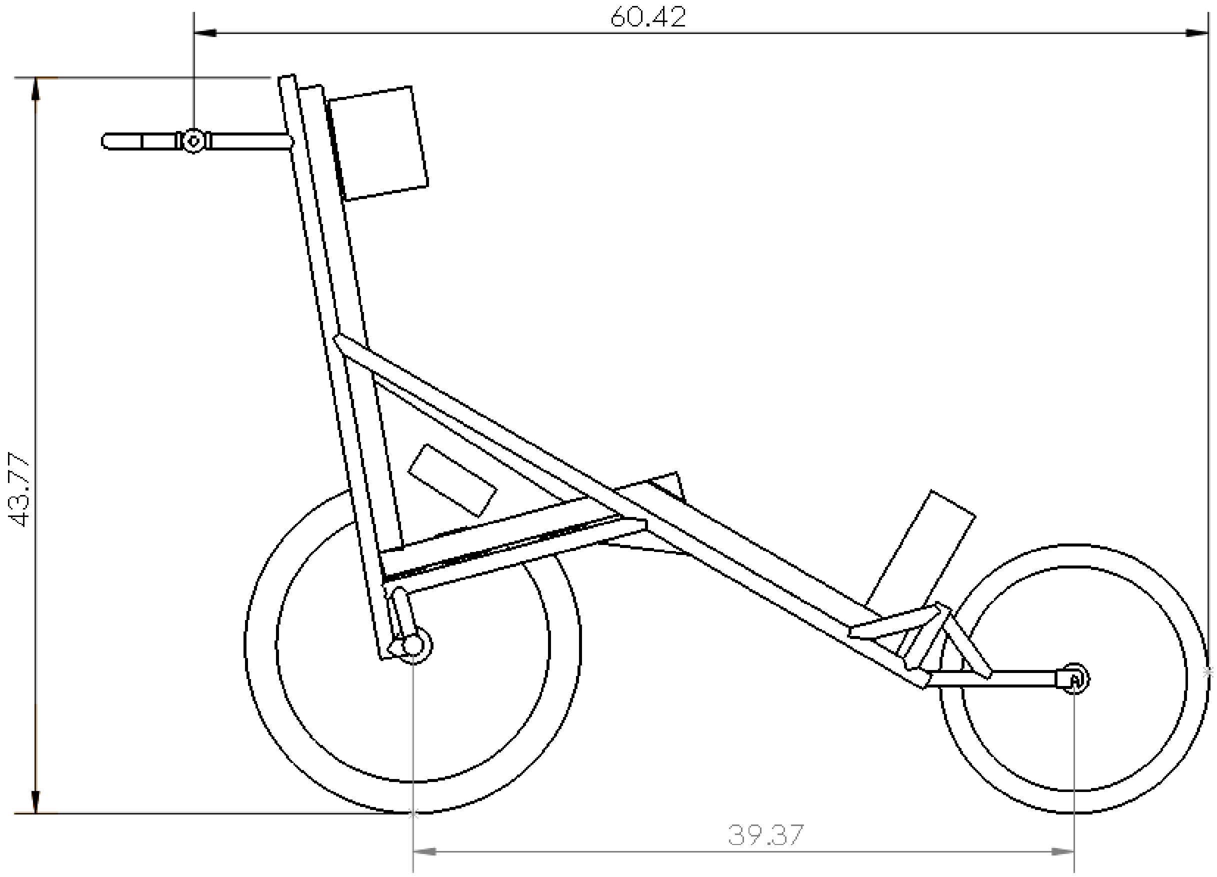


Figure 4.1.3: Key Jogger Measurements

In order to verify that this frame would be safe and strong enough for Team Joseph, we conducted various FEA simulations under extreme loading situations. Using 4130 Chromoly Steel Tubing with a yield strength of 4.6 E8 Pascals, our minimum factor of safety was 6. The minimum factor of the Aluminum frame subjected to similar loading situations was 3 when taking into account the weakness from the heat affected area. Therefore, based on our simulations, steel is confirmed to be the better material for the frame. The results of our FEA studies can be seen in Appendix I.

In Case 1 (*Figure I.1)* Joseph is modeled as weighing 100 lbs. (actual weight is 80 lbs.) and is sitting in the jogger. Whoever is pushing the jogger wants to make a turn so they push down on the handlebars which makes a moment at the handlebar joint of approximately 20 foot pounds or 40 pounds force downwards. This will be an extremely common loading situation present on every run. The stress is found to be concentrated at the rear axle. The minimum safety factor in this case is 7.

In Case 2 (*Figure I.2*) all of the wheels are fixed in place and 40 pounds of downward force is put on the handlebars. This simulation proves that main frame rails are over engineered for safety. In a realistic setting, the front wheel would come up off the ground and therefore very minimal force would be experienced by the frame rails. In this situation, the minimum safety factor is 9.

Case 3 (*Figure I.3*) models a scenario of loading Joe into the jogger. When loading him into the jogger, sometimes Josephs entire weight will be concentrated on the center point of the frame. Again modeling Joseph as weighing 100 lbs. and putting his entire weight on the center cross member, our minimum factor of safety is 6.3. This is a very strenuous, but important and realistic simulation. This loading situation was one reason why the aluminum was rejected as a material. At the center point of the frame where the cross member attaches, it is welded which would have resulted in a significantly weaker aluminum joint due to the heat affected area.

Case 4 (*Figure I.4*): When he is uncomfortable, Joseph will extend his legs and body, thus exerting force on the stroller with his back and his feet. Here Joseph is modeled as weighing 100 pounds and exerting a force of 100 pounds in the plane of the stroller down tube. In the existing stroller, Joseph was able to break the footrest when he extended so we made sure to pay careful attention to this scenario. The minimum factor of safety for this instance is 21.

Case 5 (*Figure I.5*): This is an unlikely loading situation in which Joseph, modeled as 100lbs, is essentially standing on the footrest. This simulation shows that the fork tubes are strong enough to withstand this brutal loading. We see that the stress concentration actually moves away from the fork tubes and is instead on the downtube of the frame. The thicker tube on this segment of the frame is designed to handle to loading and results in a minimum safety factor of 10.

When we were testing out Josephs existing Jogger, one thing that we noticed was that there was a lot of play in the handle bar. The handle bar rotates and locks on a hinge in order to allow different height people to push it and the play was most likely due to a low quality hinge. We did not want to have this same issue so our handlebar hinges will be high quality, aluminum hinges purchased from ATL (Advanced Locking Technologies). These hinges are each rated for a torque of 500 inch-pounds with a 5:1 safety factor so they are more than strong enough for our application. The hinges are shown in *Figure I.6.*

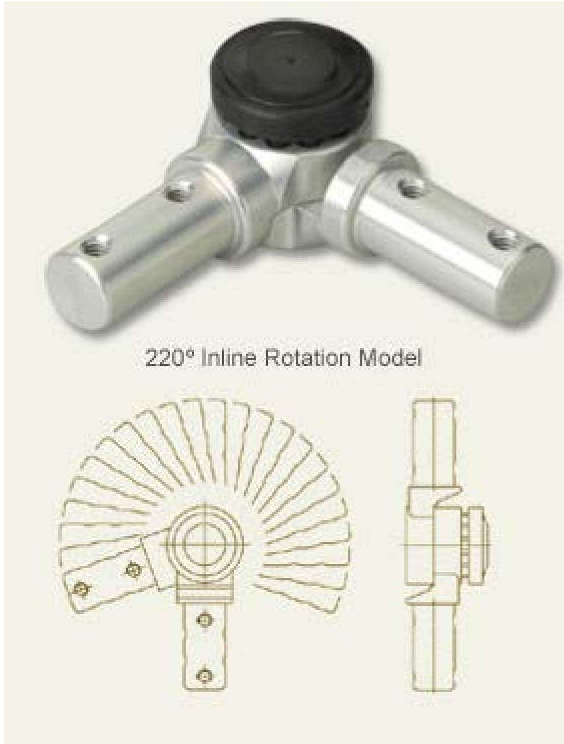


Figure 4.1.4: ATL Aluminum Locking Hinge

Manufacturing the frame is expected to be one of the more challenging aspects of this project due to its complex geometry. In order to facilitate the process, the frame was divided into 4 groups as shown in *Figure 4.1.5*. The purpose of doing this is so that the two sides that make up the frame are in one plane, that is, they can be welded on a flat surface to ensure straightness. The other sub weldments mount up at 90 degree angles which can be easily measured and jigged. Another benefit of building the frame in a manner that uses single plane assemblies is that 1:1, full scale drawings can be printed out to provide guidance to the welder. The first step in the manufacturing process is to prepare all of the tubes. With round tubing, in order to ensure a close and tight joint, the ends must be mitered. Mitering is a process where the end of a tube is cut using a hole saw of the same diameter as the outside diameter of the tube to be welded to. These miters must be very accurate because when using thin walled tubing such as our .035 inch wall, it is difficult to fill large gaps. The tubes will then be arranged according to 1:1 printout if possible or detail drawings when not in one plane. They will be tacked in place and then TIG Welded until structurally sound. The final parts to be added to the frame will be the dropouts and the foot platform. These two parts will also be welded to the frame.

Once welded, the frame will need to powder coated. Unlike aluminum, 4130 Steel will begin to corrode and rust when subjected to the elements, especially in a salty environment such as Los Osos where Team Joseph calls home. Powder coating is a high quality painting process that will enhance the visual appeal of the stroller while also protecting the frame from the elements. The frame will be painted either red or yellow to match team Joseph's colors. The final decision will be left up the Team Joseph.

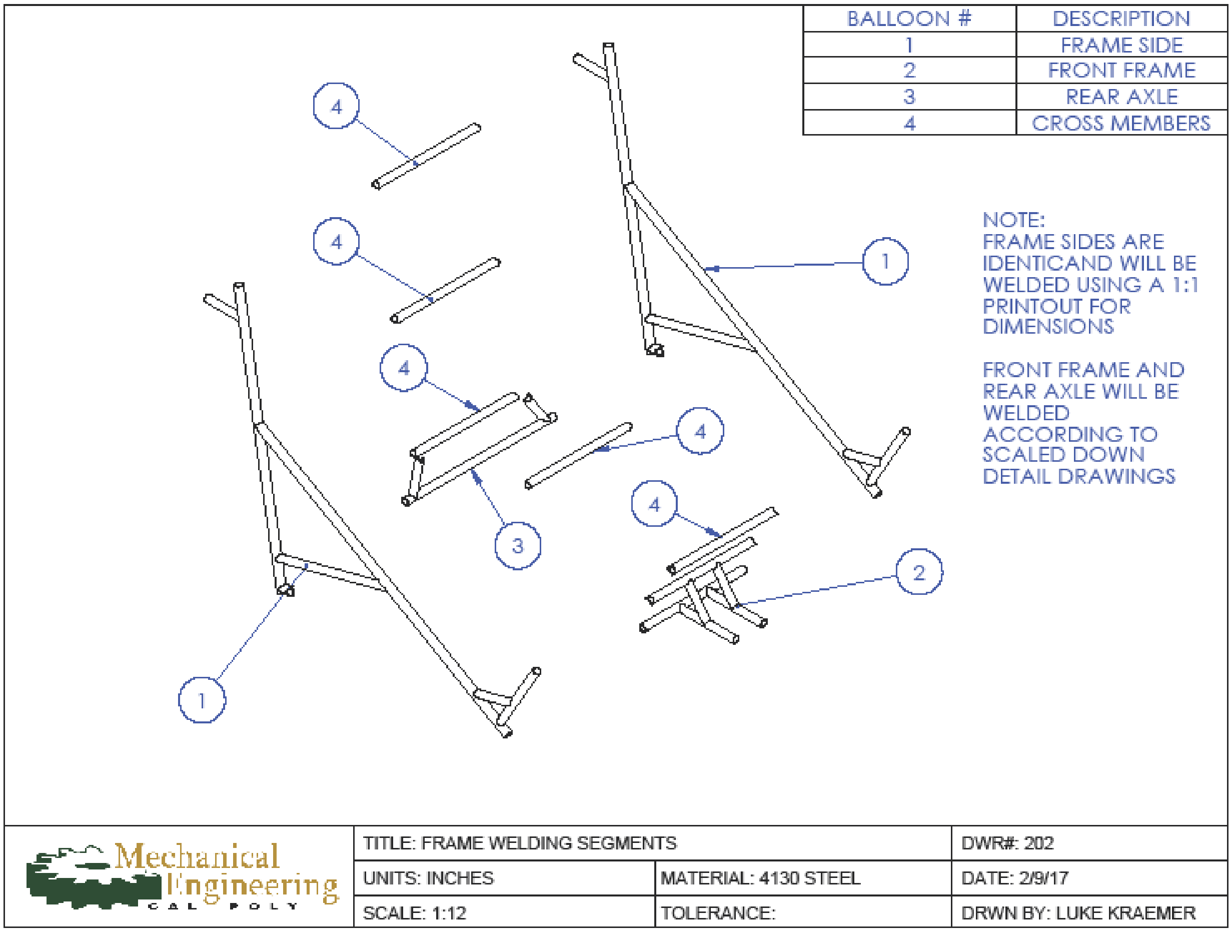


Figure 4.1.5: Sub-Groups of Frame for Welding

4.2 Seat

The seat is divided into individual parts: upper seat cushion, lower seat cushion, headrest, thigh cushion, leg bolster, and footrest cushion as seen in *Figure 4.2.1* below. The headrest will help maintain his head from sliding to the side as well as provide comfort. The two thigh cushions will help maintain his position on the seat while giving comfort to his thighs as well as a location to rest his arms. The leg bolster will help adjust his right leg length by displacing about 2 inches.

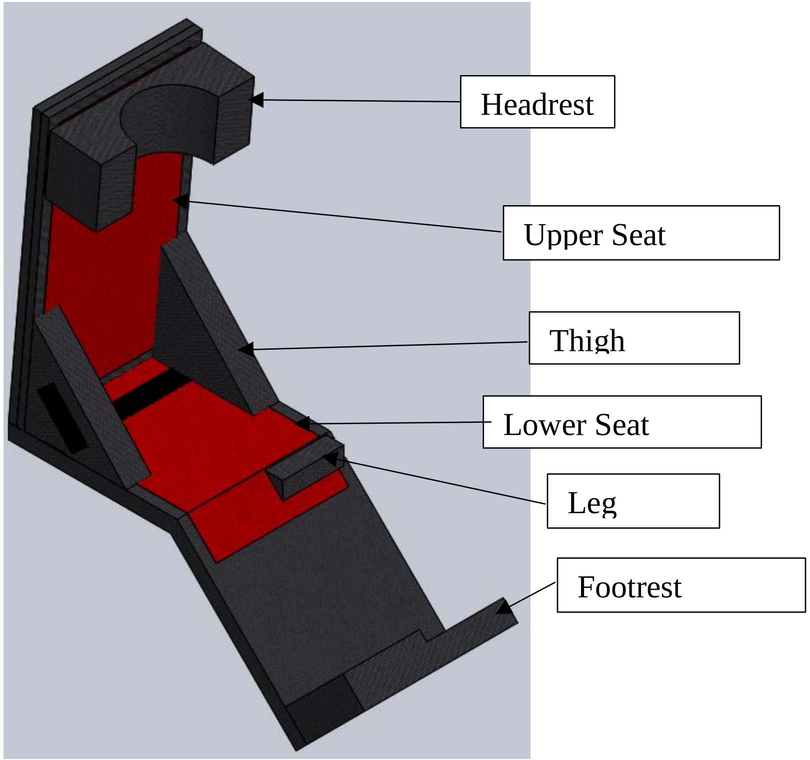


Figure 4.2.1: Final Seat Design

The seat is design to be modular as each part of the seat can be individually removed in case they need to be replaced or washed. They are attached to the frame by a strap system using Velcro as shown in *Figure 4.2.2.* The straps, which are rated with an 800-pound strength, were originally conceived to be attached to the frame by looping around the frame and buckling them, tightening the straps with a square glide. However, we were concern straps will loosen over time as noted on the current jogger as a back strap originally used to adjust Joseph's position was tied to the frame instead as the large force that Joseph exerted on it would loosen the strap. Instead, the strap ends will loop around a bar and sewn shut.

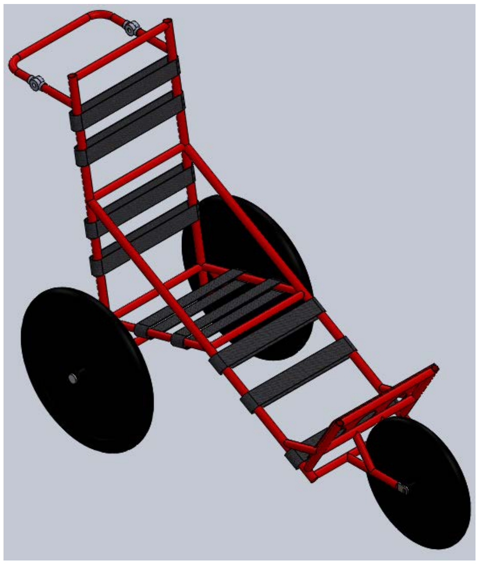


Figure 4.2.2: The frame with strap attachments where the seat will lie upon, attached by Velcro.

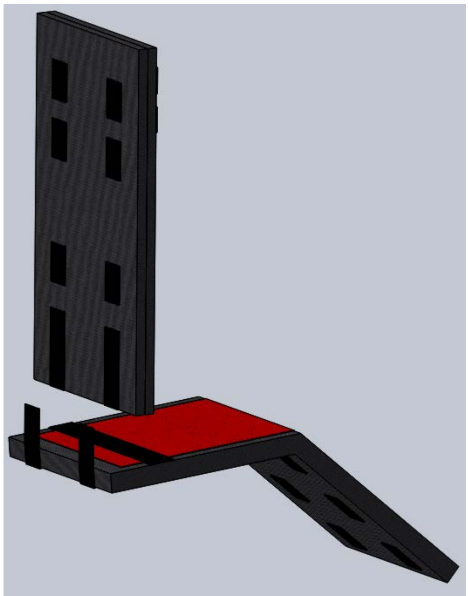


Figure 4.2.3: Method of Attachment for the Upper and Lower Seat Cushion.

The upper and lower seat cushions are also attached by Velcro as shown in *Figure 4.2.3* in order to leave a gap in the middle for the harness to pass through which will be explained in further detail in the Harness section. The upper and lower seat cushion were originally planned to be made from high density memory foam as memory foam is excellent in absorbing shocks and conforms to the shape of the body without having pressure points. However, we were greatly concerned with its heat retention as the foam grows warmer and softer after a period of time making it uncomfortable during long runs or warm days. Gel infused memory foam was then considered for it cooling properties but is only a temporary solution as it just slows down the heat retention process. After discussing with disability resource center assistive technology specialist John lee and kinesiology department director Kevin Taylor, they recommended that the seat be made from ensolite foam which is also excellent in absorbing impacts and has less heat retention. Due to the firmness and excellent shock absorbing properties, it was decided it be more suited for the back which requires more support. For additional comfort, the ensolite foam will be layered with Latex rubber foam that is typically used for high end seating. The latex foam was selected because its high resilience and longevity which can span to 30 years while having pin holes which helps dissipate heat. We tested the latex foam under weights and it was able to take back shape almost instantly. The lower portion of the seat does not require as much support so it will just be made from latex.

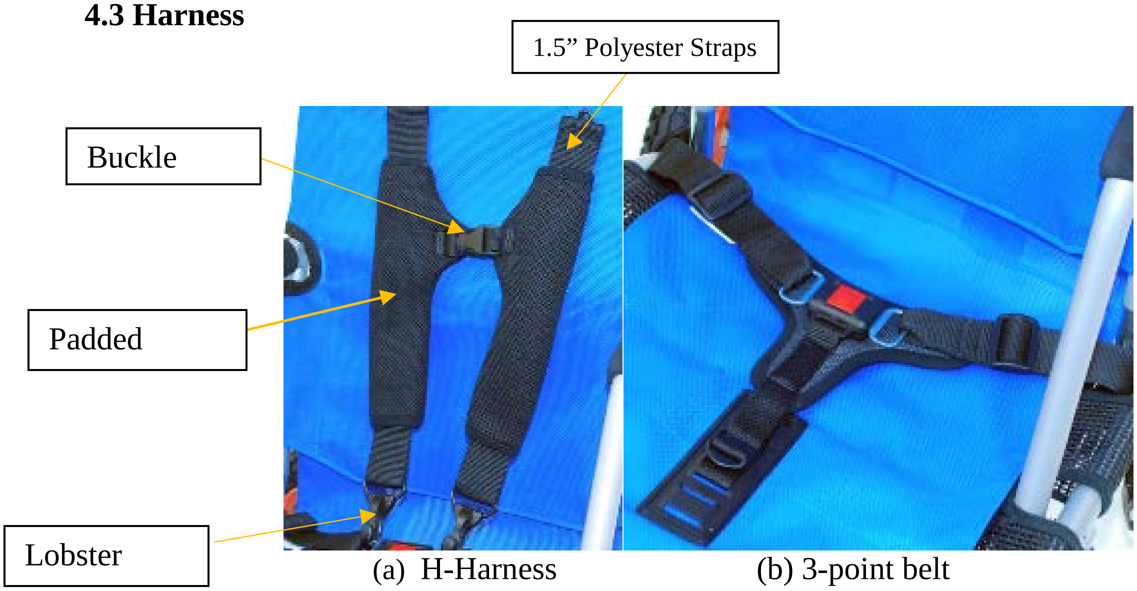
The headrest, thigh cushion, and leg bolster will be made from a high resilience foam as is used in high quality seats and is easily attainable if they need to be replaced. The footrest cushion will be made of ethafoam as it provides excellent cushion protection against persistent shocks which will help reduce the impacts. A Velcro strap will be sewn onto the frame that will Velcro around Joseph's feet to prevent it from slipping. A concern during foam selection was that the foam would absorb water during rain if accidently left out. To meditate this, the foam will be wrapped with a thin, noiseless sheet of plastic to act as a water barrier. Additionally, the seat will be upholstered with water resistant canvas fabric. The seating area will also be lined with spacer mesh to add airflow to the seat for additional cooling while also looking aesthetically pleasing.

The ensolite foam and ethafoam will be supplied by Adaptive Paddling Program (APP) in Cal Poly and the latex and high resilience foam will be supplied by foam online. The seat will be upholstered in Mitch's Stitches in San Luis Obispo. The cost of the seat assembly is shown in *Table 4.2.1*. For full detail design of the seat see Appendix B.

Table 4.2.1: Seat Assembly Cost

Item Description	**Supplier**	**Quantity**	**Cost**	**Tax**	**Shipping**	**Total Cost**
Upper Seat Ensolite Foam	APP	1	$0.00	$0.00	$0.00	$0.00
Upper Seat Latex Foam	Foam Online	1	$10.40	$0.94	$13.00	$24.34
Lower Seat Latex Foam	Foam Online	1	$24.51	$2.21	$0.00	$26.72
Headrest HR Foam	Foam Online	1	$9.46	$0.85	$0.00	$10.31
Thigh HR Foam	Foam Online	1	$6.31	$0.57	$0.00	$6.88
Leg Boaster HR Foam	Mitches Stitches	1	$0.00	$0.00	$0.00	$0.00
Footrest Ethafoam	APP	1	$0.00	$0.00	$0.00	$0.00
Silk Film	Sailrite	1	$15.95	$0.00	$12.39	$28.34
2" Velcro	Amazon	2	$16.99	$1.53	$3.99	$45.02
2" Polyester Straps	Amazon	2	$14.99	$1.35	$3.99	$40.66
Canvas Fabric	Amazon	2	$5.49	$0.49	$0.00	$11.97
Seat Labor	Mitch's Stitches	1	~$900.00	$0.00	$0.00	$900.00
Overall Total Cost						$1094.24

4.3 Harness



(a) H-Harness (b) 3-point belt

Figure 4.3.1 5-point Harness

During our design phase, we agreed on going with a 5-point harness that will keep Joseph from leaning or sliding off his jogger. *Figures 4.3.1a & 4.3.1b* show the H-harness and 3-point belt that will go on Joseph's jogger. We will purchase the 3-point belt from Convaid, a company that manufactures joggers for children with special needs. Because Convaid manufactures wheelchairs for children, they do not carry complete 5-point harnesses for individuals over 65lbs. Hence, they recommended that we purchase an H-harness and 3-point belt that will satisfy Joseph's weight of 75 lbs. However, the H-harness alone is priced at $149. Thus, we decided to purchase the materials and have our upholster, Mitch from Mitch's Stitches, sew it together. We will provide Mitch with 1.5 in. black polyester straps, plastic lobster clips, padded covers, and a side release buckle strap. When deciding what straps to purchase, polyester and nylon webbing were our choices. As seen in Appendix H, we calculated an impact force on Joseph of 172.55 lbf. in the case of a sudden stop. We decided to move forward with polyester webbing not only because it has a larger breaking strength than nylon, but also because it is a lower stretch material compared to nylon. Polyester webbing stretches between 5-15% whereas nylon stretches between 20-30% [6]. Thus, in the case of a sudden stop, we would like Joseph to experience minimal forward motion. Although nylon might be able to handle the preceding cases, we were discouraged by its ability to absorb water. Unlike nylon, polyester webbing experiences limited water absorption; thus, John should not expect any mold or mildew due to the jogger's exposure to the rain. Moreover, all materials for the H-harness will be purchased from StrapWorks, with the exception of the padded covers that will come from Amazon. Line items for each material can be seen in the bill of materials found in Appendix G. Making the H-harness versus buying it will save us approximately $50. In addition, we will provide Mitch with the 3-point belt which we will purchase from Convaid. He will also sew the complete 5-point harness to the seat. The straps from the H-harness will run through the sewn Velcro that attaches the headrest to the seat. They will then run through the back of the seat and interlace with the straps that are holding the seat to the frame and finally attach to the frame. The 3-point belt will be sewn to the seat and attached to the sides of the frame.

4.4 Footrest

The footrest is needed to be able to absorb the large impact forces that Joseph exerts when he pushes against it. Instead of having two separate footrests that adjust to his foot lengths, it will incorporate one long continues plate welded to the frame as shown below. With the piping made from 4130 chromoly steel tubing and assuming that Joseph exerts a 100 pounds onto the footrest, a FEA analysis was done as shown in *Figure 4.4.1* which yielded a safety factor of 5, this can be improved by increasing the size tubing from .035 to .065 inch wall thickness. This will significant increase the strength without increasing the weight. The footrest will be welded along with the frame at the hangar and the cost is included with the Frame cost.

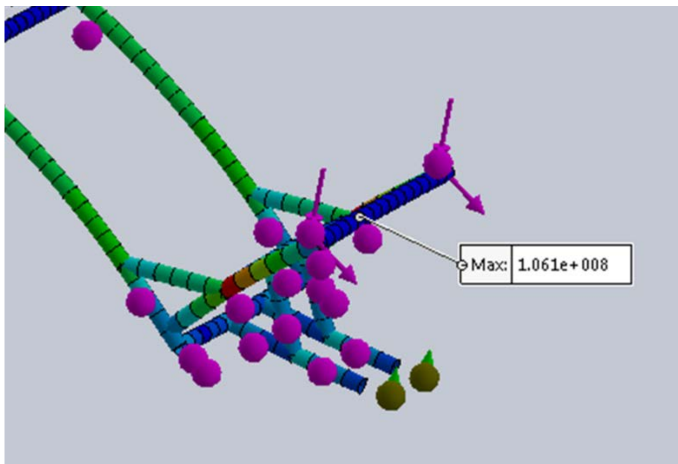


Figure 4.4.1: FEA of the footrest assuming a 100-pound force on the edge. This yielded a safety factor of 5.

In order to accommodate his different leg sizes, a cushion will be strapped onto the footrest seen in *Figure 4.4.2.* The foam material for the footrest will be made from ethafoam which is able to absorb large impact forces while maintaining its shape.

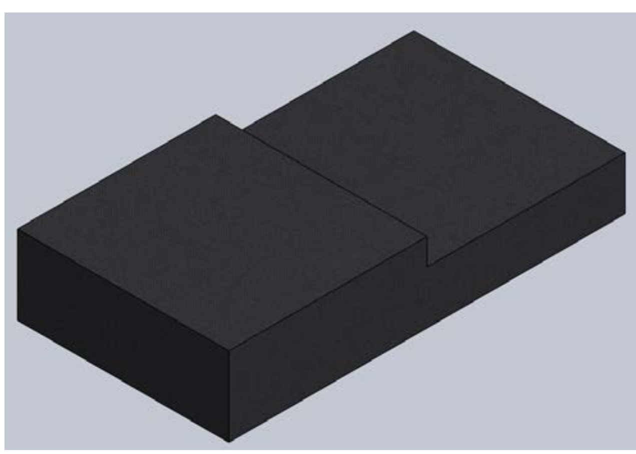


Figure 4.4.2: The footrest cushion that will lie on the footrest.

4.5 Wheels

As stated before, the reason that we are not buying pre-made complete wheels is that we are striving for quality. The market for high quality, small diameter wheels is a small one. The market for small wheels is dominated by children's bikes and strollers which are not normally designed for quality performance. In order to overcome this obstacle, we are building our own wheels. A critical component of the wheel that determines its performance is the hub. The hub is at the center of the wheel and rotates on bearings. The hubs that we will purchase are the same type as those used on high quality mountain bikes and operate on smooth rolling, sealed bearings. Additionally, the tolerances on these hubs are high which ensures that there will not be a lot of "slop" or "play" between the components of the hub. The rims are made from aluminum so that they are lightweight and strong. A high quality aluminum wheel can weigh less than 3 pounds when a similar low quality steel wheel can weigh close to 8 pounds. When you take into account that we are using 3 wheels on a stroller, the benefits of using high quality, light wheels are clear.

Both the wheels and the axle pins are going to be custom built. The back wheels will use 20mm thru axle hubs and 20-inch aluminum rims. The front wheel will use a standard quick release disc brake hub that will attach to the purchased bicycle dropouts. The hubs and rims will all be purchased online. Once we have the components on hand, we will take them to Arts Cyclery, a local bike shop, to have the rims laced to the hubs. Lacing is the process of installing spokes and tensioning them to give the rim its true, straight profile. Once the wheels have been built, the appropriate tires will be purchased. This is a simple task as tires are readily available online for cheap, around 10-20 dollars. The reason we are not purchasing the tires yet is that we need to test fit a few different tires on the rims to see which is the best fit. The rims we are purchasing have a relatively wide bead width which would make them more suitable for an off-road tire. We need to talk more with John to determine what tire he would like. From talking to Arts Cyclery, they say that they are able to build the wheels but it might take a bit of time. The gentleman we talked to quoted us at about two weeks. All of these components involved in the wheel building are shown below.

Figure 4.5.1: 20mm Origin 8 Hub used for the Rear Wheels.

Figure 4.5.2: Sram X7 Hub used for front wheel

Figure 4.5.3: Alienation Black Sheep rim is available in both 16" and 20" models. This rim will be used on both the front and rear wheels.

Figure 4.5.4: Standard Bicycle QR accepting front dropouts. Made out of steel that Can be easily welded to bond with 4130 chromoly tubing.

In order to attach the rear wheels to the frame, custom axle pins need to be made. The inner diameter of the hubs is 20mm or .78 inches. Therefore, our axle pin needs to be roughly 20mm as well. The bottom tube on the frame that the rear wheels attach too comes as .875 inches OD with an inner diameter of .75 inches. This tube will be reamed out to an inner diameter of .78 inches to accommodate a uniform shaft of 20mm in diameter. The material for the axle shaft will be 6061 Aluminum stock that we machine to size. The reason we use aluminum is that since we will not weld this part, it doesn't lose any strength. Additionally, due to the low density of aluminum, we can make the shaft solid instead of hollow. This will be much lighter than a solid steel shaft. The shaft will be machined on a manual lathe and should not offer any extreme difficulties seeing as it is a relatively simple part. Additionally, since aluminum is a soft metal, this will increase its machinability. In order to remove the rear tires, the user simply has to slide out the axle pins. To remove the front wheel, the process is equally simple. Just undo the quick release as you would do on a standard bike and remove the front wheel.

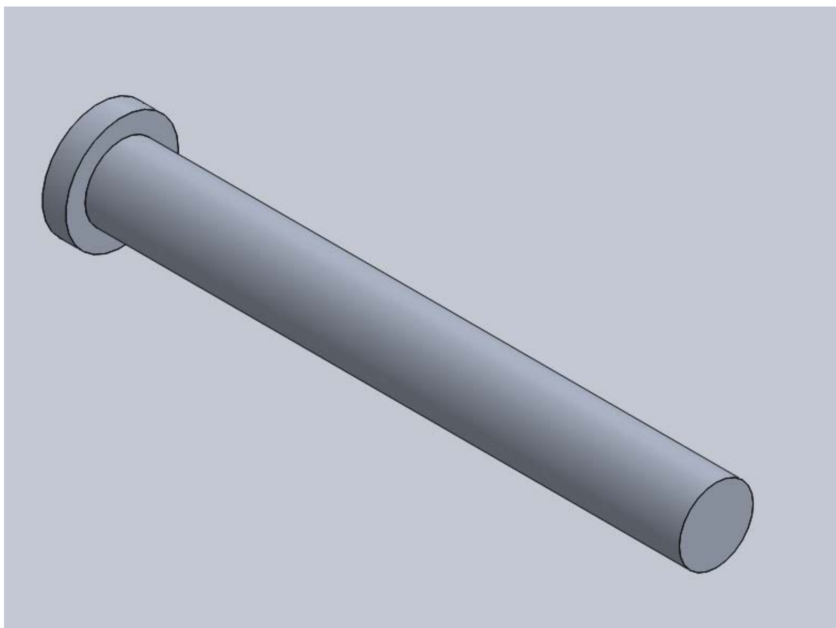


Figure 4.5.5: 20mm Axle Pin for rear wheels

4.6 Manufacturing Plan

We plan on ordering parts for all assemblies on February 14th, 2017. After the all the parts for a specific assembly arrive, those parts will begin their respective assembly process. The timeline for our manufacturing plan can be seen below in *Figure 4.6.1*. We believe we have staggered shipping times and manufacturing times correctly to have a completed jogger done by early April. This leaves at least four weeks to compensate for potential issues in the assembly process. This plan will allow us to meet our deadline of having a completed jogger for testing by May.

ID		Task Mode	Task Name	Duration	Start	Finish
1			**Ordering Parts**	**13 days**	**Tue 2/14/17**	**Thu 3/2/17**
2			Seat Parts	13 days	Tue 2/14/17	Thu 3/2/17
3			Frame Parts	13 days	Tue 2/14/17	Thu 3/2/17
4			Wheel Parts	13 days	Tue 2/14/17	Thu 3/2/17
5	✓		Harness Parts	13 days	Tue 2/14/17	Thu 3/2/17
6			**Manufacturing Plan**	**21 days**	**Fri 3/3/17**	**Fri 3/31/17**
7			Seat Manufacturing (Mitch's Stitches) + Harness	16 days	Fri 3/3/17	Fri 3/24/17
8			Wheel Manufacturing (Art's Cyclery)	10 days	Fri 3/3/17	Thu 3/16/17
9			Frame Pre-Weld Machining	10 days	Fri 3/3/17	Thu 3/16/17
10			Welding of Frame	7 days	Tue 3/14/17	Wed 3/22/17
11			Powder Coating of Frame	6 days	Fri 3/24/17	Fri 3/31/17
12			Assemble Jogger Together	0 days	Sat 4/1/17	Sat 4/1/17

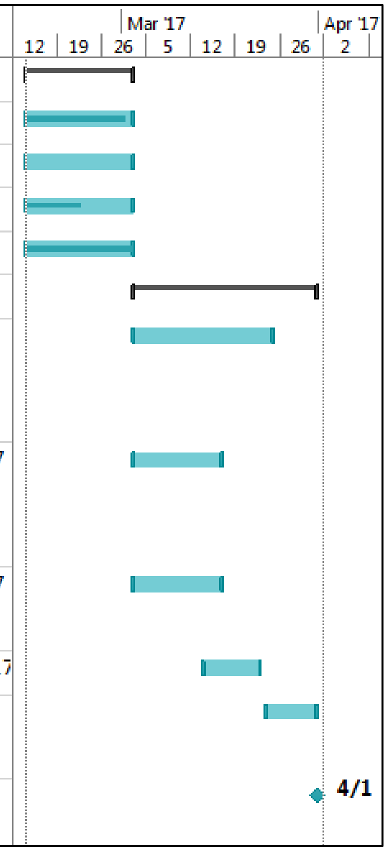


Figure 4.6.1: Manufacturing Plan Timeline.

5.0 Product Realization

This section covers the manufacturing stage of the main components of the jogger. In this section, we provide details on the changes that occurred during manufacturing from the conceptual stage. In addition, we have included our recommendations for future manufacturing of our design.

5.1 Frame

The manufacture of the frame was a long, but very rewarding process. The first step was purchasing the required tools for cutting the tubes. We knew that we had a lot of tubes to cut and we wanted to miter them accurately to ensure a close, exact fit. To do this, we purchased two different sized metal hole saws, a 1" and a 7/8" to match the outside profile of the two tube sizes used. The second step was printing out the necessary drawings in 1:1 scale on the large printers available in the ME lab. A 1:1 drawing was preferred over using scaled dimensioned drawings because when cutting tube, it is often difficult to get accurate measurements from a curved surface, especially if the tube is mitered at an angle. In order to cut the tube, two tools were used primarily, the Hole Shark, and the metal chop saw. The Hole Shark is essentially a drill press designed for hole saws. It can accommodate many different angles of miter and securely holds the work piece. The chop saw was used to cut pieces roughly to size before they were mitered, as well as to cut some 45 degree straight cuts (such as with the handlebar). Once one side of the piece was mitered, it was put up against a 1:1 drawing and the cut location for the second cut was marked in sharpie. After the second cut was made, the piece was put back up against the 1:1 drawing for comparison and quality assurance. This process was repeated for every single tube in the frame assembly.

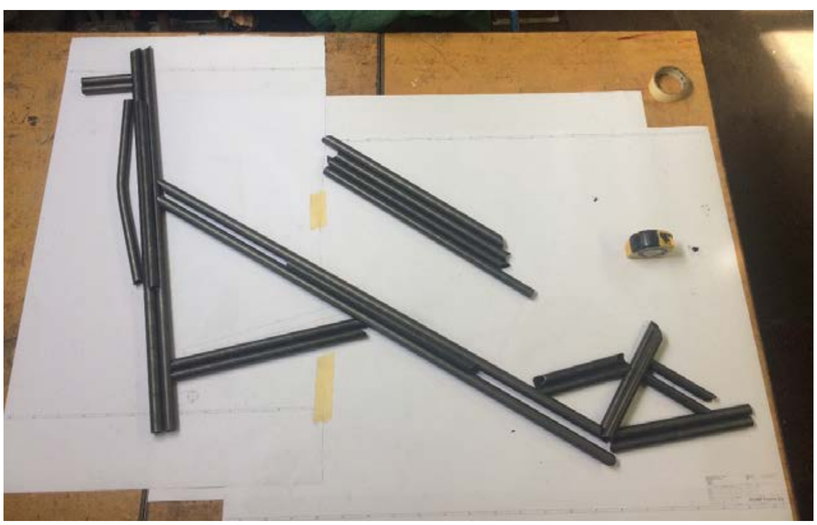


Figure 5.1.1 All the pieces of the frame cut and mitered. The paper underneath is a 1:1 printout that was used to cut the pieces to the correct lengths. Since some pieces appeared similar but were of different wall thicknesses, they were marked with sharpie to ensure we were careful with their placement.

Once the tubes were cut to length and mitered, the next step was to lightly grind off the coating on the outside of the tubes until all that was left was bare metal. We welded the frame using Tig Welding which is a very clean process. Therefore, if a tube is grinded down to bare metal in the location of the weld, the tip of the welding torch will become contaminated and result in a poor weld. Tubes cleaned at the location of weld intersections are shown below. This frame was welded in a specific order. The two sides were welded first, and then connected together. This was done because the two sides are both one plane geometries, meaning they lie flat on a flat surface. This makes welding them and fixturing them very simple. To do this, the side was placed on a 1:1 printout and the tubes oriented until they matched the lines on the drawing (as shown below). They were then clamped down securely to the welding table, had their alignment checked once more, and were then tac welded to shape. After both sides were tacked together, they were placed side by side and checked for equality. Once their similitude was verified, they were welded out.

Figure 5.1.2 One side of the frame being fixtured against a 1:1 printout before being tacked together.

The next step was attaching the two sides together with the cross members. This was probably the most challenging aspect of the frame assembly because if we messed up, the frame would not be straight and all the alignment would be off. Normally, when building a 3-D frame, a quality welding jig is used to position the tubes. Since this is a one off project and we were short on time, we had to improvise our own jig. Using various pieces of metal found around the shop, we were able to position the two sides the desired distance apart from each other while maintaining a level surface. Two large square tube posts were then erected at two locations along the “L” of the seat to keep the two sides from rotating. The alignment was then checked at numerous locations using a straight edge L until we were satisfied. The two square posts were then lightly tacked down to the welding table to hold everything in place. Once that was done, the cross members were tacked together. The whole process of joining the two sides took a very long time but in the end it was worth it. When measuring the extreme diagonal distance between the opposing corners, it was only off by 1/16”. After verifying that the frame was square, it was welded out. The rest of the welding process after this was relatively straightforward as we now had a solid, self-standing, and square frame to weld onto. Additionally, since most of the small tubes that still needed to be welded were positioned at 45 degree angles, they were easily fixtured with 45 degree magnets in the shop. To complete the welding of the frame, the front bulkhead and fork was welded, followed by the handlebar. All the welds were welded out, double checked, and any burrs or bumpy sections were ground down until smooth. The final step was to attach our three sheet metal segments and 4 structural gussets, all of which were cut on the Cal Poly waterjet. These were welded in place to ensure structural integrity and sex appeal. The final frame turned out amazing, strong, and very true. An example of the high quality of the welds is shown below.

Figure 5.1.3: Makeshift Fixture used to align both sides of jogger frame.

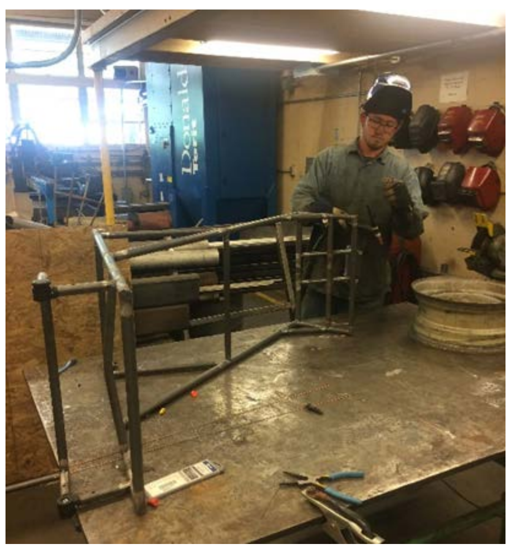


Figure 5.1.4: Welding out the frame after all joints are tacked.

Figure 5.1.5: An example of the Tig weld quality on the frame

Figure 5.1.6: The finished frame before paint

In order to finish the frame, protect it from the elements, and make it look nice, we took it to Central Cost powerdercoating for painting. From talking with John, we knew that he wanted it to be a bright shade of red that matched the red on the seat. We took a piece of the red fabric used by Mitch's Stiches on the seat and had the powdercoating company choose a shade of red that matched. The result turned out amazing as you can see below. We chose to powdercoat the frame instead of spraypainting it because we desired a high quality paint job. Powdercoating attaches the paint electrostatically to the piece and bakes it on, thus ensuring a tough, flawless finish.

Figure 5.1.7: The completed frame fresh out of powder coating.

5.2 Seat

After fitting Joseph with a prototype that will be discussed in the design verification section, we found that the seat should be longer and wider than the original design. The seat was redesign to be one single unit instead of two parts to reduce the possibility of the seat sliding off the frame and ensure the connection between the bottom and top parts of the seat with the other components slightly differing in measurements. The seat, instead of being a composite of ensolite foam and latex foam, was redesigned to be made of only latex foam to reduce the weight of the seat as well as being easier to replace. Slots were also added to the seat in order for the harness restraints to pass through it. The foot rest was changed from ethafoam to high resilience foam in order for it to compress when Joseph fully extends and adds pressure to it. To prevent Joseph arms from hitting the sides of the frame, memory pads were added that attached to the frame bars.

Originally the frame had straps that were to be sewn around the frame bars with the straps having Velcro in order to attach to the seat. However, we realized that it would be too difficult to sew straps around the frame bars so we decided to instead loop the straps around the bars and close off with a buckle. Additionally, instead of having the seat sit on the Velcro straps, the straps would loop around slots behind the seat which prove to be a better attachment of the seat to the frame.

Once the changes were made, the drawings for the seat were created and sent to Mitch’s Stitches where the seat was made as seen in the figures below.

Figure 5.2.1: Completed seat

Figure 5.2.2 Harness slots

Figure 5.2.3 Frame bar padding

Figure 5.2.4 Back seat slots

5.3 Harness

The 5-point harness shown in *Figure 5.3.1* was sewn and assembled by us. We attached the linking components such as the buckles, lobster clips, and strap adjusters to the 1.5-inch black polyester straps and secured it to the frame by looping around it. We then sewed the seams near each component to provide fixedness. In addition, all five pair of straps are hemmed on both ends in order to avoid disengagement from the frame. Our sewing locations on the straps were limited to where our sewing machine can reach. Thus, we did not sew any seams near the tubes of the frame. All the straps are attached to the frame and run through the seat with extra webbing for adjustment by the user. Moreover, we added padded covers to the torso straps for comfort, and two pairs of slots to run the torso straps through the seat in case Joseph grows taller.

There was not much deviation from the planned design. However, as described above, we attached the 3-point crotch support to the frame by looping its strap instead of sewing it to the seat as planned.

We concluded our evaluation of the harness with two recommendations for future manufacturing of our design. First, we would suggest to purchase clips that can hold the straps together when laid over each other. This component will make the harness look more presentable and easier to handle. In addition, we would advise purchasing grommets for the slots to stop the straps from rubbing on the foam and chipping it off. This component will avoid crumbling of the seat foam.

Figure 5.3.1: 5-point harness on Joseph's Jogger

5.4 Wheels

The wheels were assembled and built at Arts Cyclery in San Luis Obispo. We provided Arts Cyclery with the hubs and rims for each wheel, they provided the spokes and labor. Building these three wheels proved to be more difficult than the bike shop anticipated. This was due to the small, uncommon size of the rims we were using. Most custom made wheels are 24 or 26 inches in diameter. Ours were 16 and 20 inches. Because of this, shorter spokes were required and took time to order. The spokes ordered were still too short so Arts Cyclery ended up custom cutting all 108 spokes in the wheel set (36 per wheel). The wheels are true, strong, and look really nice. When installed on the jogger, they rolled very smoothly and strongly outperformed the wheels on the existing jogger. The wheels have 2-inch-wide, all terrain tires mounted on them. The tires and tubes were kindly donated by Arts Cyclery. The wide tires ensure smooth operation on all terrain.

In order to mount the rear 20mm thru axle hubs, two custom axles needed to be machined. In order to keep the weight down, the axles were machined from round aluminum stock. The stock was cut to length on a horizontal band saw, and then turned on a manual lathe to the desired dimensions, which were measured with a digital micrometer.

Figure 5.4.1: Machining of one rear axle shaft on a manual lathe in the hanger.

The axle for the front wheel was included with the front hub, so the only additional hardware needed for mounting the wheel was 2 dropouts. The dropouts were simple to manufacture from 3/16” steel plate. The process started with making a template from cardstock, and using a cutoff wheel to cut out the general shape. The two dropouts were than held together and grinded to their finished profile using a bench mounted belt sander. The dropouts were mounted on a manual mill and a 1/4” end mill was used to cut out the slot for the axle.

The mount for the hydraulic disc brake caliper was machined the same way as the two dropouts, except it was completed after the frame was done. This was because we needed to know the exact position of the caliper when attached to the disc brake. To create the template, we mounted the wheel in the front dropouts, attached a disc brake to the hub, fitted a caliper to the brake, and measured the distance from the fork leg. A template was created and the brake mount was then cut with a cut off wheel from 3/16” plate. The holes were marked and drilled with a center drill, then finished with a 1/4” bit on the drill press.

Figure 5.4.2: Finished drop outs welded to the frame. In order to ensure correct spacing between them when welded, a 100mm spacer was put in-between when they were tacked on. The disc brake mount is shown on the lower fork leg.

5.5 Final Product

The fabrication of Joseph's Jogger was a success, but it definitely involved a number of lessons. We experienced a problem with our upholster that delayed the assembly and testing of the jogger by a month. In addition, our source for the wheels also failed to provide us with our order in time. Thus, we learned to be strict with deadlines, as pushed deadlines strongly affected our plan of completing tasks in a timely manner and proceed with testing. It also failed to leave time for adjustments and last minute improvements. Moreover, we would also recommend ordering parts ahead of time even if it means storing it for a month before it is actually needed. This will prevent issues with delayed shipping and not having all parts in by senior expo. If done again, we would put more time into finding reliable sources for the fabrication of our main components and inquiring cost estimates, as we paid more than quoted for our seat. We recommend comparing quotes between laborers as well as with vendors in order to optimize our budget.

6.0 Design Verification

This section will cover the steps we took to ensure the safety and functionality of the jogger and their results. Summary of our testing results can be found in the Design Verification Plan and Report (DVP&R) in Appendix E.

6.1 Frame Prototype

To first test our frame dimensions, we created a prototype frame out of square tubing as can be seen in the figure below. This frame allowed us to determine that our current jogger model provided was too tight of a fit for Joseph as the frame was too narrow and the Joseph legs extended pass the frame. Additionally, the bar at the back of the frame proved to be uncomfortable even with foam padding and titled the body forward. Using this information, we were able to alter our prototype by increasing the width by 4 inches and length by 3 inches. The back bar was also moved to be at shoulder height and in the final design was made to be bent to be more comfortable. With this new prototype, we found that Joseph fit appropriately in the jogger. We then remodeled our Solidworks and FEA to match the changes made to our prototype. Making this prototype was extremely useful, as it allowed us to catch a crucial error without much punishment.

Figure 6.1.1: Initial frame prototype

Figure 6.1.2: Improved frame prototype

6.2 Test Descriptions and Results

Due to time constraints, we were not able to test the jogger in weightless and weight runs as thoroughly as proposed in the design verification plan. Instead, we elected to test the other aspects of the jogger. In this section, we will describe our tests and testing procedures that we used to verify the success of our project.

6.2.1 Weld Test

This test was designed to test the ability for the jogger to support weight. For this trial we were looking for the jogger to safely support over 100 lbs. of weight. To test this, we placed Josh Egli onto the jogger and pushed him around. This can be seen in the *Figure 6.2.1.1*.

Figure 6.2.1.1: Weld test

Josh Egli, 192 lbs, was safely supported by the frame. We successfully pushed him for over a mile, and executed turns of all angles. The frame supported him with every movement, and provided a safe and comfortable ride.

6.2.2 Lean Test

This test was designed to determine the angle at which the jogger would tip if tilted in the horizontal plane. To test this, we tilted the jogger horizontal and measured with a protractor until it tipped. This can be seen in the figure below.

Figure 6.2.2.1: Lean test

The results of this test showed that the jogger did not tip over until surpassing a horizontal angle of 45 degrees. This greatly surpassed our required angle of a 15-degree tip. We also tested this tilt up to 15 degrees with Josh Egli riding in it, and it safely withstood a tilt of 15 degrees. For safety purposes we did not tilt past 15 degrees with him in the jogger.

6.2.3 Incline Test

This test was designed to determine the angle at which the jogger would tip if tilted on an incline. To test this, we tilted the jogger vertically and measured with a protractor until it tipped. This can be seen in the figure below.

Figure 6.2.3.1: Incline test

The results of this test showed that the jogger could support over a 55-degree angle with a lean in the vertical direction. We also tested this with Josh Egli riding in it, and found that it was safe up until 45 degrees of tilt. We imagine with Joseph in the jogger the actual tipping point in the vertical direction will be somewhere between these two results.

6.2.4 Footrest Test

This test was designed to model the pressure Joseph normally exerts on the footrest and on the back of the seat. To test this, we had Josh Egli sit in the seat and push into the footrest with his legs and push into the back of the seat with his back.

Josh Egli has maxed out on the leg press machine at over 400 lbs. We felt if the jogger could successfully support his maximum force, then we would have no issues to worry about with Joseph. Josh slowly increased the force applied to the jogger until he reached his maximum press. On our first trial, we did have one of the buckles located on the middle back break. This was due to the positioning of the buckle. After repositioning all of the buckles and replacing that piece, we repeated the test three times without issue.

6.2.5 Weight Test

This test was designed to determine the weight of the completed jogger assembly. Due to our inability to find a scale large enough to measure the jogger, we had Josh Egli pick up the jogger after lifting a series of 45 pound plates for calibration. This can be seen in the *Figure 6.2.5.1*.

Figure 6.2.5.1: Weight Test

Due in part to poor scheduling, and issues with receiving parts from our suppliers, we were not able to find time with a big enough scale to accurately weigh the jogger. We had Josh Egli lift the jogger and use his weight lifting knowledge to semi accurately gauge the weight. His "expert" analysis said that we missed the mark with our 45 lb. weight goal, but did say it wasn't unreasonably heavy. We still found the jogger easy to push uphill and downhill with this extra weight.

6.2.6 Handlebar Test

This test was designed to determine the ease of use of handlebar adjustment during motion. This can be seen in the *Figure 6.2.6.1*.

Figure 6.2.6.1: Handlebar Test

The handlebars are easy to rotate whether it be while running or stationary.

6.2.7 Jogging Test

This test was designed to test the ease of use of the jogger. To test this, we ran the jogger over multiple terrains for multiple distances.

We put an extensive amount of miles on the jogger to test the stability, ease of turning, and functionality of the jogger. Through our tests without a subject in it, we found that the sunshade was falling off due to the constant vibration of going over little bumps. This lead us to purchasing pipe clamps to secure the sunshade to the jogger. These trials also helped us learn that there were no other issues with the jogger. We also experienced no issues when testing the jogger with a person sitting in it. The straps stayed snug even after four miles, and everything else worked as planned.

6.2.8 Harness Test

This test was designed to test the ease of use of the harness. To test this, we took the harness on and off multiple times and adjusted the length of all the straps. This can be seen in the *Figure 6.2.8.1*

Figure 6.2.8.1: Harness Test

In this trial, Carol looked to see how quickly she could remove and connect the straps and harness system. After 5 trials, Carol was able to get me in and completely out of the harness in an average of 42.7 seconds. We believe this is a reasonable time to get the harness on and off, and should provide John and Joseph with no issues.

7.0 Conclusion

This project meant a lot to not only our group, but also to Joseph, his father, and the members of Team Joseph. We are glad to have been able to enhance Joseph's participation in marathons by providing him with a customized jogger that adapts to his needs. Although we did experience a number of obstacles along the way, the hours put into designing, manufacturing, and testing Joseph's new jogger have paid off.

We would like to thank John and Joseph for allowing us to work on this project, our advisor Sarah Harding for guiding us throughout the year and for her endless support, and our sponsor Michael Lara and Team Joseph for their participation and dedication to making Joseph's Jogger a huge success. As depicted in *Figure 7.1*, our team not only delivered a successful project to Joseph Cornelius and his father, but we also delivered a part of us that we will never forget. The time we spent with the Cornelius family was unforgettable and this project has been very rewarding!

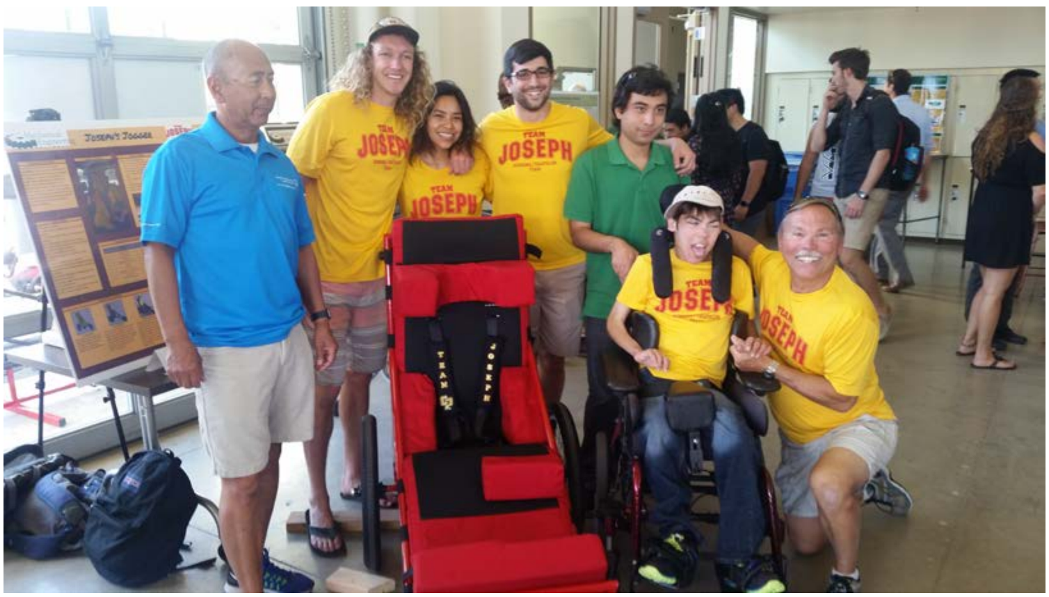


Figure 7.1 Senior Expo (left to right: Michael Lara, Luke Kraemer, Carolina Reyes, Josh Egli, Robert Trujillo, Joseph Cornelius, John Cornelius)

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[6] Gibson, John. "Racing Seatbelt Guide - The Science of Seatbelts." *Hot Rod Network*. Hot Rod Newsletter, 15 June 2016. Web. 09 Jan. 2017.

Appendix A: QFD, Decision Matrices

Customer	Grouping	Voices	Item No.	Importance	A: Max weight of device	B: Max Length of device	C: Max Width of device	D: Max user height	E: Max user weight	F: Max user width	G: Product lifetime	H: Adjustable handle bar height	I: Zero reachable pinch points	J: Minimum strength of foot plat	K: Low Cost	L: Off the shelf components	Hoyt	Wik	Existing (Adaptive)	Ottobock	Bob
		Lightweight	1	3	9	3	3	3	3	3			1	1			4	3	2	4	5
		Easily Transportable	2	4	9	9	9	3	3	3							2	2	3	4	4
		Adjustable handle bar	3	3				1				9	1			3	1	4	1	4	2
		Correct Body Posture for Joe	4	5		3	3							3	9	3	1	4	2	3	1
		Distribute weight on hip	5	5			3		3	3							1	4	2	4	1
		Upright Position	6	5		1	1		3	3			9		3	3	2	4	2	4	4
		Body restraint system	7	4	1			3	3	3	9		3		1	1	1	2	5	3	1
		Smooth Ride over bumps	8	5	3	1	1		3		1		3		9	3	3	4	2	4	3
		Low maintenance	9	3							9				9	9	5	4	4	4	5
		Braking System	10	4	9				9		1					9	5	1	5	4	4
		Canopy	11	2	1						1				1	3	4	4	4	1	3
		Weatherproof	12	3							9				3	1	4	3	5	4	4
		Safety	13	5	1				3		1		9	9	3		5	4	5	3	4
		Strong foot platform	14	4	1				1		9		1	9			1	2	3	2	1
		Targets			40 lbs	60"	23"	60"	100 lbs	15"	15 yrs	52"	0	100 lb distributed load	$2,500	Min. 75%					
		Weighted Importance			129	70	85	36	118	48	142	27	127	99	162	130	782				
		% Importance			0.165	0.090	0.109	0.046	0.151	0.061	0.182	0.035	0.162	0.127	0.207	0.166					

Measures: columns A–L. Customer Ratings: Bad 1 2 3 4 5 Good.

Figure A.1: Quality Function Deployment (QFD)

Pugh Decision Matrices

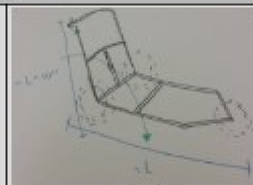
Frame						
	Weight	 Design 1	 Design 2	 Design 3	 Design 4	
Easily Transportable	4	-	-	0	-	0
Lightweight	3	+	-	+	+	0
Distribute weight on hip	5	+	+	+	+	0
Easy to Push	4	+	+	+	+	0
Low Center of Gravity	4	+	+	+	0	0
Safety	5	+	+	0	+	0
Low Maintenece	3	+	0	0	+	0
Correct Body Posture	5	+	+	+	+	0
Strength	4	+	+	+	0	0
Total (Weight*Design)	**37**	**33**	**20**	**25**	**30**	**0**

Figure A.2: Frame Pugh Matrix for Joseph's Jogger

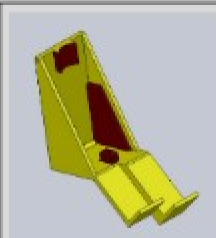
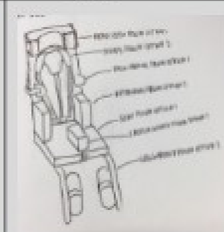
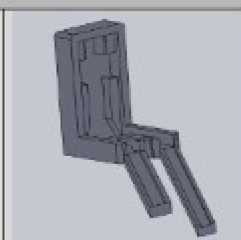
Seat					
	Weight	 Design 1	 Design 2	 Design 3	 Datum
Head	5	+	+	+	0
Restraint	5	-	+	-	0
Leg Support	4	+	0	0	0
Crotch	4	+	+	+	0
Comfort	5	+	+	+	0
Maintence/Replaceability	3	0	+	0	0
Weatherproof	3	0	0	0	0
Correct Body Posture	5	+	+	+	0
Strength	5	0	0	+	0
Collapsibilty	2	-	-	-	0
Ease of manufacture	5	+	-	-	0
Total (Weight*Design Idea)	**41**	**20**	**20**	**12**	**0**

Figure A.3: Seat Pugh Matrix for Joseph's Jogger

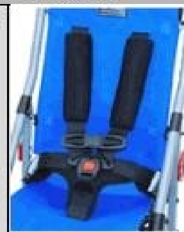
Harness					
	Weight	 Design 1	 Design 2	 Design 3	
Restraints Torso	5	+	+	+	0
Reinforces Crotch Support	3	-	+	0	0
Avoids Bard Button	5	-	0	-	0
Practical (easy to buckle)	4	0	0	-	0
Comforted Straps (Padded Straps)	3	-	+	+	0
Total (Weight*Design)	**20**	**-6**	**11**	**-1**	**0**

Figure A.4: Harness Pugh Matrix for Joseph's Jogger

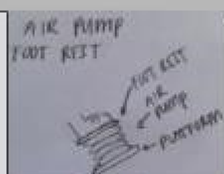
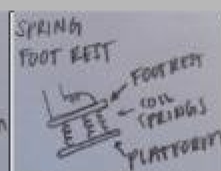
Footrest					
	Weight	 Design 1	 Design 2	 Ottobock Design 3	 Datum
Durable	5	+	+	+	0
Low Maintenance	5	0	0	+	0
Adjustable	3	+	+	0	0
Pinch Points	4	-	0	-	0
Weatherproof	5	0	-	-	0
Ease of Manufacture	3	-	0	-	0
Total (Weight*Design Idea)	**22**	**1**	**4**	**-2**	**0**

Figure A.5: Footrest Pugh Matrix for Joseph's Jogger

Wheels					
	Weight	 Design 1	 Design 2	 Design 3	
Stability	5	0	-	-	0
Stationary Front	3	0	0	-	0
Performance	5	+	+	-	0
Low C.O.G	4	0	-	-	0
Low Maintenance	5	0	0	-	0
Cost	2	-	-	-	0
Total (Weight*Design)	**24**	**3**	**-6**	**-19**	**0**

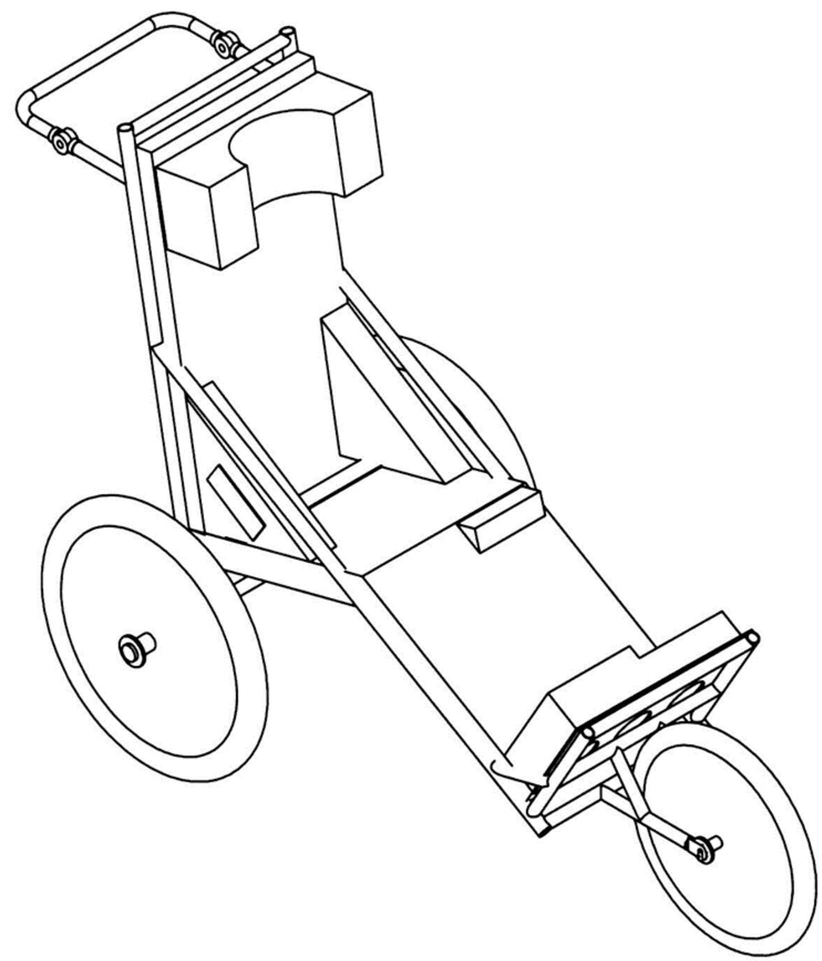
Figure A.6: Wheels Pugh Matrix for Joseph's Jogger

Appendix B: Drawings

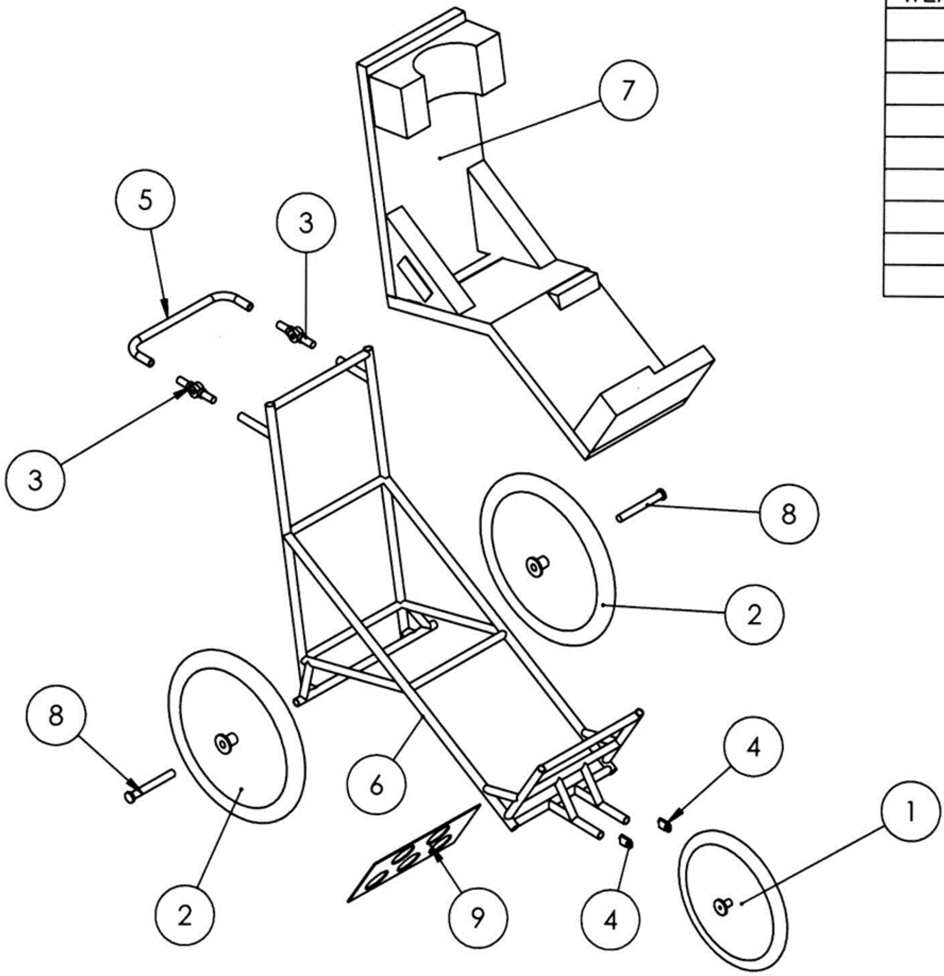
100 JOGGER ASSEMBLY
- 101 ASSEMBLY EXPLODED VIEW

200 FRAME ASSEMBLY
- 201 FRAME CUT LIST
- 202 FRAME WELDING SEGMENTS
- 203 WELD SEGMENT ATTACHMENT POINTS
- 204 FRONT FRAME WELDMENT
- 205 REAR AXLE WELDMENT
  - 210 TUBE 1
  - 211 TUBE 2
  - 212 TUBE 3
  - 213 TUBE 4
  - 214 TUBE 5
  - 215 TUBE 6
  - 216 TUBE 7 AND 15
  - 217 TUBE 8 AND 14
  - 218 TUBE 9
  - 219 TUBE 10 AND 16
  - 220 TUBE 11
  - 221 TUBE 12
  - 222 TUBE 13
- 230 HANDLEBAR
- 240 FOOT PLATFORM
- 250 AXLE PIN

300 SEAT ASSEMBLY
  - 301 EXPLODED SEAT ASSEMBLY
  - 302 STRAP ATTACHMENT
- 310 SEAT CUSHION
- 320 HEADREST CUSHION
- 330 THIGH CUSHION
- 340 LEG BOLSTER
- 350 FOOTREST CUSHION
- 360 2 INCH STRAP SPECIFICATION SHEET
- 370 2 INCH VELCRO SPECIFICATION SHEET

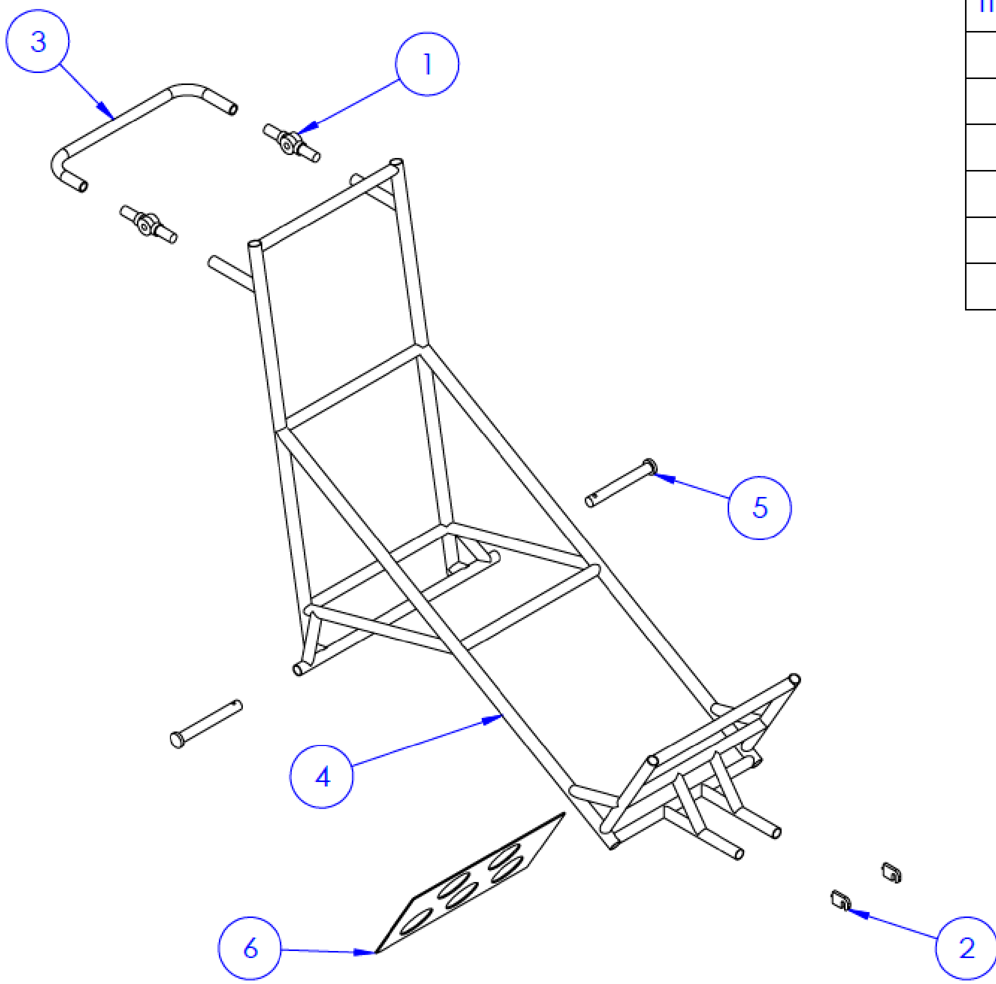


Mechanical Engineering CAL POLY	TITLE: JOGGER ASSEMBLY		DWR#: 100
	UNITS: INCHES	MATERIAL: VARIOUS	DATE: 2/9/17
	SCALE: 1:10	TOLERANCE:	DRWN BY: LUKE KRAEMER



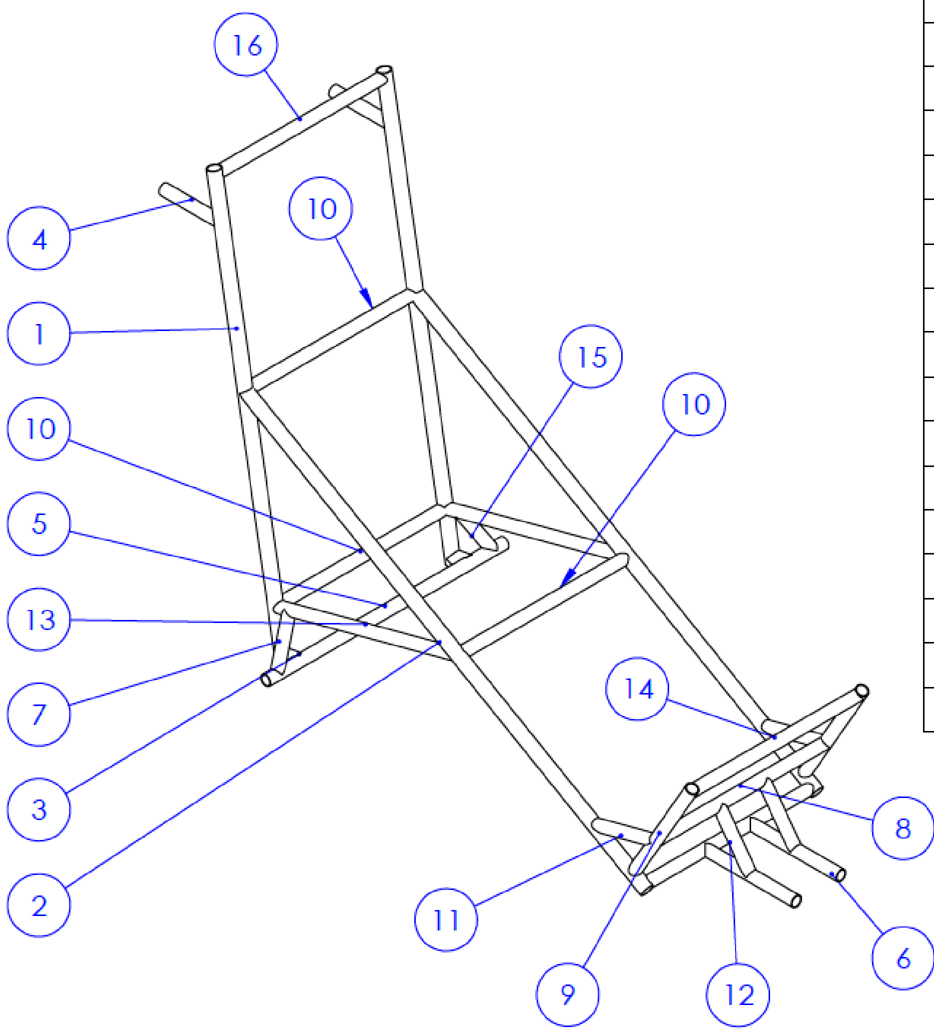
ITEM NO.	DESCRIPTION	QTY.
1	16 Inch Wheel	1
2	20 Inch Wheel	2
3	HalfHinge	2
4	Dropout	2
5	Handlebar	1
6	Stroller Frame Steel	1
7	SEAT	1
8	Axle Pin	2
9	FootPlatform	1

Mechanical Engineering CAL POLY	TITLE: ASSEMBLY EXPLODED VIEW		DWR#: 101
	UNITS: INCHES	MATERIAL: VARIOUS	DATE: 2/9/17
	SCALE: 1:16	TOLERANCE:	DRWN BY: LUKE KRAEMER



ITEM NO.	PART DESCRIPTION	QTY.
1	HalfHinge	2
2	Dropout	2
3	Handlebar	1
4	Stroller Frame Steel	1
5	Axle Pin	2
6	FootPlatform	1

Mechanical Engineering CAL POLY			
	TITLE: FRAME ASSEMBLY		DWR#: 200
	UNITS: INCHES	MATERIAL: VARIOUS	DATE: 2/8/17
	SCALE: 1:12	TOLERANCE:	DRWN BY: LUKE KRAEMER

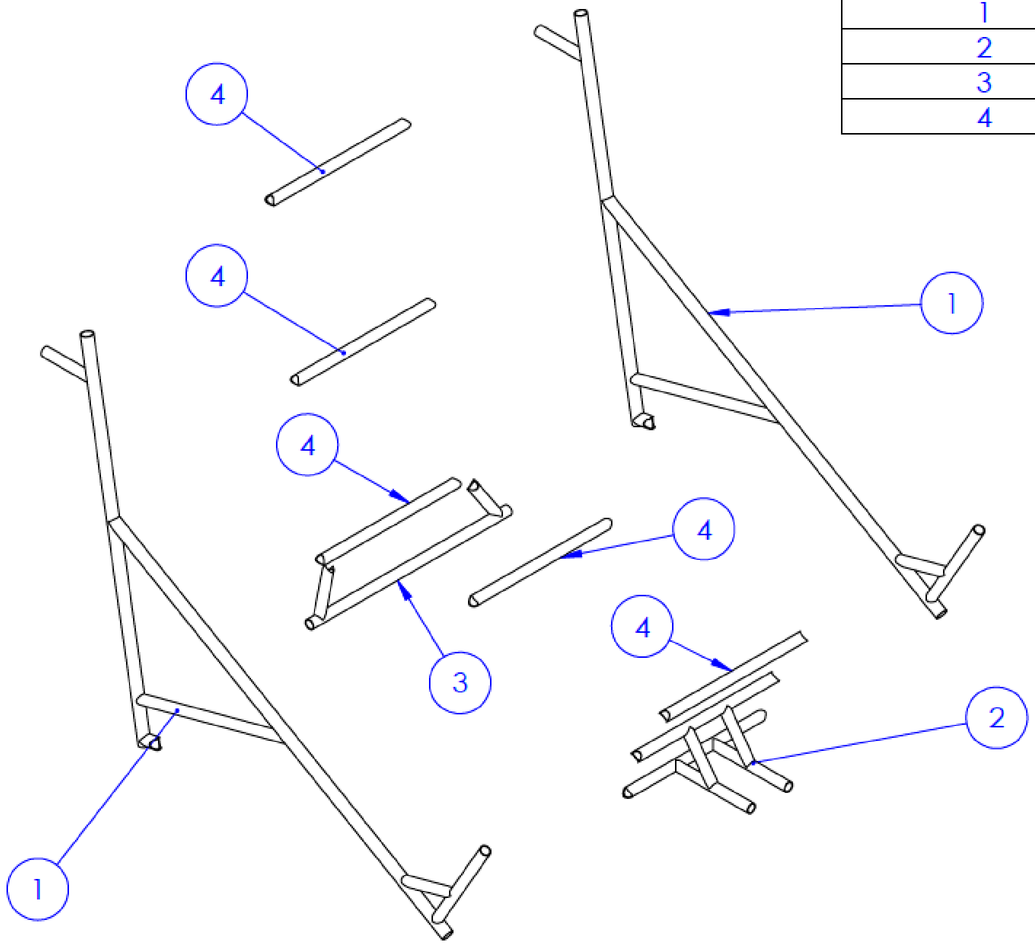


ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	2	1 OD x 0.065 Wall	35.14
2	2	1 OD x 0.065 Wall	40.94
3	2	1 OD x 0.065 Wall	1.56
4	2	0.875 OD x 0.065 Wall	4.88
5	1	0.875 OD x 0.065 Wall	21
6	2	0.875 OD x 0.065 Wall	8
7	1	0.875 OD x 0.065 Wall	4.08
8	1	0.875 OD x 0.065 Wall	15
9	2	0.875 OD x 0.065 Wall	10.2
10	3	0.875 OD x 0.035 Wall	14.52
11	2	0.875 OD x 0.035 Wall	5.41
12	2	0.875 OD x 0.035 Wall	4.89
13	2	0.875 OD x 0.035 Wall	16.17
14	1	0.875 OD x 0.035 Wall	15
15	1	0.875 OD x 0.065 Wall	4.08
16	2	0.875 OD x 0.065 Wall	14.52

NOTE:
LENGTH REPRESENTS MAX
LENGTH MEASURED
AFTER MITER

Mechanical Engineering CAL POLY	TITLE: FRAME CUT LIST	DWR#: 201
	UNITS: INCHES / MATERIAL: 4130 STEEL	DATE: 2/8/17
	SCALE: 1:10 / TOLERANCE:	DRWN BY: LUKE KRAEMER

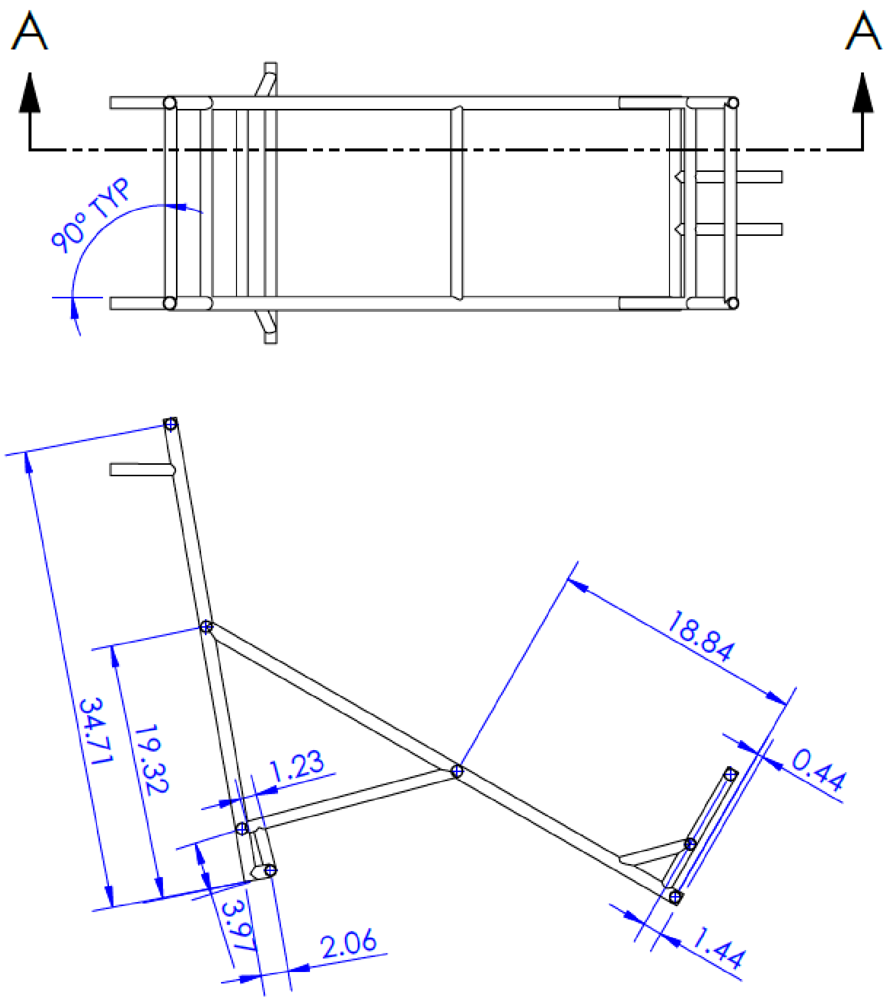
BALLOON #	DESCRIPTION
1	FRAME SIDE
2	FRONT FRAME
3	REAR AXLE
4	CROSS MEMBERS



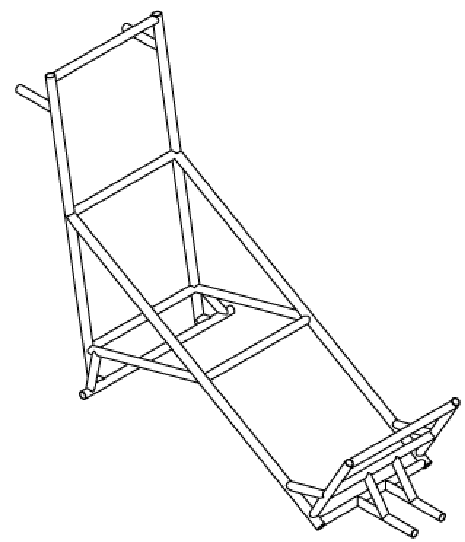
NOTE:
FRAME SIDES ARE IDENTICAND WILL BE WELDED USING A 1:1 PRINTOUT FOR DIMENSIONS

FRONT FRAME AND REAR AXLE WILL BE WELDED ACCORDING TO SCALED DOWN DETAIL DRAWINGS

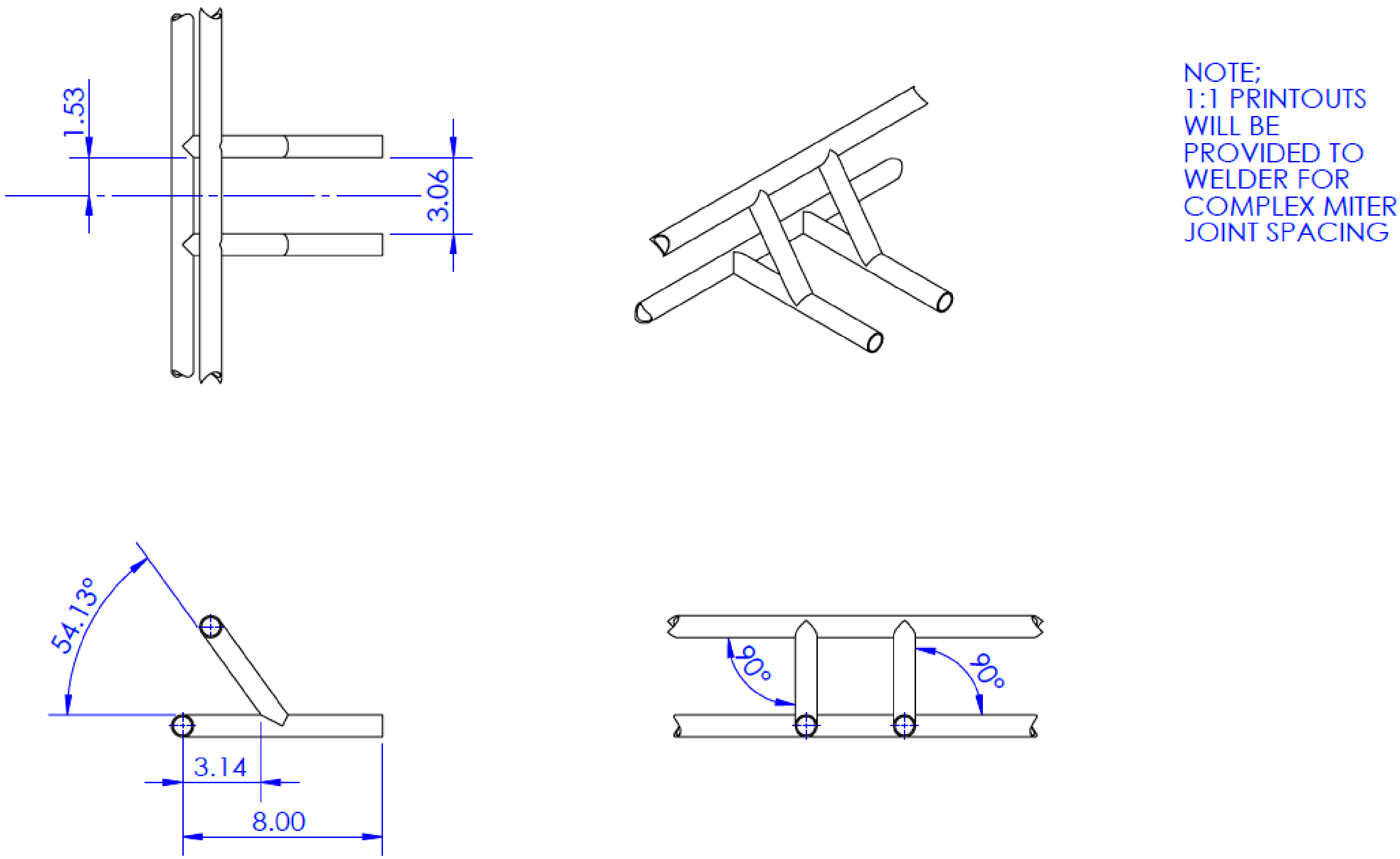
Mechanical Engineering CAL POLY	TITLE: FRAME WELDING SEGMENTS		DWR#: 202
	UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
	SCALE: 1:12	TOLERANCE:	DRWN BY: LUKE KRAEMER



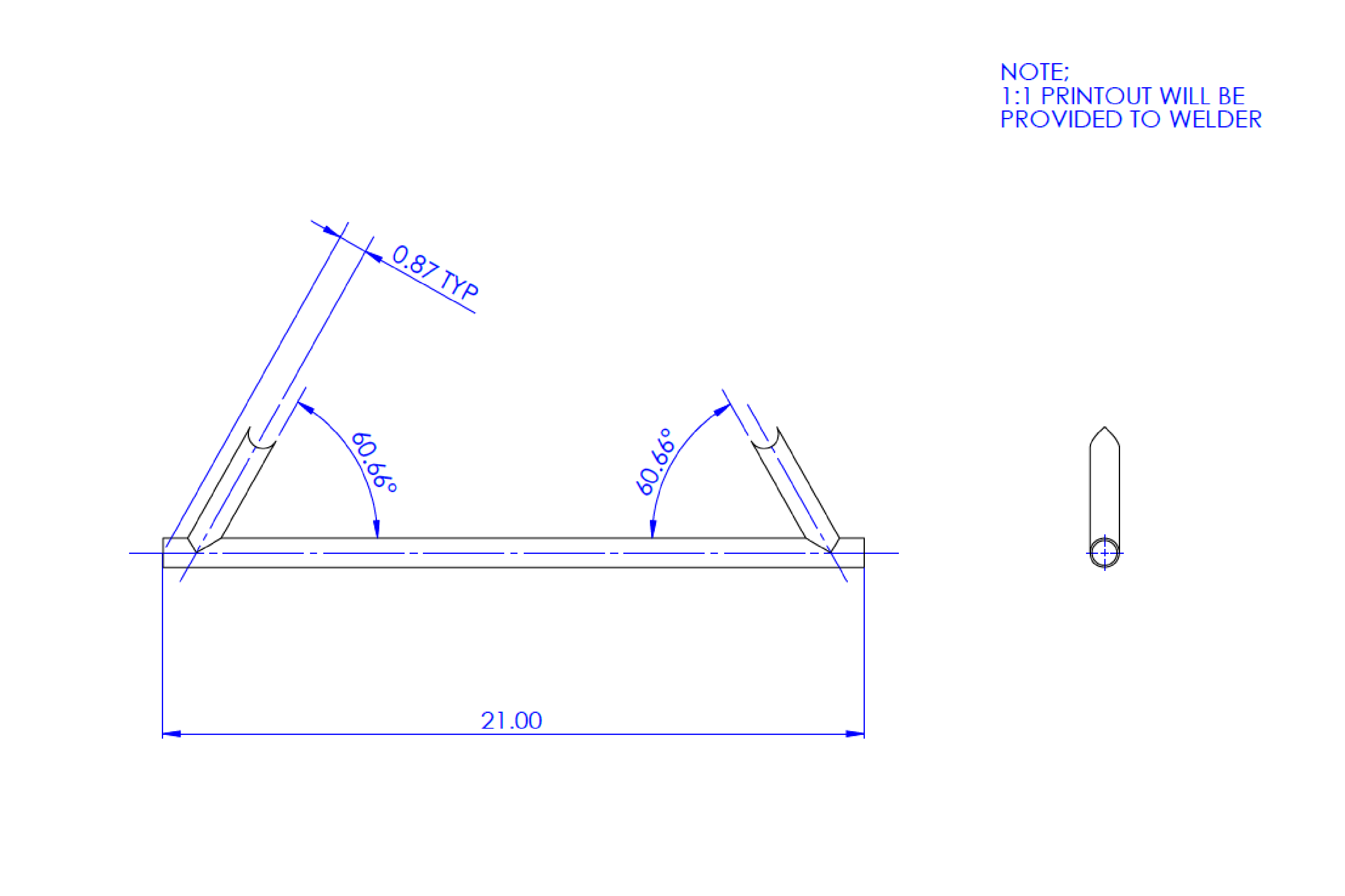
NOTE:
FRAME SIDES ARE WELDED USING 1 : 1 PRINTOUT FOR DIMENSIONS. THIS DRAWING SHOWS WHERE THE CROSS MEMBERS AND, REAR AXLE, AND FRONT FRAME WELD TO.



Mechanical Engineering CAL POLY	TITLE: WELD SEGMENT ATTACHMENT POINTS	DWR#: 203
UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
SCALE: 1:12	TOLERANCE:	DRWN BY: LUKE KRAEMER

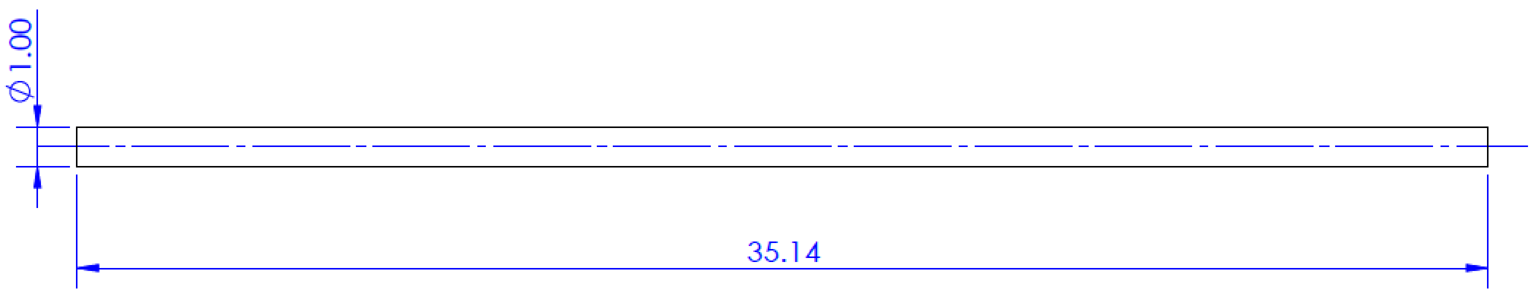


Mechanical Engineering CAL POLY	TITLE: FRONT FRAME WELDMENT	DWR#: 204
	UNITS: INCHES / MATERIAL: 4130 STEEL	DATE: 2/9/17
	SCALE: 1:6 / TOLERANCE:	DRWN BY: LUKE KRAEMER

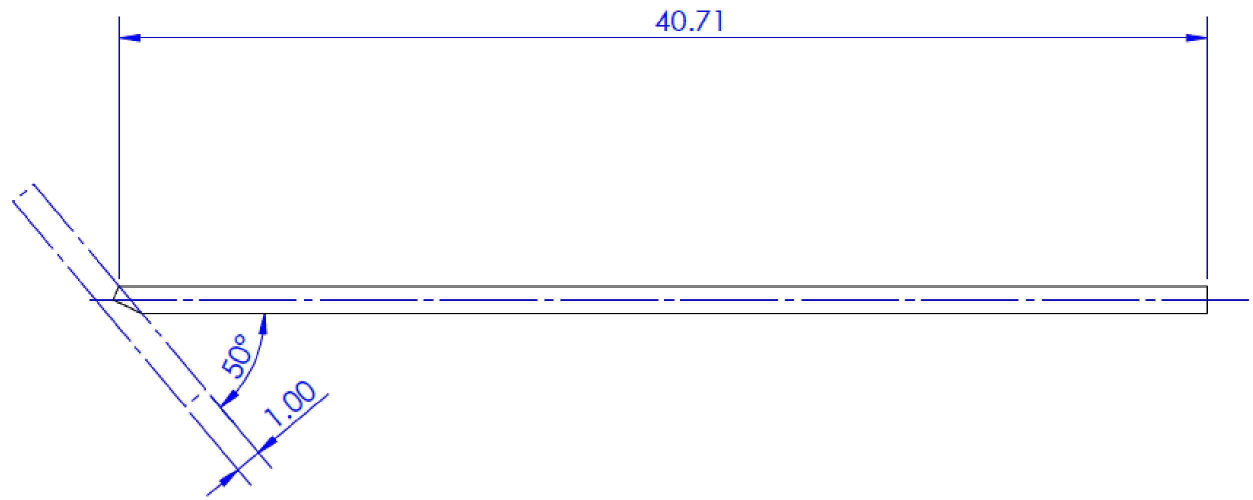


TITLE: REAR AXLE WELDMENT		DWR#: 205
UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
SCALE: 1:4	TOLERANCE:	DRWN BY: LUKE KRAEMER

Mechanical Engineering CAL POLY

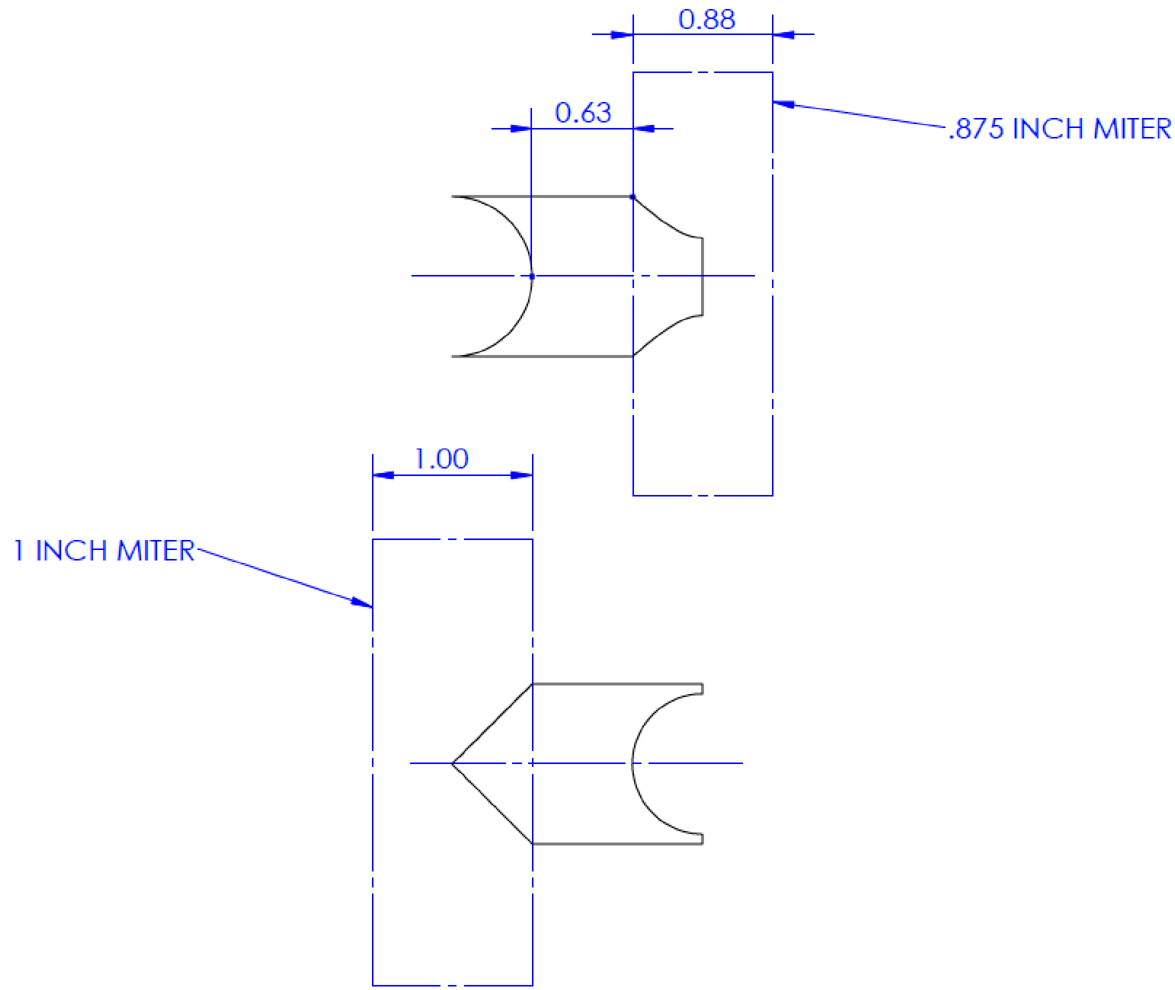


Mechanical Engineering CAL POLY	TITLE: Tube 1		DWR#: 210
	UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
	SCALE: 1:4	TOLERANCE:	DRWN BY: LUKE KRAEMER

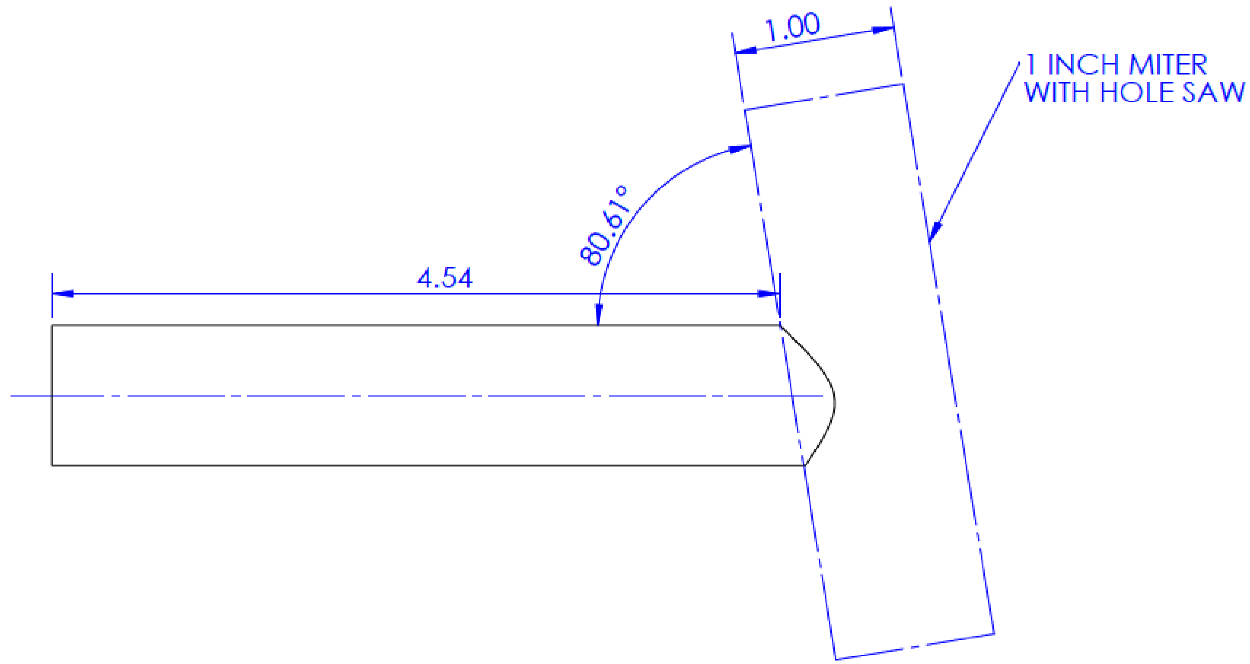


NOTE:
TUBE IS MITERED USING
1 INCH HOLE SAW

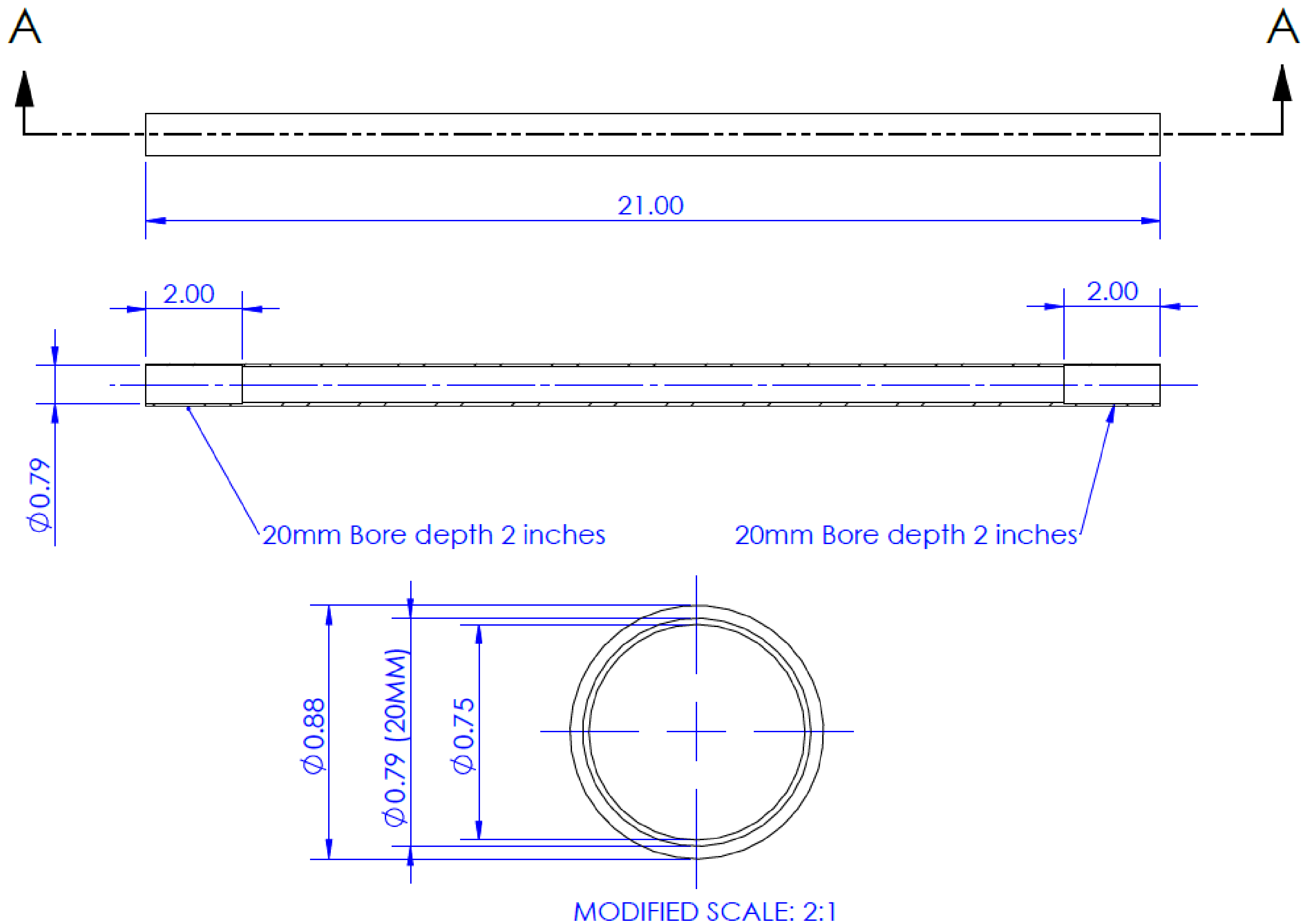
Mechanical Engineering CAL POLY	TITLE: TUBE 2	DWR#: 211
UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
SCALE: 1:6	TOLERANCE:	DRWN BY: LUKE KRAEMER



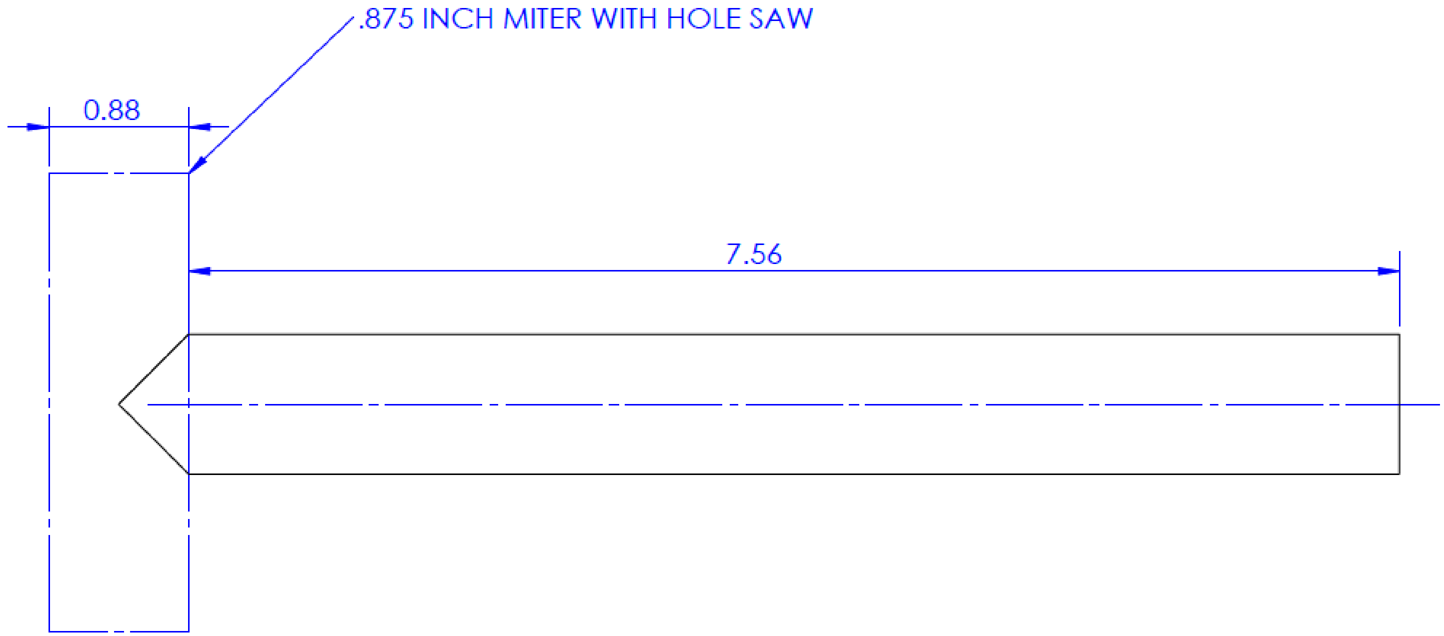
TITLE: TUBE 3		DWR#: 212
UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
SCALE: 1:1	TOLERANCE:	DRWN BY: LUKE KRAEMER



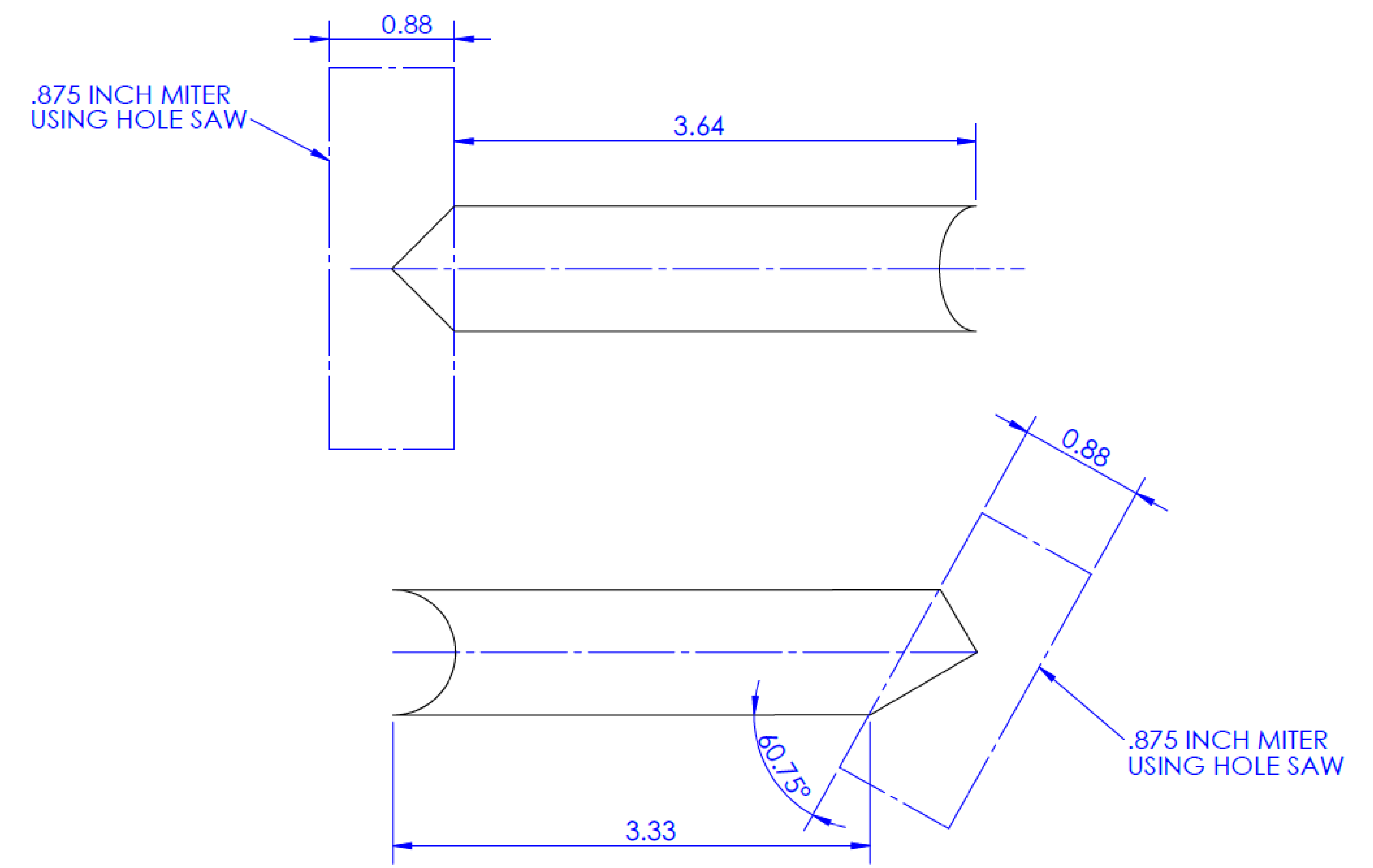
Mechanical Engineering CAL POLY	TITLE: TUBE 4		DWR#: 213
	UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
	SCALE: 1:1	TOLERANCE:	DRWN BY: LUKE KRAEMER



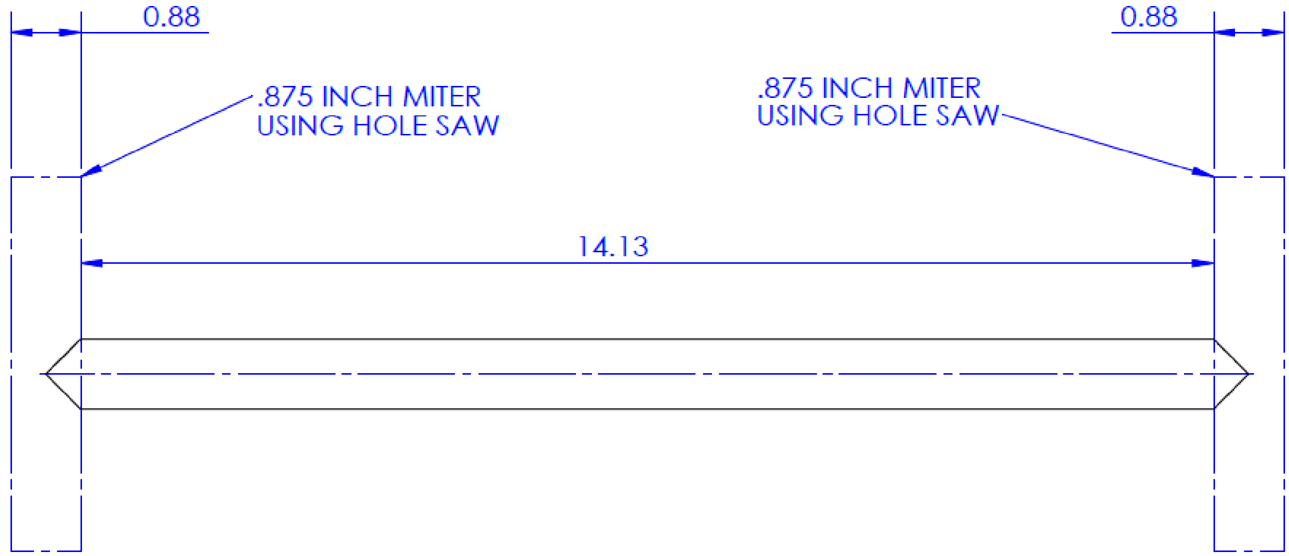
TITLE: TUBE 5		DWR#: 214
UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
SCALE: 1:3	TOLERANCE:	DRWN BY: LUKE KRAEMER



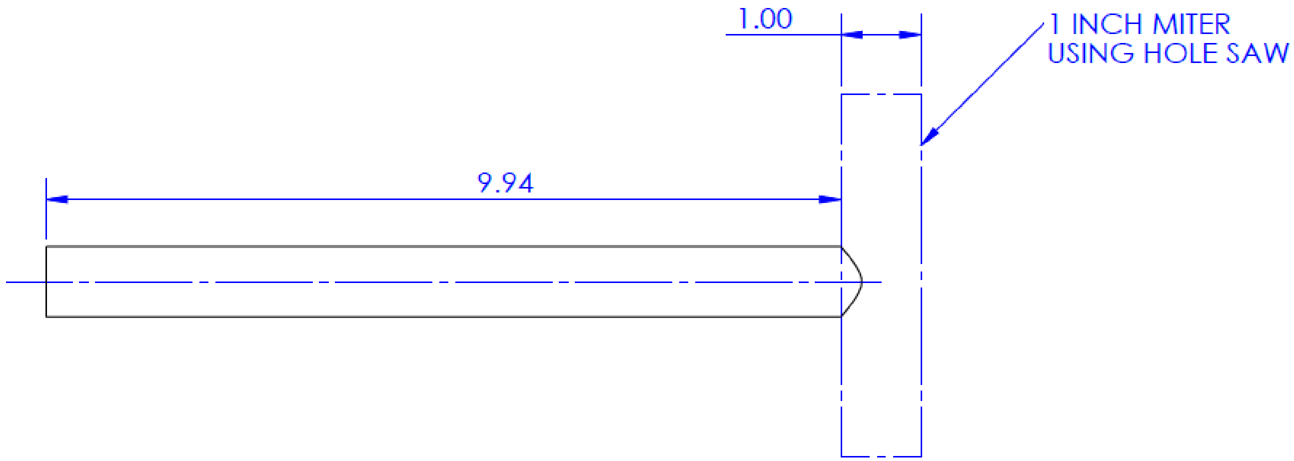
TITLE: TUBE 6		DWR#: 215
UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
SCALE: 1:1	TOLERANCE:	DRWN BY: LUKE KRAEMER



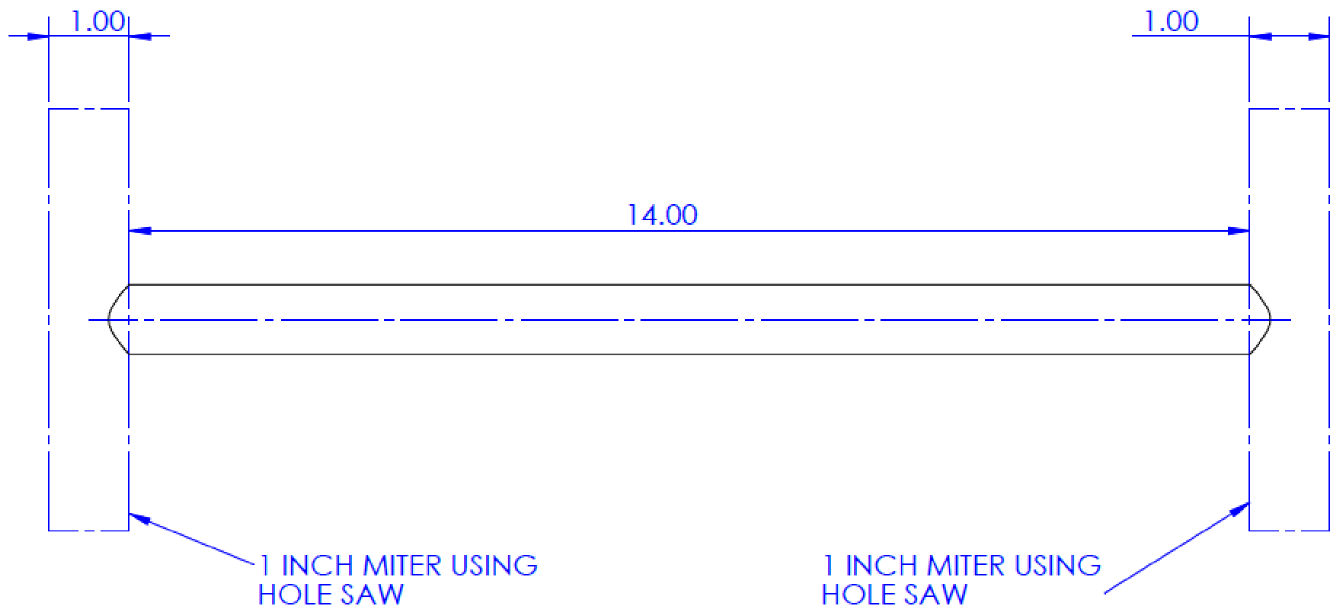
Mechanical Engineering CAL POLY	TITLE: TUBE 7 AND 15		DWR#: 216
	UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
	SCALE: 1:1	TOLERANCE:	DRWN BY: LUKE KRAEMER



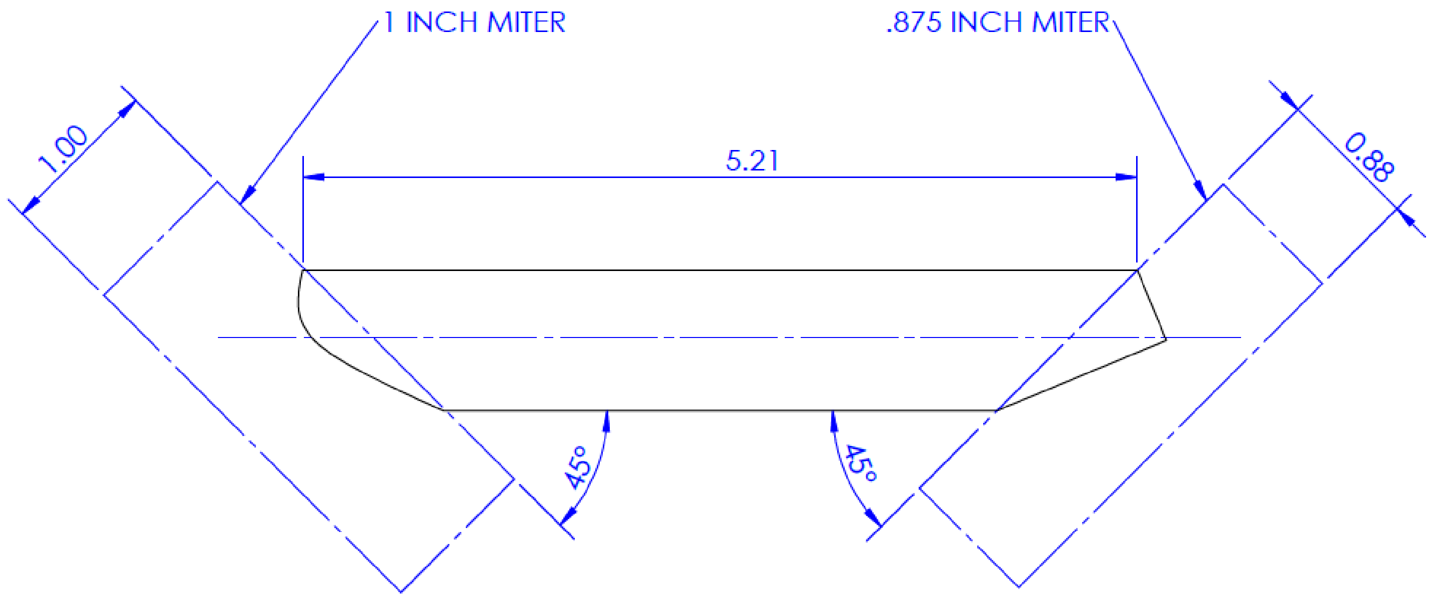
Mechanical Engineering CAL POLY	TITLE: TUBE 8 AND 14		DWR#: 217
	UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
	SCALE:1:2	TOLERANCE:	DRWN BY: LUKE KRAEMER



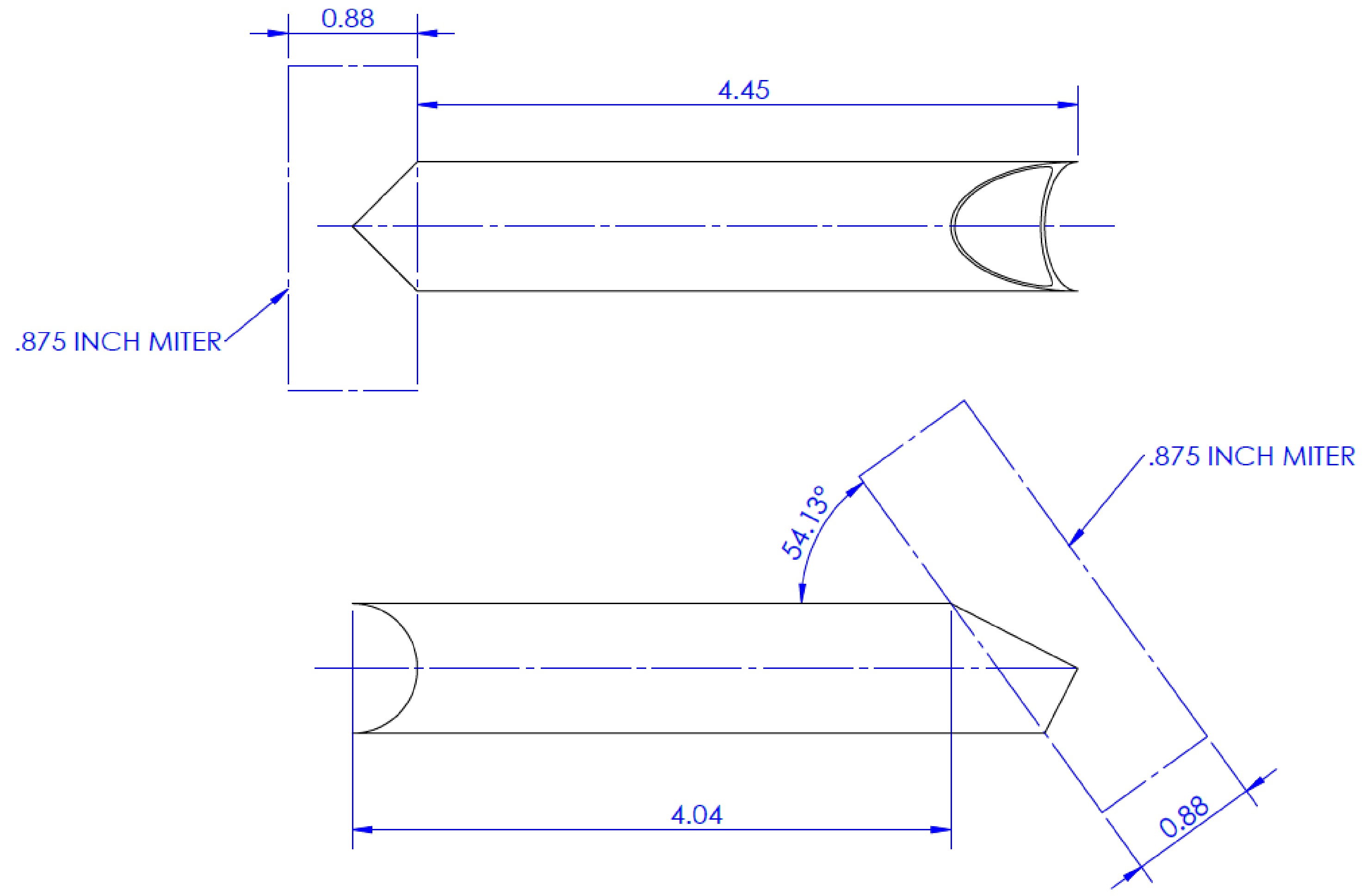
Mechanical Engineering CAL POLY	TITLE: TUBE 9		DWR#: 218
	UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
	SCALE: 1:2	TOLERANCE:	DRWN BY: LUKE KRAEMER



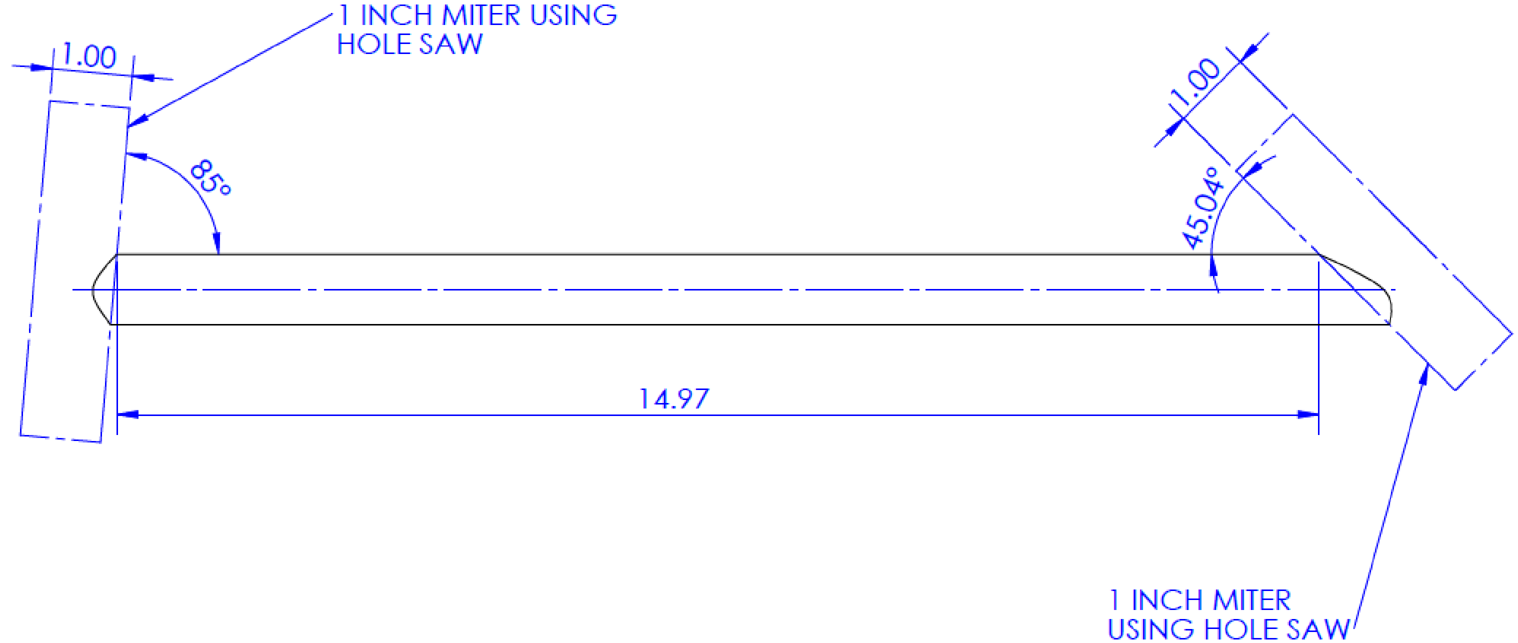
Mechanical Engineering CAL POLY	TITLE: TUBE 10 AND 16		DWR#: 219
	UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
	SCALE: 1:2	TOLERANCE:	DRWN BY: LUKE KRAEMER



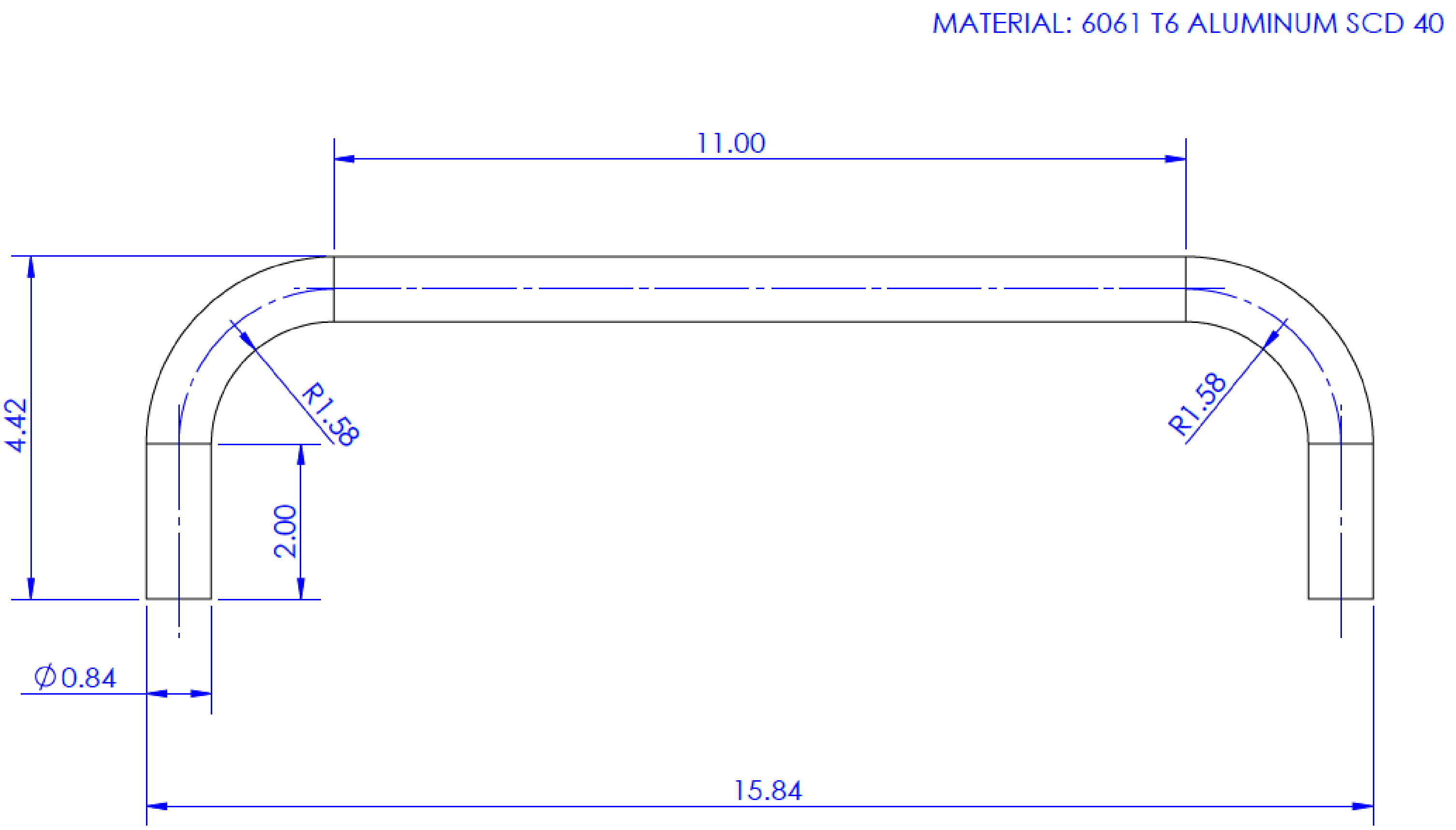
Mechanical Engineering CAL POLY	TITLE: TUBE 11		DWR#: 220
	UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
	SCALE: 1:1	TOLERANCE:	DRWN BY: LUKE KRAEMER



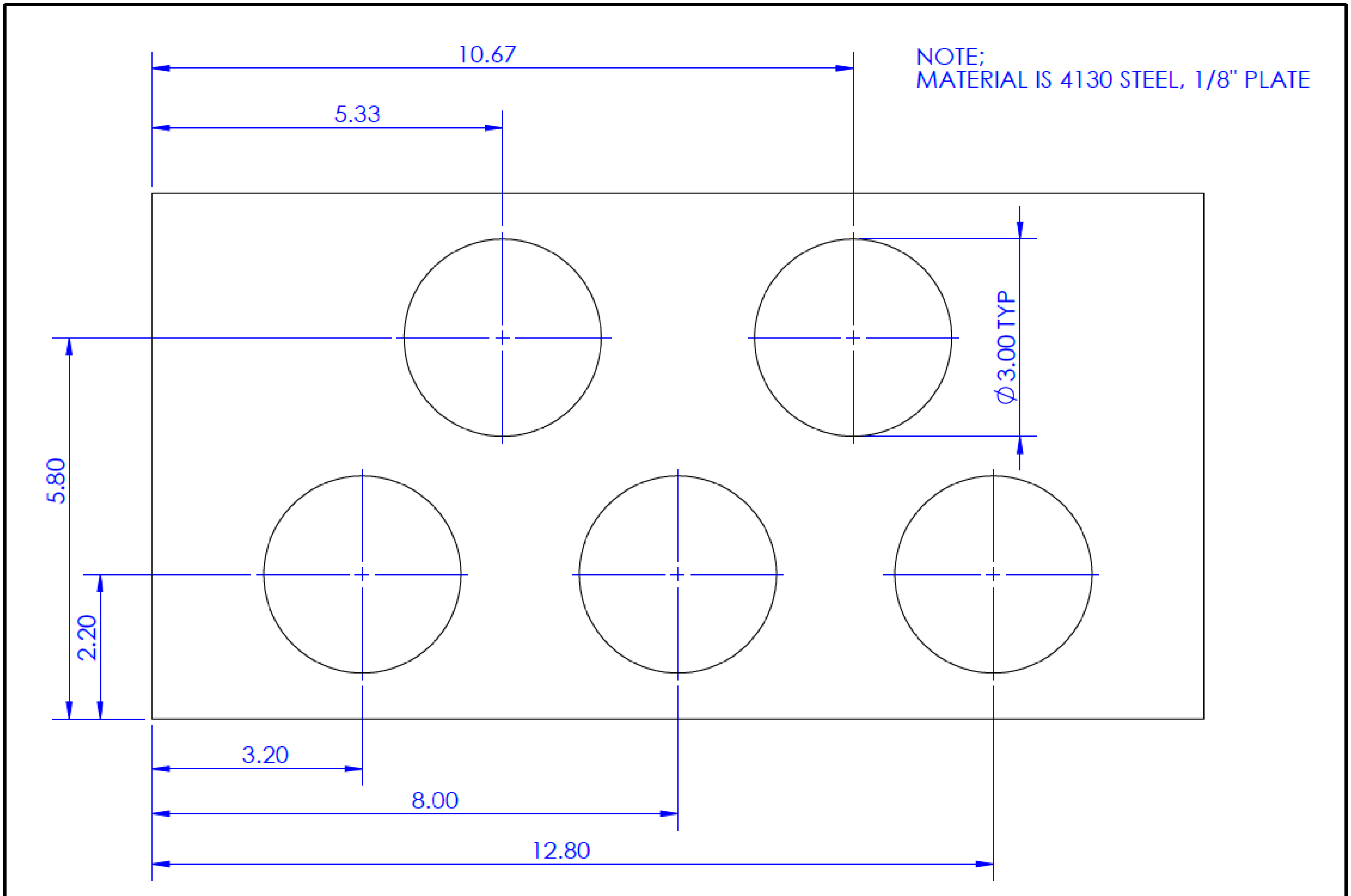
TITLE: TUBE 12		DWR#: 221
UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
SCALE: 1:1	TOLERANCE:	DRWN BY: LUKE KRAEMER



Mechanical Engineering CAL POLY	TITLE: TUBE 13		DWR#: 222
	UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
	SCALE: 1:2	TOLERANCE:	DRWN BY: LUKE KRAEMER

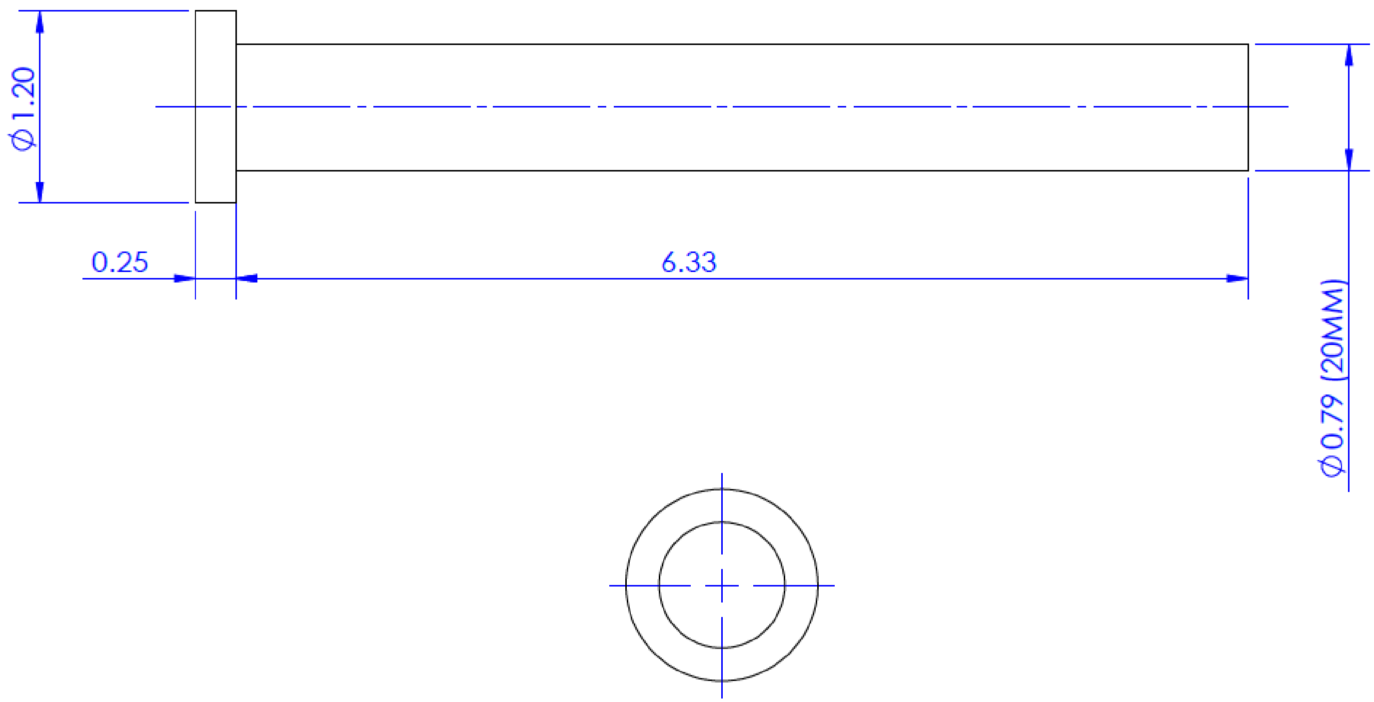


Mechanical Engineering CAL POLY	TITLE: HANDLEBAR		DWR#: 230
	UNITS: INCHES	MATERIAL: 6061 ALUMINUM	DATE: 2/9/17
	SCALE: 1:2	TOLERANCE:	DRWN BY: LUKE KRAEMER

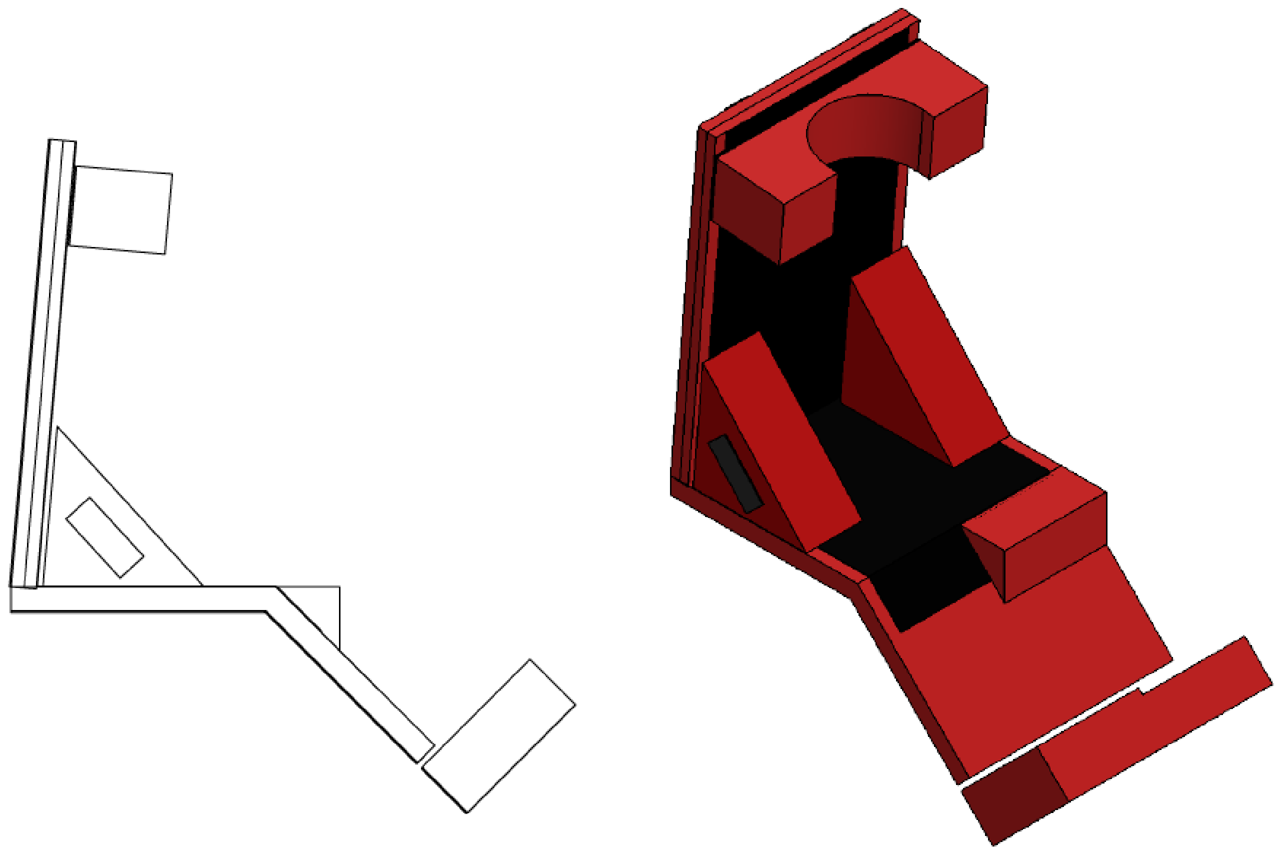


TITLE: FOOT PLATFORM		DWR#: 240
UNITS: INCHES	MATERIAL: 4130 STEEL	DATE: 2/9/17
SCALE: 1:2	TOLERANCE:	DRWN BY: LUKE KRAEMER

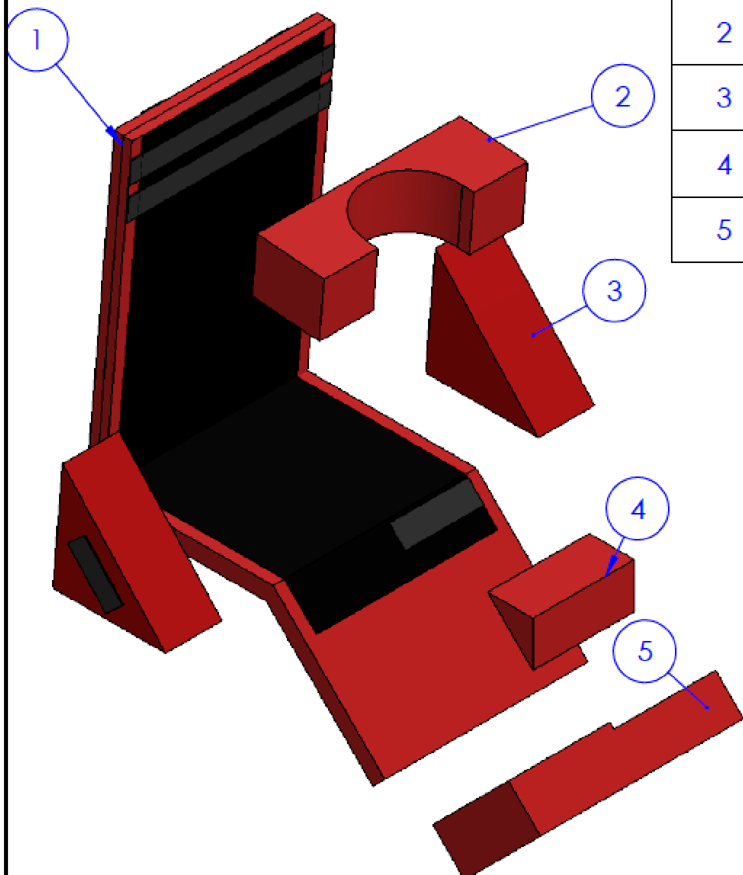
Mechanical Engineering CAL POLY



Mechanical Engineering CAL POLY	TITLE: AXLE PIN	DWR#: 250
UNITS: INCHES	MATERIAL: 6061 ALUMINUM	DATE: 2/9/17
SCALE: 1:1	TOLERANCE:	DRWN BY: LUKE KRAEMER

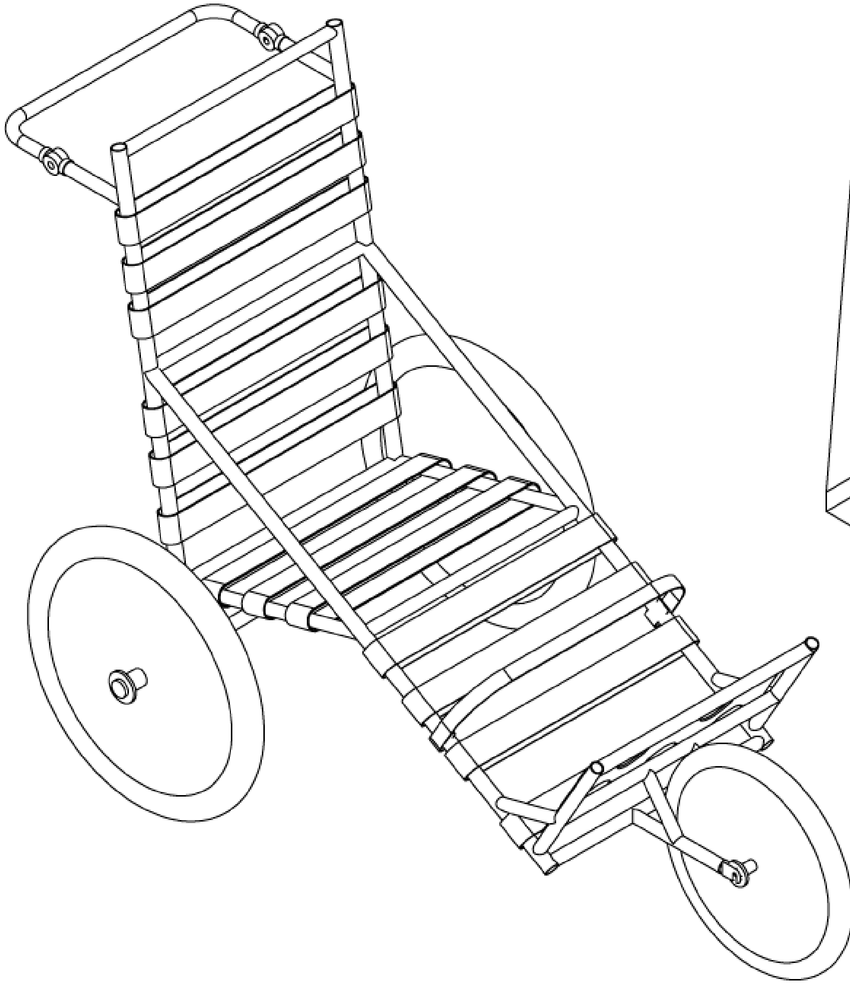


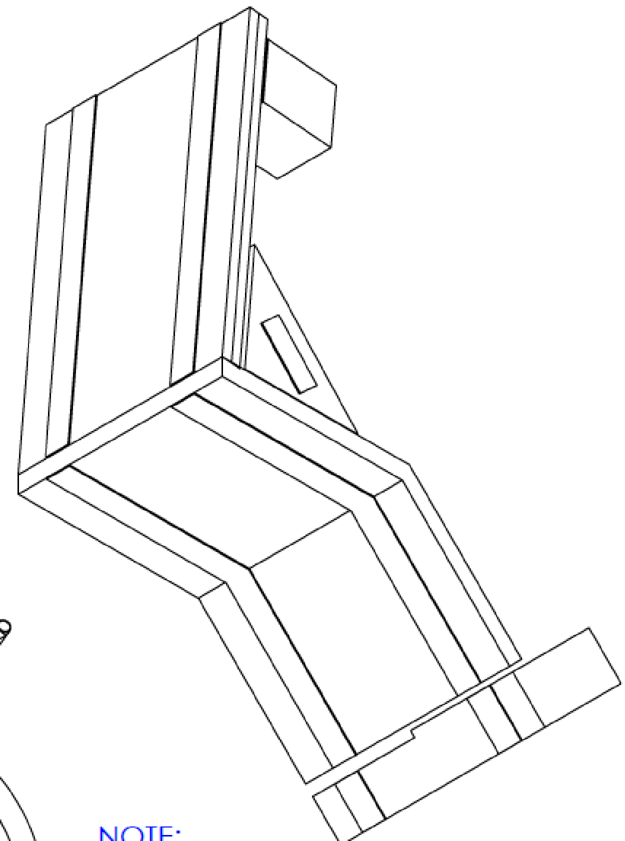
Mechanical Engineering CAL POLY	TITLE: SEAT ASSEMBLY		DWR#:300
	UNITS: ---	MATERIAL: ---	DATE: 2/5/17
	SCALE: 1:10	TOLERANCE: ---	DRWN BY: ROBERT TRUJILLO



ITEM NO.	PART NUMBER	DESCRIPTION	MATERIAL	QTY.
1	310	SEAT CUSHION	LATEX	1
2	320	HEADREST CUSHION	180-18	1
3	330	THIGH CUSHION	HIGH RESILIENCE	2
4	340	LEG BOLSTER	HR 34	1
5	350	FOOTREST CUSHION	HR 34	1

Mechanical Engineering CAL POLY	TITLE: EXPLODED SEAT ASSEMBLY		DWR#: 301
	UNITS: ---	MATERIAL: ---	DATE: 2/5/17
	SCALE: 1:10	TOLERANCE: ---	DRWN BY: ROBERT TRUJILLO

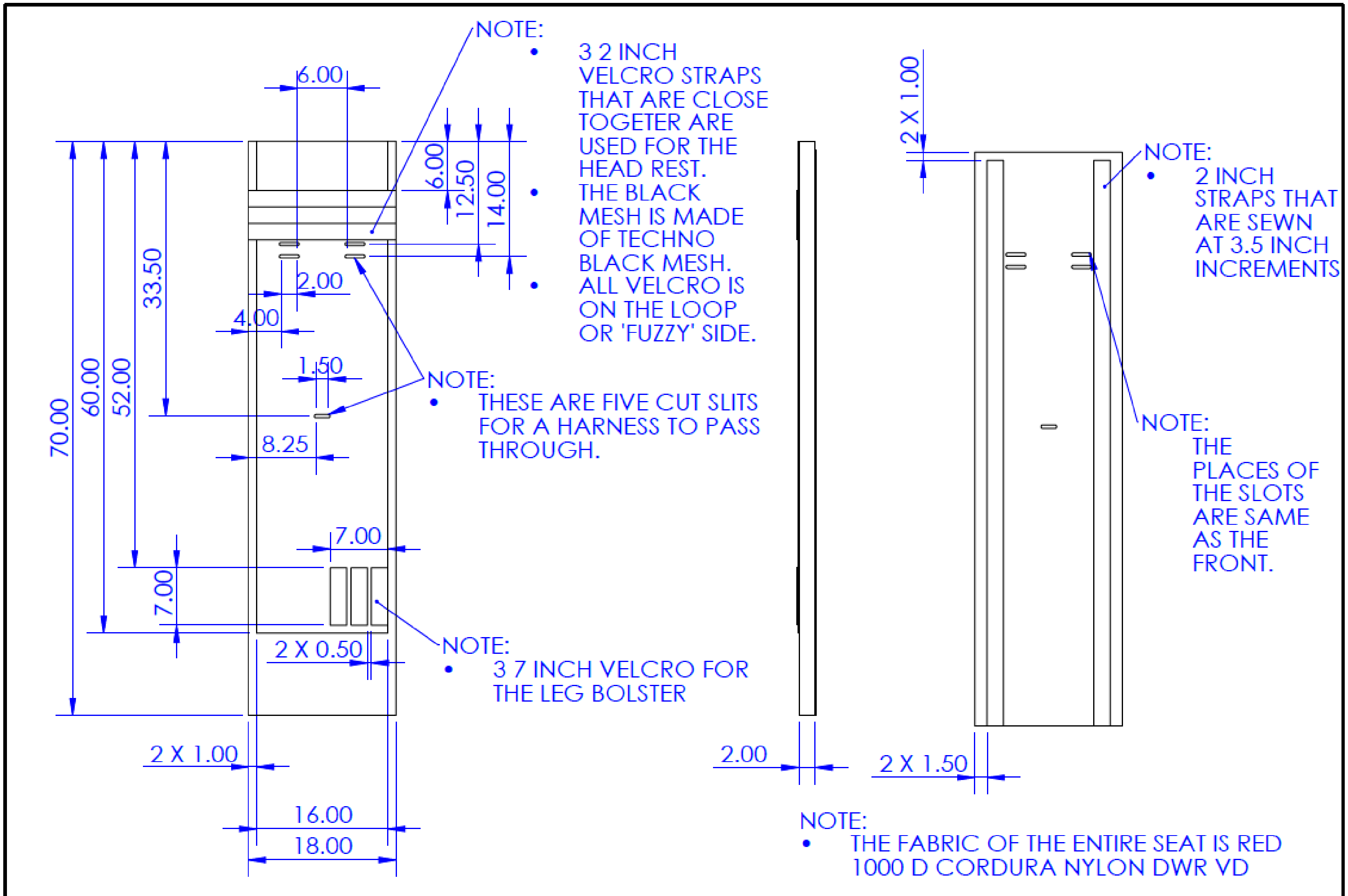




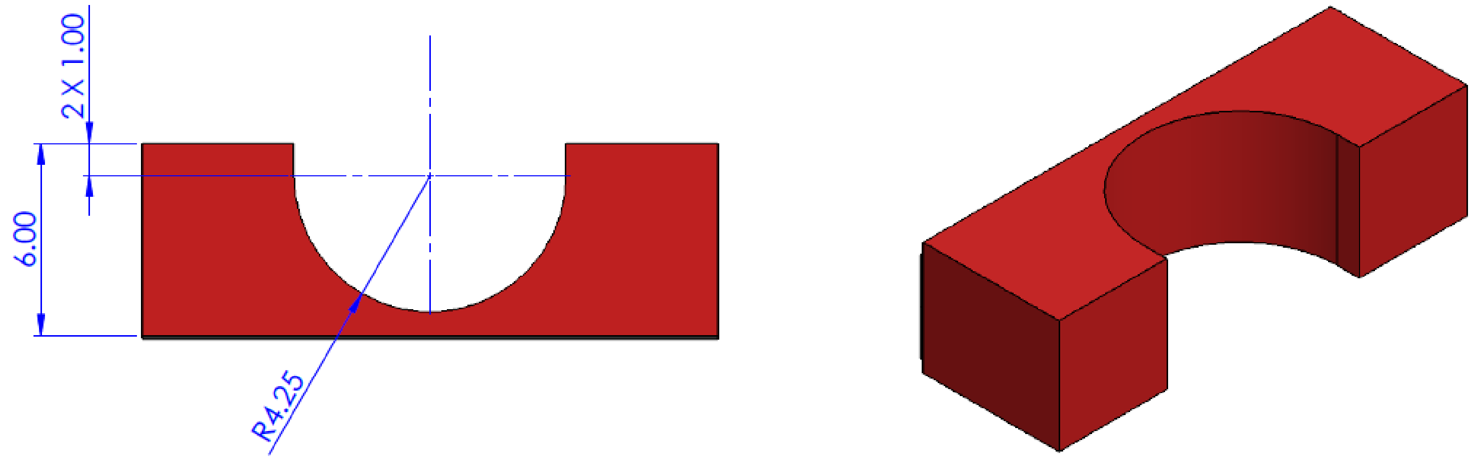
NOTE:

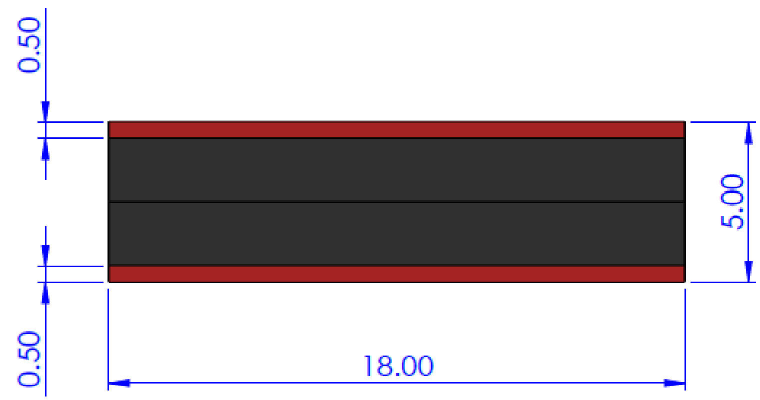
1. THE SEAT IS ATTACHED TO THE STRAPS BY THE STRAPS GOING THROUGH LOOPS CREATED ON THE BACKSIDE OF THE SEAT .
2. THE STRAP CLOSE AROUND THE FRAME AND ARE TIGHTEN AND CLOSED BY A BUCKLE.

Mechanical Engineering CAL POLY	TITLE: STRAP ATTACHMENT		DWR#: 302
	UNITS: INCHES	MATERIAL: ---	DATE: 2/9/17
	SCALE: 1:10	TOLERANCE: ---	DRWN BY: ROBERT TRUJILLO



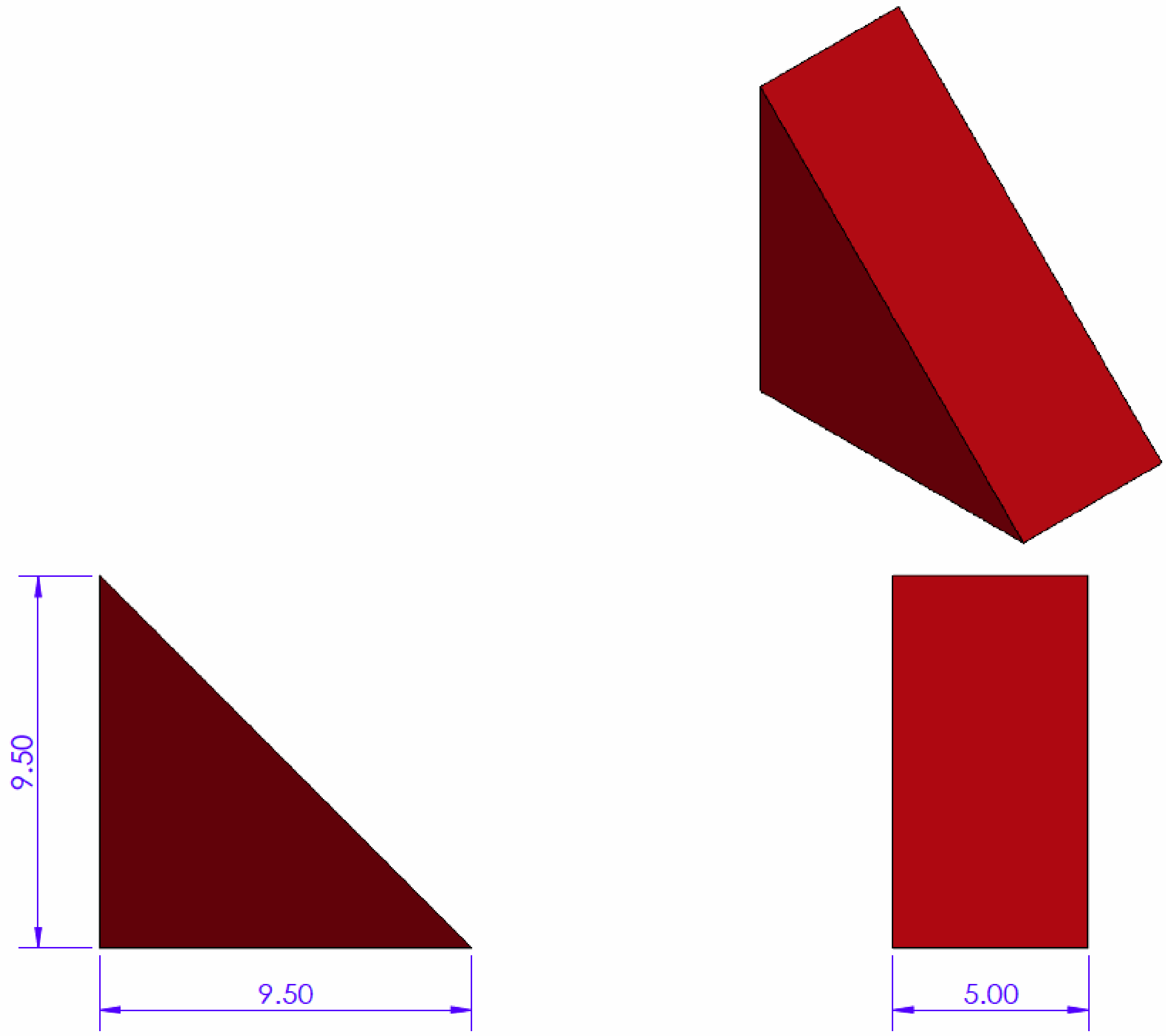
TITLE: SEAT CUSHION		DWR#: 310
UNITS: INCHES	MATERIAL: LATEX	DATE: 2/5/17
SCALE: 1:16	TOLERANCE: 1/4"	DRWN BY: ROBERT TRUJILLO



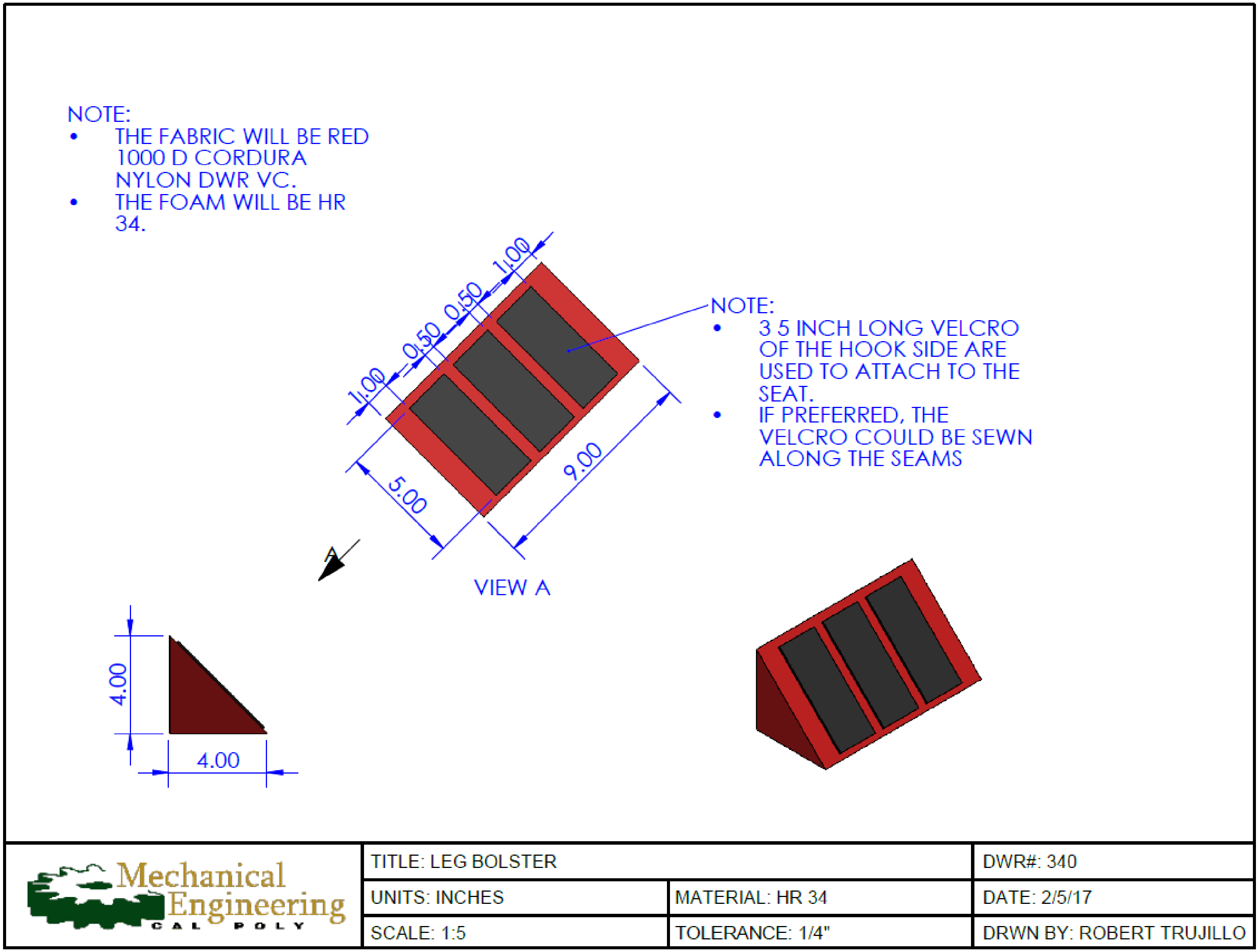


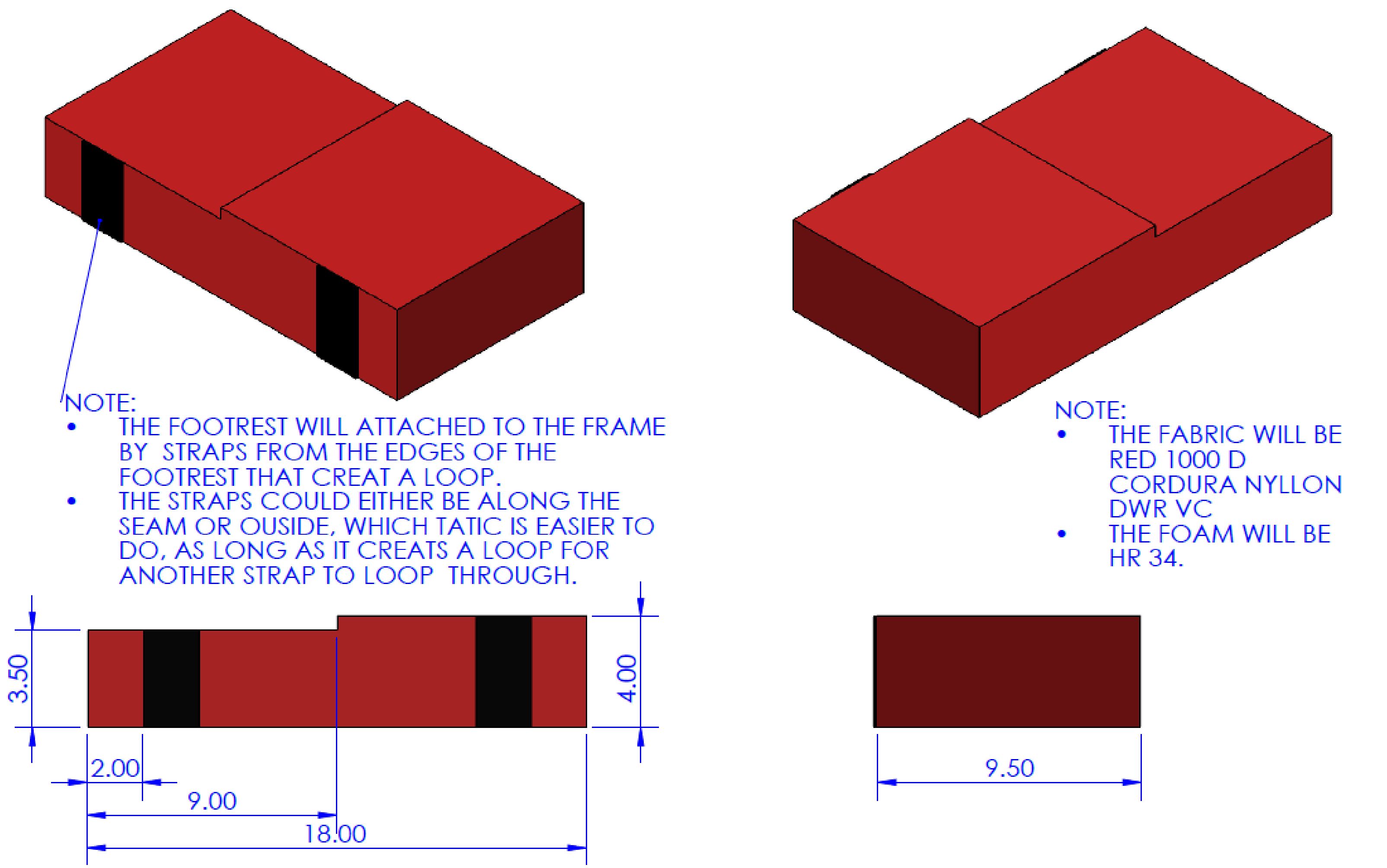
NOTE:
- TWO 2" VELCRO PIECES ARE 5" EACH ON THE HOOK SIDE THAT WILL ATTACH TO THE UPPER SEAT PORTION. THEY ARE SEWN BACK TO BACK.
- THE FOAM WILLL BE 180-18 FOAM.

Mechanical Engineering CAL POLY	TITLE: HEADREST CUSHION		DWR#: 320
	UNITS: INCHES	MATERIAL: 180-18 FOAM	DATE: 2/5/17
	SCALE: 1:5	TOLERANCE: 1/4"	DRWN BY: ROBERT TRUJILLO



TITLE: THIGH CUSHION		DWR#: 330
UNITS: INCHES	MATERIAL: HIGH RESILIENCE	DATE: 2/5/17
SCALE: 1:4	TOLERANCE: 1/4"	DRWN BY: ROBERT TRUJILLO


NOTE:
• THE FABRIC WILL BE RED 1000 D CORDURA NYLON DWR VC.
• THE FOAM WILL BE HR 34.
1.00
0.50
0.50
1.00
5.00
9.00
NOTE:
• 3 5 INCH LONG VELCRO OF THE HOOK SIDE ARE USED TO ATTACH TO THE SEAT.
• IF PREFERRED, THE VELCRO COULD BE SEWN ALONG THE SEAMS
A
VIEW A
4.00
4.00
Mechanical Engineering
CAL POLY
TITLE: LEG BOLSTER
DWR#: 340
UNITS: INCHES
MATERIAL: HR 34
DATE: 2/5/17
SCALE: 1:5
TOLERANCE: 1/4"
DRWN BY: ROBERT TRUJILLO



TITLE: FOOTREST CUSHION		DWR#: 350
UNITS: INCHES	MATERIAL: HR 34	DATE: 2/5/17
SCALE: 1:5	TOLERANCE: 1/4"	DRWN BY: ROBERT TRUJILLO

Mechanical Engineering CAL POLY

Roll over image to zoom in

Houseables

Houseables Polypro Webbing Strap, Polypropylene Heavy Flat Strapping, 2 Inch W x 25 Yards (Two 12.5 Yard Rolls), Black, UV Resistant Fabric, Waterproof for Bags, Backpacks, Handles, Luggage, Slings

35 customer reviews

Price: $14.99 ✓Prime | **Fast, FREE Shipping** with Amazon Prime

In Stock.

Want it Saturday, Feb. 11? Order within **13 hrs 20 mins** and choose **Saturday Delivery** at checkout. Details

Sold by Houseables and Fulfilled by Amazon. Gift-wrap available.

- WEATHER RESISTANT: Two 12.5 Yard Rolls, each roll provides you with 12.5 Yard(2" width) of sustainable polypro webbing. Made from thermoplastic resins, polypropylene webbing will not stretch like nylon webbing and is resistant to weather and water damage.
- INDOOR OR OUTDOOR USE. The webbing has a generous stretch and a taut surface that is ideal for most any type of general-purpose strapping need. The super strong material has a long-lasting effectiveness that is suitable for indoor or outdoor use, eliminating concerns of drying out or mildew exposure.
- DESIGNED FOR MEDIUM-TO-HIGH TRAFFIC SEATING SURFACES. With a tensile strength of 800 pounds per inch, this fine strapping supports plenty of weight and strain. It's stretch-resistant so it maintains its shape even when bent at an unusual angle.
- YOU CAN DO A LOT WITH A SINGLE ROLL: This multi-purpose reinforcement tool makes for a brilliant strap solution for harnesses, luggage, backpacking, and towing. It is also commonly used for hiking, camping, climbing, rafting, backpacking, and other outdoor activities.
- 90 Day 100% MONEY BACK GUARANTEE: We offer a No Hassle 90 Day 100% Money Back Guarantee. If, within the first 90 days, you are notcompletely satisfied with your purchase for any reason, just let us know and we will refund you all your money

New (2) from $14.99 & FREE shipping on orders over $49.00. Details

PART NUMBER:370

Roll over image to zoom in

Country Brook Design

Country Brook Design 2 Inches Black Sew on Hook and Loop, 10 Yards

191 customer reviews | 15 answered questions

Price: $16.99 Prime | **Fast, FREE Shipping** with Amazon Prime

In Stock.

Want it Saturday, Feb. 11? Order within **12 hrs 23 mins** and choose **Saturday Delivery** at checkout. Details

Sold by Country Brook Design Inc. and Fulfilled by Amazon. Gift-wrap available.

New (1) from $16.99 & FREE shipping on orders over $49.00. Details

Specifications for this item

Part Number	HL-BLA-2-10
Brand Name	Country Brook Design
Material Type	Nylon
Color	Black
Size	2 Inch
UNSPSC Code	53140000

See more product details

Appendix C: List of Vendors

Vendor	Contact Information	Item	Pricing
StrapWorks	1 (541) 741-0658	1.5” Straps	$0.82/ft
StrapWorks	1 (541) 741-0658	1.5 " Lobster Clips	$0.58/clip
Amazon	1 (888) 280-4331	Padded Covers for Straps	$8.02
StrapWorks	1 (541) 741-0658	Buckle Strap	$3.76
Amazon	1 (888) 280-4331	2" Velcro	$16.99
Amazon	1(888) 280-4331	Polyester Straps	$14.99
Amazon	1(888) 280-4331	Canvas Fabric	$5.49
APP		Upper Seat Foam	$0.00
APP		Leg Boaster Foam	$0.00
Arts Cyclery	1(800)835-1540 181 Suburban Rd. San Luis Obispo, Ca 93401	Wheel Building	$50.00
ATL	(248)443-9664 6632 Telegraph Rd. Ste 298 Bloomfield Hills, MI 483013012		$87.00
Convaid	1(888) 266-8243 2830 California St. Torrance, Ca 90503	3-Point Position Belt	$49
Dans Comp	1(888)888-3267 1 Competition Way, Mt. Vernon, IN 47620	16 Inch Rim Alienation	$40.00
Dans Comp	1(888)888-3267 1 Competition Way, Mt. Vernon, IN 47620	20 Inch Rim Alienation	$35.00
Foam Online	(805) 964-2001 Upholstery Decor, Inc. 5788 Hollister Ave. Goleta, CA 93117	Lower Seat Foam	$7.28
Foam Online	(805) 964-2001 Upholstery Decor, Inc. 5788 Hollister Ave. Goleta, CA 93117	Headrest Foam	$9.46
Foam Online	(805) 964-2001 Upholstery Decor, Inc. 5788 Hollister Ave. Goleta, CA 93117	Footrest Foam	$4.68

Foam Online	(805) 964-2001 Upholstery Decor, Inc. 5788 Hollister Ave. Goleta, CA 93117	Thigh Foam	$6.31
Jenson USA	(888)880-3811	Sram X7 Front Hub Disk	$35.00
Niagara Cycles	(716) 297-2764 2749 Military Rd Niagara Falls , NY 14304	Origin 8 20mm Thru Axle Hub	$34.00
Online Metals	(800)704-2157 1848 Westlake Ave N Suite A Seattle, WA 98109	4130 Steel Tube 1" OD .065 Wall	$5.00
Online Metals	(800)704-2157 1848 Westlake Ave N Suite A Seattle, WA 98109	4130 Steel Tube 1" OD .035 Wall	$5.00
Online Metals	(800)704-2157 1848 Westlake Ave N Suite A Seattle, WA 98109	4130 Steel Tube .875" OD .065 Wall	$6.40
Sailrite	(800)348-2769 2390 E 100 S Columbia City, IN 46725 USA	Silk Film	$15.95

Table C.1: List of vendors and contact information.

Appendix D: Vendor Suppled Components Specs and Data Sheets

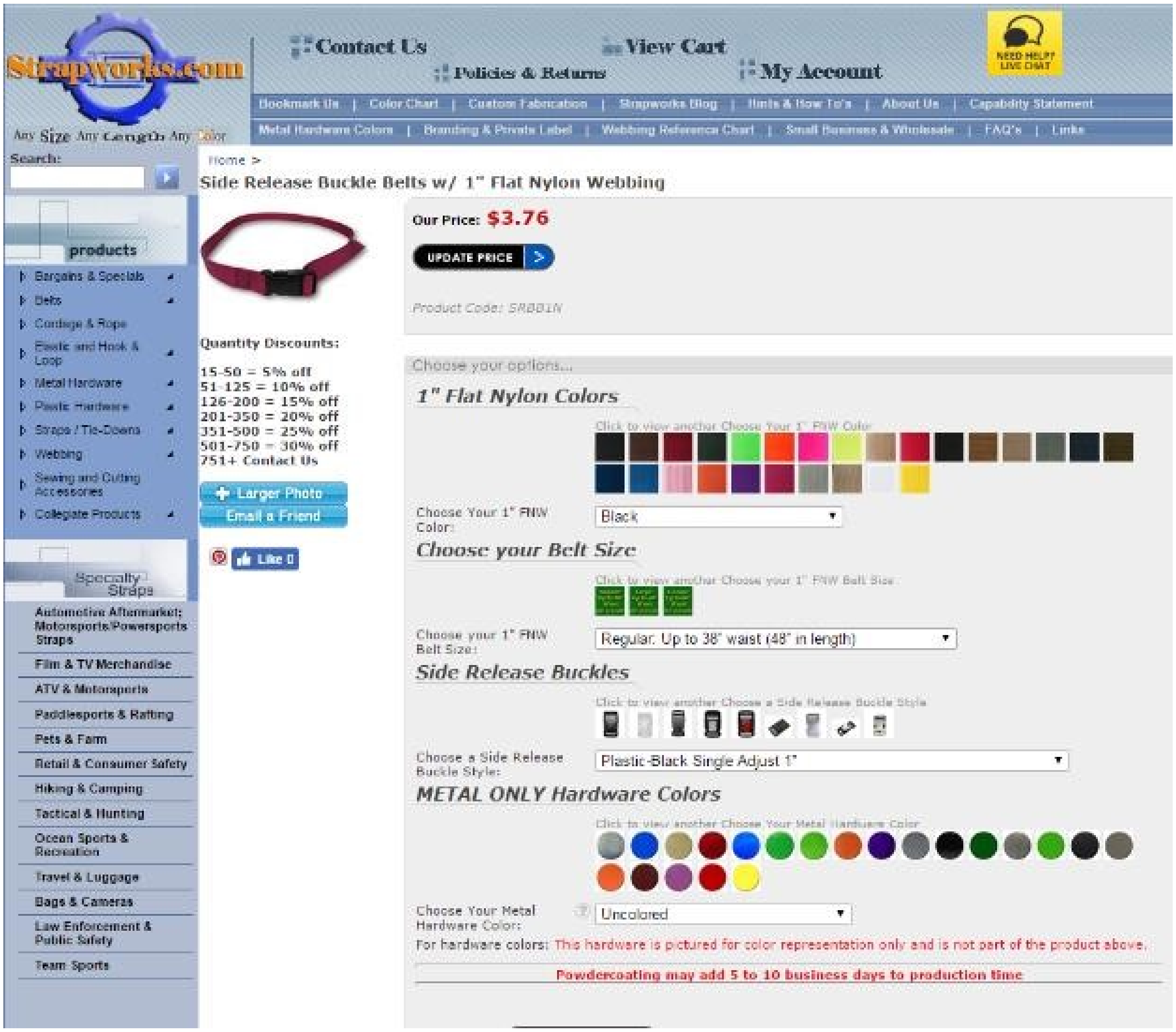


Figure D.1: Harness Material: Buckle Belt

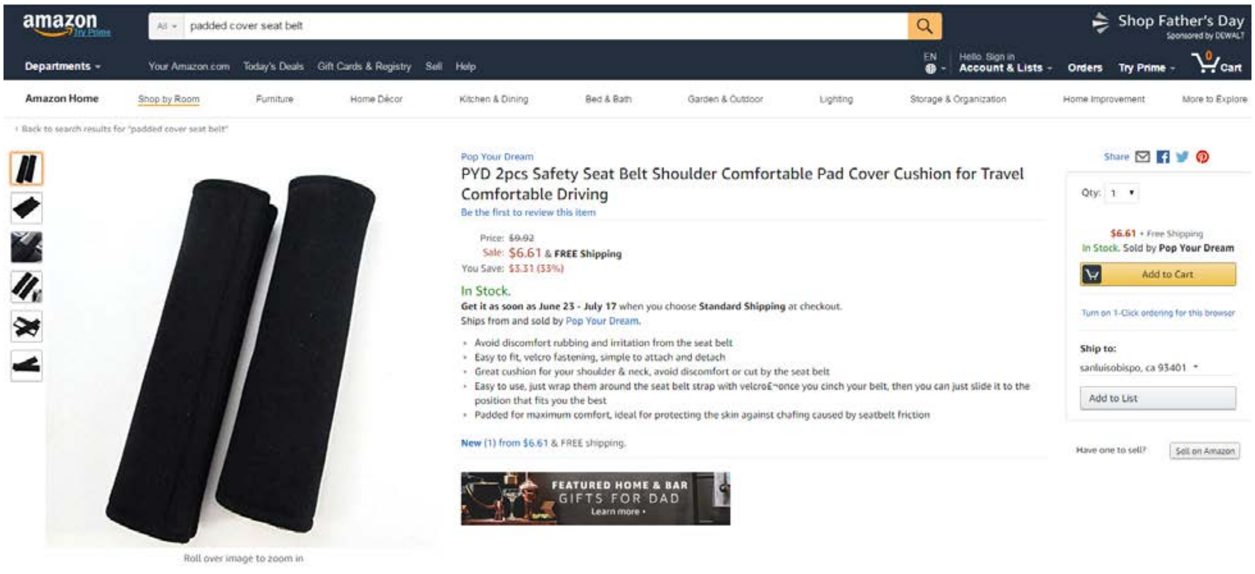


Figure D.2: Harness Material: Padded Covers

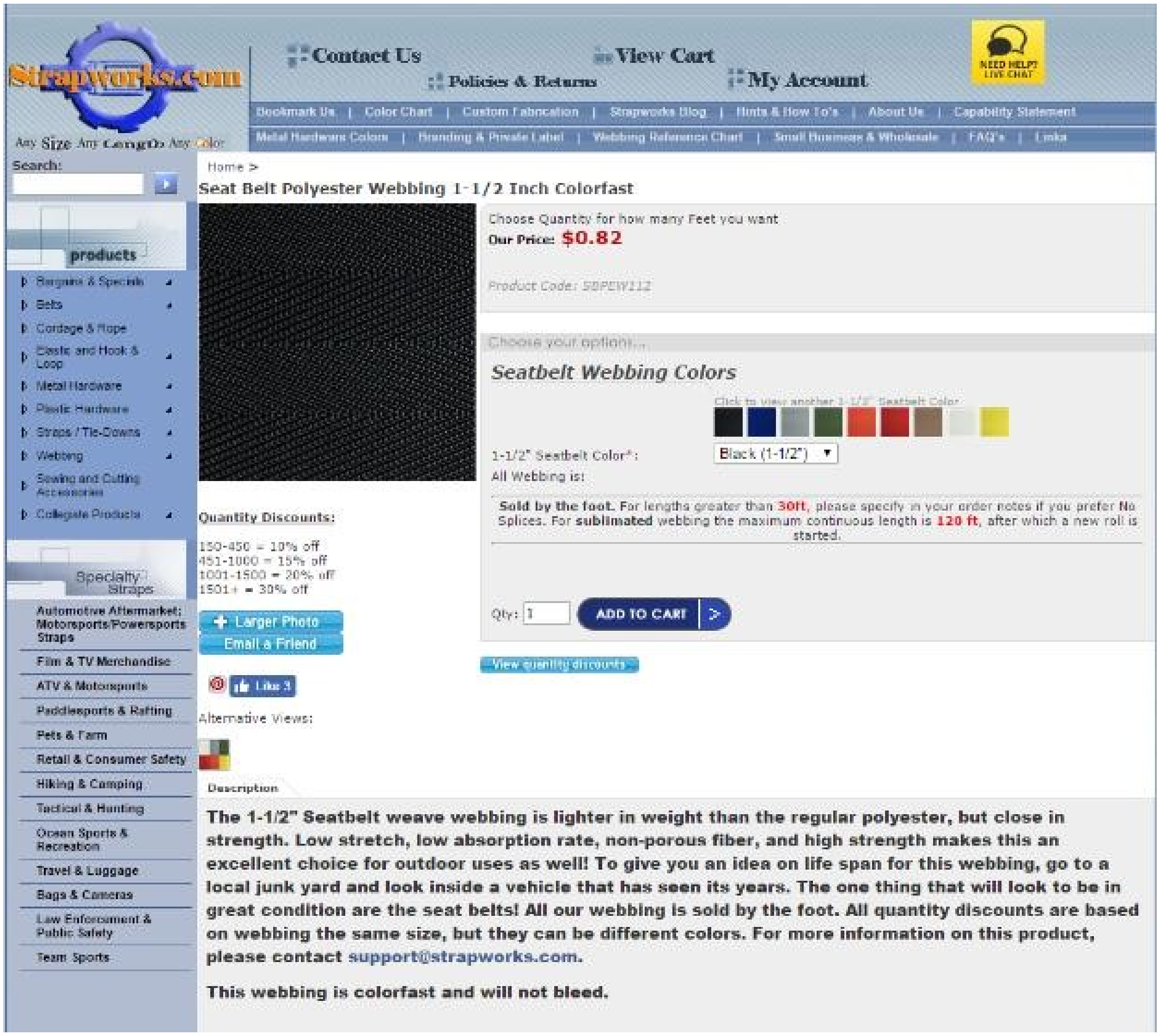


Figure D.3: Harness Material: Polyester Straps

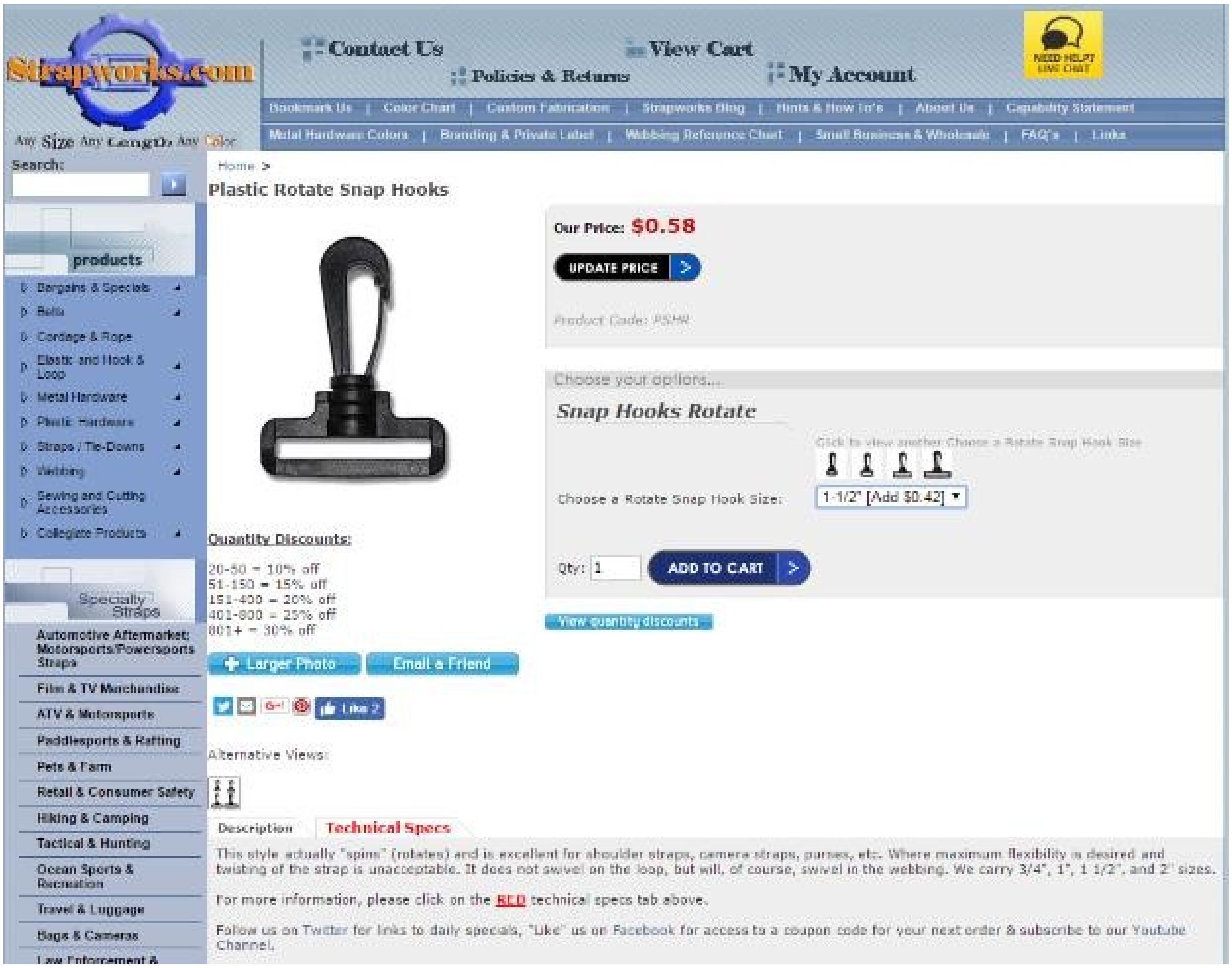


Figure D.4: Harness Material: Lobster Clips

Convaid
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Home » Wheelchair Parts & Accessories » Cruiser Accessories & Options » Cruiser Pelvis Positioning Options »

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3-Pt Postion Belt w/ Depth Adj Crotch Strap

Standard Features:

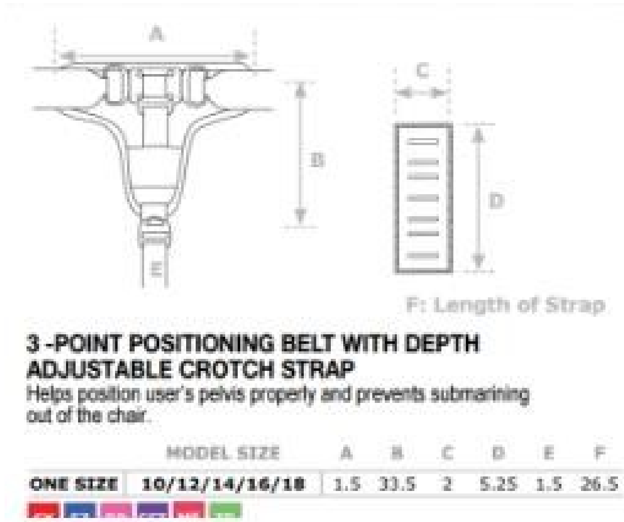
Adjusts to keep the individual securely in position. This 3 point belt with Depth Adj Crotch Strap has been meticulously crash tested to make sure it will live up to Convaid standards. Convaid wheelchairs are manufactured to the highest quality and style, specializing in compact-folding, lightweight wheelchairs for all age ranges, which avoid a medical look.

Parts pricing listed is for "on-chair" (initial wheelchair purchase) orders only. Please call 1-888-CONVAID (1-888-266-8243) for pricing for "parts only" orders.

Option Price: $49.00

Click image to enlarge

Brochure | Find a Dealer



3 -POINT POSITIONING BELT WITH DEPTH ADJUSTABLE CROTCH STRAP

Helps position user's pelvis properly and prevents submarining out of the chair.

	MODEL SIZE	A	B	C	D	E	F
ONE SIZE	10/12/14/16/18	1.5	33.5	2	5.25	1.5	26.5

(e) Harness Material: 3-Point Belt

Figure D.5: Safety Harness Materials

Appendix E: Design Verification Plan

ME 430 DVP&R Format													
Report Date: June 2, 2017			Sponsor	Michael Lara					Component/Assembly		Joseph's Jogger	REPORTING ENGINEER: ROBERT TRUJILLO	
TEST PLAN										TEST REPORT			
Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsi	Test Stage	SAMPLES		TIMING		TEST RESULTS			NOTES
						Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	Weld Test	Using sand bags, add 100 lbs to stroller and push for it over pavement, grass, dirt, cobblestone, and gravel	Stroller doesn't fail/fracture, withstand 100 lb load	Luke	PV	1	T	5/30/2017	5/30/2017	Pass			Supported the weight of over 192 lbs.
2	Lean Test	Measure Stroller Lean with 100 lb load until tipover	Does not tip over at 15 degrees from ground	Carol	DV	1	T	5/30/2017	5/30/2017	Pass	30 degrees		
3	Incline Test	Using obstacles with different incline, measure max incline until tips backwards	Does not tip over at 40 degrees from ground	Carol	DV	1	T	5/30/2017	5/30/2017	Pass	15 degrees		
4	Footrest test	Measure strength of the footrest by applying 100lb distributed load. Measure strength of footrest by applying 75 lbs to left side alone (Joseph's stronger leg).	Withstand 100 lb distributed load	Luke	DV	1	T	5/30/2017	5/30/2017	Pass			
5	Device Weight	Measure on a scale	Under 45 lb	Josh	DV	1	T	5/30/2017	5/30/2017	Fail			Did not had equipment to accurately test weight but had felt heavier than 45 lbs.
6	Length Device	Measure with a measuring tape	Under 60 inches	Josh	DV	1	T	5/30/2017	5/30/2017	Fail		3 inches	
7	Width of Device	Measure with a measuring tape	Under 36 inches	Josh	DV	1	T	5/30/2017	5/30/2017	Pass	16 inches		
8	Handle Bars adjustability	Measure from ground max and min height	Adjustable for pushers of height 4'6" to 6'6"	Robert	PV	1	T	5/30/2017	5/30/2017	Pass			
9	Comfort of handlebar (grip and adjust)	While running, adjust handle to min and max position 3 times each direction	Easy to adjust without having to stop running	Luke	PV	1	T	5/30/2017	5/30/2017	Pass			
10	Pinch Points	Using pencil, poke through openings in stroller that appear to be pinch points. Close the mechanism and observe whether pencil gets caught or not.	0 pinch points	Carol	CV	1	T	5/30/2017	5/30/2017	Pass			
11	Ease of pushing	Push over pavement, grass, dirt, gravel, and cobblestone with 100lb load	Push without hesitation	Carol	PV	1	T	5/30/2017	5/30/2017	Pass			
12	Ease of using harness	Measure time it takes to put harness on and remove.	Under 90 seconds	Carol	PV	1	T	5/30/2017	5/30/2017	Pass	~45 sec		

Table E.1: Design Verification Report.

Appendix F: Gantt Chart

ID		Task Mode	Task Name	Duration	Start	Finish
1			**Ordering Parts**	**13 days**	**Tue 2/14/17**	**Thu 3/2/17**
2			Seat Parts	13 days	Tue 2/14/17	Thu 3/2/17
3			Frame Parts	13 days	Tue 2/14/17	Thu 3/2/17
4			Wheel Parts	13 days	Tue 2/14/17	Thu 3/2/17
5	✓		Harness Parts	13 days	Tue 2/14/17	Thu 3/2/17
6			**Manufacturing Plan**	**22 days**	**Fri 3/3/17**	**Sat 4/1/17**
7			Seat Manufacturing (Mitch's Stitches) + Harness [Planned]	16 days	Fri 3/3/17	Fri 3/24/17
8			Seat Manufacturing (Mitch's Stitches) + Harness	15 days	Fri 4/28/17	Thu 5/18/17
9			Wheel Manufacturing (Art's Cyclery) [Planned]	10 days	Fri 3/3/17	Thu 3/16/17
10			Wheel Manufacturing (Art's Cyclery)	30 days	Mon 4/3/17	Fri 5/12/17
11			Frame Pre-Weld Machining [Planned]	10 days	Fri 3/3/17	Thu 3/16/17
12			Frame Pre-Weld Maching	9 days	Wed 4/19/17	Sun 4/30/17
13			Welding of Frame [Planned]	7 days	Tue 3/14/17	Wed 3/22/17
14			Welding of Frame	10 days	Mon 5/1/17	Fri 5/12/17
15			Powder Coating of Frame [Planned]	6 days	Fri 3/24/17	Fri 3/31/17
16			Powder Coating of frame	9 days	Sat 5/13/17	Wed 5/24/17
17			Assemble Jogger Together [Planned]	0 days	Sat 4/1/17	Sat 4/1/17
18			Brake System	4 days	Wed 5/24/17	Mon 5/29/17
19			Harness Restraint	4 days	Wed 5/24/17	Mon 5/29/17
20			Assemble Jogger Together	0 days	Mon 5/29/17	Mon 5/29/17
21			**Testing**	**14 days**	**Sat 5/13/17**	**Wed 5/31/17**
22			Test Frame	14 days	Sat 5/13/17	Wed 5/31/17
23			Test Footrest	14 days	Sat 5/13/17	Wed 5/31/17
24			Test Seat	14 days	Sat 5/13/17	Wed 5/31/17
25			Test Straps	14 days	Sat 5/13/17	Wed 5/31/17
26			Test Handle Bars	14 days	Sat 5/13/17	Wed 5/31/17
27			Test Canopy	14 days	Sat 5/13/17	Wed 5/31/17
28			Test completed	0 days	Wed 5/31/17	Wed 5/31/17
29			Expo	0 days	Fri 6/2/17	Fri 6/2/17

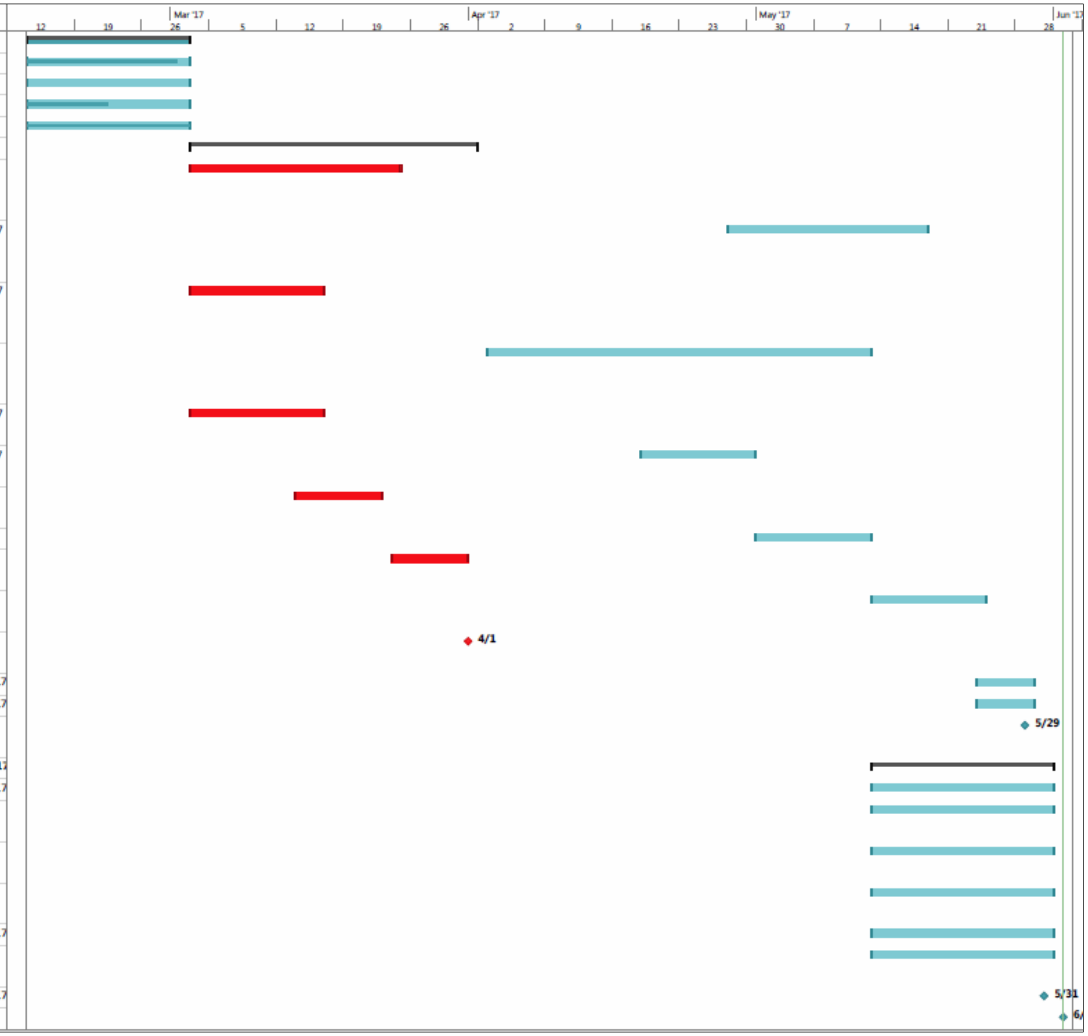


Figure F.1: Gantt chart showing the planed dates tasks will be worked on for the duration of Joseph's Jogger in red and the actual dates in blue.

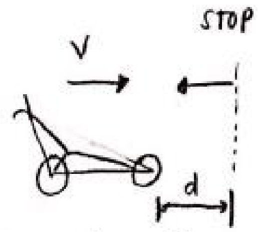
Appendix G: Bill of Materials

Subsystem	Item Description	Supplier	Quantity	Cost
Harness	3-Pt Positioning Belt w/ Depth Adj. Croth Strap	Convaid Products	1	$62.92
	Buckles and Slides	Strap works	1	$58.52
	Straps, fastners, and buckle for harness	Quality Fabrics	1	$17.27
Seat	Foam	Foam Online	1	$74.64
	Straps for Footrest	Quality Fabrics	1	$14.16
	2 x Country Brook Design 2 Inch Heavy Black Polypro Webbing	Amazon	1	$23.90
	Fabric & Sewing Supplies	Beverleys	1	$47.32
	2 inch Plastic Triglides	Amazon	1	$12.98
	Country Brook Design 2 Inches Black Sew on Hook and Loop, 10 Yards	Amazon	1	$22.54
	2 x eBoot 1 pair Car Seat Belt Strap Covers Shoulder Pad	Amazon	1	$15.76
	Iron on Letters	Beverly's	1	$10.76
	Iron on CP Logo	Cal Poly University	1	$9.65
	Cushion Wrap Silk Film	Salrite Enterprises	1	$28.48
	Seat Labor	Mitch's Stitches	1	$1,400.00
Frame & Wheels	Prototype Steel	Online Metals	1	$231.57
	Test Alloy Steel 4130 NORMALIZED Tube	Online Metals	1	$64.88
	Final Steel & Welding Material & Wheel Labor	Various	1	$766.00
	Powder Coating	Central Coast Powder	1	$155.00
	Welding Labor	Luke's Brother	1	$400.00
	Bike Tires/Metal/Grip Tape	ATL	1	$95.22
	Aluminum 6061-T6 Pipe	Amazon	1	$6.96
	Alienation, Black Sheep 16" Rim, 36H Black	Walmart	1	$23.44
	Alloy Steel 4130 Tubes	Online Metals	1	$191.57
	2 of: HUB FT OR8 MT3100 36x110x20mmTA 6B SB BK	Amazon	1	$81.32
	Shimano Deore M525A 36h Front Disc Hub Black	Amazon	1	$25.94
	2 x Cinema 333 Rim Black	Bakerized Action Sports	1	$71.99
Total	**Total Cost**	**Baker Kobb Grant & Phi Sigma Kappa**	**-**	**$3,912.79**

Table G.1: Bill of Materials

Appendix H: Hand Calculations for Forces on Joseph

HARNESS: FORCE ON JOSEPH



$$F_{avg}\, d = -\frac{1}{2} m v^2$$

$$KE = \frac{1}{2} m v^2$$

GIVENS

JOSEPH WEIGHS $W = 75\text{ lbs}$

$d = 1\text{ ft}$

$V = 8.3\text{ mi/hr}$

$$V = 8.3\text{ mi/hr} \; \frac{5280\text{ ft}}{1\text{mi}} \; \frac{1\text{hr}}{3600\text{s}} = 12.17\text{ ft/s}$$

$$W = 75\text{ lbs} = mg$$

$$m = 75\text{lbs}/32.2\text{ ft/s}^2 = 2.33\text{ slugs}$$

$$KE = \frac{1}{2}(2.33\text{ slugs})(12.17\text{ ft/s})^2 = 172.55\text{ slugs}\cdot\text{ft}^2/\text{s}^2$$

$$F_{avg}\, d = -\frac{1}{2} m v^2 = -172.55\text{ slugs}\cdot\text{ft}^2/\text{s}^2$$

$$d = 1\text{ft}$$

$$F_{avg} = -172.55\text{ slugs}\cdot\text{ft/s}^2$$

FORCE ON JOSEPH = 172.55 lb_f

Figure H.1: Hand Calculations for Force on Joseph.

Appendix I: FEA Analysis for Frame

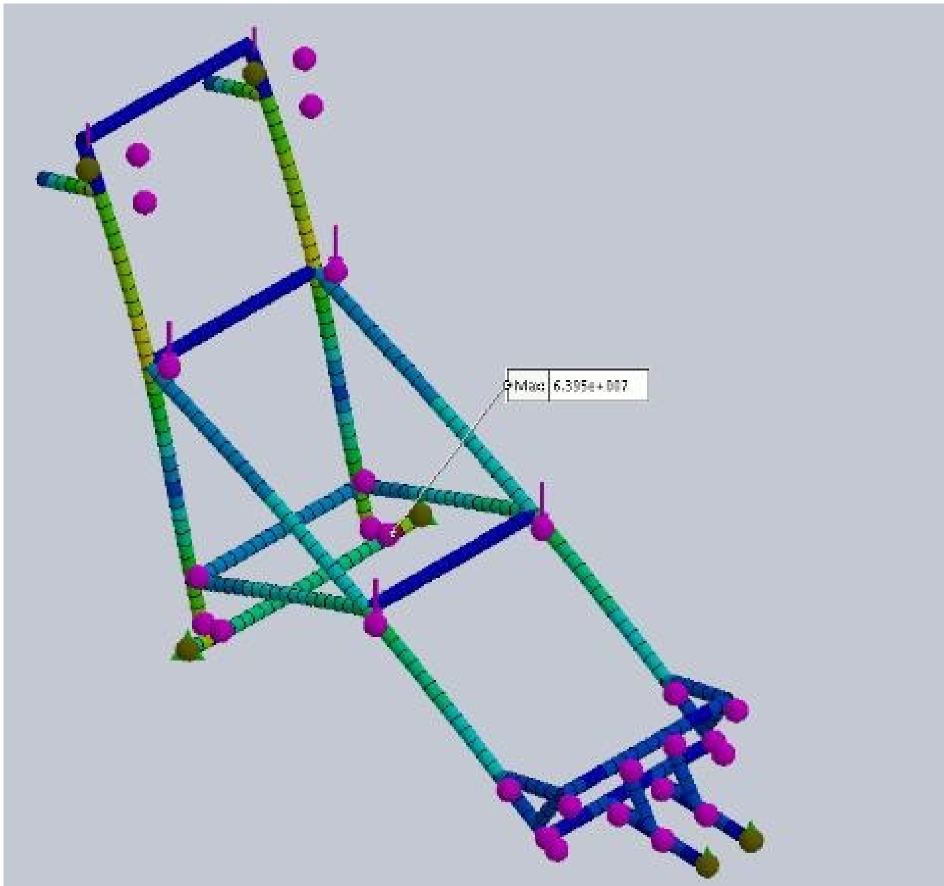


Figure I.1: Loading Case 1. Study models Joseph sitting in the jogger while someone pushes down on the handlebars to execute a turn. The force is concentrated at the axles.

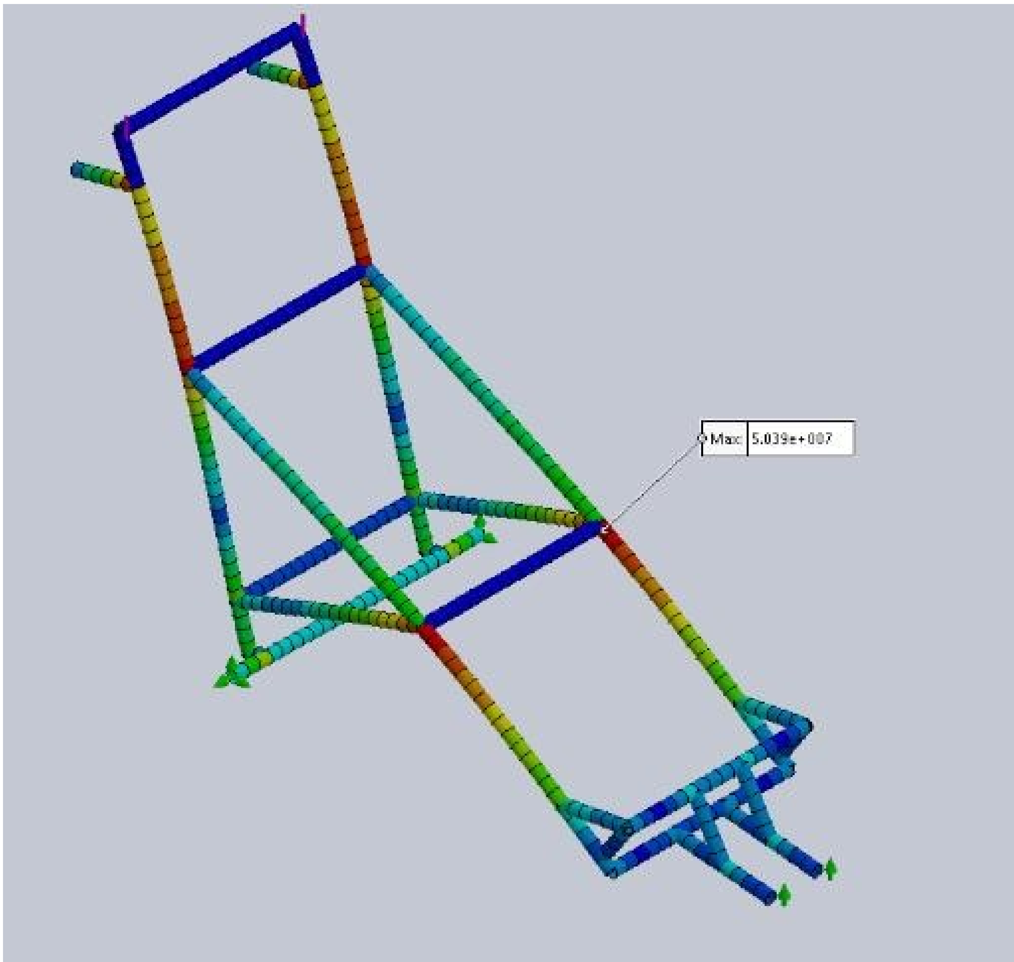


Figure I.2: Loading Case 2. In this study, the jogger is assumed to be empty and the front wheel is held stationary. Vertical force is applied at the handlebar. The stress is concentrated at the center of the long member.

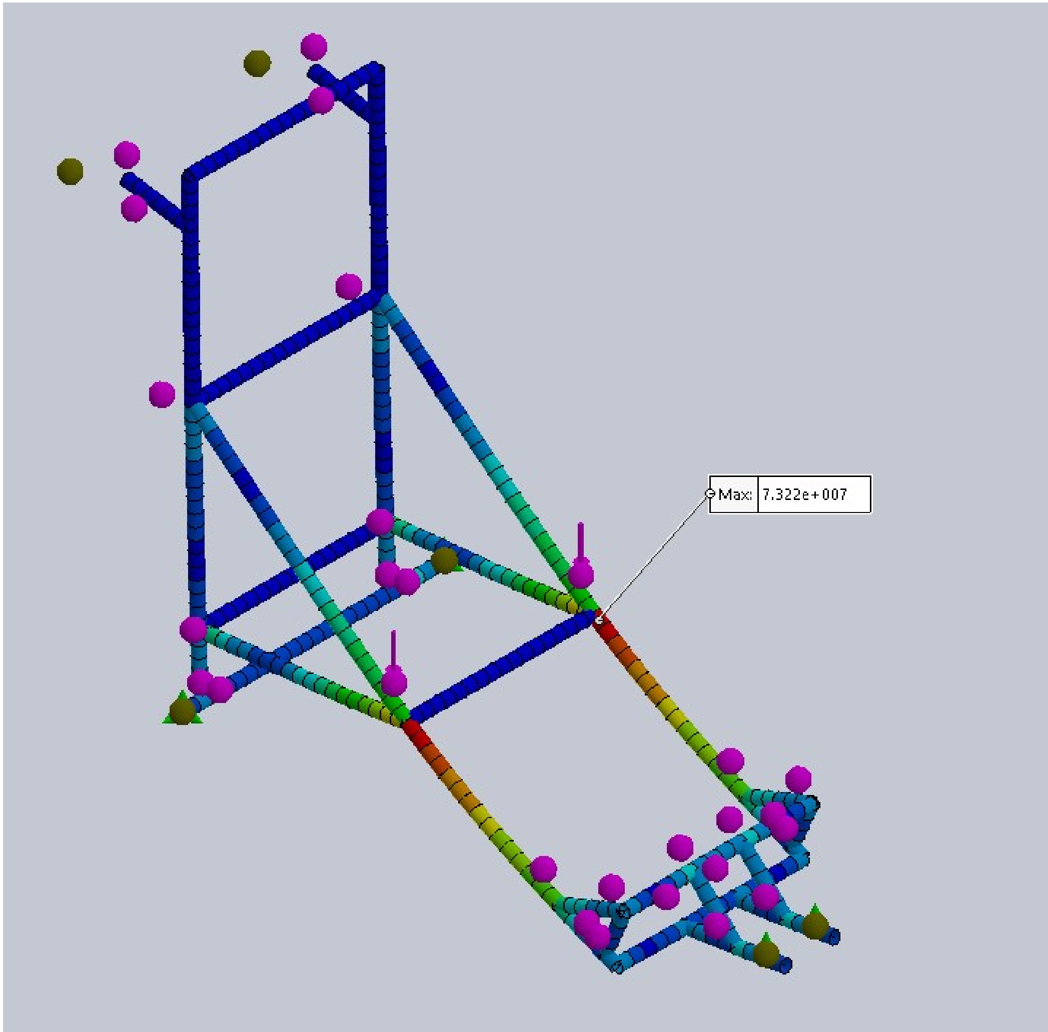


Figure I.3: Loading Case 3. Study models Joseph sitting in the Jogger without any outside forces acting on it. The stress is concentrated at the center of the long bar at the location of Joseph's knees.

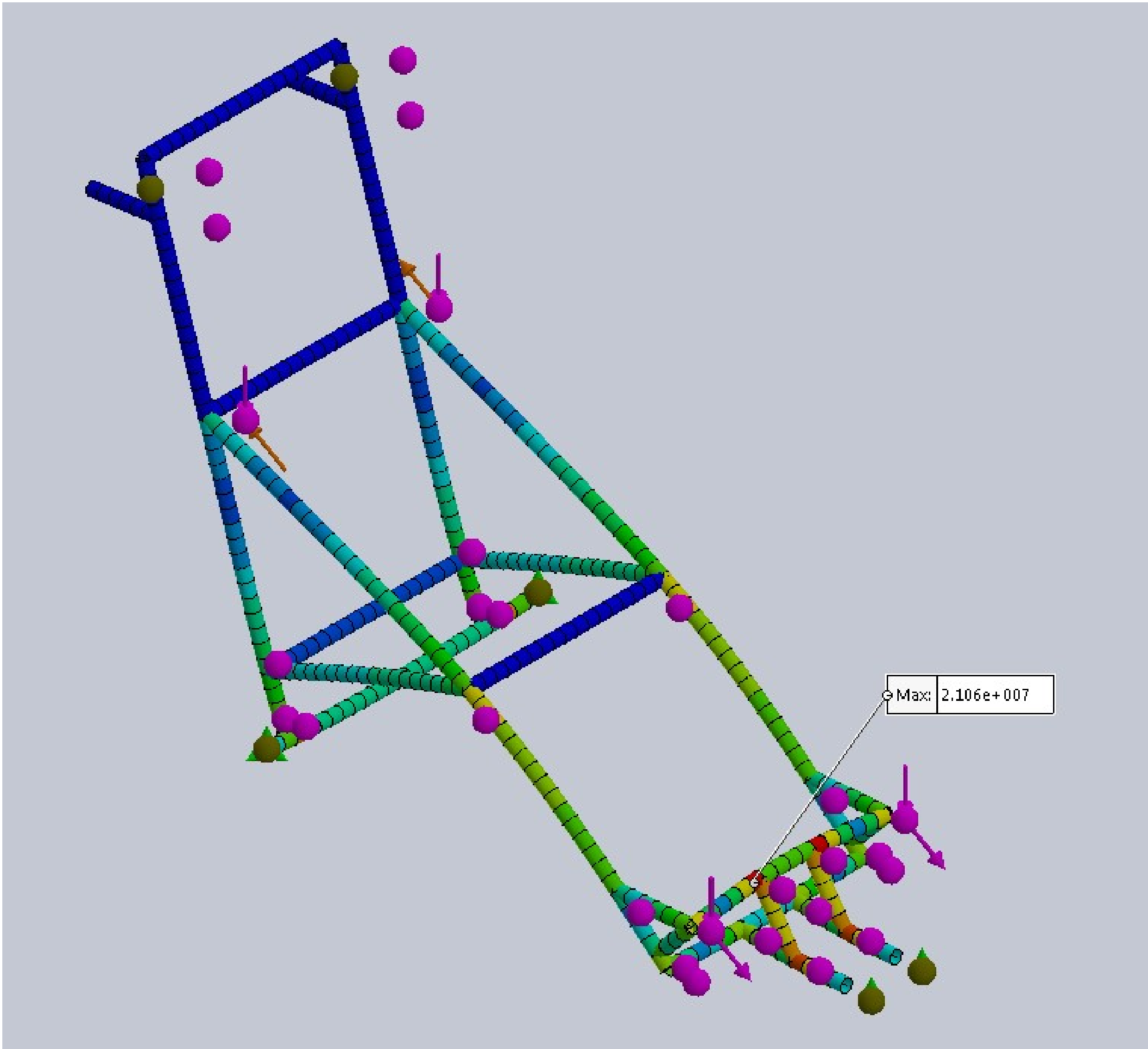


Figure I.4: Loading Case 4. This study looks into the forces stresses produced when Joseph strains and extends against the footrest. The forces are concentrated at the center of the front bulkhead.

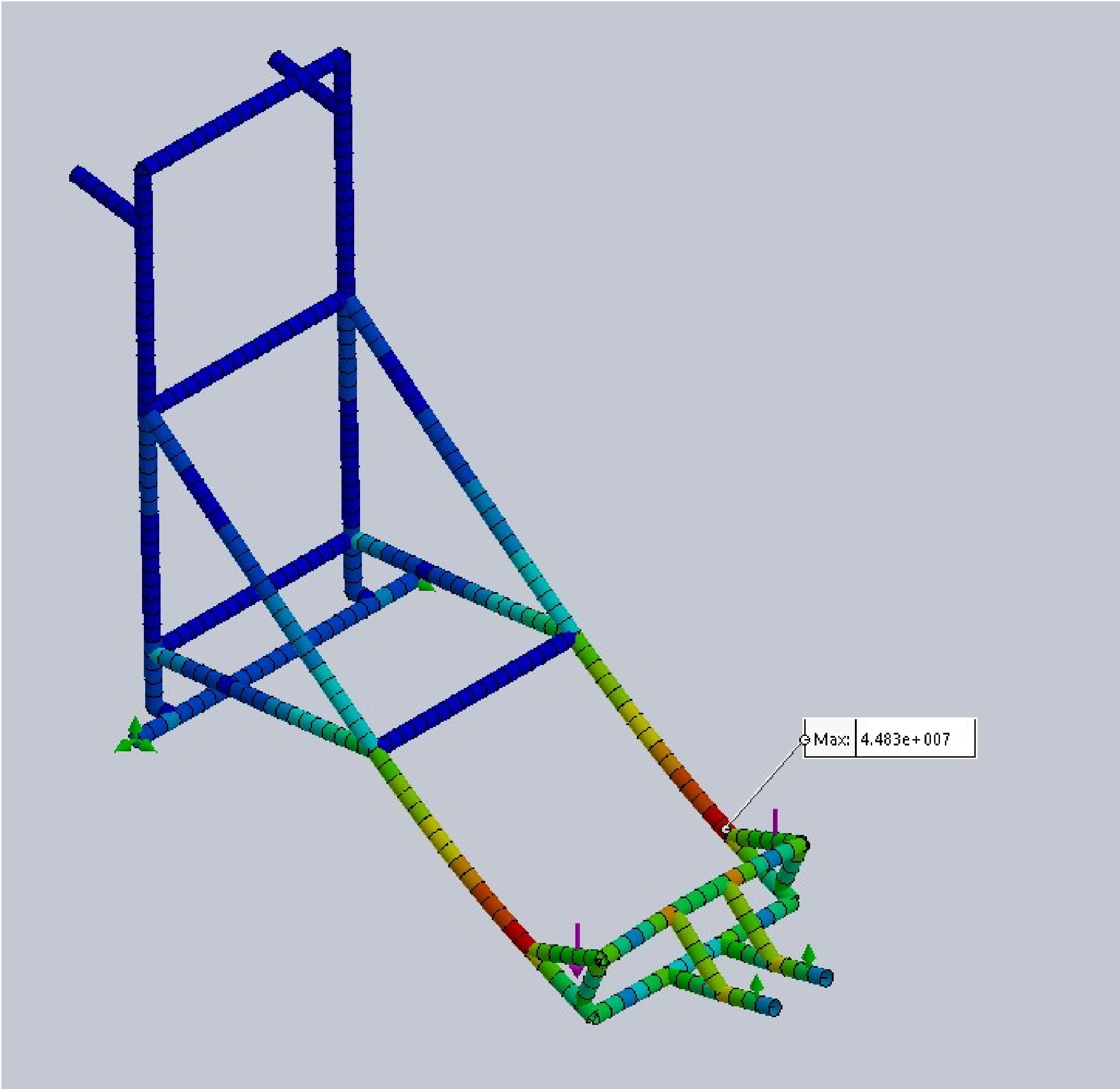


Figure I.5: Loading Case 5. This study models the unlikely case that Joseph would put all his weight on the front of the Jogger. The stress is concentrated at the lower end of the long member.

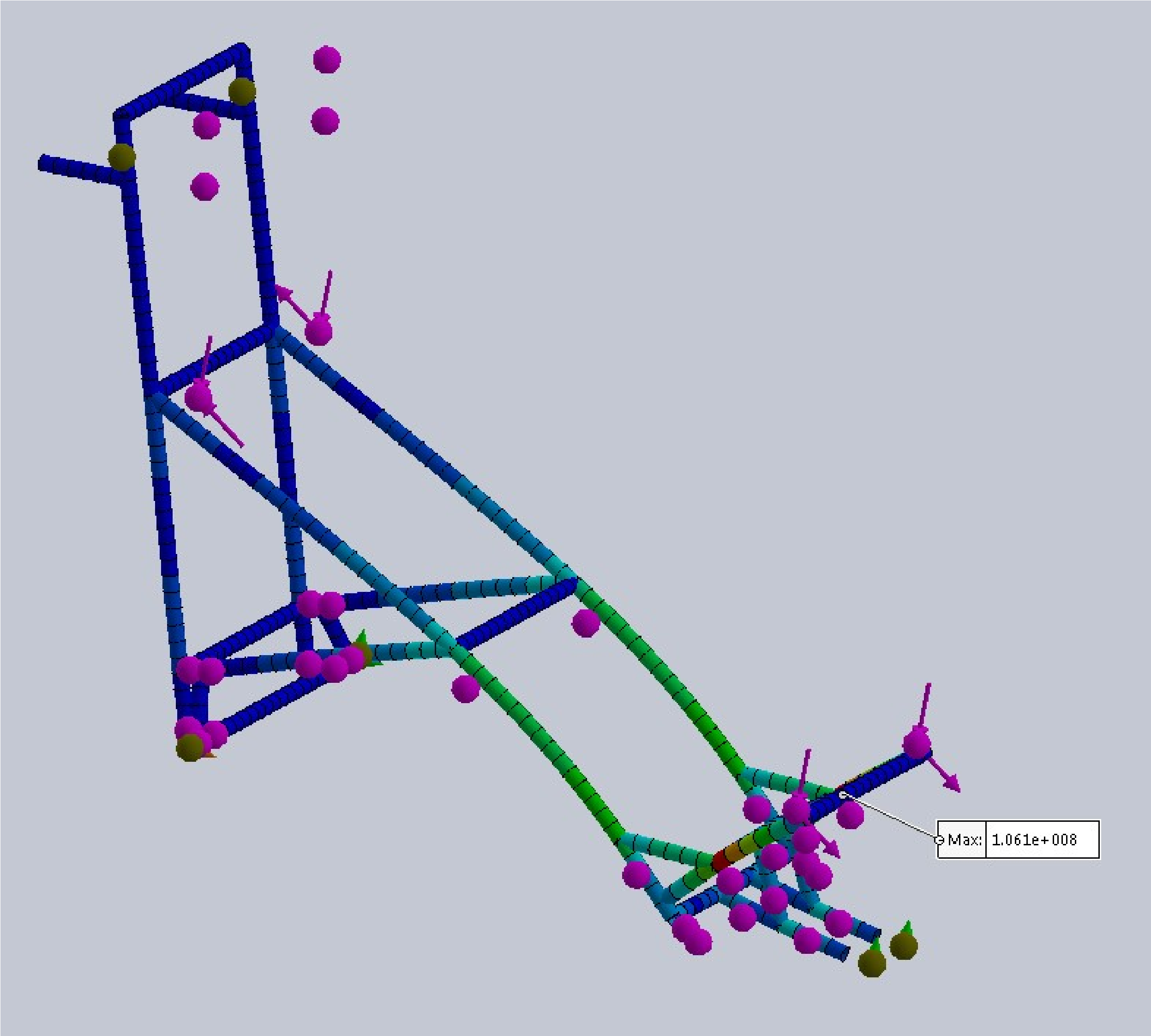


Figure I.6: Loading Case 6. This study models Joseph in full extension when he is in a state of discomfort. The frame has a modified front bulkhead for added strength and comfort.

Appendix J: Safety Checklist

DESIGN HAZARD CHECKLIST

Team: Joseph's Jogger Advisor: Sarah Harding

Y	N	
☐	☒	1. Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and sheer points?
☒	☐	2. Can any part of the design undergo high accelerations/decelerations?
☐	☒	3. Will the system have any large moving masses or large forces?
☐	☒	4. Will the system produce a projectile?
☐	☒	5. Would it be possible for the system to fall under gravity creating injury?
☐	☒	6. Will a user be exposed to overhanging weights as part of the design?
☐	☒	7. Will the system have any sharp edges?
☐	☒	8. Will any part of the electrical systems not be grounded?
☐	☒	9. Will there be any large batteries or electrical voltage in the system above 40 V?
☐	☒	10. Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
☐	☒	11. Will there be any explosive or flammable liquids, gases, or dust fuel as part of the system?
☐	☒	12. Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
☐	☒	13. Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
☐	☒	14. Can the system generate high levels of noise?
☒	☐	15. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc?
☒	☐	16. Is it possible for the system to be used in an unsafe manner?
☐	☒	17. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

For any "Y" responses, add (1) a complete description, (2) a list of corrective actions to be taken, and (3) date to be completed on the reverse side.

Figure J.1: Safety Checklist

Appendix K: Owner's Manual

Handlebar Operation: The handlebar on Joseph's Jogger is adjustable to accommodate users of different heights. To change the height of the handlebar, simply press in both buttons on the hinges simultaneously, and rotate the handlebar in the desired direction. To lock handlebar back in place, simply release the buttons.

Brake Operation: Your new jogger is outfitted with a powerful hydraulic disc brake. Unlike cheaper mechanical braking systems, this brake only requires one finger for operation. This means that you do not have to apply much force to the lever for strong stopping power. Provide first time jogger users verbal warning that the brake is sensitive and strong. Excessive force applied to the lever will result in the front tire locking up, skidding, and perhaps a loss of control.

Seat Removal / Installation: The seat attaches to the frame with numerous straps along the seat length. These straps are fastened to the frame with high quality buckles. To remove the seat, simply unbuckle the buckles and take off the seat. The straps can be individually removed by sliding them out of the strap holders. For optimum performance and comfort, ensure that the straps are fastened snugly and securely. Loose straps will result in undesired movement of the seat and may cause the passenger discomfort.

Rear Wheel Removal: The rear wheels attach to the frame with a 20mm thru axle and locking pin. To remove the wheels, slide off the pin's wire safety, take out the pin, and slide out the axle. To install the rear axle, reverse this process. For maximum safety, it is a good practice to ensure that the large head of the locking pin is positioned on top.

Front Wheel Removal: The front wheel is attached to the frame by means of a quick release mechanism. To remove the wheel, simply release the lever. The wheel will then slide out. To put the wheel back on, first make sure that the lever is open and that the disc brake is on the side of the caliper. Position the wheel in the slots and slide it in. Note: if the wheel doesn't slide in easily, gentle pressure may need to be applied to the fork legs to spread them apart. Tighten the quick release mechanism until adequate resistance is felt when the lever is pushed in. Push in lever and make sure the wheel spins freely without brake interference.

Tire Pressure: The tire pressure in all three tires will affect the feel and performance of the jogger. All three tires should kept between 20 and 30 psi for optimum performance. The tires can be inflated and deflated using a standard bicycle pump. If a tire is not holding air, the pneumatic tube inside is most likely damaged. If the owner feels competent, they can patch it themselves, but we recommend removing the affected wheel and taking it to your local bike shop.

Securing Passenger to Harness: The passenger will be secured in the harness as shown in the picture on the right. Before sitting Joseph in the jogger, make sure that all the harness straps are out of the way. (This makes it easier to access them when they are connected.) Route the top shoulder straps over his shoulders and connect them to the crotch support. Ensure a snug fit and tighten as needed.