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Rickshaw for Common Ground

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RICKSHAW FOR COMMON GROUND

by

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Rickshaw for Common Ground Abstract

For this project my team and I were asked to design and manufacture a rickshaw, a device which will enable disabled individuals to experience outdoor hiking trails, for a non-profit organization based in Logan, Utah called Common Ground. Common Ground specializes in helping people with disabilities experience the outdoors in ways that would otherwise be impossible. The rickshaw will help Common Ground achieve its goals by providing them with a way to transport people with disabilities on moderately difficult hiking trails (i.e. Wind Caves Trail in Logan Canyon). In the past, Common Ground had use of a rickshaw that had two wheels attached by a rigid base to the frame.

This previous design was not conducive for use on steep and/or rocky terrain and made loading and unloading passengers difficult. This previous design was used until one of the front handles failed at a weld location. The new rickshaw design we developed for this project improved upon the previous design and was analyzed and tested to ensure the final rickshaw product would be capable of withstanding all forces the rickshaw would experience while going on hiking trails. From the team's analysis it was concluded that the final rickshaw product met the requirements and safety factors. The final rickshaw product also offers a safer and stronger design along with a more ergonomic experience for the rickshaw passenger as well as for the front and rear drivers.

The final rickshaw product can carry up to a 200 lb. person and is capable of maneuvering and overcoming obstacles typical of hiking trails of moderate difficulty. In addition, the final rickshaw product contains a parking brake that allows the rickshaw to provide a solid base for loading/unloading and for rest stops throughout the duration of the hike.

UtahStateUniversity

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Design Baseline Document

Rickshaw for Common Ground

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1 PROBLEM DEFINITION

1.1 OBJECTIVE

The Team has been asked to design and manufacture a rickshaw for a non-profit organization based in Logan, Utah called Common Ground Outdoor Adventures (hereafter referred to as Common Ground). Common Ground specializes in helping people with disabilities experience the outdoors in ways that would otherwise be impossible. The rickshaw will help Common Ground achieve its goals by providing them with a way to chauffer people with disabilities on moderately difficult hiking trails (i.e. Wind Caves Trail in Logan Canyon).

In the past, Common Ground had use of a rickshaw that had two wheels attached by a rigid base to the frame (see Figure 1.1). The design was such that a single driver pulled from the front of the rickshaw, but a second driver could push the seat from behind if necessary. Prior to the design phase, a test was performed at Wind Caves Trail using this existing rickshaw (see Appendix I).

Figure 1.1. Existing rickshaw during test at Wind Caves Trail in Logan Canyon.

This previous design was not conducive for use on steep and/or rocky terrain and made loading and unloading passengers difficult (see Figure 1.2). This previous design was used until one of the front handles failed at a weld location. The Team intends to improve upon the previous rickshaw design to avoid catastrophic failure as before and provide the passenger and drivers with a more ergonomic experience.

Figure 1.2. Existing rickshaw during the test at Wind Caves Trail in Logan Canyon. One wheel is traversing over a rock while the other remains on the trail. This causes the seat of the rickshaw to tilt to the side (roll) creating unstable and unsafe conditions for passengers. 1) Note the location where the handle failed due to the driver attempting to correct this condition during operation.

To meet Common Ground's needs, the newly-designed rickshaw shall be able to hold a person up to 200 lbs. It shall also be capable of maneuvering and overcoming obstacles typical of hiking trails of moderate difficulty (i.e. Wind Caves Trail in Logan Canyon). In addition, the rickshaw shall contain a parking brake to allow for rest stops throughout the duration of the hike.

1.2 FUNDAMENTAL ASSUMPTIONS

Assumptions regarding appropriate use of the rickshaw are as follows:

1.2.1 The rickshaw will be powered by pedestrians rather than cyclists.

1.2.2 The rickshaw will not be used during adverse weather conditions (i.e. rain, snow, sleet, etc.) and/or during winter months.

1.2.3 The rickshaw will only be used between dawn and dusk, thus avoiding being used in the dark.

1.2.4 The rickshaw will only be used on appropriately rated trails.

Modeling assumptions, particular to the individual analyses contained in Appendices E - H, are documented and described in the context of the calculations contained in said appendices.

1.3 ENGINEERING REQUIREMENTS

The following requirements are sourced from, and update, the requirements found in the Capstone Design Requirements Contract effective as of April 18, 2018 (see Appendix B).

1.3.1 The rickshaw brake system shall be capable of holding the fully-loaded rickshaw stationary on an incline up to 20 degrees (36.4% grade) with an applied force of 15 lbf or less.

Source: On average, an adult female can apply a maximum hand force of 61 lbf [1]. However, to accommodate brake usage over an extended period, it was determined that approximately 25% of the maximum force could be applied. This percentage corresponds to 15 lbf.

Verification Evidence: The rickshaw was loaded with 202.4 lbs. and was placed on a 20-degree incline. A force of 12.7 lbf (measured via luggage scale) was applied to the brakes. Visual inspection was performed to ensure the applied force held the rickshaw stationary (see Appendix L).

1.3.2 The rickshaw brake system shall be operable by the rear driver.

Source: After testing a one-wheeled rickshaw with the brake lever accessible to the rear driver, this was determined to be the desired brake location.

Verification Evidence: Visual inspection and testing were performed to ensure that the brakes can be operated by the rear driver (see Appendix L).

1.3.3 The rickshaw shall have a parking brake capable of holding a fully-loaded rickshaw stationary on an incline up to 20 degrees.

Source: Including a parking brake in the design allows for user adjustments and rest stops along the trail.

Verification Evidence: The rickshaw was loaded with 202.4 lbs. and was placed on a 20-degree incline. The parking brake was engaged. Visual inspection was performed to ensure the parking brake held the rickshaw stationary (see Appendix L).

1.3.4 The rickshaw braking system parts shall be easily repairable and replaceable.

Source: Sponsor/client specified requirement.

Verification Evidence: The Sponsor pre-approved the brake system regarding maintenance.

1.3.5 The rickshaw frame shall be higher than 10 in. off the ground.

Source: Maximum obstacle height on Wind Caves Trail is 10 in.

Verification Evidence: A tape measure was used to determine the lowest point of the frame when the rickshaw was loaded with 202.4 lbs. to ensure compliance. The bottom of the axle attachment on the wheel base was the lowest point of the frame and was measured to be 10 in. from the ground. The next lowest location, the foot supports, were measured to be 11 in. from the ground (see Appendix J).

1.3.6 The total length of the rickshaw shall not exceed 10 ft.

Source: Wind Caves Trail has switchbacks that require the rickshaw to be able to turn inside a diameter of 10 ft.

Verification Evidence: The total length of the rickshaw was measured via tape measure to ensure compliance. It measured 9 ft. 5 in. (see Appendix J).

1.3.7 The maximum width of the frame shall not exceed 4 ft.

Source: Trees and other obstacles become an issue if the total width of the rickshaw exceeds 4 ft. [2].

Verification Evidence: The total width of the frame was measured via tape measure to ensure compliance. Without the cup holder attached, the frame measured 1 ft. 10 in. With the cup holder attached, it measured 2 ft. 3 in. (see Appendix J).

1.3.8 The rickshaw shall be equipped with a seat between 18 in. and 30 in. off the ground while loading and unloading.

Source: The rickshaw height will aid in the loading and unloading of passengers. The average height of an ADA approved wheelchair is 19 in. [4]. A standard bar stool is 30 in.

Verification Evidence: The height from the ground to the seat was measured via tape measure to ensure compliance. While in the loading/unloading position, the top edge of the seat measured 27 in. from the ground, and the inside of the bucket seat measured 24 in. from the ground (see Appendix J).

1.3.9 The rickshaw shall be equipped with height adjustable user-interface handles with a range between 29 in. and 45 in. from the ground.

Source: This range accommodates women with a hip height of 29.1 in. (5% percentile) and men with a hip height of 39.4 in. (95% percentile) [3].

Verification Evidence: A tape measure was used to verify that, on level ground, the rickshaw handles are adjustable to meet the specified waist height range. When the front handles are in the lowest setting (29 in.) the back handles can range between 29 in. and 49 in. When the front handles are in the highest setting (45 in.) the back handles can range between 24 in. and 40 in. (see Appendix J).

1.3.10 The rickshaw shall be equipped with adjustable foot supports for the passenger, which accommodates a person with a leg length between 36 in. and 45 in.

Source: This range accommodates women with a leg length of 36 in. (5% percentile) and men with a leg length of 45 in. (95% percentile) [1].

Verification Evidence: The length from the back of the seat to the foot support was measured via tape measure. A leg length range of 31" to 48" is accommodated (see Appendix J).

1.3.11 The rickshaw shall be equipped with a parking stability assist device.

<u>Source:</u> The parking stability assist device allows for the rickshaw to be parallel to the ground allowing for easier loading and unloading.

<u>Verification Evidence:</u> The unloaded rickshaw was placed on level ground with the parking stability assist device engaged. No external forces were applied to the rickshaw. Visual inspection was performed to ensure the rickshaw was approximately parallel to the ground. A 202.4 lbf weight was loaded onto the rickshaw to ensure stability was maintained.

1.4 GOALS

1.4.1 The rickshaw parking stability assist device should be engaged and disengaged while keeping the rickshaw parallel to the ground.

<u>Source:</u> The parking stability assist device provides a way for the rickshaw to be stabilized for passenger loading and unloading. The front driver will not need to set the rickshaw handles on the ground before engaging the parking stability assist device.

<u>Verification Evidence:</u> The front driver pulled the quick-release pins to enable the parking stability assist device to be engaged. The back driver pulled the brake, and the device was engaged. The rickshaw was then lowered by both drivers to validate that the parking stability assist device held the rickshaw parallel to the ground. The front driver replaced the quick-release pins before the process was repeated in reverse to disengage the parking stability assist device. Visual inspection was performed to ensure the rickshaw remained parallel to the ground.

1.4.2 The rickshaw seat should be capable of reclining between 0 and 30 degrees, as measured from a vertical, flat surface.

<u>Source:</u> This goal is to provide client comfort.

<u>Verification Evidence:</u> Unfortunately, due to an unforeseen budget decrease, this goal could not be achieved. The seat cannot recline independently from the rest of the rickshaw frame.

1.4.3 The rickshaw should have an integrated cup holder and storage space.

<u>Source:</u> Sponsor needs space to hold supplies while on the trail. According to the sponsor, the cup holder is to provide the client a more independent experience.

<u>Verification Evidence:</u> Visual inspection was performed to verify that the rickshaw contains an integrated cup holder and storage space.

2 SYSTEM OVERVIEW

The rickshaw designed and manufactured for this project is shown in Figure 2.1. The rickshaw system is made up of four subsystems: the frame, wheel base, brakes, and ergonomics. The components, materials, and specifics of each of these subsystems are detailed in their respective subsections.

Figure 2.1. The rickshaw system.

As outlined in the requirements contract in Appendix B, the rickshaw system must safely transport a person with disabilities on hiking trails. To achieve this, two drivers stabilize the rickshaw while providing the rickshaw with the momentum necessary to maneuver up and down moderately difficult hiking trails. The front driver is mainly responsible for pulling/pushing on the front handles of the rickshaw and uses a harness to provide additional forward momentum. The back driver provides most of the stabilization for the rickshaw but also pushes the rickshaw forward using the back handles. In addition, the back driver is responsible for braking.

The rickshaw subsystems (the frame, wheel base, brakes, and ergonomics) are essential in meeting the requirements and achieving the goals of this project as outlined in Section 1.1. The frame is designed to distribute most of the rickshaw's weight to the wheel. Additionally, the design is intended to give the rickshaw drivers a way to effectively push and stabilize the rickshaw (see Figures 3.1-3.4). The wheel base provides a way to lower the passenger chair to a suitable height for loading/unloading the rickshaw passenger. The wheel base also gives the rickshaw a firm and stable foundation to load/unload the passenger and allows for breaks during hiking expeditions (see Figure 4.1). When the rickshaw is descending trails, the brakes provide the drivers a way to control the speed of the rickshaw. Additionally, when ascending trails, the brakes allow the drivers to stop the rickshaw if necessary (see Figures 5.1-5.3). The ergonomics help the drivers and the passenger have a comfortable and user-friendly experience with the rickshaw (Figure 6.1-6.7).

The rickshaw system and its subsystems effectively meet the goals and requirements described in the requirements contract (except for Goal 1.4.2 regarding a reclining seat – see 1.4.2 for more details). The subsystems contribute to the overall success of the rickshaw system. Sections 3-5 describe in greater detail each subsystem and the associated requirements satisfied by each subsystem.

3 Frame Subsystem

The frame subsystem is composed of the detachable front handles, the seat assembly, and the adjustable rear handles as shown in Figure 3.1 below.

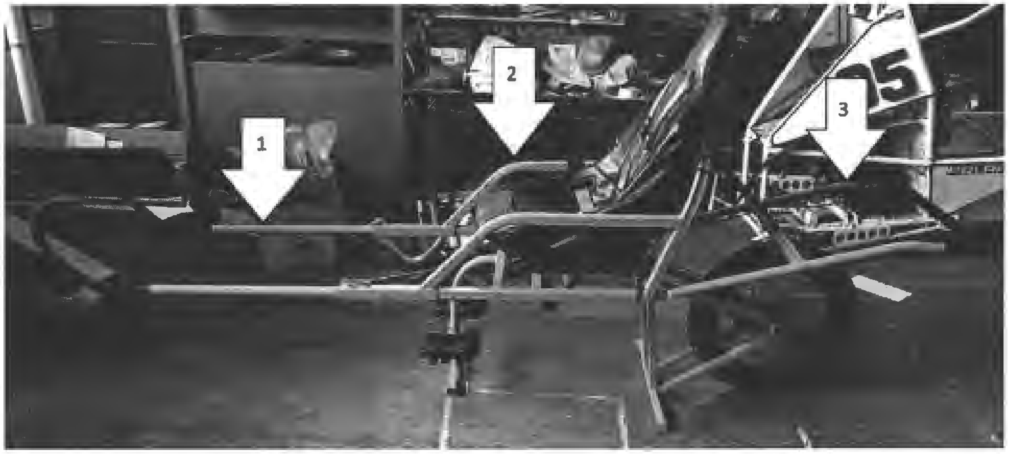


Figure 3.1. The frame subsystem: (1) the detachable front handles, (2) the seat assembly, and (3) the adjustable rear handles.

3.1 Front Handles

The front handles were made from AISI 1020 steel and are shown in Figure 3.2. They were designed to be detachable, so the rickshaw could be stored and transported easily when not in use. The front handles attach to the seat assembly with quick release pins. The candy cane design was incorporated to allow the front driver flexibility in where they could place their hands. Testing proved that having the front driver put their hands at the base of the curve was best for navigating flat terrain. However, putting their hands at the curve's middle was optimal for traversing steeper terrain. The front handles are made from circular tubing, which provides comfort for the front driver.

Figure 3.2. The detachable front handles.

3.2 SEAT ASSEMBLY

The seat itself was taken from the rickshaw previously owned by Common Ground. The seat assembly, as shown in Figure 3.3, was made from AISI 1010 steel rather than AISI 1020 steel because of the lower anticipated stresses acting on it (see Appendix F). Square tubing was used in the seat assembly for ease of machinability. The seat assembly also contains adjustable foot supports for the passenger (see Section 6.1.1 and Figure 6.1 for more details).

Figure 3.3. The seat assembly.

3.3 REAR HANDLES

The rear handles were made from AISI 1020 steel and are shown in Figure 3.4. They were designed to be adjustable to accommodate drivers of various heights per requirement 1.3.9. This was done by attaching a two-piece assembly of square tubing with a single hole drilled in the outer piece and multiple holes drilled in the inner piece. A quick release pin holds the assembly together, and the rear handles pivot

about clevis pins. Like the front handles, the rear handles were made from circular tubing to provide comfort for the rear driver.

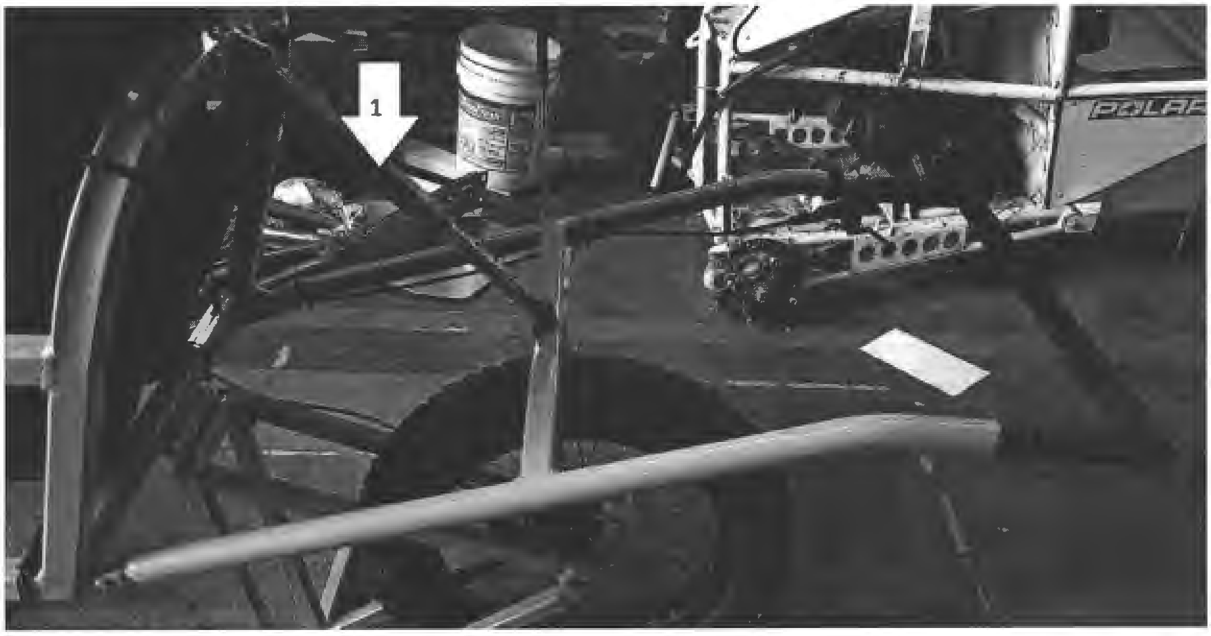


Figure 3.4. The adjustable rear handles. 1) Two-piece assembly with quick release pin that allows the rear handles to be adjusted.

3.4 Satisfaction of Design Requirements 1.3.5-1.3.7

The design of the rickshaw required specific frame dimensions. These requirements were met as follows:

- Req. 1.3.5- The lowest part of the frame is 10 in. at the axle and 11 in. at the foot support
- Req. 1.3.6- Total length of the rickshaw is 9 ft. 5 in.
- Req. 1.3.7- Total length of the rickshaw is 24 in.

3.5 Satisfaction of Design Requirements 1.3.8-1.3.10

Requirements 1.3.8 and 1.3.9 regard the seat height and adjustability of the handles and foot supports. These requirements were met as follows:

- Req. 1.3.8- The seat is 24 in. from the ground during unloading/loading
- Req. 1.3.9- Rear handles adjust from 22 in. to 49 in. from the ground
- Req. 1.3.10- Foot supports are adjustable to accommodate people with leg lengths of 31 in. to 48 in.

3.6 COST AND STRESS ANALYSES

See Appendix C for the Bill of Materials and Appendix F for a Finite Element Analysis (FEA) of the rickshaw.

3.7 TEST RUN

Once completed, the rickshaw was taken to Wind Caves Trail for a trial run. This test proved that the frame and its subcomponents were sufficiently strong to withstand the anticipated stresses. Qualitatively, the new rickshaw was an improvement over the rickshaw previously owned by Common Ground.

4 WHEEL BASE SUBSYSTEM

The wheel base consists of a metal cross beam and two V-forks that secure the axle and hinge about the back end of the rickshaw. It also includes the hinge, the pin tangs, the fork joint alignment parts, the fork hubs, and the wheel. See the attached drawing package in Appendix D for part names and assemblies. The main purpose of the wheel base is to attach the wheel, axle, and brake system to the rest of the rickshaw frame. In addition, the wheel base subsystem acts as the parking stability assist device (see Figure 4.1).

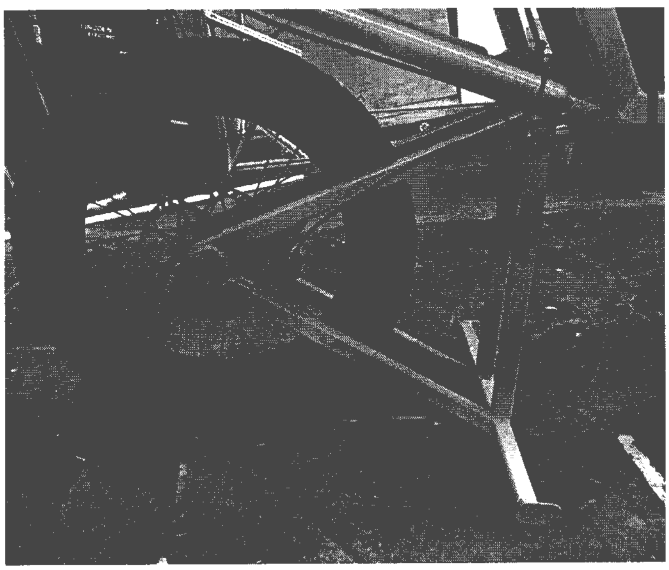


Figure 4.1. Deployed wheel base subsystem that serves as the parking stability assist device.

4.1 ONE-WHEELED DESIGN VERSUS TWO-WHEELED DESIGN

During the design phase, two different rickshaw designs were explored. One design consisted of a wheel base that had two wheels, and the other design utilized only one wheel. Each design offered its own benefits and drawbacks. The Team was unable to reach a consensus on which design path provided the best results. It was decided that testing needed to be conducted to aid in making this design choice.

Two different tests were conducted. The tests included taking the original rickshaw up Wind Caves Trail in Logan Canyon. The second test included borrowing a one-wheeled rickshaw and testing it at Antelope Island. The sponsor was present for the second test and had previously used the old rickshaw, so they were able to give feedback on which design they preferred. After the second test with the one-wheeled design, the sponsor requested that the one-wheel design approach be used [5].

4.1.1 Testing the two-wheeled rickshaw at Wind Caves Trail.

To test a two-wheeled design, the Team took the previous rickshaw owned by Common Ground to Wind Caves Trail (see Appendix I). During the test, it was difficult to keep the rickshaw stable. This was because the trail thinned to a width less than the distance between the wheels, causing the rickshaw to tilt when one of the wheels rode up the shoulder. It is suggested that this behavior caused the previous rickshaw's handle to fail. In addition, the tilting of the rickshaw required a second driver, positioned at the rear, to stabilize the rickshaw despite the added support of two wheels.

4.1.2 Testing the one-wheeled rickshaw at Antelope Island.

To test a one-wheeled design, the team traveled to Antelope Island, Utah. Antelope Island State Park allowed the Team to use the park's Joelette Trekking Chair, a one-wheeled rickshaw device. It was immediately apparent that, while more effort was required to keep the rickshaw stable on one wheel, its ability to handle more difficult trails was improved from the two-wheeled design. The rickshaw had increased maneuverability in terms of turning, handling single-track trails, and traversing over/around obstacles.

4.1.3 Testing conclusion for the one- and two-wheeled rickshaw designs.

In conclusion, while designing the rickshaw with a second wheel would add stability on a flat trail, a one-wheeled design is required to handle desired trails (i.e. Wind Caves Trail). Considering the types of obstacles and necessary maneuverability for these trails, a one-wheeled rickshaw is required. As such, a one-wheeled rickshaw was chosen by the sponsor [5].

4.2 WHEEL AND AXLE SELECTION

The rickshaw wheel was custom built by Utah Trikes in Payson, UT. The wheel utilizes a 20 in. by 4 in. fat tire on a 20 in. by 54 mm rim. It incorporates 36 DT Swiss spokes and an Origin 8 thru-axle. The axle is 100 mm by 15 mm with 148 mm total length.

4.2.1 Choosing the 20 in. by 4 in. fat tire.

Most mountain bike tires range between 2 and 2.5 in. wide. The Team decided to use a wider tire because of the added stability and suspension. A wider tire has more surface area, which applies more grip to the ground. This additional surface area also provides a wider base to assist in stabilizing the rickshaw. Wider tires also run at a lower pressure, which provides better control and creates a suspension effect. Because the rickshaw has no suspension, the Team decided this feature was essential to make the ride enjoyable for the passenger. A 20 in. diameter was chosen to decrease the height of the passenger during operation. This in turn lowers the center of mass, decreasing the force needed to stabilize the rickshaw.

4.2.2 Selecting a thru-axle.

The two main types of mountain bike axles are quick release axles and thru-axles. A quick release axle can easily be removed but has a small diameter. A thru-axle takes more effort to remove but has a thicker diameter. The additional thickness in a thru-axle adds strength and stiffness and minimizes power loss. Since the weight of the entire rickshaw rests on the axle, the Team decided to use a thru-axle in the design because of its added strength and stiffness.

4.2.3 Reasoning behind purchasing a custom wheel.

The team could not find a compatible wheel from any local or online vendors. This is because wheels with the desired dimensions are not typically disc brake compatible. Most mountain bike wheels that are disc brake compatible are 26 in. or larger. A 20 in. wheel is usually found only on youth or BMX bikes. Because of this issue, the team decided the wheel needed to be custom built.

Wheel-building requires very precise measurements, experience, and knowledge. This is because of the number of spoke connections and complicated compatibility between component. The Team opted not to accept the risk of incorrectly building the wheel. Doing so would have proven detrimental to the success of the project and likely would have resulted in loss of time and money. Therefore, the Team decided to have the wheel custom built by Utah Trikes in Payson, UT who specialize in building unique wheels.

4.3 TESTING AND FULFILLMENT OF REQUIREMENT 1.3.3

Requirement 1.3.3 stated the fully-loaded rickshaw must be held stationary by the parking stability assist device. Verification by visual inspection was conducted. The rickshaw was loaded with 200 lbf and placed on a 20-degree incline. It was found that the rickshaw remained stationary during testing. See Appendix L for more details.

4.4 TESTING AND FULFILLMENT OF REQUIREMENT 1.3.8

Requirement 1.3.8 stated that the seat height must be between 18 in. and 30 in. off the ground while loading/unloading the rickshaw. The verification method involved measuring the rickshaw with the parking stability assist device deployed as if loading a passenger into the rickshaw. It was found that the seat height measured 24 in. from the ground. See Appendix J for more details.

4.5 TESTING AND FULFILLMENT OF REQUIREMENT 1.3.11 AND GOAL 1.4.1

Requirement 1.3.11 stated that the rickshaw must be designed with a parking stability assist device, and goal 1.4.1 suggested that the rickshaw should remain approximately level with the ground while the parking stability assist device was deployed. The verification method involved visual inspection to ensure those two design parameters were met. During testing, the parking stability assist device pin was pulled, the rear brake was actuated, and the rickshaw was lifted by both drivers. This allowed the parking stability assist device to roll the rickshaw forward and down onto the front bar of the wheel base subsystem. The rickshaw stayed parallel with the ground during deployment, and the parking stability assist device kept the rickshaw stable while resting on the ground.

4.6 MAJOR CHALLENGES

4.6.1 Determining and meeting tight tolerances for the wheel support.

It was suggested that the weight of the rickshaw be distributed onto the wheel hub as well as the axle. This presented a challenge because it required that parts be made with increased precision to ensure that contact was made with the hub and the axle. The Team had Terry Zollinger, USU Machinist, make fork alignment and fork hub parts (see Appendix D) to ensure the necessary precision was accomplished.

Another challenge was the width between the forks of the wheel base. It needed to be small enough to ride on the hub and avoid causing increased bending stresses within the frame. This was accomplished by measuring the distance between the ends of the hubcaps and machining two fork alignment parts that slip into the negative space of the fork connector pieces. This allowed the fork, axle, and hub to be aligned and have the correct spacing. All parts were welded together to ensure the correct fit.

4.6.2 Aligning the axle and wheel properly.

Along with the fork alignment part, Terry Zollinger machined the fork hubs. These were specifically designed to fit into the fork alignment parts. This was done to ensure that the orientation of the two slots that rest on the wheel hub, as well as the axle, were aligned. The fork alignment parts, fork hub, and forks of the wheel base were welded while they were fastened and aligned for ease of fabrication.

5 BRAKES SUBSYSTEM

The brakes subsystem includes the brake caliper, rotor, hoses, and the actuation of the brake lever. The caliper is the Shimano SLX BR-M700 hydraulic caliper. The rotor is the Shimano 203 mm RT66 6 bolt. The attachments of the caliper to the frame and rotor are shown in Figure 5.1.

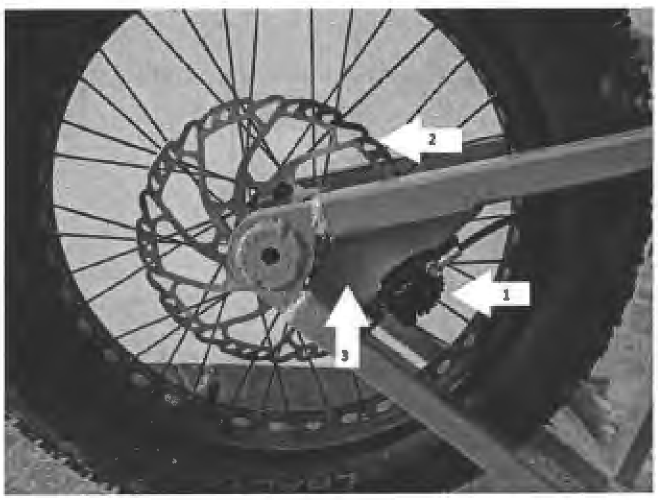


Figure 5.1. Connection of the caliper to the caliper mount and frame forks.1) Caliper 2) Rotor 3) Caliper Mount

The hydraulic hose from the caliper to the brake lever is attached to the rickshaw by zip ties as shown in Figure 5.2.

Figure 5.2. Attachment of the brake handle and hose to the frame. 1) Location of the brake lever.

5.1 ANALYSIS OF HYDRAULIC DISC BRAKE ROTOR SIZE

To determine the rotor size for a hydraulic brake, analysis needed to be done to determine the stopping power of the brake. By Requirement 1.3.1, the brake needed to hold the rickshaw stationary with a maximum applied force of 15 lbf. This force was assumed to be a reasonable force for an average person to apply over an extended period (i.e. one hour). The Brake Analysis Report, found in Appendix G, goes over the calculations and procedure of this analysis. The general assumptions and conclusion are stated below.

Assumptions:

- Maximum rickshaw speed of 15 mph
- Applied brake force of 14 lbf to the lever

Conclusion:

- 203 mm rotor is needed

5.2 SHIMANO SLX BR-M700 HYDRAULIC BRAKE CALIPER AND LEVER

The Shimano SLX BR-M700 hydraulic brake was chosen because of:

- High durability to wear and tear
- Maximum stopping power
- Recommended by professionals
- Easily replaceable and repairable

5.3 SHIMANO RT66 6 BOLT ROTOR

The Shimano RT66 203 mm rotor was chosen because of:

- High durability to wear and tear
- 203 mm produces the highest stopping power
- A 6 bolt is more cost-effective than a center lock rotor
- Compatible with the Origin 8 axle hub that was used in the wheel

5.4 CALIPER MOUNTING

The brake caliper is mounted to the frame using two bolts as shown in Figure 5.3. When fully attached, the caliper must be centered over the rotor with no rubbing from the brake pads. If there is contact, the caliper must be loosened and re-adjusted. The bolts can be reached with a pair of pliers or a wrench from the side and/or between the tire spokes.

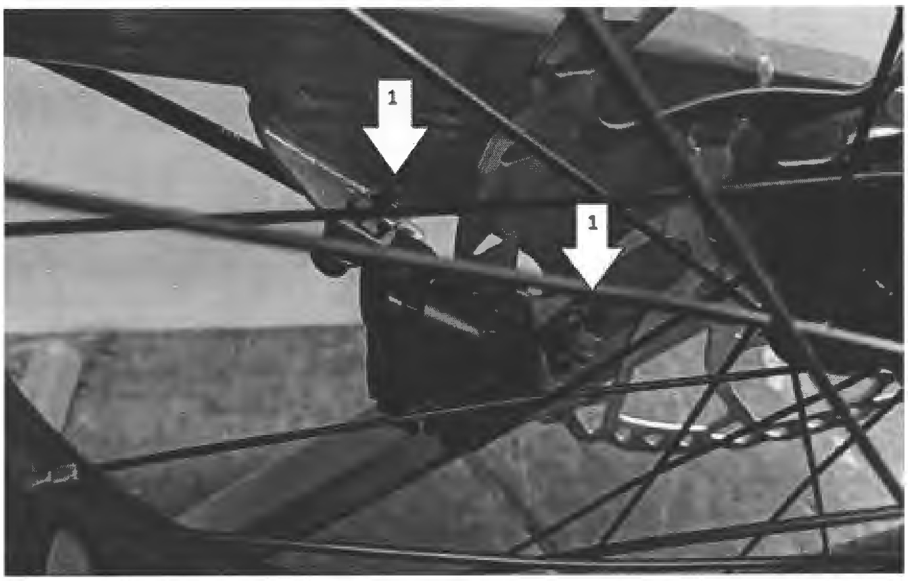


Figure 5.3. Attachment of the caliper to the caliper mount via the two screws and bolts. 1) Bolt locations.

5.5 TESTING AND FULFILLMENT OF REQUIREMENTS 1.3.1. & 1.3.3

The brake subsystem needed to fulfill requirements 1.3.1-1.3.4. These requirements are important to provide safety for the drivers and passenger. Requirements 1.3.1 and 1.3.3 required testing of the brake subsystem. The brake and parking brake needed to keep the rickshaw stationary for a trail inclined up to 20-degrees. The Brake Functionality Test Document in Appendix L goes into detail about the procedure of these tests. It was determined that:

- Maximum force of 12.7 lbf applied to the brake lever kept the rickshaw with a 202.4 lbf load stationary on the 20-degree incline
- Parking brake kept the rickshaw with a 202.4 lbf load stationary on the 20-degree incline

5.6 TESTING AND FULFILLMENT OF REQUIREMENTS 1.3.2. & 1.3.4

Requirements 1.3.2 and 1.3.4 required visual inspection. It was found that the brakes are operable by the rear driver and can be easily repaired and replaced by any bike shop or individual with bike brake knowledge. None of the components are custom made and can be purchased from multiple vendors.

5.7 MAJOR CHALLENGES

5.7.1 Manufacturing the caliper mount.

The caliper mount was difficult to manufacture because of the needed precisions. The caliper must fit over the rotor with no contact when the brakes are inactive. Since the caliper mount is not threaded, the bolts had to be accessible from both sides. These challenges were met by the following:

- Precise measurement of welding and locations of the caliper mount
- Bolts are accessible from the side or between the tire spokes with an appropriate wrench or pliers

5.7.2 Selecting a brake type.

There are three types of bicycle brakes that could potentially work for the rickshaw. These include hydraulic, mechanical, and v-brake. It was difficult to decide which brake is the most efficient, has the highest stopping power, and is easily repairable. A test was necessary to determine which brake type was best regarding efficiency and stopping power. All three brake types were individually tested with a cargo of around 200 lbf on a 20-degree incline. This was done to measure the force required to keep the bike stationary. This test is further described in the Pre-Design Brake Test Report found in Appendix K. It was determined that the hydraulic brakes had the best stopping power with a maximum force of 24 lbf applied to the handle. The other brakes both required above 30 lbf.

6 ERGONOMICS

The ergonomic subsystem contributes to a better passenger- and driver-interface. The components that make up the ergonomics subsystem include:

- Passenger foot supports
- Passenger harness
- Padding for the passenger seat
- Passenger cup holder
- Front driver harness
- Driver handles
- Rear driver push strap
- Storage space
- Grip tape for front and rear driver handles
- Powder coat

6.1.1 Incorporating passenger foot supports.

From Requirement 1.1.3, the rickshaw passenger foot supports need to accommodate a passenger with a leg length between 36 in. and 45 in. Figure 6.1 shows the adjustable foot supports. The foot supports are adjusted by unscrewing the wingnut in the rear of the foot supports and inserting the bolt into one of the six holes. The supports feature a plastic frame on which the passenger's feet may be placed. Velcro straps are used to hold the passenger's feet in place while the rickshaw is in motion.

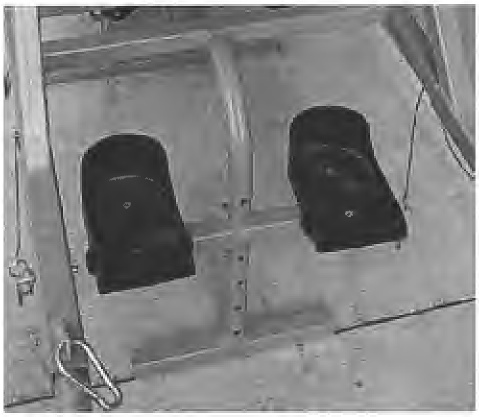


Figure 6.1. Passenger foot supports.

6.1.2 Incorporating a passenger harness.

The passenger harness is a four-point Tanaka® racing harness that allows the drivers to buckle and unbuckle the passenger. This harness features a standard car-type seat belt buckle as shown in Figure 6.2. This harness keeps the passenger secured in the seat when traversing various hiking trail obstacles.

Figure 6.2. Passenger four-point Tanaka® harness.

6.1.3 Adding high-density foam padding to the passenger seat.

Per Common Ground's request, padding was purchased and added to the bucket seat. The high-density foam padding provides comfort for the rickshaw passenger.

6.1.4 Incorporating a passenger cup holder.

Goal 1.4.3 requested that the rickshaw have a cup holder for the passenger (see Figure 6.3). The cup holder allows the passenger the option of having a beverage within reach during their hiking experience.

Figure 6.3. Passenger cup holder.

6.1.5 Incorporating a front driver harness.

During field testing at Antelope Island, the front driver harness was found to be beneficial to the rickshaw design. The harness allows for more effective pulling of the rickshaw up steep inclines. Having the harness strapped over the shoulders allows the front driver to efficiently use more of their full body when pulling the rickshaw. A front strap secures the harness on the shoulders. In field testing the Joelette, the harness tended to slip off the front driver's shoulders. The harness purchased for the Common Ground rickshaw has the front buckle, is rated to carry a load of 400 lbs., and has padding on the shoulder straps.

Figure 6.4. Front driver harness.

6.1.6 Designing the front and rear driver handles.

Requirement 1.1.2 outlined the adjustability of the front and rear driver handles to accommodate drivers of various heights. The front handles have a U-shaped (i.e. candy cane) curve, as shown in Figure 6.5, which allows drivers of various heights to push the rickshaw. Additionally, this handle design allows the front driver to push the rickshaw at various angles to maximize the pushing force. The rear handles are user-adjustable by an adjuster pin that allows the selection of different heights (see Figure 6.6).

Figure 6.5. Front driver handles.

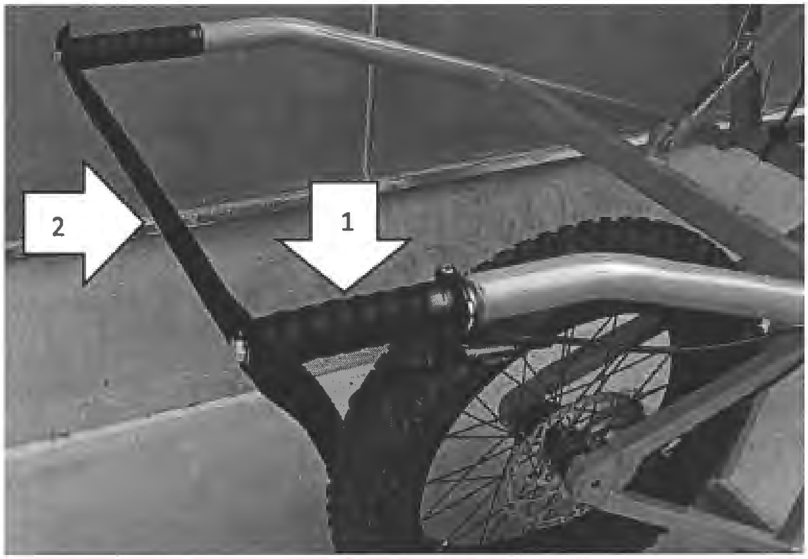


Figure 6.6. Rear driver handles including: 1) Rear driver handles and grip tape, and 2) Rear driver push strap.

6.1.7 Adding grip tape to the front and rear handle bars.

Grip tape (shown on the front and rear handles in Figures 6.5-6.6) was added to the handles to provide a grip surface for the front and rear drivers. The grip tape is SRAM® Supercork Bicycle Bar Tape. This tape is designed for outdoor use, offers a durable grip, is cost-effective, and easily replaceable.

6.1.8 Incorporating a rear driver waist strap.

Initially a rear driver waist strap was not incorporated into the rickshaw design, but the trial run at Wind Caves trail with the newly-designed rickshaw revealed that it was determined to be an essential part of the rickshaw design. Field testing the Joelette rickshaw at Antelope Island showed that a waist strap helped the rear driver use their lower body to more effectively push the rickshaw up inclines.

Solid cylindrical metal, sized to fit into the hollow, rear handle bars, was tapped for 3/8 in. bolts and welded into the handle bars. Using the leftover straps from the harness, a 24.5-inch strap was made by doubling the unused harness straps and sewing them together. Holes were cut in the strap to match the bolt hole locations on the two rear handle bars. Metal grommets were then inserted into the holes, and the strap was bolted on to the rickshaw frame (see figure 6.6).

6.1.9 Incorporating storage space.

Goal 1.4.3 requested that the rickshaw have an integrated storage space. A mesh netting bag was purchased was placed behind the seat as shown in Figure 6.7. The mesh netting bag provides a space for necessary items (i.e. first aid kit, snacks, etc.).

Figure 6.7. Storage space.

6.1.10 Having the rickshaw powder coated.

The rickshaw was powder coated to protect the metal frame from moisture, debris, and other potential damage. Powder coating was chosen over painting because powder coating has greater durability. As requested by Common Ground, the rickshaw was powder coated orange.

6.1.11 Passenger Seat Reclining Feature

Goal 1.4.2 specified that the rickshaw should be capable of reclining between 0 and 30 degrees. After designing, communicating with the sponsor, and taking the project budget into consideration, this goal was determined to be non-essential.

6.2 VERIFICATION OF REQUIREMENTS 1.3.9-1.3.10 AND GOALS 1.4.2-1.4.3

Requirement 1.3.9 specified that the front and rear handles have a range between 29 in. and 45 in. from the ground. From the Rickshaw Dimension Test Document in Appendix J it was determined that both the front and rear handles meet and exceed requirement 1.3.9.

Requirement 1.3.10 details that the foot supports for the passenger shall be able to accommodate a person with a leg length between 36 in. and 45 in. From testing, it was determined that the rickshaw foot support has a range between 31 and 48 in. Thus, the foot support meets and exceeds Requirement 1.3.10 (see Appendix J).

Goal 1.4.2 was that the rickshaw should be able to recline between 0 and 30 degrees. As stated in section 6.1.11 of this report, this goal was determined to be non-essential and was not included into the final design of the rickshaw.

Goal 1.4.3 stated the rickshaw should have an integrated cup holder and storage space. From visual inspection of the final product, the rickshaw has a detachable storage space (see figure 6.8) and detachable cup holder (see figure 6.3). Thus Goal 1.4.3 is fulfilled.

7 ANCILLARY TOPICS

7.1 BUDGET AND EXPENSES

The Team was awarded $1200 to manufacture the rickshaw. Of this $1200, the Team used $1162.65 leaving a project margin of $37.35. Figure 7.1 outlines the expenses for the project.

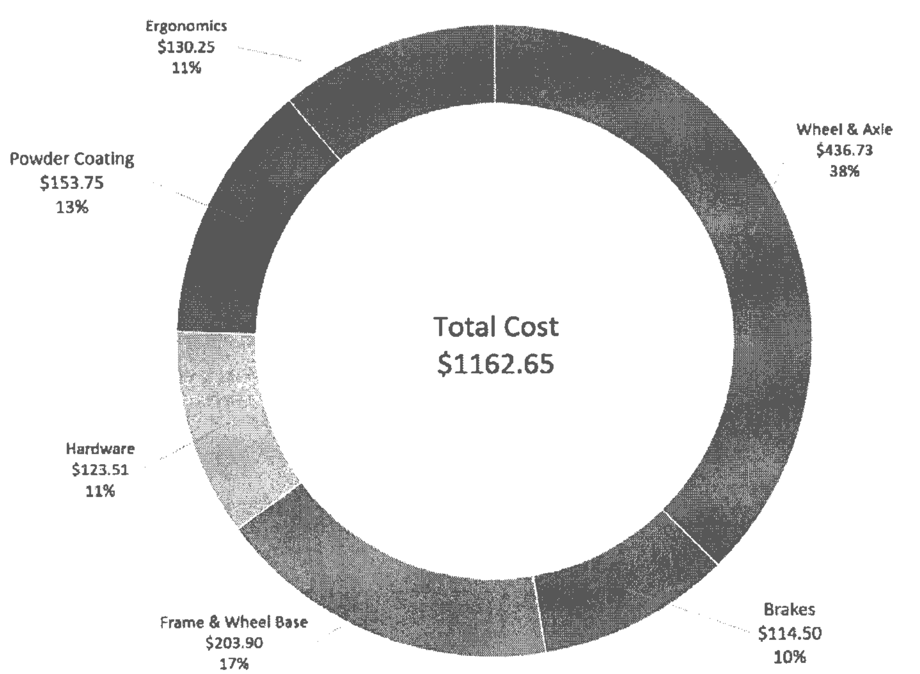


Figure 7.1. Budget and expenses overview.

Some items integrated in the rickshaw system were donated (i.e. the bucket seat, foot supports, etc.). In addition, some of the raw materials and hardware used were freely accessible in the Student Prototype Lab. For a complete list of items used and their prices, see the Bill of Materials found in Appendix C.

7.2 LESSONS LEARNED

The Team gained understanding and experience regarding the entire engineering process and developed professional skills.

7.2.1 Defining the scope of a project including developing engineering requirements.

When assigned, the scope of the Rickshaw project was not fully defined. The Team was asked to build a rickshaw with a maximum budget of $1500 (later reduced to $1200) that was capable of taking people with disabilities on hiking trails. As engineers, it was the Team's duty to solidify the scope of the project, ensuring that it would meet the customer's needs while remaining feasible. This included defining the terms "rickshaw" and "hiking trail" as these have various meanings. During this process, the Team learned the importance of setting realistic requirements that narrow the scope of the project to ensure their ideas coincided with the customer's ideas.

While this process initially took the team approximately three months to complete, the extended length of time spent on the Requirements Contract enabled the team to be more effective throughout the remainder of the project. The initial time spent defining the scope of the project eliminated wasted time later. However, the Team learned that changes along the way (i.e. budget reduction) require flexibility from team members and the customer. This flexibility required uninhibited communication between the Team and Common Ground. This open communication also ensured the delivered product met the customer's needs while remaining feasible.

7.2.2 Developing interpersonal skills including teamwork and communication.

The Team learned valuable lessons in teamwork and communication. Working as a member of a team can be an advantage, but it also has its challenges. It requires that each team member contributes their equally (however that is determined by the team as a whole) and follows-through on each of their commitments. In this instance, most commitments were kept in full and completed on time. On many occasions, more responsibilities were delegated than team members had time for, but the Team learned that it is better to have too much to do than too little. This strategy ensures that time is not wasted doing little or nothing.

The Team learned the value of meeting on a regular basis to discuss the project. The weekly team meetings allowed each member to report on their progress, ask for needed help, and accept new commitments. These meetings became a crucial element to the success of the Team and ensured uninhibited communication between the entire Team. It also nurtured a culture of sharing and being respectful of ideas, even when these ideas went against those of other team members. These ideas were discussed and tested before the Team would agree on what was ultimately the best solution for the problem at hand. Each team member learned the importance of putting the overall success of the project above their own ideas.

In addition to communication within the Team, communication with the Sponsor taught valuable lessons. The communication between the Team and Sponsor was done mainly via email. At times, email was ineffective because the communication was too slow. During these times, the Team made attempts to contact the Sponsor via telephone and/or personal visits. For the most part, communication was sufficient, but a more consistent form of communication would have been beneficial.

While day-to-day communications were less formal, the Preliminary, Critical, and Final Design Review (PDR, CDR, FDR respectively) presentations allowed team members to gain valuable lessons in formal communication. During these presentations, team members were expected to dress professionally, use professional language, and communicate both verbal and visual information effectively. During the CDR, the Team presented material that had not been previously discussed with the Sponsor, including requirements that would not be met due to changes in budget and design. Because of this experience, the Team learned the importance of providing the Sponsor with information regarding changes to the design or requirements prior to formal presentations to avoid surprising the Sponsor with unforeseen deviations.

7.2.3 Developing organizational skills including documentation and delegation.

One of the most important lessons learned by the Team is the value of organization. In the initial stages of the project, a Google Drive folder was created to keep all the Team's files organized and documented. This ensured each team member had unrestricted access to every file. Edusourced was also used to keep a detailed budget up to date and allow the Sponsor access to completed deliverables.

Aside from file organization, the Team organized themselves into specialty groups, which ensured that every sub-system within the project was designed and completed on time. Two team members were assigned to design and perform analysis on the frame, two team members were assigned to design and perform analysis on the wheel and brakes, and one team member was assigned to design the ergonomic features of the rickshaw. The responsibility of documenting purchases and budgeting was also delegated to a team member. This taught the Team the importance of delegation and accepting responsibility within an organized team structure.

7.2.4 Understanding the value of testing and prototyping.

The Team also learned the value of testing similar systems in determining the best solution. This became particularly important in determining if the rickshaw should have one or two wheels. The Team could not come to a consensus on whether a one- or two-wheeled rickshaw would provide the necessary functionality while remaining stable enough to be viable. Ultimately, the Team concluded that testing on a one- and two-wheeled rickshaw needed to be performed.

The Team was given access to these two design types and, on various occasions, tested both designs on similar terrain to determine if one was more stable than the other. This testing was key in reaching the final design of a one-wheeled rickshaw. Even if the Team did not have access to these rickshaws, prototypes of a one- and two-wheeled rickshaw would have been fabricated to provide the Team with the understanding necessary to deliver a successful product.

7.2.5 Understanding manufacturability and fabrication processes.

The Team gained experience and understanding of manufacturing and fabrication processes. The Utah State University Student Prototype Lab (SPL) provided the Team with all the necessary tools, equipment, and machinery to fabricate the entire rickshaw. Team members gained experience welding, drilling, sanding/grinding, milling, and lathing.

During the manufacturing process, team members learned how to meet required tolerances by being precise when taking measurements and careful when performing the required action (i.e. cut or weld). For instance, once the main body of the rickshaw frame had been welded, the Team noticed a slight misalignment, causing the rickshaw to rock when on flat ground. The Team carefully worked the rickshaw back into alignment, but this required precious time and ultimately set the project back a couple of days. Had better care been given during the original process, this time would not have been lost. Using spot welds to hold the entire frame together prior to completing the welds would have been very beneficial.

7.2.6 Distinguishing between cost-effective items and cheap items.

The Team learned the importance of distinguishing between items that are cost-effective and items that are cheap. Being cost-effective implies that a product, while less expensive than other options, will perform its necessary functions. However, often the less-expensive option is not always the best option. If an item does not perform necessary functions and/or is poorly made, it is considered cheap.

For example, the axle that was purchased for the rickshaw was cost-effective. Even though it was less expensive than other options, it performed the necessary functions and provides the needed strength. However, the cup holder that was purchased for the rickshaw, while less expensive than other options, was cheaply made. Shortly after its placement on the rickshaw, the Velcro strap on the cup holder began to tear away from the rest of the cup holder. As a result, a team member had to re-sew the strap.

Cost per use is an additional aspect to consider when making purchases. For example, if the Team spent \$10 on the current cup holder, but it only lasts five hikes, its cost per use would be \$2. If the Team had spent \$50 on a cup holder that lasted 100 hikes, its cost per use would be \$0.50, becoming the more cost-effective solution.

7.3 RECOMMENDED FUTURE WORK

Much of the future work for the rickshaw was determined while the Team did a trial run on Wind Caves Trail in Logan Canyon. Other items of future work were determined by observation upon completion of the project.

7.3.1 Developing an electric assist.

The current iteration of the rickshaw performed as expected during the trial run on Wind Caves Trail. It was able to overcome each of the obstacles along the trail. The Team determined the limiting factor was not the rickshaw; the limiting factor was the strength and endurance of the drivers.

To mitigate this limiting factor, it is suggested that time and money be dedicated to designing an electric assist to help propel the rickshaw up steep sections of the trail. Inexpensive electronic wheel kits with voltage ranging from 36V to 48V cost around \$200. Future resources would need to be provided, and

detailed research would need to be performed, to determine feasibility of such electronic wheel kits. Integration of these kits could be challenging with the current design. As such, other electric motors and options should be explored. Required voltage and desired output would also need to be determined.

7.3.2 Adding padded armrests.

During the trial on Wind Caves Trail, it was determined that padded armrests, although unnecessary, would provide the passenger a more comfortable ride. Pre-owned wheelchair armrests could be re-purposed for use on the rickshaw as a cost-effective option. Other options should be explored to ensure durability and feasibility.

7.3.3 Designing the seat to be better suited for a variety of disabilities and lower the center of mass.

The scope of the project did not include designing a seat for the rickshaw. The current seat used in the rickshaw was provided from a previous rickshaw owned by Common Ground and is better suited for racing. Depending on the type and degree of disability, the seat may not provide passengers with proper neck and/or back support. For the rickshaw to be suitable for a wider range of disabilities, the seat should be replaced with a new seat that has been designed with these issues in mind.

In addition, the current seat has about 5 in. of thickness from the base to where the passenger sits. This adds height to the passenger during operation, increasing the height of the center of mass and, in turn, making it more difficult to stabilize. Eliminating this unnecessary seat thickness would provide drivers with better control and require less energy.

7.3.4 Shortening the forks.

The forks provide more space than necessary between the top of the wheel and the rickshaw frame. Because they are longer than necessary, the forks add to the overall height of the passenger during operation. This raises the center of mass and makes it more challenging to stabilize the rickshaw. Shortening the forks would require less energy and provide drivers with better control.

8 REFERENCES

1 Ulman, D.G., 2015. *The Mechanical Design Process,* 5th ed., McGraw-Hill Education, pg. 452.

2 *Standards for Trail Construction,* Available at: <www.nps.gov/noco/learn/management/upload/NCT_CH4.pdf> [Accessed Date: 15 October 2016].

3 Riley, B., *Formula SAE Anthropometric Reference Data 5th Percentile Female and 95th Percentile Male,* Updated 23 November 2015. Available at: <www.fsaeonline.com/content/FSAE%Rules95th_2016.pdf> [Accessed Date: 22 October 2016].

4 *Americans with Disabilities Act, 1991, Title III ADA Regulation*, Available at: <www.ada.gov/descript/.reg3a/figA3ds.htm> [Accessed Date: 16 October 2016].

5[†] Abby Bohrer, (abby.cgoa@gmail.com), "Joelette Testing at Antelope Island", Clay Christensen (Clay.Christensen@usu.edu), et al., 20 December 2017.

[†] Reference attached in Appendix A

Appendix A

Attached References

Joelette Testing at Antelope Island Capstone x

Nicholas Neeley Abby, Judging by the doodle poll, Saturday, Monday, or Tue... 12/15/17

3 older messages

Abby Bohrer <abby.cgoa@gmail.com> 12/20/17

to Clay, Nicholas, Tyler, me, Andrew, Doc

Hi all,

To follow up from my meeting with my boss, we have decided that the one wheel design is what we would like to see and we do not feel a two-wheel prototype is necessary. He is on board with the idea of emergency brakes in the front and main braking system in the back. Let me know what you need from us further, thanks!

Best,

...

Abby Bohrer

Appendix B

Requirements Contract

Capstone Design Requirements Contract **Rickshaw for Common Ground**	USU MAE Capstone Design Program Utah State University 4130 Old Main Hill Logan, UT 84322-4130
Award Amount: $1200.00	**Period of Performance:** 08/28/2017 to 04/20/2018
Capstone Sponsor: Common Ground Outdoor Adventures 335 North 100 East Logan, Utah 84321 To: Clay Christensen	**Faculty Advisor:** Jackson Graham Assistant Professor of Practice Phone: 435-797-5684 Fax: 435-797-2417 Email: jackson.graham@usu.edu

Introduction

This is a capstone design requirements Contract for a Utah State University (USU) Mechanical and Aerospace Engineering (MAE) Capstone Design Program student capstone design project (herein "Project"). It documents agreement between the MAE Capstone Design Program student team executing the Project (herein "Team") and the organization sponsoring the Project (herein "Sponsor") on engineering requirements and specifications applicable to the Project. This Contract is a student training aid, and is not legally binding for any individual or organization. The terms of the Capstone Sponsor Agreement continue as the only official terms of the Project.

Agreement

The parties agree to scope, requirements, and strategies in accordance with the Contract; as modified by subsequent written change requests generated by the Team, approved by the Sponsor, and limited by the Capstone Sponsor Agreement.

USU MAE CAPSTONE DESIGN PROGRAM

By:
Name: Tate Shorthill
Title: Project Manager
Date: 3/20/18

By:
Name: Jackson Graham
Title: Faculty Advisor
Date: 3/20/18

SPONSOR

By:
Name: Clay Christensen
Title: Mentor
Date: 4/18/18

CLIENT

By:
Name. Abby Bohrer
Title: Daily Activities Coordinator
Date: 5/20/18

SCHEDULE OF ARTICLES

1. **Statement of Work**

1.1. The Team shall deliver a fully-functional rickshaw capable of carrying a single 200-pound person with disabilities on hiking trails.

1.2. The delivered design shall provide individuals with disabilities access to hiking trails that would not be accessible by standard wheelchair.

1.2.1. The rickshaw shall be capable of being operated by two individuals.

1.2.2. The rickshaw shall be capable of carrying a single 200-pound passenger.

1.2.3. The rickshaw shall contain a brake system operable by the rear driver.

1.2.4. The rickshaw shall contain a parking brake.

1.2.5. The rickshaw shall contain a parking stability assist device to aid in loading and unloading passengers on a level, hard surface.

1.2.6. The rickshaw shall be capable of navigating hiking trails that standard wheelchairs are not capable of accessing.

1.2.7. The rickshaw shall contain a restraining harness capable of keeping the passenger upright.

1.2.8. The rickshaw shall be capable of being operated by drivers of different heights.

2. **Fundamental Design Assumptions**

2.1. The rickshaw design will be powered by pedestrians rather than cyclists.

2.2. The rickshaw will not be used during adverse weather conditions and/or during winter months.

2.3. The rickshaw will only be used on appropriately rated trails.

3. **Engineering Requirements and Goals**

3.1. The rickshaw brake system shall be capable of holding the fully-loaded rickshaw stationary on an incline up to 20 degrees (36.4% grade) with an applied force of 15 lbf or less.

<u>Source:</u> On average, an adult female can apply a maximum hand force of 61 lbf [1]. However, to accommodate brake usage over an extended period, it was determined that approximately 25% of the maximum force could be applied. This percentage corresponds to 15 lbf.

<u>Verification Strategy:</u> The fully-loaded rickshaw will be placed on a 20 degree incline. A force up to 15 lbf (measured via luggage scale) will be applied to the brakes. Visual inspection will be performed to ensure the applied force holds the rickshaw stationary.

3.2. The rickshaw brake system shall be operable by the rear driver.

<u>Source:</u> After testing a one-wheeled rickshaw with the brake lever accessible to the rear driver, this was determined to be the desired brake location.

<u>Verification Strategy:</u> Verification will be done by visual inspection and testing to ensure that the brakes can be operated by the rear driver.

3.3. The rickshaw shall have a parking brake capable of holding a fully-loaded rickshaw stationary on an incline up to 20 degrees.

<u>Source:</u> Including a parking brake in the design allows for user adjustments and rest stops along the trail.

Verification Strategy: The fully-loaded rickshaw will be placed on a 20 degree incline. The parking brake will be engaged. Visual inspection will be performed to ensure the parking brake holds the rickshaw stationary.

3.4. The rickshaw braking system parts shall be easily repairable and replaceable.

Source: Sponsor/client specified requirement.

Verification Strategy: Sponsor shall approve brake system in regard to maintenance.

3.5. The rickshaw frame shall be higher than 10 in. off the ground.

Source: Maximum obstacle height on The Wind Caves hiking trail is 10 in.

Verification Strategy: A tape measure will be used to determine the lowest point of the frame when the rickshaw is fully-loaded to ensure compliance.

3.6. The total length of the rickshaw shall not exceed 10 ft.

Source: The Wind Caves hiking trail has switchbacks that require the rickshaw to be able to turn inside a diameter of 10 ft.

Verification Strategy: The total length of the rickshaw will be measured via tape measure to ensure compliance.

3.7. The maximum width of the frame shall not exceed 4 ft.

Source: Trees and other obstacles become an issue if the total width of the rickshaw exceeds 4 ft. [2].

Verification Strategy: The total width of the frame will be measured via tape measure to ensure compliance.

3.8. The rickshaw shall be equipped with a seat between 18 in. and 30 in. off the ground while loading and unloading.

Source: The rickshaw height will aid in the loading and unloading of passengers. The average height of an ADA approved wheelchair is 19 in. [4]. A standard bar stool is 30 in.

Verification Strategy: The height from the ground to the seat will be measured, via tape measure, to ensure compliance.

3.9. The rickshaw shall be equipped with height adjustable user-interface handles with a range between 29 in. and 45 in. from the ground.

Source: This range accommodates women with a hip height of 29.1 in. (5% percentile) and men with a hip height of 39.4 in. (95% percentile) [3].

Verification Strategy: Verify by measurement with a tape measure that, on level ground, the rickshaw handles are adjustable to meet the specified waist height range.

3.10. The rickshaw shall be equipped with adjustable foot supports for the rider, which accommodates a person with a leg length between 36 in. and 45 in.

Source: This range accommodates women with a leg length of 36 in. (5% percentile) and men with a leg length of 45 in. (95% percentile) [1].

Verification Strategy: The length from the back of the seat to the foot support shall be measured, via tape measure, to verify that the above mentioned leg length range is accommodated.

3.11. The rickshaw shall be equipped with a parking stability assist device.

Source: The parking stability assist device allows for the rickshaw to be parallel to the ground allowing for easier loading and unloading.

Verification Strategy: The unloaded rickshaw will be placed on level ground with the parking stability assist device engaged. No external forces will be applied to the rickshaw. Visual inspection will be performed to ensure the rickshaw is approximately parallel to the ground. A 200 lbf weight will be loaded onto the rickshaw to ensure stability is maintained.

3.12. The rickshaw parking stability assist device should be engaged and disengaged while keeping the rickshaw parallel to the ground.

Source: The parking stability assist device provides a way for the rickshaw to be stabilized for passenger loading and unloading. The front driver will not need to set the rickshaw handles on the ground before engaging the parking stability assist device.

Verification Strategy: The front driver will engage the parking stability assist device. The rickshaw will then be lowered by both drivers to validate that the parking stability assist device will hold the rickshaw parallel to the ground.

3.13. The rickshaw seat should be capable of reclining between 0 and 30 degrees, as measured from a vertical, flat surface.

Source: This goal is to provide client comfort.

Verification Strategy: The angle that the seat can recline will be measured with the Compass app on the iPhone 7.

3.14. The rickshaw should have an integrated cup holder and storage space.

Source: Sponsor needs space to hold supplies while on the trail. According to the sponsor, the cup holder is to provide the client a more independent experience.

Verification Strategy: This will be verified by visual inspection.

4. **Communications**

4.1. The Mentor shall be available to respond to email correspondence or telephone calls at least one hour per week.

4.2. Common Ground shall be available to respond to phone calls, texts, and/or email within one to two business days.

4.3. The Team shall report to Common Ground on design and production milestones via email/appointment within one business day.

4.4. The Team shall submit copies of the final and any intermediate written reports to the Sponsor, via EduSourced, upon completion of the work. The Team will notify the Mentor via email/phone call/at weekly meeting, etc. when new written reports have been completed and are available for review. EduSourced is available at https://usumechanicalaero.edusourcedapp.com/login

4.5. The final report shall contain a comprehensive summary of final design performance against all Article 3 engineering requirements and goals. Evidence of requirement and goal achievement shall be referenced. If a requirement or specification has not been met, such failure shall be fully documented and explained in the report.

4.6. The final report shall describe the final design's subassemblies and components, their functions, operation, performance, interfaces, and design justifications.

5. **Sponsor-Furnished Property or Labor**

5.1. The Sponsor shall furnish the Team with parts (seat, shocks, etc.) from the existing rickshaw.

5.2. The Sponsor shall allow the Team access to the Janet Quinney Lawson AT Lab with prior authorization.

6. References

[1] Ulman D.G., 2015, *The Mechanical Design Process*, 5th ed., McGraw-Hill Education, pg. 452.

[2] Standards for Trail Construction, https://www.nps.gov/noco/learn/management/upload/NCT_CH4.pdf

[3] Formula SAE Anthropometric Reference Data 5th Percentile Female and 95th Percentile Male. Riley, B. Updated 23 November 2015. www.fsaeonline.com/content/FSAE%Rules95th_2016.pdf

[4] Americans with Disabilities Act, 1991, "Title III ADA Regulation", www.ada.gov/descript/.reg3a/figA3ds.htm

Appendix C

Bill of Materials

Item No.	Part Name/Description *Referencing Drawings*	Part Number	Vendor/Manufacturer	Cost Ea.	QTY.	Total
1	30" 1010 Steel Square Tubing (1.5' x 1.5" x 0.12") *Drawings: 001 and 002*	RM 7596C18120	Ipaco	N/A	1	$5.25
2	27' 1010 Steel Square Tubing (1.25" x 1.25" x 0.12") *Drawings: 001, 002, 003, 004, 005, and 013*	RM 7596C14120	Ipaco	N/A	1	$49.14
3	12' 1010 Steel Square Tubing (1.0" x 1.0" x 0.12") *Drawings: 001, 009, 014, and 015*	RM 7596C10120	Ipaco	N/A	1	$17.40
4	16" 1010 Steel Square Tubing (0.75" x 0.75" x 0.12") *Drawing: 008*	RM 7596C0C120	Ipaco	N/A	1	$1.40
5	3' 1010 Steel Bar (2" x 0.25") *Drawings: 001, 004, and 014*	RM 1575C042	Ipaco	N/A	1	$3.03
6	7' 1010 Steel Round Tubing (1" x 0.12") *Drawings: 001, 006, and 012*	RM 7584C10120	Ipaco	N/A	1	$9.03
7	20' 1020 Steel Round Tubing (1.25" x 0.12") *Drawings: 001, 007, and 010*	RM 7584C14120DOM	Ipaco	N/A	1	$81.16
8	3/8" Grommets *Drawing: N/A*	886946917622	Michael's	N/A	2	$4.29
9	Stainless Steel Wire Lanyard *Drawing: N/A*	30345T127	McMaster-Carr	$6.94	5	$34.70
10	Steel Surface-Mount Hinge *Drawing: 001*	16175A41	McMaster-Carr	$11.44	1	$11.44
11	Clevis Rod End Blank *Drawing: 001*	6414K13	McMaster-Carr	$6.38	4	$25.52

Item No.	Part Name/Description *Referencing Drawings*	Part Number	Vendor/Manufacturer	Cost Ea.	QTY.	Total
12	¼" dia. x 1-½" Quick Release Pin *Drawing: 001*	98485A135	McMaster-Carr	$1.90	4	$7.60
13	¼" dia. x 1" Quick Release Pin *Drawing: N/A*	98485A130	McMaster-Carr	$1.77	1	$1.77
14	5/16" x 1.25" Bolt 10 ct. *Drawing: N/A*	92240A306	McMaster-Carr	$3.73	1	$3.73
15	5/16" Washers 100 ct. *Drawing: N/A*	90107A030	McMaster-Carr	$10.29	1	$10.29
16	5/16" Hex Nuts 100 ct. *Drawing: N/A*	90473A030	McMaster-Carr	$4.17	1	$4.17
17	24" x 1/8" x 2" Low Carbon Steel Sheet *Drawings: 001, 003, 010, 015*	8910K399	McMaster-Carr	$6.75	1	$6.75
18	8" x 8" x ¼" Low Carbon Steel Sheet *Drawing: 001*	6544K23	McMaster-Carr	$30.63	1	$30.63
19	Zip Tie *Drawing: N/A*	4715409150367	The Home Depot	N/A	5	$2.56
20	¼" Hex Nuts *Drawing: N/A*	AHH	The Home Depot	$0.25	3	$0.75
21	¼" Cut Washer *Drawing: N/A*	AEC	The Home Depot	$0.19	6	$1.14
22	¼-20" x 1-½" Hex Bolt *Drawing: N/A*	BAH	The Home Depot	$0.47	3	$1.41

Item No.	Part Name/Description ***Referencing Drawings***	Part Number	Vendor/Manufacturer	Cost Ea.	QTY.	Total
23	3/8" Wing Nut *Drawing: N/A*	887480023916	The Home Depot	N/A	1	$1.18
24	3/8" Washers *Drawing: N/A*	ACB	The Home Depot	$0.14	2	$0.28
25	3/8" x 2-½" Hex Bolt *Drawing: N/A*	ATA	The Home Depot	$0.37	1	$0.37
26	8" x 1/2" Velcro Strap 5 ct. *Drawing: N/A*	075967907266	The Home Depot	$3.47	1	$3.47
27	¾" Self-tapping Screws for Metal *Drawing: N/A*	HD	Ipaco, Inc.	$0.24	3	$0.72
28	3/8-16" x 1" Hex Bolt *Drawing: N/A*	HD BHL	Ipaco, Inc.	N/A	2	$0.43
29	20"x54mm Fat Rim for CXS 36H *Drawing: N/A*	N/A	Utah Trikes	$89.95	1	$89.95
30	DT Swiss Spoke and Nipple *Drawing: N/A*	N/A	Utah Trikes	$2.00	36	$72.00
31	MT-3100 MTB Hub *Drawing: N/A*	37671	Utah Trikes	$59.95	1	$59.95
32	20" x 4" Tire for CXS *Drawing: N/A*	N/A	Utah Trikes	$59.95	1	$59.95
33	Padded Nylon Sled Harness *Drawing: N/A*	ES-H ProdID_21437	Iron Company	$32.99	1	$32.99

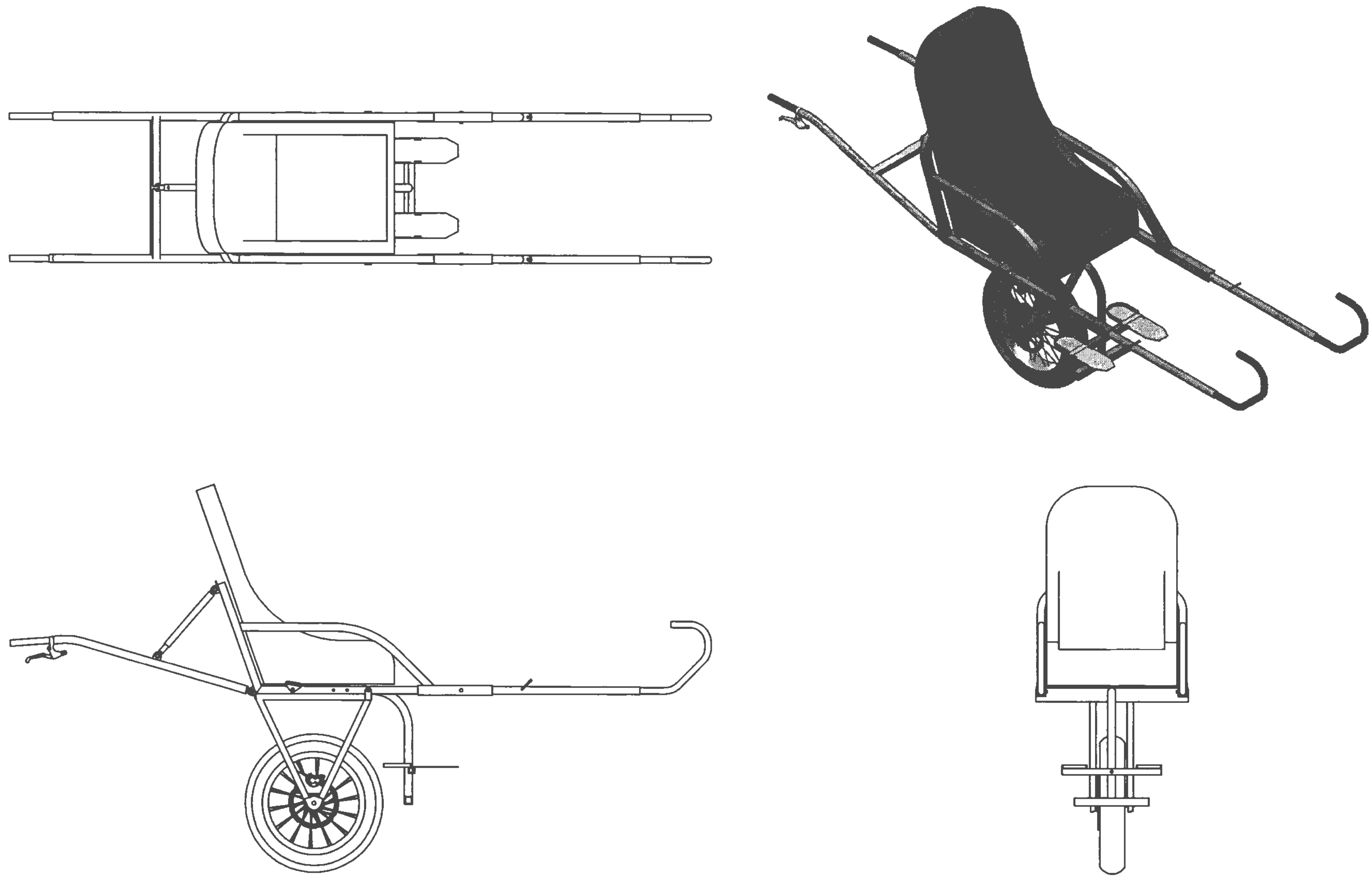
Item No.	Part Name/Description *Referencing Drawings*	Part Number	Vendor/Manufacturer	Cost Ea.	QTY.	Total
34	ZTL Cup Holder *Drawing: N/A*	N/A	Amazon	$10.99	1	$10.99
35	Cargo Net *Drawing: N/A*	N/A	Amazon	$9.99	1	$9.99
36	Velcro Straps 2 ct. (18” x 1”) *Drawing: N/A*	90107	Amazon	$5.20	1	$5.20
37	Mybecca High Density Foam *Drawing: N/A*	N/A	Amazon	$19.99	1	$19.99
38	SRAM Supercork Bike Bar Tape *Drawing: N/A*	N/A	Amazon	$8.75	2	$17.50
39	Sammons Preston Wheelchair Shoe Holder *Drawing: N/A*	081566603	Amazon	$28.00	1	$28.00
40	Summit Racing Poly Performance Seat *Drawing: N/A*	SUM-G1100-1	Summit Racing	$35.97	1	$35.97
41	Summit Racing Seat Cover *Drawing: N/A*	SUM-G2111B	Summit Racing	$31.97	1	$31.97
42	Tanaka 4 Point Buckle Harness *Drawing: N/A*	111724103874	eBay	$24.56	1	$24.56
43	Shimano SLX BR-M7000 Brake *Drawing: N/A*	BR199C01REAR	JensonUSA	$74.99	1	$74.99
44	Shimano RT66 6-Bolt 203mm *Drawing: N/A*	BR245L01 203	Jenson USA	$21.99	1	$21.99

Item No.	Part Name/Description *Referencing Drawings*	Part Number	Vendor/Manufacturer	Cost Ea.	QTY.	Total
45	Rockshox Maxle 15 x 100mm axle *Drawing: N/A*	710845768200	The Sportsman Ltd	$38.89	1	$38.89
46	1-½" Cast Flat Metal Slides *Drawing: N/A*	MS-C	Strapworks	$0.70	2	$1.40
47	1-½" Metal D-Rings *Drawing: N/A*	MDR	Strapworks	$0.60	2	$1.20

TOTAL $957.09

Appendix D

Drawing Package



Mechanical & Aerospace ENGINEERING
Utah State University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: RICKSHAW ASSEMBLY

MATERIAL: N/A

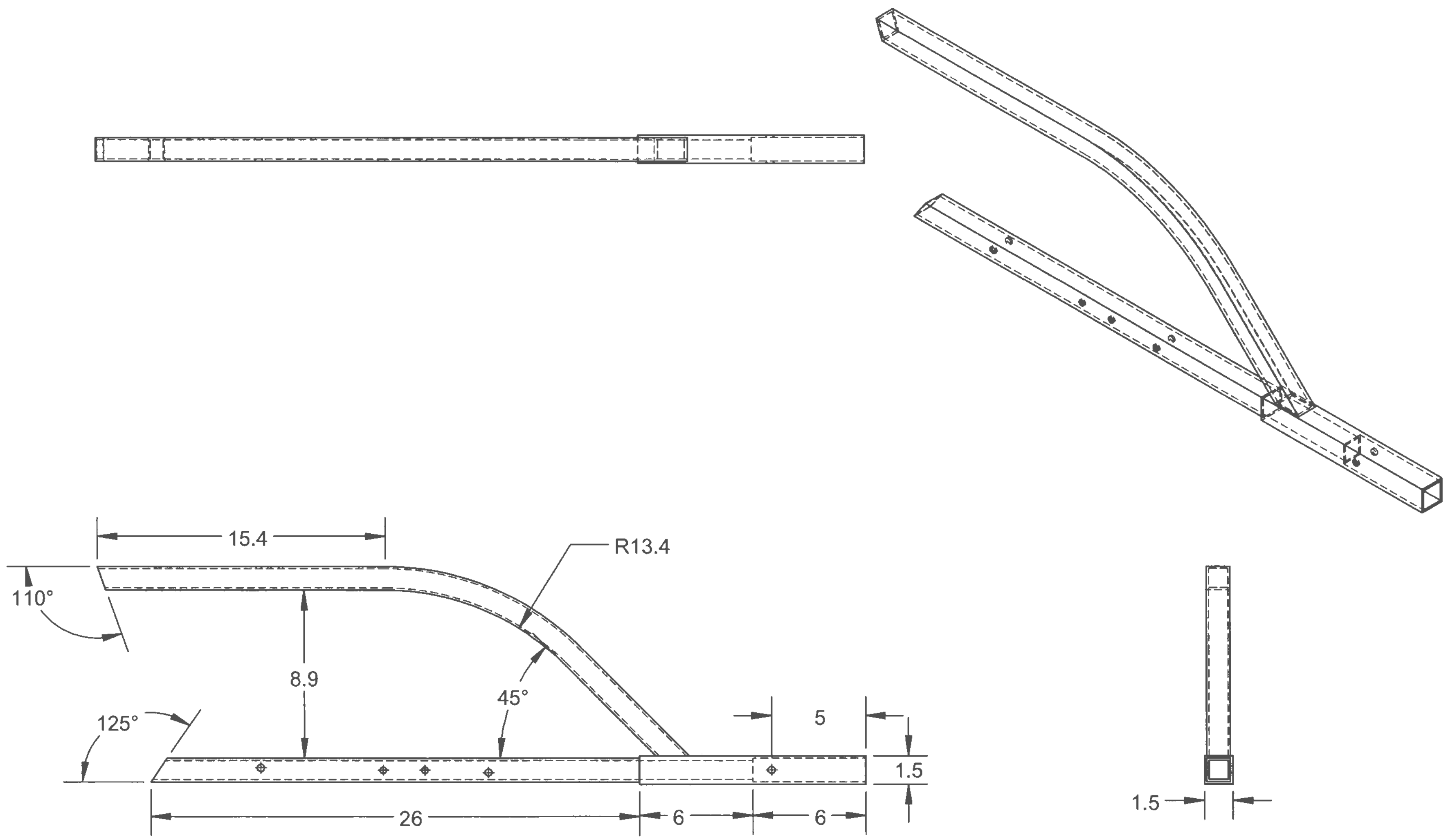
FINISH: N/A

DATE APPROVED: 4/23/2018

SHEET SCALE: 1:24

SHEET NUMBER: 1 of 1

All bars not dimensioned are standard 1.25" x 0.12" square tubing



Mechanical & Aerospace ENGINEERING
Utah State University

PROJECT: COMMON GROUNDS RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: **ARM REST**

MATERIAL: AISI 1010 Steel, hot rolled bar

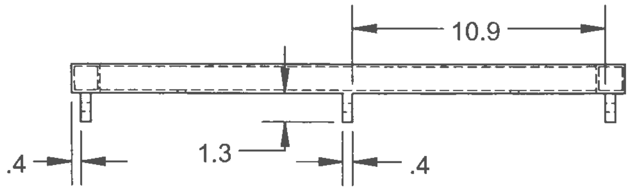
DATE APPROVED: 4/23/2018

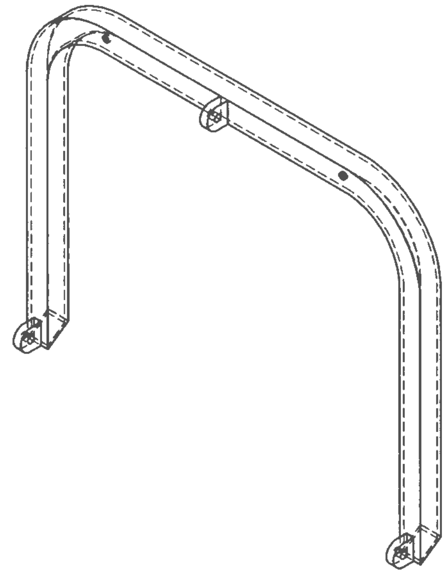
FINISH: ORANGE POWDER COAT

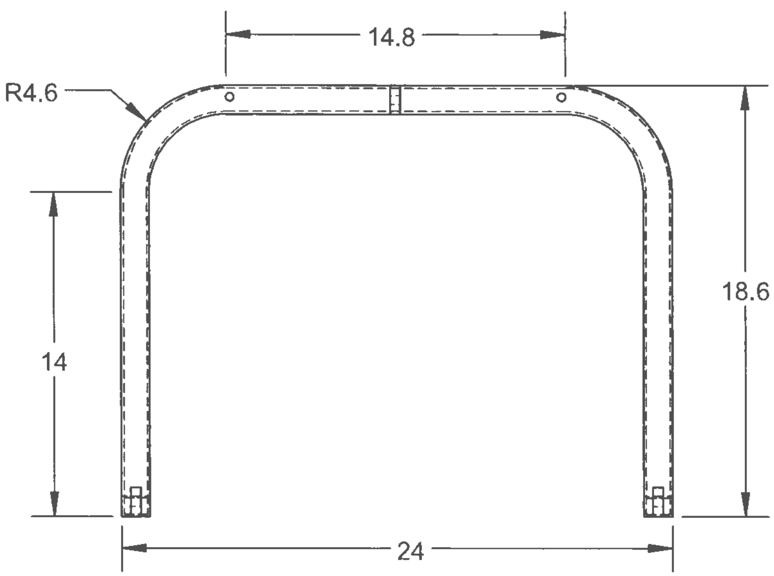
SHEET SCALE: 1:8

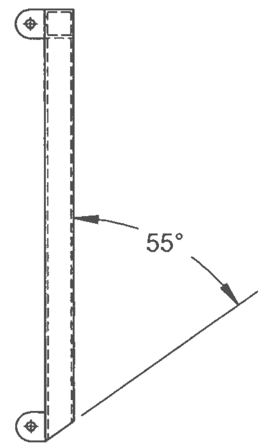
SHEET NUMBER: 1 of 1

All bars are 1.25" x 0.12" standard square tubing









Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW

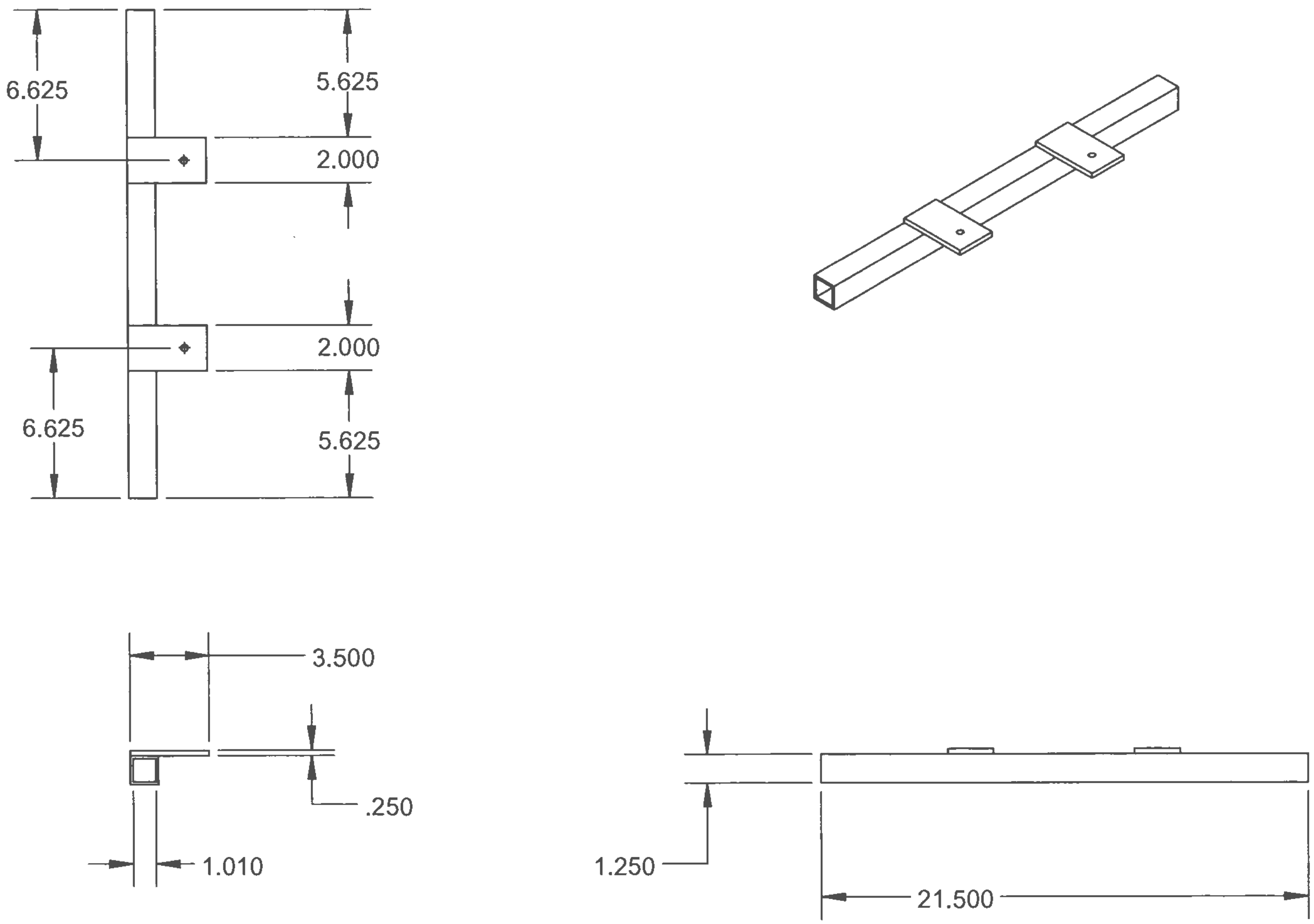
DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: **BACK REST**	
MATERIAL: AISI 1010 Steel, hot rolled bar	DATE APPROVED: 4/23/2018
FINISH: ORANGE POWDER COAT	SHEET SCALE: 1:8 — SHEET NUMBER: 1 of 1



Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: FRAME CROSS BAR

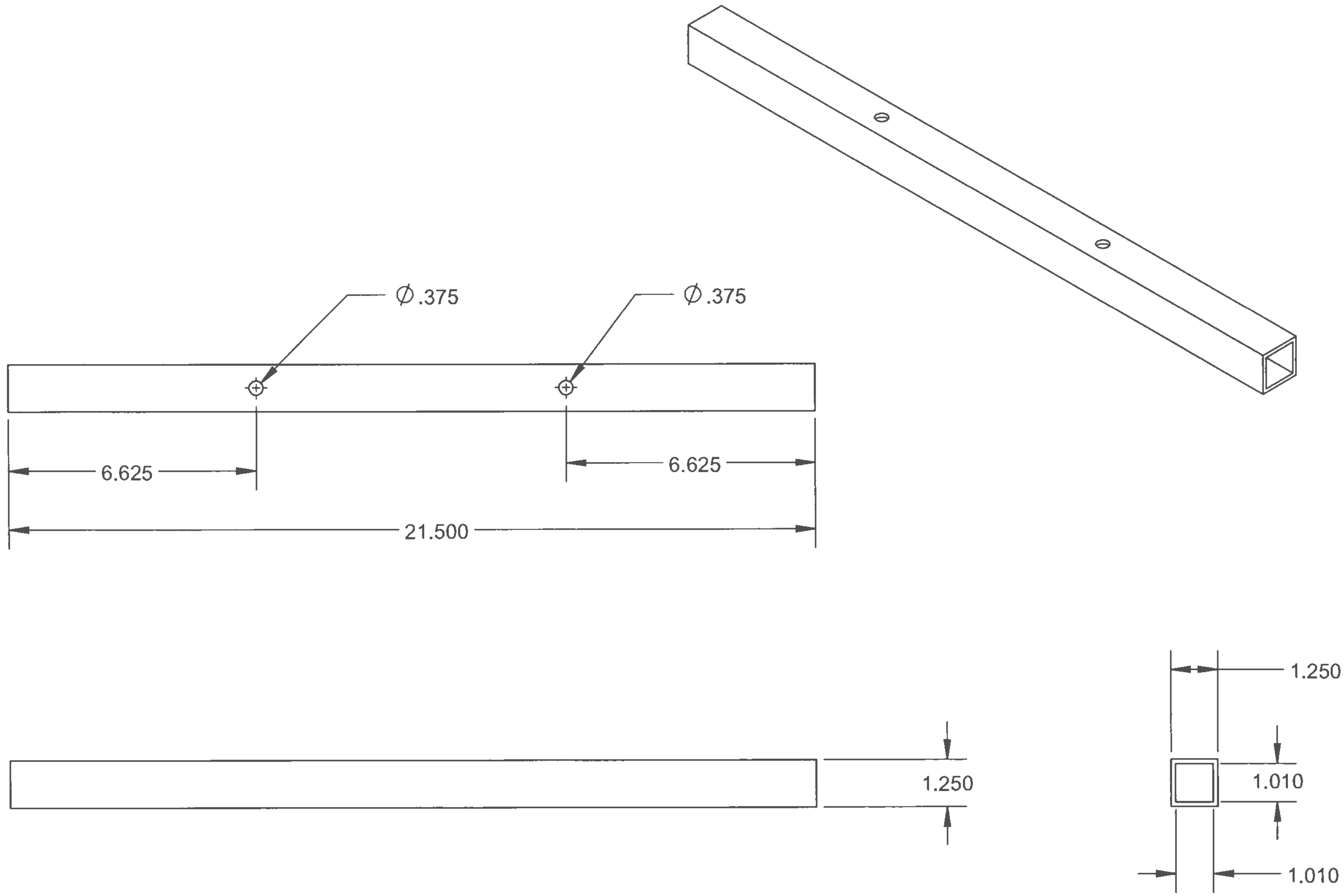
MATERIAL: AISI 1010 Steel, hot rolled bar

DATE APPROVED: 4/23/2018

FINISH: ORANGE POWDER COAT

SHEET SCALE: 1:8

SHEET NUMBER: 1 of 1



Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

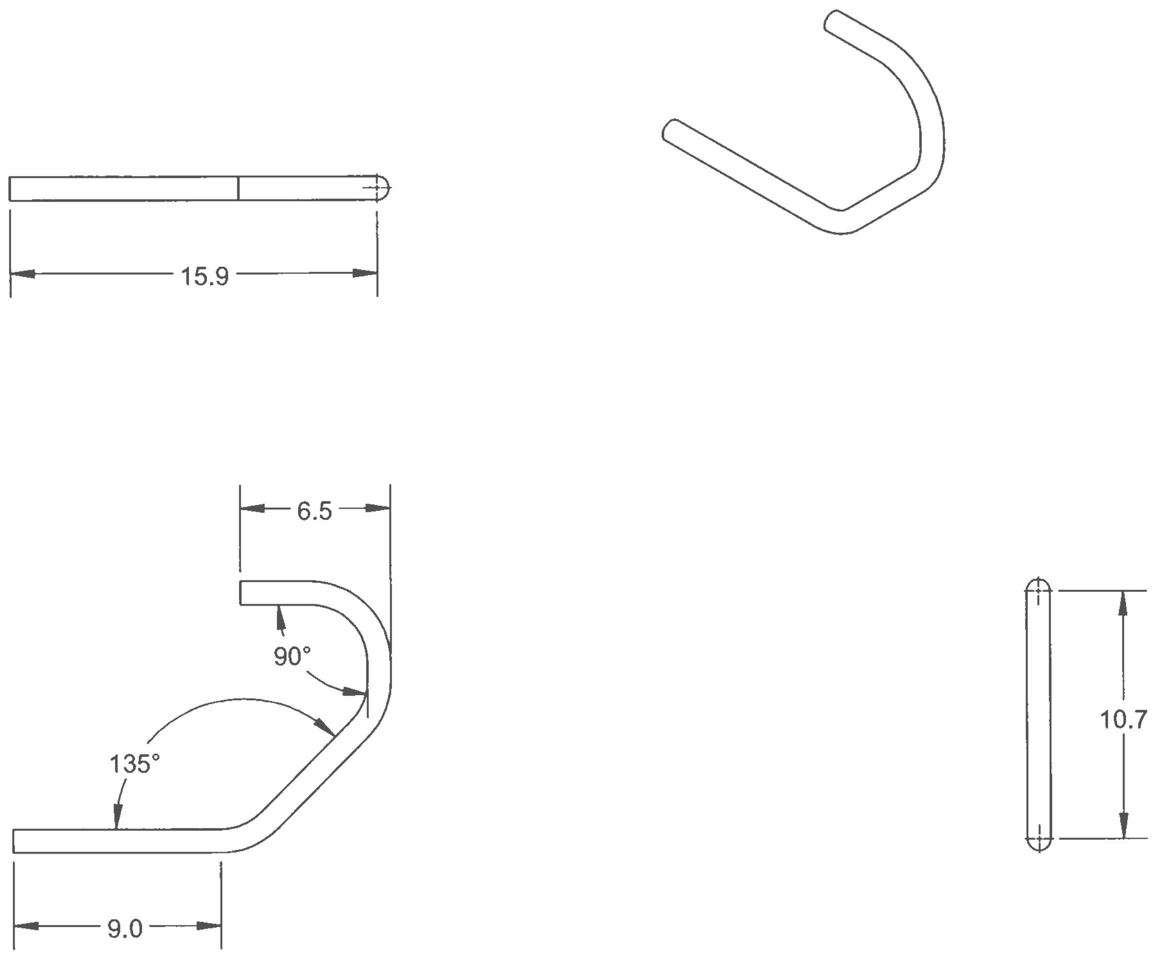
SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: **SEAT CROSS TUBING**

MATERIAL: AISI 1010 Steel, hot rolled bar	DATE APPROVED: 4/23/2018
FINISH: ORANGE POWDER COAT	SHEET SCALE: 1:4 / SHEET NUMBER: 1 of 1



Mechanical & Aerospace ENGINEERING

UtahState University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED

DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:

LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005

ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1

MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: FRONT DRIVER ARM 1 INCH SECTION

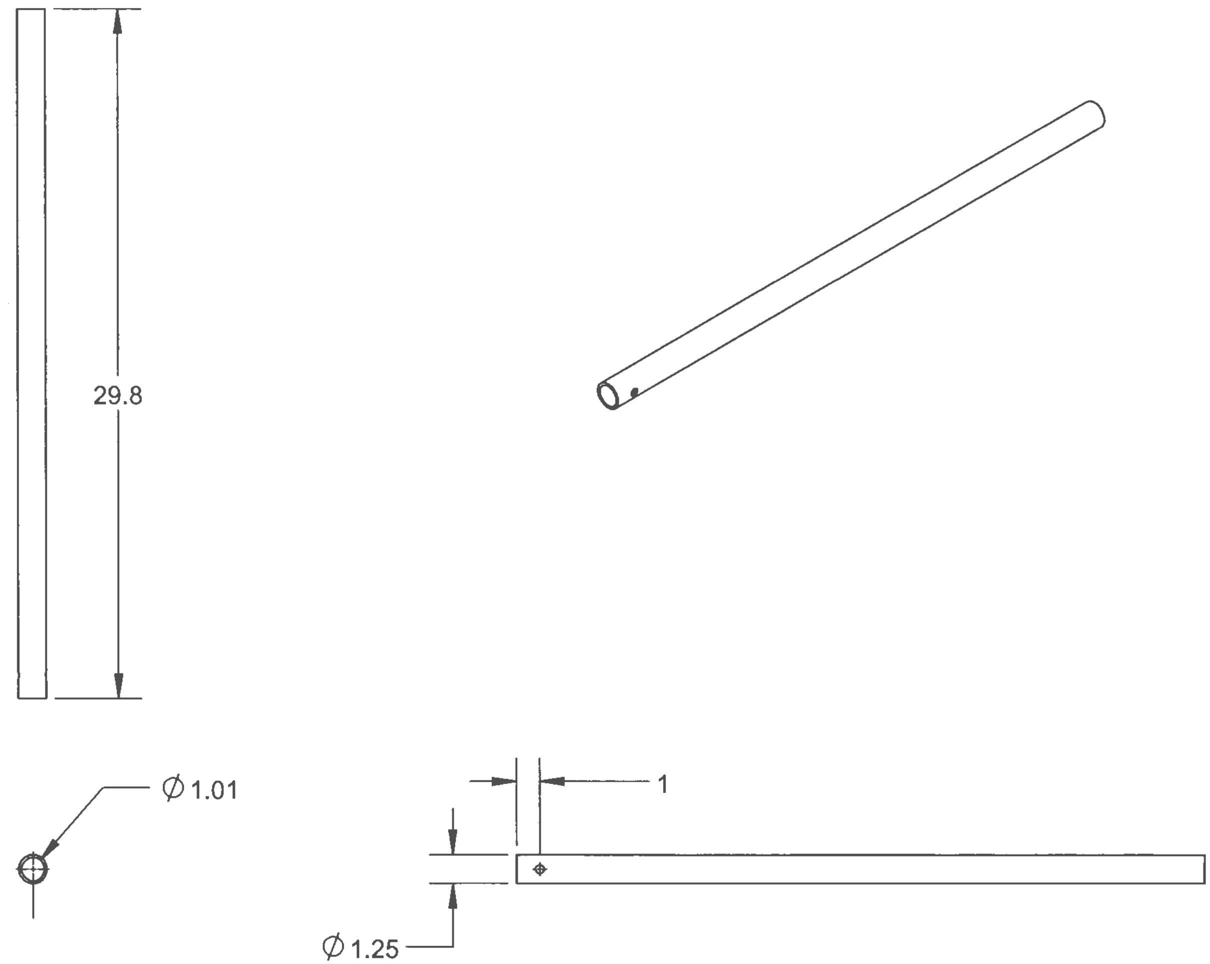
MATERIAL: AISI 1010 Steel, hot rolled bar

DATE APPROVED: 4/23/2018

FINISH: ORANGE POWDER COAT

SHEET SCALE: 1:8

SHEET NUMBER: 1 of 1

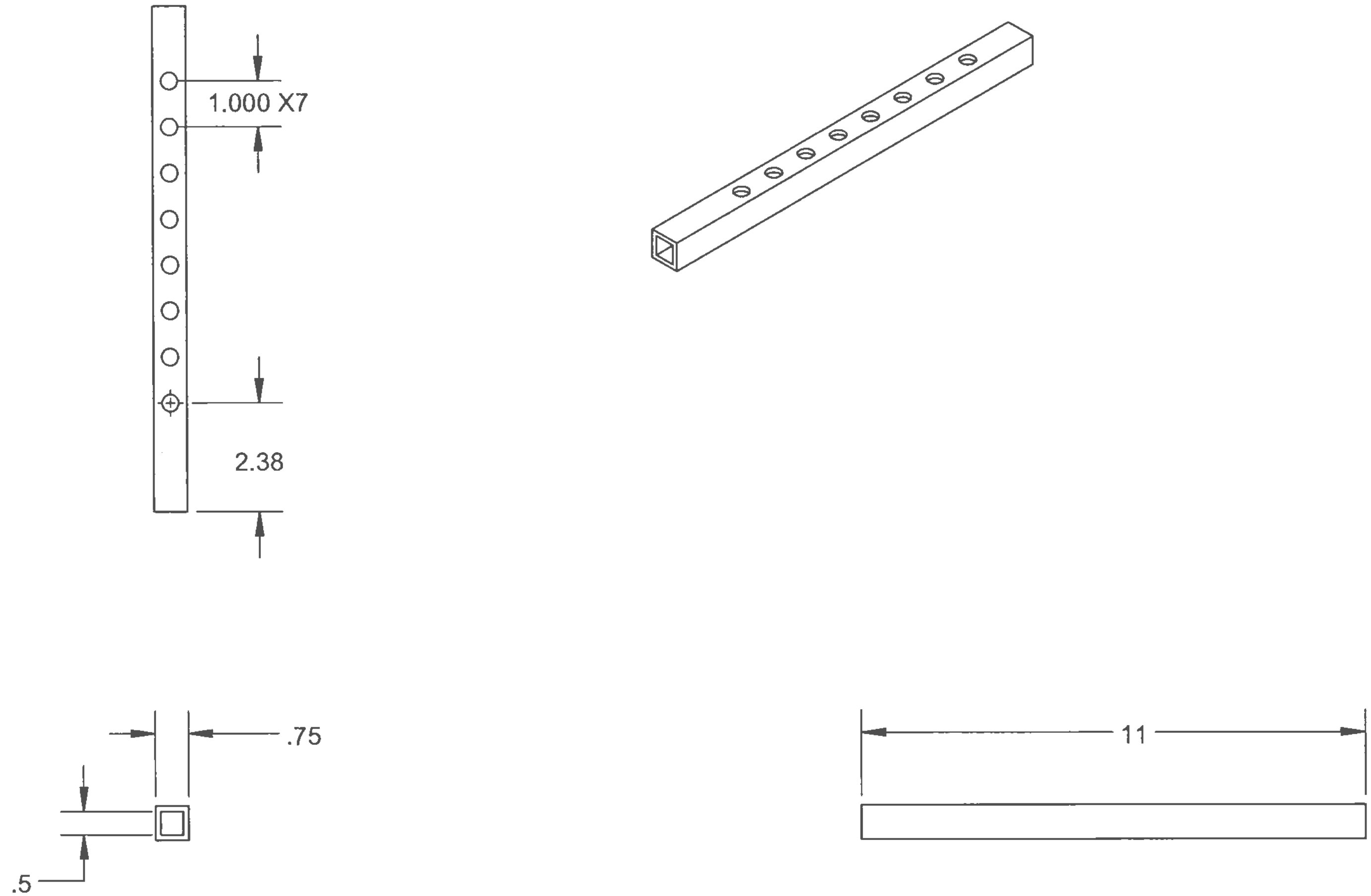


Mechanical & Aerospace ENGINEERING Utah State University	PROJECT: COMMON GROUND RICKSHAW
	DRAFTED BY: NICHOLAS NEELEY
PART/ASSEM NAME: FRONT DRIVER ARM	
MATERIAL: AISI 1020 Steel, Cold Rolled	DATE APPROVED: 4/23/2018
FINISH: ORANGE POWDER COAT	SHEET SCALE: 1:8 — SHEET NUMBER: 1 of 1

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches



Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: REAR DRIVER CROSS BAR 1

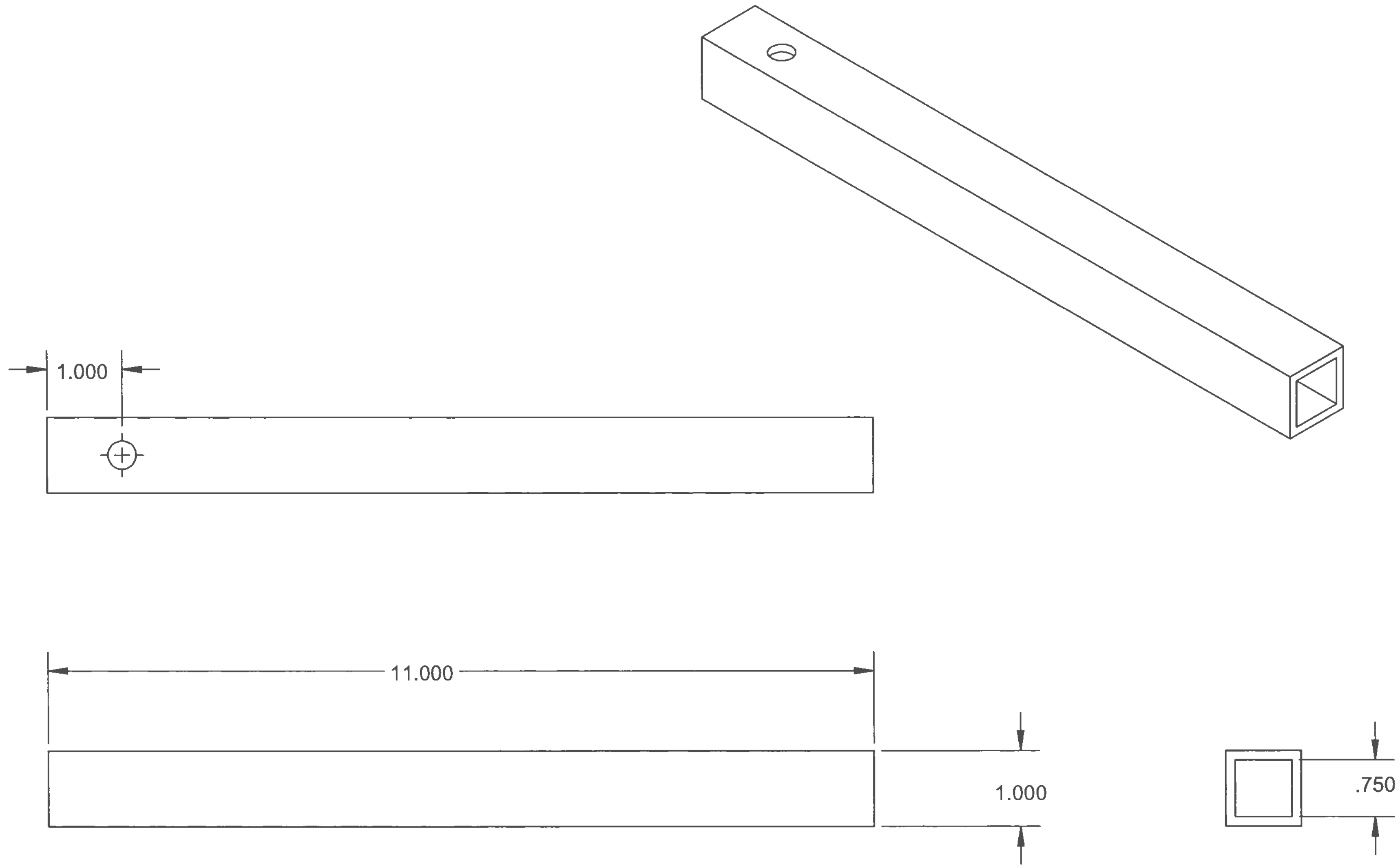
MATERIAL: AISI 1010 Steel, hot rolled bar

DATE APPROVED: 4/23/2018

FINISH: ORANGE POWDER COAT

SHEET SCALE: 1:4

SHEET NUMBER: 1 of 1



Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

PART/ASSEM NAME: REAR DRIVER CROSS BAR 2

MATERIAL: AISI 1010 Steel, hot rolled bar

DATE APPROVED: 4/23/2018

FINISH: ORANGE POWDER COAT

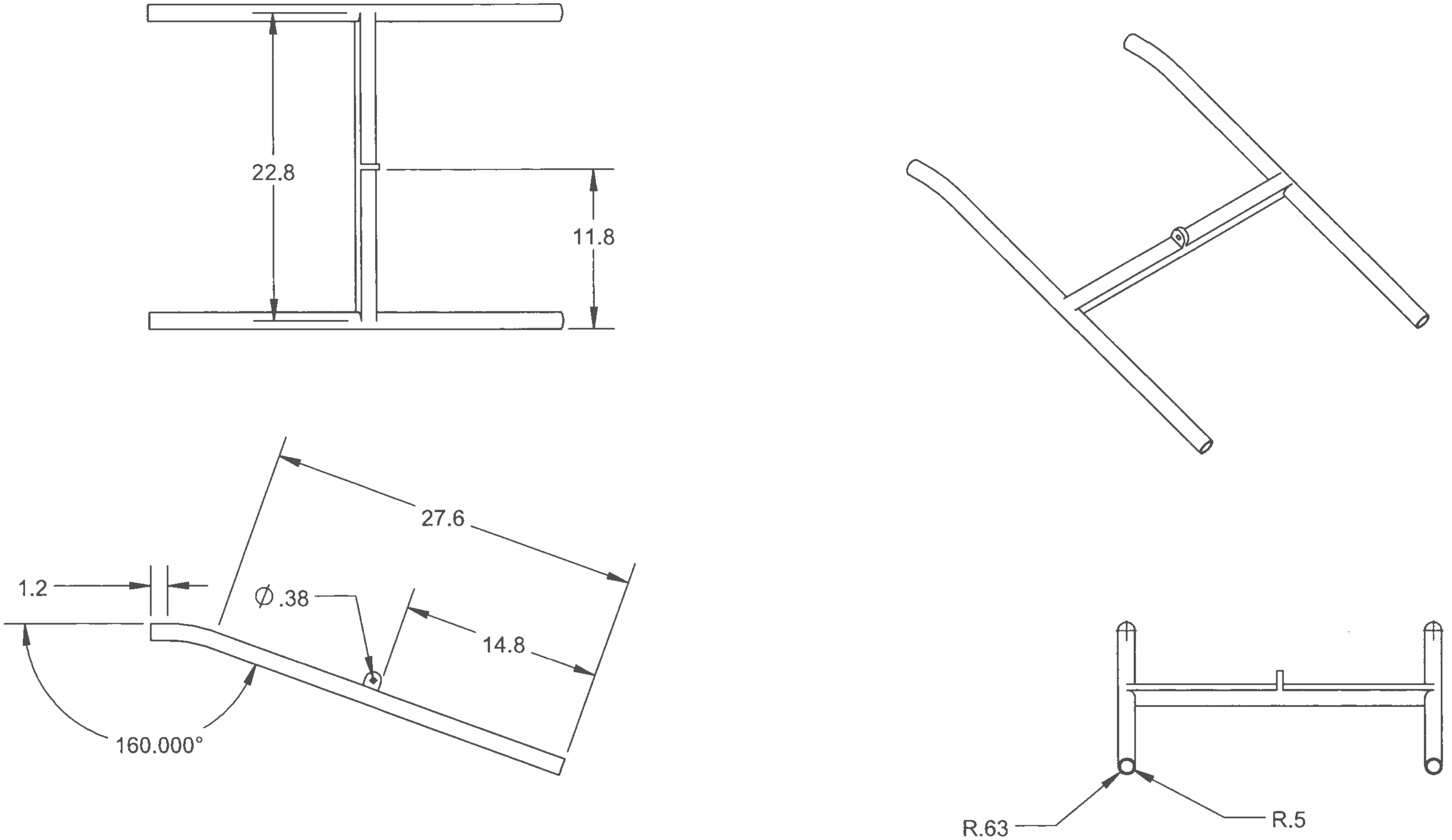
SHEET SCALE: 1:2

SHEET NUMBER: 1 of 1

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches



Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: REAR DRIVER HANDLE

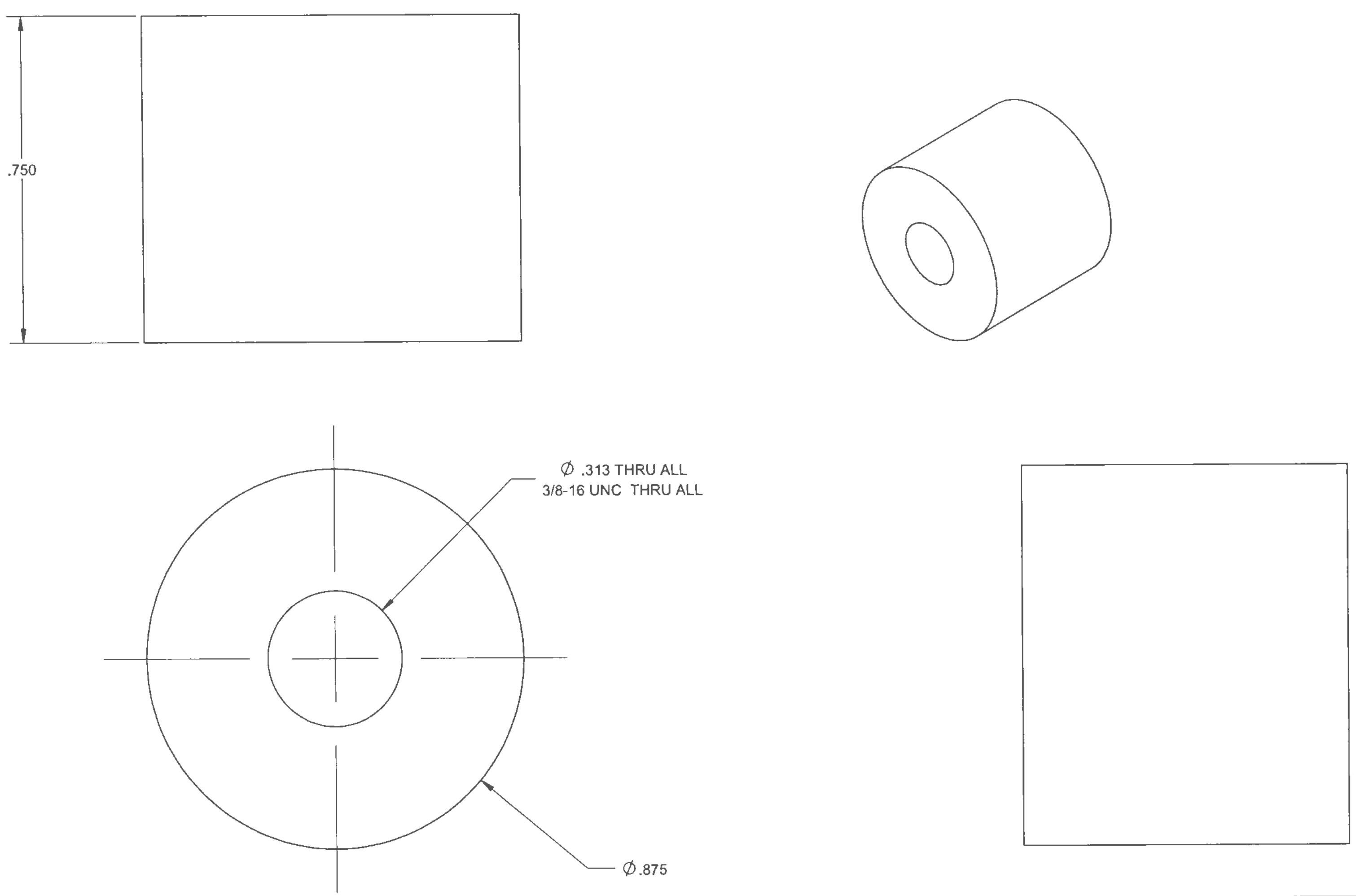
MATERIAL: AISI 1020

DATE APPROVED: 4/23/2018

FINISH: ORANGE POWDER COAT

SHEET SCALE: 1:12

SHEET NUMBER: 1 of 1

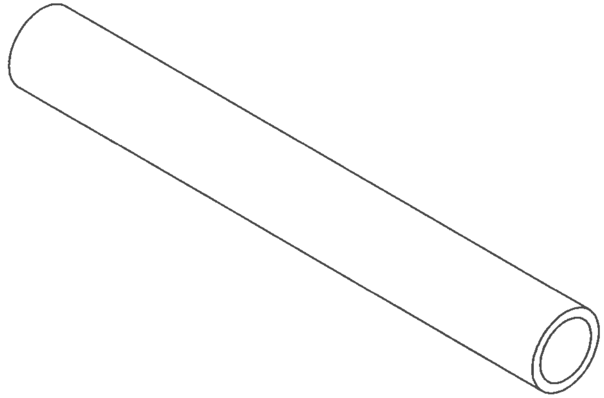


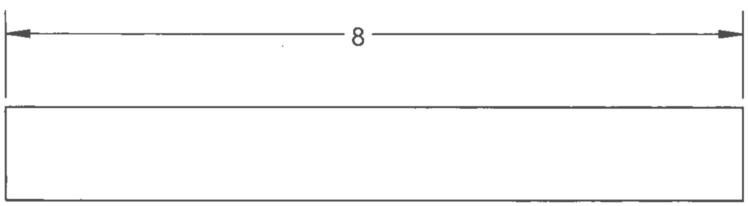
Mechanical & Aerospace ENGINEERING Utah State University	PROJECT: Common Ground Rickshaw
	DRAFTED BY: Tyler Mitchell
PART/ASSEM NAME:	Waist Strap
MATERIAL: AISI 1010 Steel, hot rolled	DATE APPROVED: 4/28/2018
	SHEET SCALE: 4:1 — SHEET NUMBER: 1 of 1

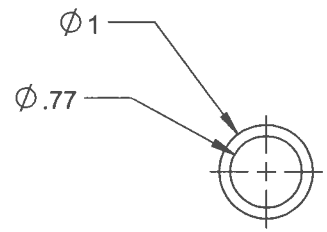
SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS (inches): X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS (degrees): X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches







Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: **REAR ERGO HANDLE**

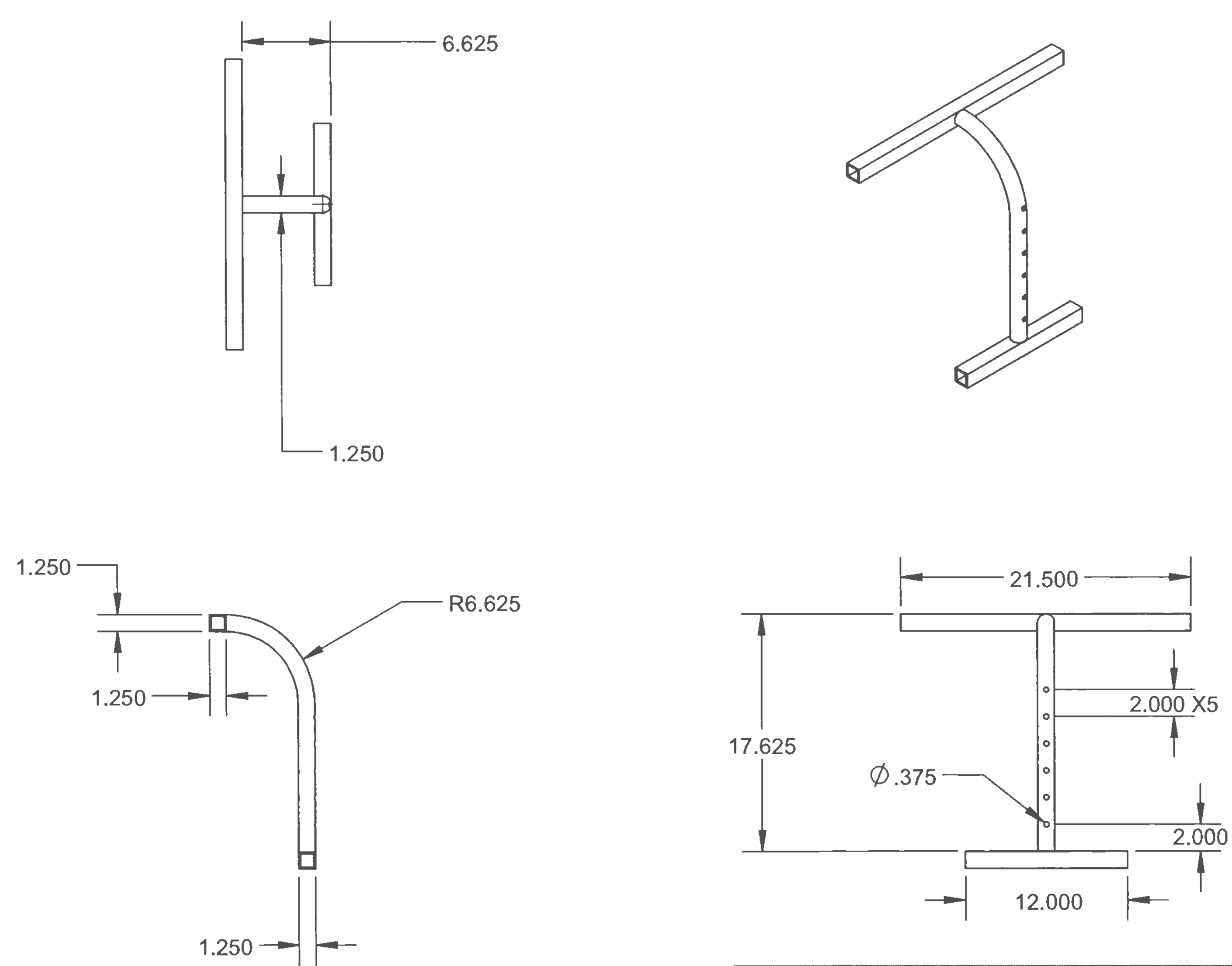
MATERIAL: AISI 1010 Steel, hot rolled bar

DATE APPROVED: 4/23/2018

FINISH: ORANGE POWDER COAT

SHEET SCALE: 1:2

SHEET NUMBER: 1 of 1



Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT:
COMMON GROUND RICKSHAW

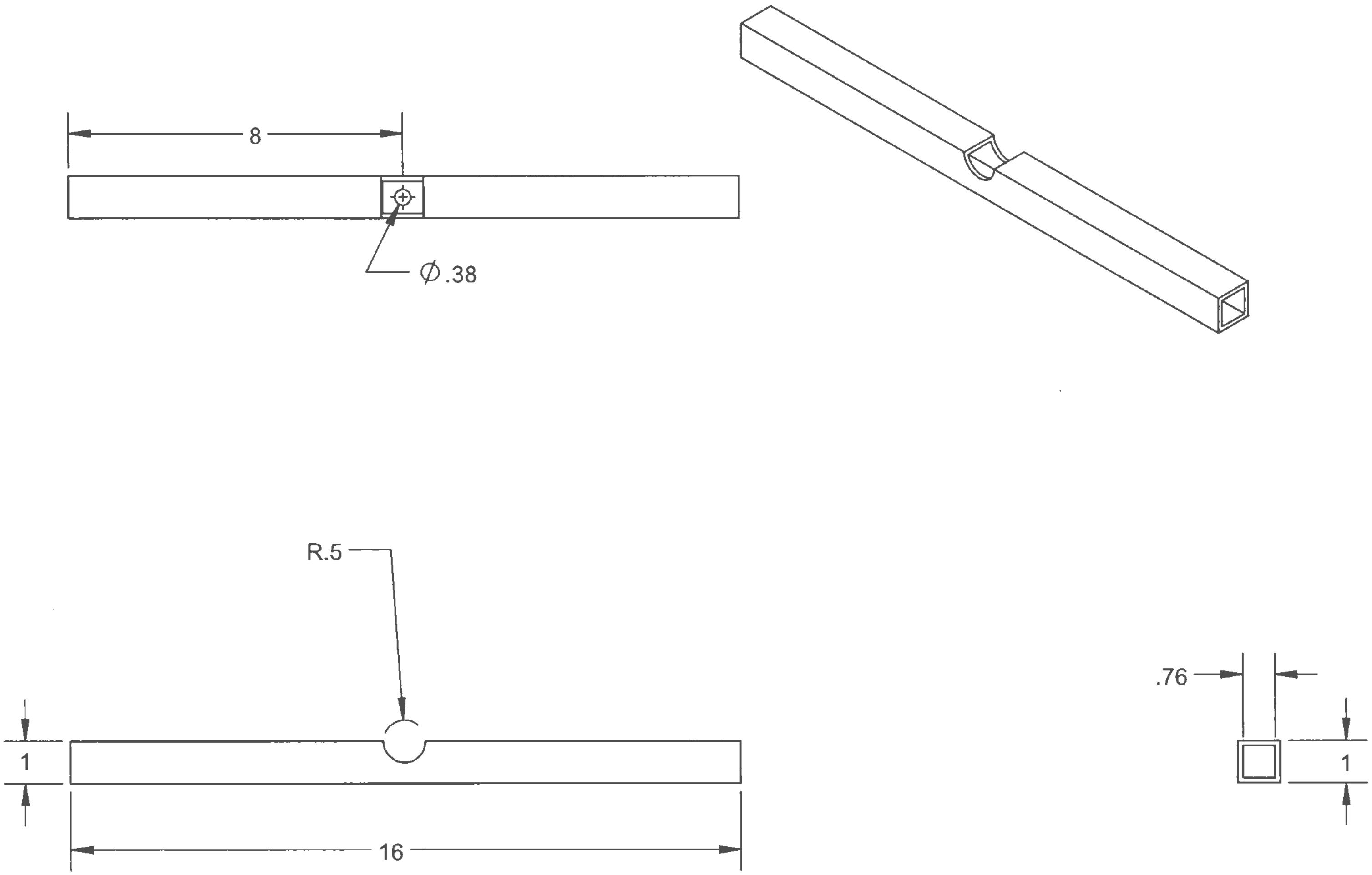
DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: FOOT REST	
MATERIAL: AISI 1010 Steel, hot rolled bar	DATE APPROVED: 4/23/2018
FINISH: ORANGE POWDER COAT	SHEET SCALE: 1:12 — SHEET NUMBER: 1 of 1



Mechanical & Aerospace ENGINEERING
Utah State University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: CALF SUPPORT BAR

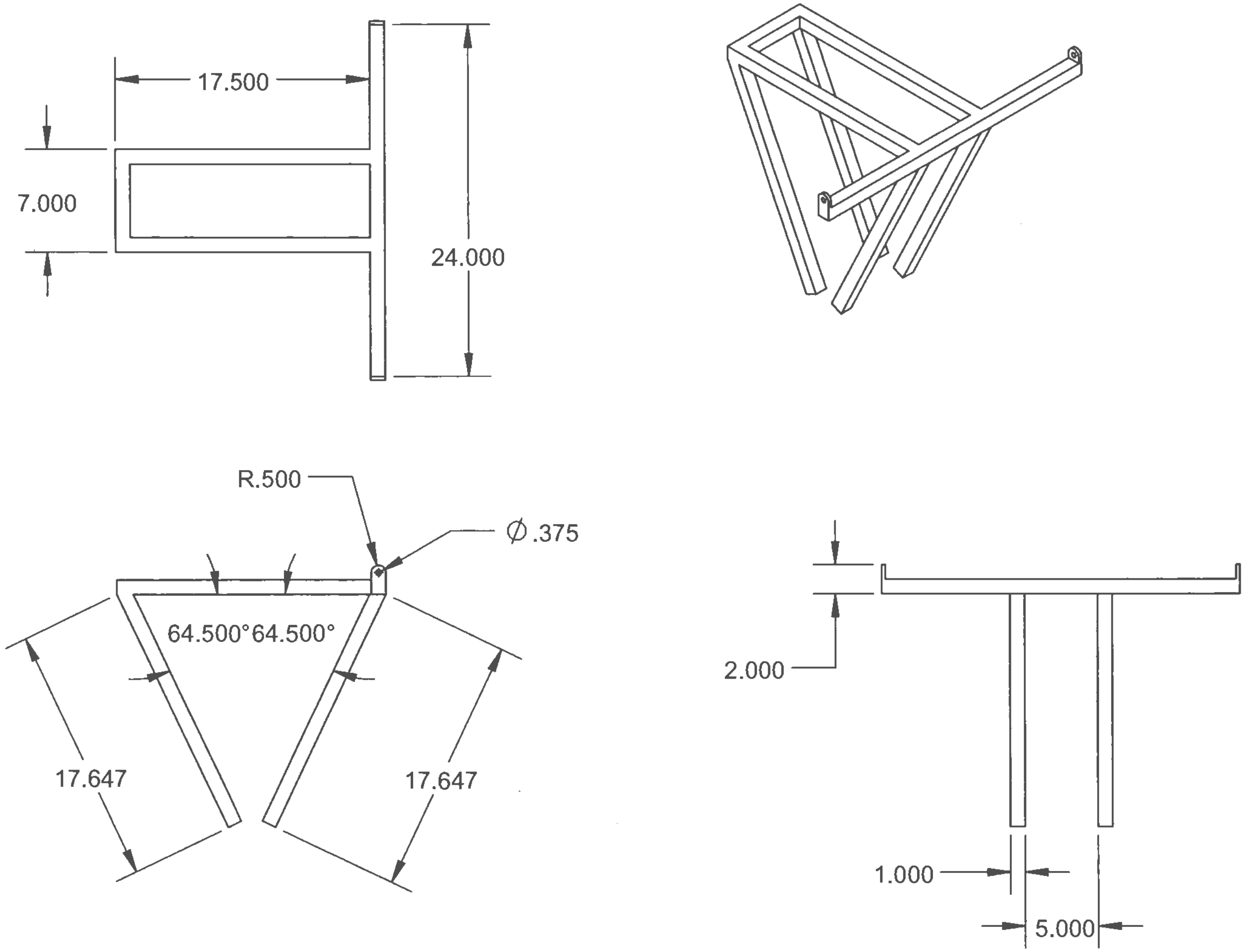
MATERIAL: AISI 1010 Steel, hot rolled bar

DATE APPROVED: 4/23/2018

FINISH: ORANGE POWDER COAT

SHEET SCALE: 1:4

SHEET NUMBER: 1 of 1



Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: WHEEL BASE

MATERIAL: AISI 1010 Steel, hot rolled bar

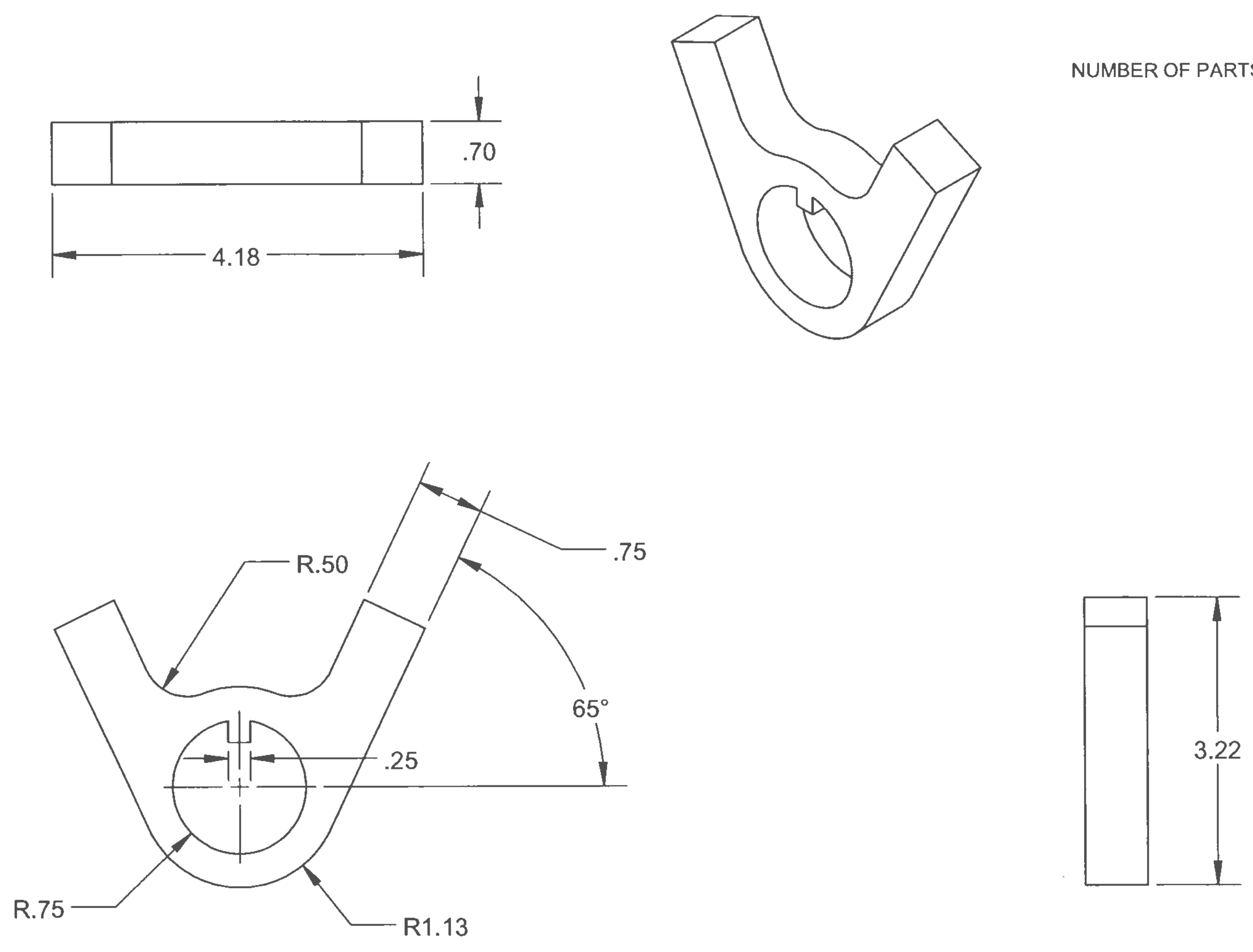
DATE APPROVED: 4/23/2018

FINISH: ORANGE POWDER COAT

SHEET SCALE: 1:12

SHEET NUMBER: 1 of 1

NUMBER OF PARTS TO BE CREATED: 2



PART SYMMETRIC ABOUT VERTICAL CENTER LINE

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

PART/ASSEM NAME: FORK JOINT ALIGNMENT

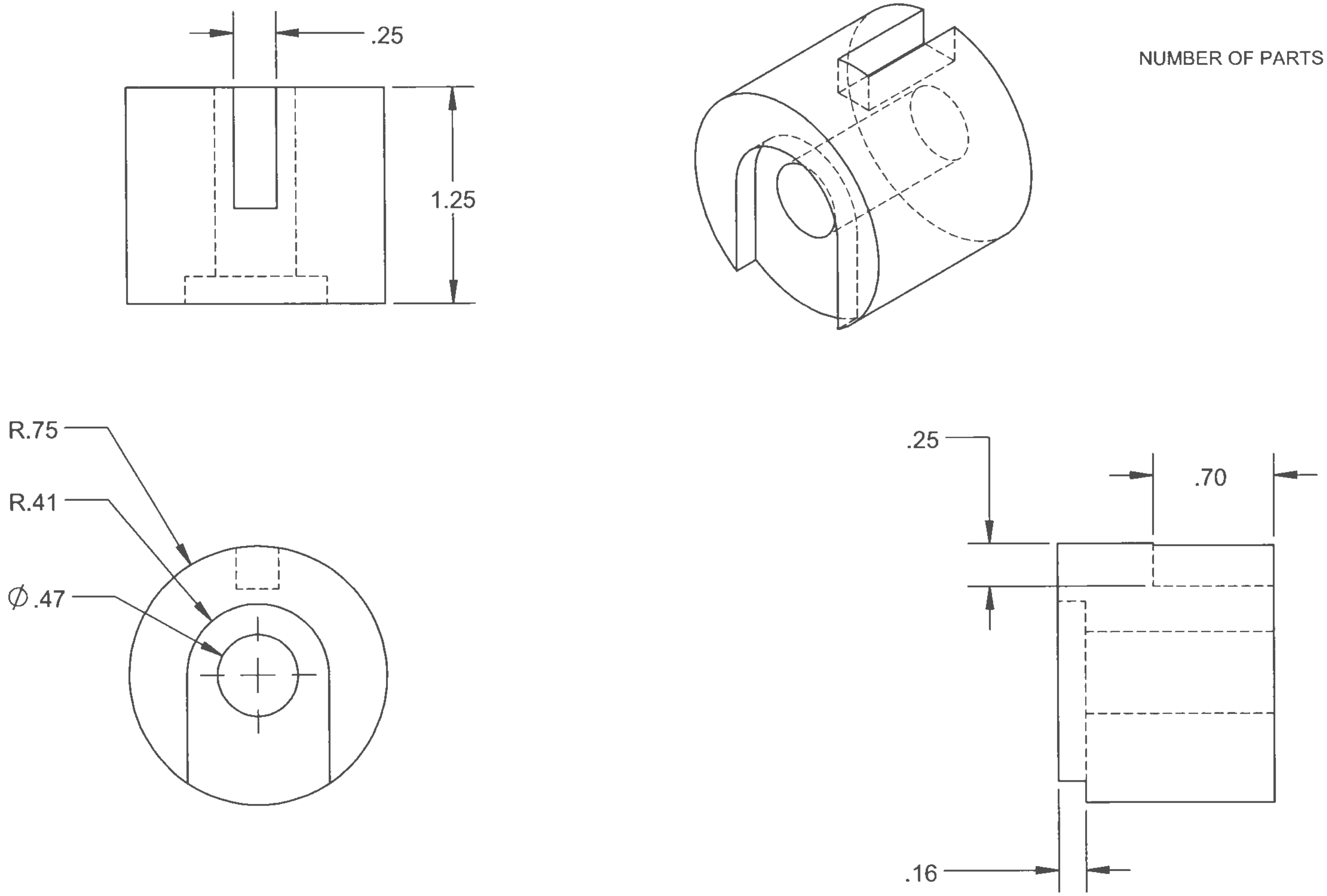
MATERIAL: AISI 1010 Steel, hot rolled bar

DATE: 4/23/2018

FINISH: ORANGE POWDER COAT

SHEET SCALE: 1:2

SHEET NUMBER: 1 of 1



NUMBER OF PARTS TO BE CREATED: 2

Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

PART/ASSEM NAME: FORK HUB

MATERIAL: 1010 HOT ROLLED STEEL

DATE : 4/23/2018

FINISH: ORANGE POWDER COAT

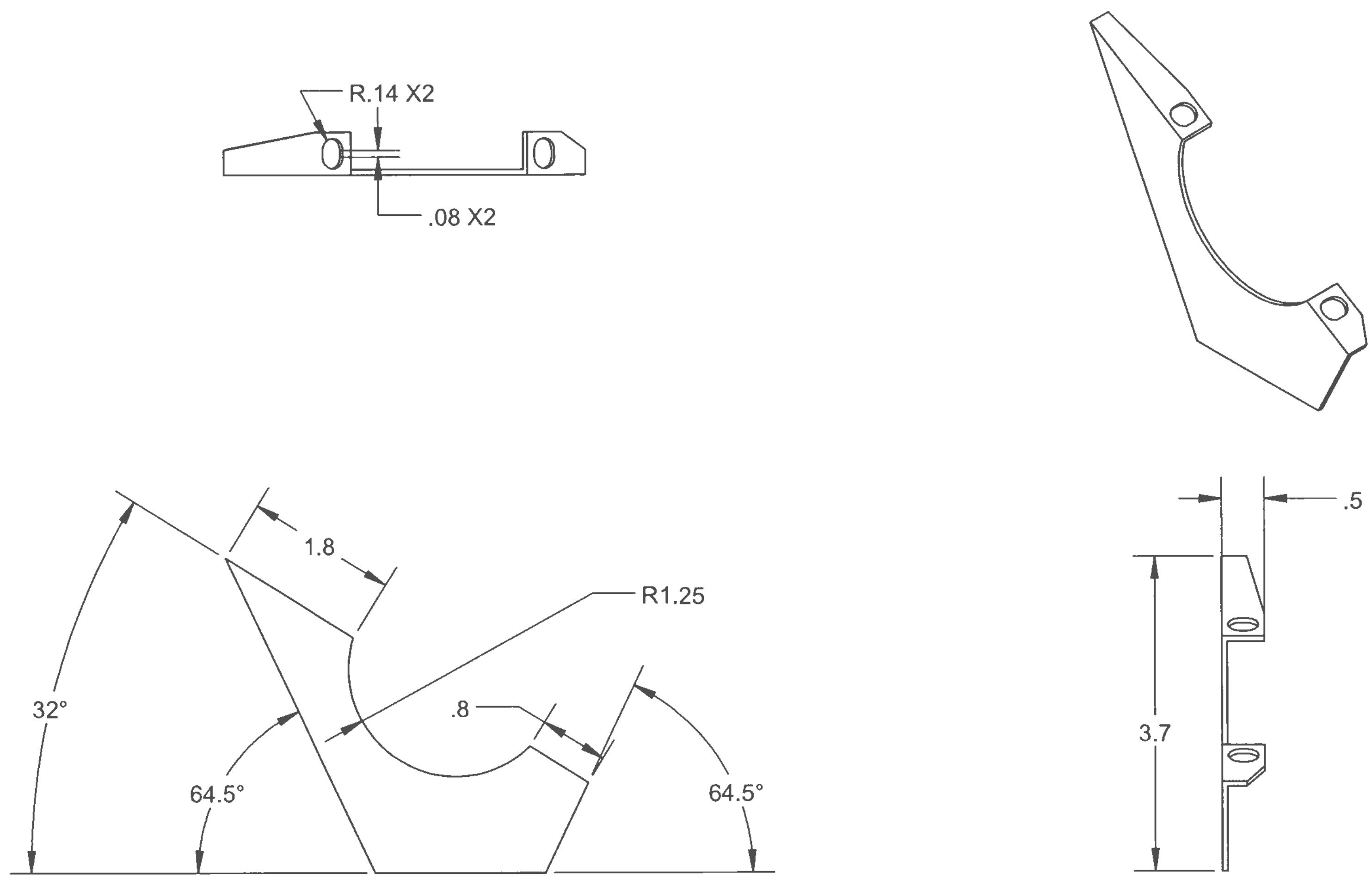
SHEET SCALE: 1:1

SHEET NUMBER: 1 of 1

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches



Mechanical & Aerospace ENGINEERING
Utah State University

PROJECT: COMMON GROUND RICKSHAW

DRAFTED BY: NICHOLAS NEELEY

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

PART/ASSEM NAME: CALIPER MOUNT

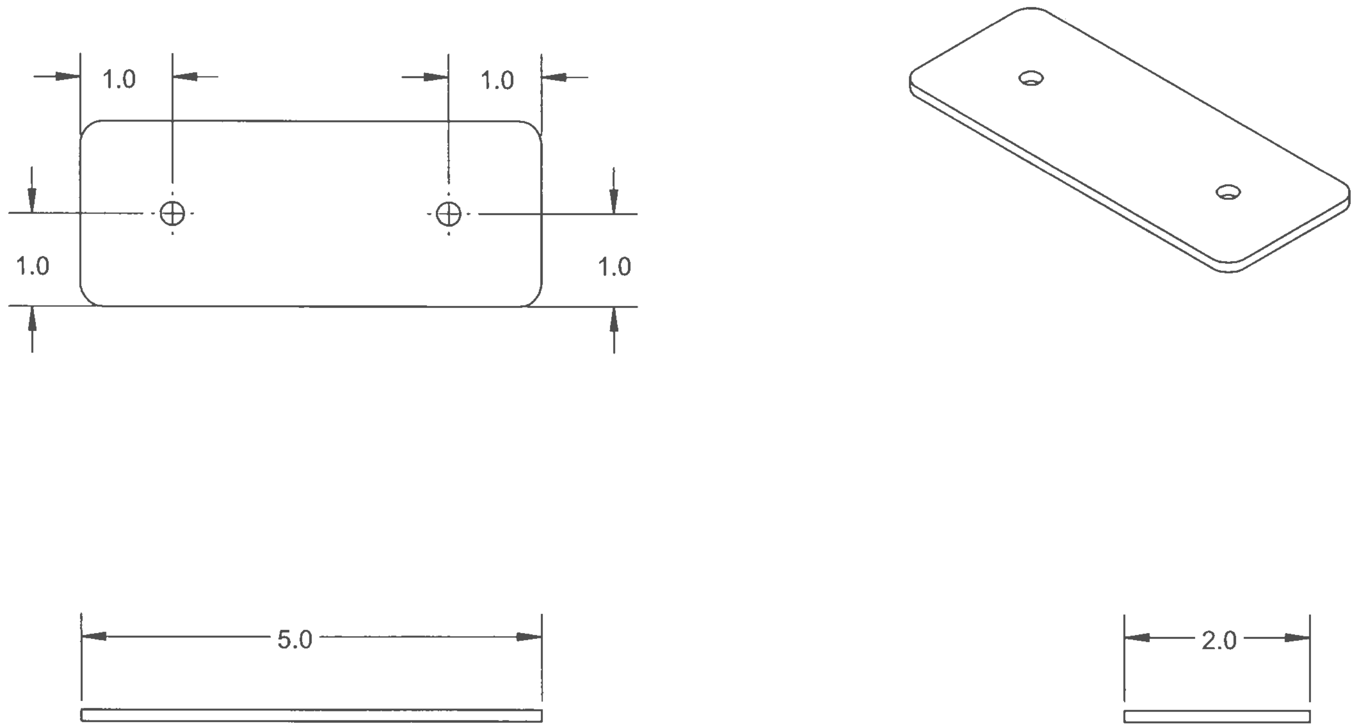
MATERIAL: AISI 1010 Steel, hot rolled bar

DATE APPROVED: 4/23/2018

FINISH: ORANGE POWDER COAT

SHEET SCALE: 1:2

SHEET NUMBER: 1 of 1



SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED

DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:

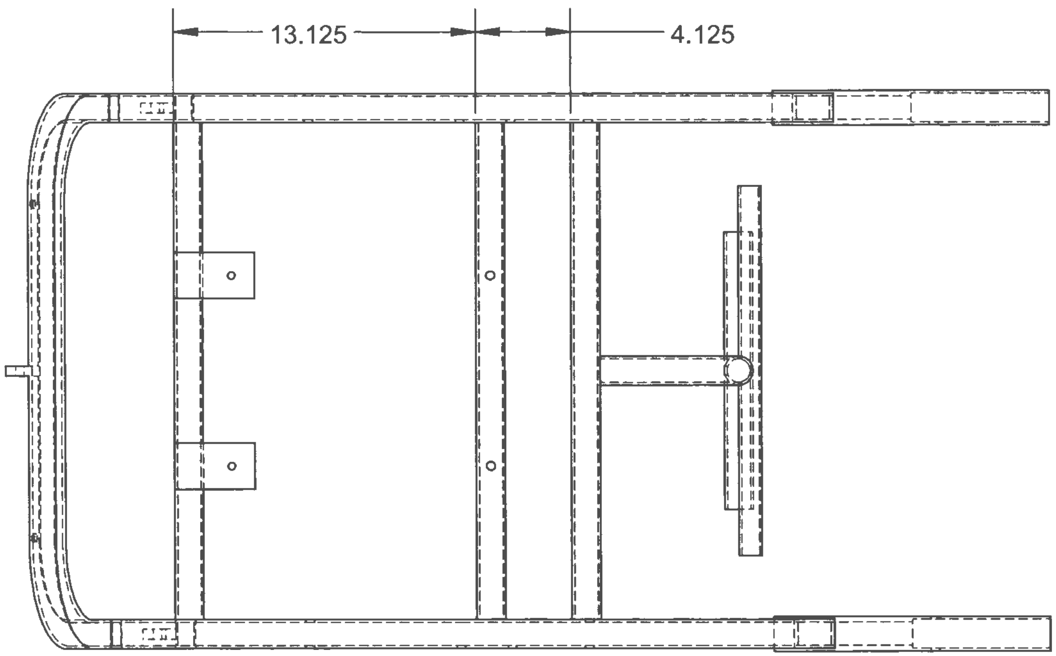
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005

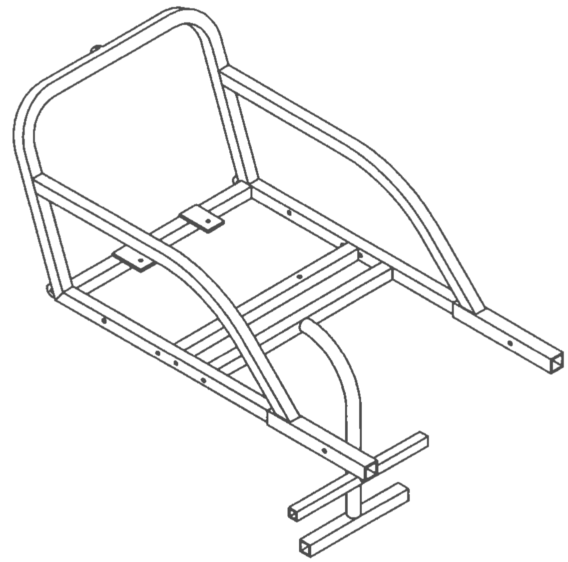
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1

MINIMUM SURFACE FINISH: 1000 microinches

Mechanical & Aerospace ENGINEERING
UtahState University

PROJECT: COMMON GROUND RICKSHAW	
DRAFTED BY: NICHOLAS NEELEY	
PART/ASSEM NAME: **FOOT SUPPORT**	
MATERIAL: 1010 HOT ROLLED STEEL	DATE APPROVED: 5/2/2018
FINISH: ORANGE POWDER COAT	SHEET SCALE: 1:2 — SHEET NUMBER: 1 of 1





Mechanical & Aerospace ENGINEERING UtahState University	**PROJECT:** COMMON GROUND RICKSHAW
	DRAFTED BY: NICHOLAS NEELEY
PART/ASSEM NAME:	**SUBFRAME ASSEMBLY**
MATERIAL: 1010 HOT ROLLED STEEL	DATE APPROVED: 5/2/2018
FINISH: ORANGE POWDER COAT	SHEET SCALE: 1:16 | SHEET NUMBER: 1 of 1

SPECIFICATIONS AND TOLERANCES

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

Appendix E

External Forces Analysis Report

Force and Moment Analysis

Problem Statement:

As a worse case scenario, the front and rear drivers of the rickshaw will pick the rickshaw up off the ground. The forces necessary to achieve this scenario are to be determined. This document will be used to conduct structural analysis, as well as pin shearing analysis. See Figure 1.

Knowns:

Loaded rickshaw is approximately 260 lbf.
Rickshaw is static
Moment arms for front and rear driver are known. See Figure 1.
Rickshaw load is assumed to be a concentrated load on the seat and through the axle.

Find:

Forces applied by the front and rear driver.

Equations Needed:

$\Sigma M = 0$ $\Sigma F = 0$

Procedure:

Summing the moments about point 1:

$$\Sigma M = 260 \text{ lbf } (54 \text{ in.}) - F_{rear\ driver} \text{ lbf } (54 \text{ in.} + 44 \text{ in.}) = 0$$

Summing the forces in the vertical direction:

$$\Sigma F = -260 \text{ lbf} + F_{rear\ driver} \text{ lbf} + F_{front\ driver} \text{ lbf} = 0$$

Solution:

$F_{rear\ driver} = 143.3$ lbf $F_{front\ driver} = 116.7$ lbf

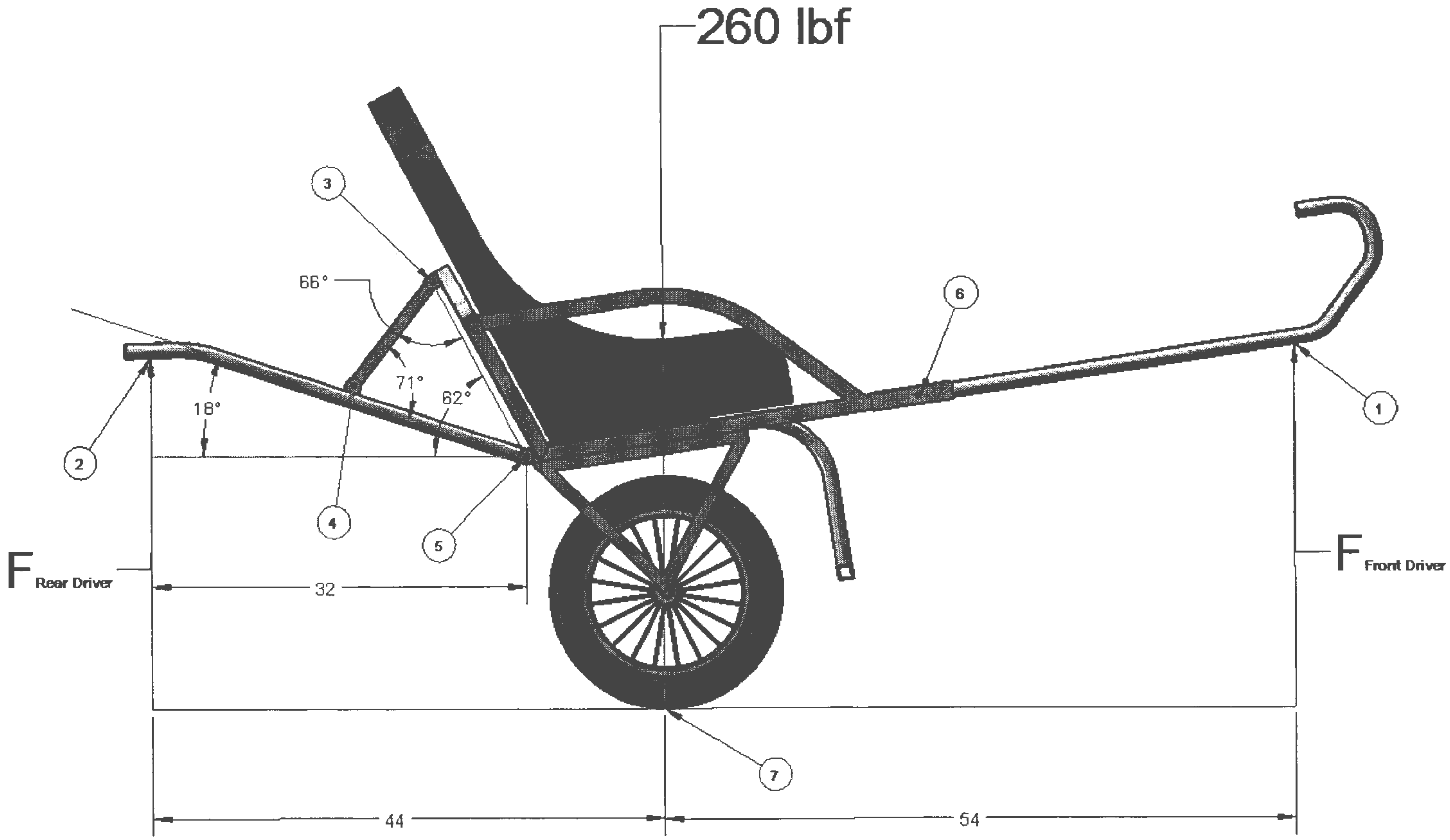


Figure 1. Rickshaw diagram with location of applied forces.

Appendix F

Finite Element Analysis Report

FEA Analysis Document

Problem Statement:

Stresses and displacements need to be determined based on several loading scenarios for the Rickshaw system. The purpose of this analysis is to ensure that the rickshaw frame geometry, thickness, and material is structurally sound enough to withstand normal operational use.

Find:

The peak stress associated with each possible scenario. Scenarios are described below.

Lift scenario: This scenario is the worst-case scenario due to the geometry and length of the rickshaw. In it, each driver applies the necessary force to completely lift the rickshaw and its passenger off the ground. This might happen in situations when a tall obstacle is met on the trail, or possibly when a tight turn needs to be made and a point pivot of the rickshaw needs to occur.

Operational Scenario: This scenario occurs when the rickshaw is moving at a constant velocity or stationary but not unfolded. The drivers apply the necessary force to balance the rickshaw.

Unfolded and Stationary Scenario: This scenario occurs when the rickshaw is unfolded and set down onto the ground. The purpose is to enable the drivers/rider to take a break on the trail, and also the assist in lowering the seat and stabilize the rickshaw while the passenger is getting into the rickshaw.

Procedure:

Mesh: All meshes were produced using solidworks automeshing.

Loads: The loading scenario was the same in each case. Sixty-five pounds was applied at each bolt hole for the seat. This simulates the fully loaded 260 lb rickshaw.

Constraints:

Case 1 - Lift Scenario: This scenario is constrained in vertical direction at the handles to simulate the drivers picking up and supporting the rickshaw.

Case 2 - Operation Scenario: This scenario is constrained in the X, Y, and Z at the axle to simulate the rickshaw being supported by the wheel with the drivers perfectly balancing the rickshaw via the handle.

Case 3 - Unfolded and Stationary Scenario: This scenario is constrained in the X and Y directions at the feet of the wheel base and the bottom of the foot support. This simulates the rickshaw being deployed and resting on the ground.

Solution (Peak Stresses and Locations):

Case 1:

As seen in Figure 1, peak stress is 10.9 ksi and is located at the interface of the front driver handles and the main frame. This stress is mostly due to bending. The material of that tubing will have to be increased from 1010 steel to 1020 steel as it will not meet the desired 3 to 5 rating for the safety factor otherwise.

Fig. 1. Finite element model and analysis for Case 1, the lifting scenario.

Case 2:

As seen in Figure 2, peak stress is 3.81 ksi and is located at the seat support/attachment that comes off the frame. The safety factor associated with this stress and loading scenario is well above the desired 3 to 5 range. No changes need to occur regarding material selection.

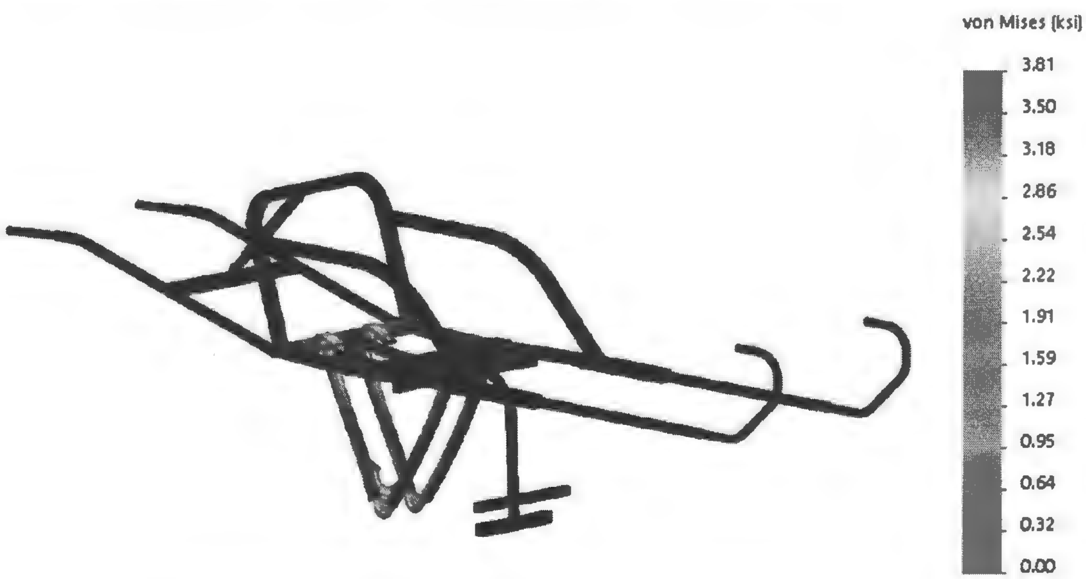


Fig. 2. Finite element model and analysis for Case 2, the operating scenario.

Case 3:

As seen in Figure 3, peak stress is 14.59 ksi and is located at the hinge that pivots the wheel base around the main frame. The hinge material is 1020 steel and can meet the desired 3 to 5 rating for the safety factor.

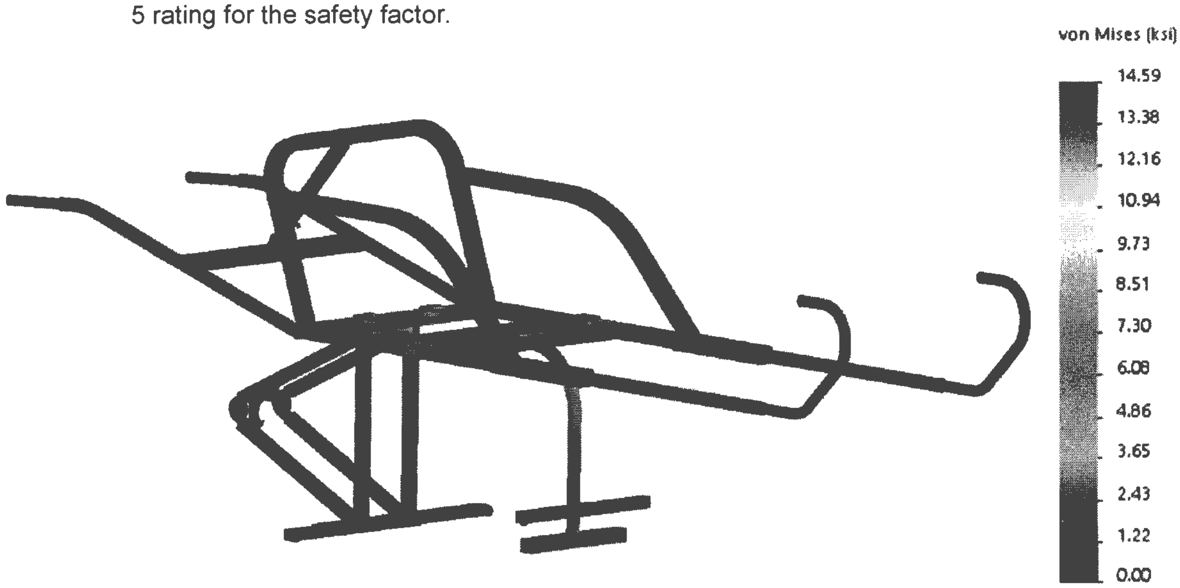


Fig. 3. Finite element model and analysis for Case 3, the unfolded and stationary scenario.

Conclusion:

The loading scenario that proved to be most crucial in the design is the scenario in which the fully loaded rickshaw is picked up off the ground. To accommodate the stress associated with that scenario, the steel of the front driver handlebars need to be increased from a 1010 to a 1020 grade. No further changes are required.

Appendix G

Brake Analysis Report

Brake Analysis: Rotor Diameter

Problem Statement: Determine an appropriate rotor diameter.

See Figure 1.

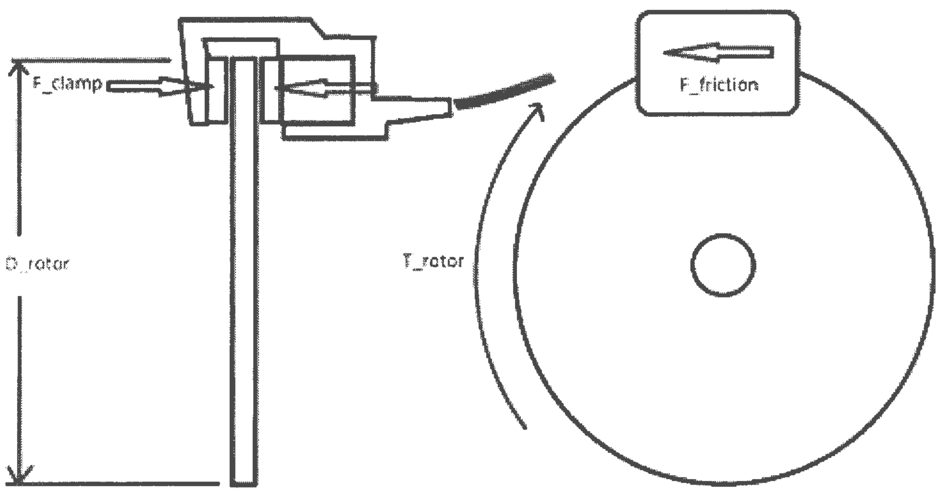


Fig. 1. Free body diagram of brake rotor and caliper.

Knowns:

Maximum force applied by the driver to the brake handle, F_{diver}, is 14lbf (62.275N)

Maximum velocity of rickshaw, v_{max}, is 15mph (12.92m/s)

Estimated stopping distance from max velocity, x, is 7m

Tire dimensions are 20in x 4in (0.508m x 0.1016m)

Mass of loaded rickshaw, m, is 250lbm (113.4kg)

Rotor thickness, t, is 0.00185mm

Coefficient of friction, μ_{bp}, is assumed to be 0.4

Caliper piston diameter, D_{piston}, is 22mm

Diameter of master cylinder, D_{mc}, is 10mm

Brake handle ratio, (L_1/L_2), is 7

Find:

Rotor Torque, T_{rotor}

Rotor Diameter, D_{rotor}

Equations Needed:

$F_{handle} = F_{driver}(L_1/L_2)$ $\quad$ $P_{mc} = F_{handle} / A_{mc}$

$P_{cal} = P_{mc}$ $\quad$ $F_{cal} = P_{cal} \times A_{cal}$

$F_{clamp} = 2 \times F_{cal}$ $\quad$ $F_{friction} = F_{clamp} \times \mu_{bp}$

$T_{rotor} = F_{friction} \times R_{rotor}$ $\quad$ $\Sigma F = ma$

Procedure:

Brake handle:

$F_{driver} := 14\text{lbf} = 62.275\,\text{N}$

$L_1 := 7$

$L_2 := 1$

$$F_{handle} := F_{driver} \cdot \left(\frac{L_1}{L_2}\right) = 435.926\,\text{N}$$

Master cylinder:

$D_{mc} := 10\text{mm} \qquad \Pi := 3.14159$

$$A_{mc} := \left(\frac{1}{4}\right)\Pi\left(D_{mc}\right)^2 = 7.854 \times 10^{-5}\,\text{m}^2$$

$$P_{mc} := \frac{F_{handle}}{A_{mc}} = 5.55 \times 10^6\,\text{Pa}$$

Brake fluid & hoses:

Assumptions: There are no losses along the length of the brake hose. The pressure transitted to the caliper is the same as the pressure of the master cylinder.

$P_{cal} := P_{mc} = 5.55 \times 10^6\,\text{Pa}$

Caliper:

$D_{piston} := 22\text{mm}$

$$A_{cal} := \left(\frac{1}{4}\right) \cdot \pi \cdot \left(D_{piston}\right)^2 = 3.801 \times 10^{-4}\,\text{m}^2$$

The one-sided, linear mechanical force generated by the caliper (taking into account two pistons) is:

$F_{cal} := P_{cal} \cdot 2A_{cal} = 4.22 \times 10^3\,\text{N}$

Theoretically, the clamping force will be equal to twice the linear mechanical force.

$F_{clamp} := 2F_{cal} = 8.44 \times 10^3\,\text{N}$

Brake pads:

The clamping force creates friction between the brake pads and the rotor that acts perpendiclar to the rotation of the rotor.

Assume coefficient of friction to be: $\mu_{bp} := 0.4$

$$F_{friction} := F_{clamp} \cdot \mu_{bp} = 3.376 \times 10^{3}\,N$$

Rotor:

The torque in the rotor is related to the friction from the brake pads. It will be equal to the total torque required to stop the rickshaw.

$$m_{rickshaw} := 113kg \qquad x := 7m$$

$$v_{max} := 12.92\,\frac{m}{s}$$

$$a := \frac{v_{max}^{\;2}}{2x} = 11.923\,\frac{m}{s^{2}}$$

$$F_{stop} := m_{rickshaw} \cdot a = 1.347 \times 10^{3}\,N$$

$$R_{tire} := \frac{508}{2}mm = 0.254\,m$$

$$T_{stop} := F_{stop} \cdot R_{tire} = 342.223\,J$$

$$R_{rotor} := \frac{T_{stop}}{F_{friction}} = 0.101\,m$$

$$D_{rotor} := 2R_{rotor} = 0.203\,m$$

Solution:

$$T_{rotor} := T_{stop} = 342.223\,J$$

$$D_{rotor} = 0.203\,m$$

Conclusion :

Thus, an appropriate rotor diameter to stop the rickshaw from maximum velocity is 0.203m (203mm).

Appendix H

Stability Analysis Report

Stablity Analysis

Problem Statement:
To determine the proper amount of force needed by the rear driver to bring the rickhaw from 20 degrees back to perpendiuclar to the ground.This analysis is to make sure if the rickshaw does start to tip that the average driver can apply the force. See Figure 1.

Knowns :

Loaded rickshaw is approximatly 250 lbf
Max angle of 20 degrees
Proposed lever arm of ( ) ft from the center of the rickshaw
Center of gravity is approximatly ( ) ft from the ground
20 inch from base to top of tire
12 inch from top of tire to center of gravity

Find :

The applied force F by the rear driver to correct the angle offset.

Equations needed:

$\sum M = 0$ sin(theta) = x/h cos(theta)= l/h

Procedure:

cos(20)=h/34 h= 31.94 in
sin(20)=x/34 x= 11.62 in
cos(20)=(l-x)/12 l-x=11.27 in

$\sum M$= -250 lbf*(11.62 in) + F*(11.62 in+11.27 in)=0

Solution:

F=126.9 lbf to right the rickshaw

Conclusion :

The force needed to right the rickshaw from a 20 degree incline is 126.9 lbf.

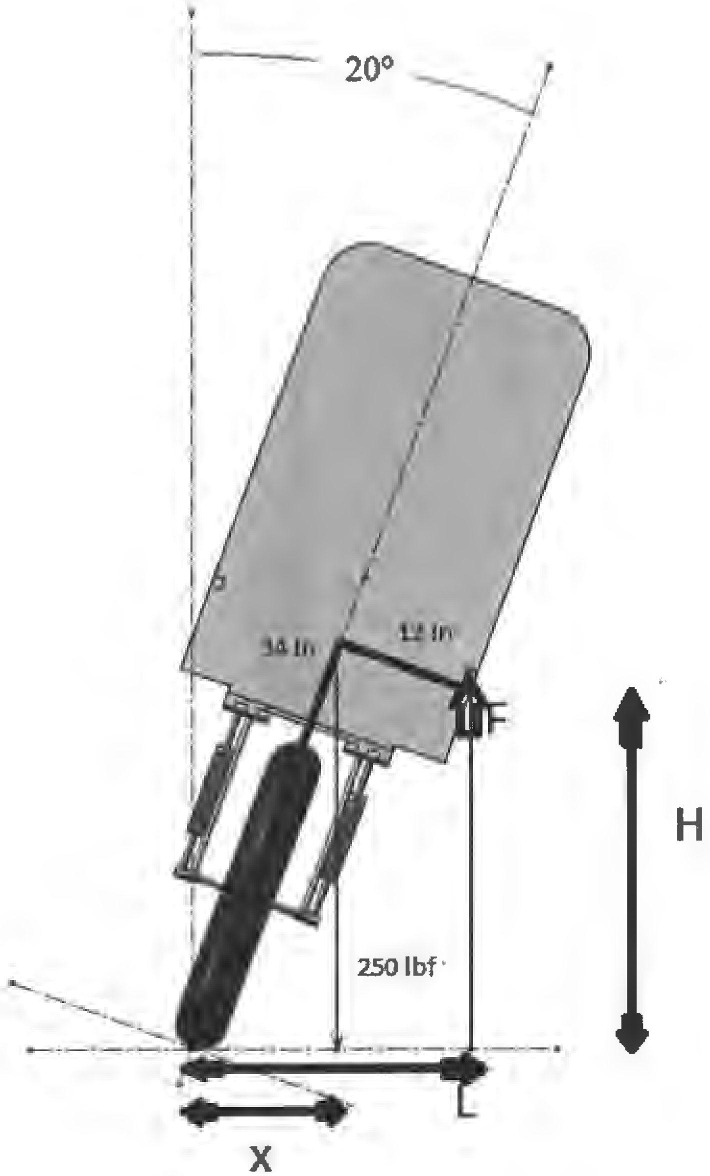


Figure 1. Diagram of Slanted Rickshaw at 20 degrees.

Appendix I

Existing Rickshaw Trail Test Report

Existing Rickshaw Trail Test

1 PURPOSE

The purpose of this test was to evaluate the two-wheeled rickshaw design on the Sponsor specified basis for a trail.

2 SCOPE

- Operator Ergonomics
- General Force Requirements
- One-wheel vs two-wheel conceptual analysis
- Trail obstacle analysis
- Existing shock analysis
- Transportability

3 METHODS

Common Ground has an existing rickshaw provided to them from a previous company. The Team wanted to test the usability of this rickshaw on trails with inclines. The Rickshaw was loaded up into a truck and transported to the Wind Caves trail found in Logan Canyon. The rickshaw was then tested as follows:

- Loaded with a 160 lbs passenger and pulled up the first quarter mile section of the trail
- Operated by two drivers, one in the back and one in the front
- Handles for front driver were adjusted to test different pull force and ease of use
- Rickshaw was pulled with both wheels active on the ground and then with only one active wheel
    - Examined the stability and ability to drive in a straight line of both setups
- Drove over obstacles that were a height up to 8 inches to see how the rickshaw handles the trail

4 TEST OUTCOMES

- Two average sized men are capable of pulling the loaded rickshaw with a 160 lbs passenger up the Wind Caves trail
- The current two-wheel design is not acceptable for driving up a moderate hiking trail
    - Two wheels provide more stability but are too wide for safe maneuvering of the trails
    - One wheel provides better turn radius and maneuverability of the trails.

        - Two drivers are required in order to maintain stability
- The current handle adjustability was sufficient
    - Handles located at the waist provided better support and power
    - Handle grips are hard to hold onto when applying high forces up a steep incline
- The shocks provided good support but would bottom out and cause the seat to hit the tires
- The rear driver has to lift the seat in order for the rickshaw to climb over the 8 inch obstacles.

Appendix J

Dimension Test Report

Rickshaw Dimension Requirements

1 PURPOSE

The purpose of this test is to verify all dimension requirements for the rickshaw are met.

2 SCOPE

The dimensions of the Rickshaw need to be measured to verify requirements from the Requirement Contract. The locations of interest and their respective requirement go as follows:

- The lowest part of the frame will be higher than 10 in. off the ground (Req. 3.5)
- The frame shall not exceed 10 ft. in length (Req. 3.6)
- The frame shall not exceed 4 ft. in width (Req. 3.7)
- The seat will be between 18 in. and 30 in. off the ground while unloading and loading (Req. 3.8)
- The user handles shall have a range between 29 in. and 45 in. from the ground (Req. 3.9)
- The rider foot supports are adjustable for a person with a leg length between 36 in. and 45 in. (Req. 3.10)

3 PREREQUISITES

3.1 MATERIALS LIST

- Measuring Tape

4 GENERAL INSTRUCTIONS

4.1 RICKSHAW SETUP

The Rickshaw will be in operation status. This includes the front and back handles are pinned in place and the unloading/loading mechanism in the travel position.

4.2 LOCATIONS

Static locations including the following will be measured via measuring tape:

- Total length (rear to front handles)
- Total width

- Frame height from ground
- Seat height from ground when in loading/unloading position
- Leg support measured from the lowest attachment location to the seat bucket
- Leg support measured from the highest attachment location to the seat bucket
- Rear driver handles measured from the ground to the highest adjustment location
- Rear driver handles measured from the ground to the lowest adjustment location
- Front Driver handles measured from the ground to the lowest hand position
- Front driver handles measured from the ground to the highest hand position.

5 Acceptance

The measured outcomes will be verified by all five team members to ensure correctness.

5.1 Testing Outcomes

- Total length: 9 ft 5 in
- Total width: 22 in
- Frame height from ground: 11 in
- Seat height from ground when the unloading/loading position: 24 in.
- Leg support measured from the lowest attachment location to the seat bucket: 48 in.
- Leg support measured from the highest attachment location to the seat: 31 in.
- Rear driver handles measured from the ground to the highest adjustment location: 49 in.
- Rear driver handles measured from the ground to the lowest adjustment location: 24 in.
- Front Driver handles measured from the ground to the lowest hand position: 29 in.
- Front driver handles measured from the ground to the highest hand position: 45 in.

5.2 Engineering Team Certification

5.2.1 Confirm that testing is complete, that testing results are appropriately documented herein, and that the testing was executed according to this procedure, inclusive of any variations or additions documented via red-line changes.

	Printed Name	Signature	Date
Engineer:	Austin Neuner		05/02/2018
Engineer:	Tyler Mitchell		05/02/2018

6 REFERENCES

[1] Requirement Contract

Appendix K

Pre-Design Brake Test Report

Pre-Design Brake Analysis Test

1 PURPOSE

The purpose of this test was to check the necessary force applied to three brake systems in order to restrain any movement.

2 SCOPE

Requirement 3.2 states that a force less than 6 lbf, when applied to the brakes, must be able to keep the rickshaw stationary on an incline plane of 20° [1]. Three different brake systems were tested to see if they can meet this requirement. If not, further analysis will be done to see how the system can be adjusted to meet the requirement. The three brakes tested included v-brakes, mechanical disc, and hydraulic disc.

3 GENERAL INSTRUCTIONS

To test the brakes, three bikes were used such that each had one of the brake systems to be examined. These bikes were taken to a location that had a slope of 20° and a ground terrain similar to a hiking trail.

The rider's weight and a loaded backpack were weighed to be approximately 200 lbs with a force scale. The bikes weight was also included to simulate a total of 240 lbs. It is assumed the fully-loaded rickshaw will weigh around 240 lbs.

To measure the needed force on the brakes, the bike is placed on the 20° incline with the rider and any extra weight being on the seat. The front brake is applied to see if the bike would remain stationary. The force applied to the brake was measured by a luggage scale and recorded. This procedure was done for each of the three bikes.

3.1 TESTING OUTCOMES

- None of the current brake systems are able to hold the bike stationary using only an applied 6lbf
- Hydraulic Brake with 6.29 in (160 mm) rotor and 3 in lever
  - 24 lbf required
- Mechanical Brake with 6.29 in (160 mm) rotor and 3.5 in lever
  - 35 lbf required
- V-Brake with 4 in lever
  - 32 lbf required
- Increasing handlebar length, rotor sizes, and more disc calibers can lower the needed force and is shown in Appendix A

3.2 ENGINEERING TEAM CERTIFICATION

3.2.1 Confirm that testing is complete, that testing results are appropriately documented herein, and that the testing was executed according to this procedure, inclusive of any variations or additions documented via red-line changes.

Engineer:	Austin Neuner		05/02/2018
	Printed Name	Signature	Date
Engineer:	Tyler Mitchell		05/02/2018
	Printed Name	Signature	Date

4 REFERENCES

[1] Requirement Contract

Appendix L

Brake Functionality Test Report

Brake Functionality Test

1 PURPOSE

The purpose of this test is to ensure the brakes on the Rickshaw will be able to stop the rickshaw and meet all design requirements. These requirements include the maximum trail angle, applied force to the brake, and the use of a parking brake.

2 SCOPE

The brakes will be tested with a fully-loaded (approximately 200 pounds on seat) rickshaw to analyze if the brakes can keep the rickshaw stationary. These tests will include the following setups:

- Rickshaw inclined on a 20-degree slope with a 15 lbf applied to the brake (Req. 3.1)
- Visual inspection to make sure the brake is operable by the rear driver (Req. 3.2)
- Applied parking brake with the fully-loaded rickshaw on a 20-degree slope (Req. 3.3)

The tests will be sufficient for validation if during all the setups above the rickshaw stays stationary during the test.

3 PREREQUISITES

To conduct the test, the brakes must be completely attached to the rickshaw. The caliper must be firmly attached with no rubbing from the brake pads on the rotor. The brake handles must be firmly attached to the back handles of the rickshaw. The weather must be within Assumption 2.2 from the Requirement Contract. The rickshaw must then be taken to a dry trail that has an incline of 20 degrees.

3.1 MATERIALS LIST

3.1.1 Parts and Assemblies

- Luggage Scale
- 200-pounds of weight in any form
- Phone with angle measuring capabilities
- Parking brake attachment

4 GENERAL INSTRUCTIONS

4.1 VISUAL INSPECTION

This section is to verify Requirement 3.1, which stated that the brake must be operable by the rear driver. To ensure this, visual inspection should be done to verify that the brakes are indeed attached to the rear handles and easily accessible by the rear driver.

Is the brake operable by the rear driver: YES [ ] No [ ]

4.2 BRAKE LEVER FORCE

This section is to verify Requirement 3.1. To conduct the test:

- The fully-loaded rickshaw is placed on the trail with an incline of 20 degrees.
- Brake lever is pulled by the luggage scale to measure the force needed.
- Record the force given by the scale once the force is sufficient to keep the rickshaw from moving.

Force needed to keep the rickshaw stationary: ________________

4.3 PARKING BRAKE CAPABILITY

This section is to verify Requirement 3.3. To conduct the test:

- The fully-loaded rickshaw is placed on the trail with an incline of 20 degrees.
- The stability assist device is set in unloading/loading position and the parking brake strap is then placed on the lever.
- Visual inspection should then verify that the rickshaw does not move with the parking brake strap attached.

Does the parking brake strap keep the rickshaw stationary: YES [ ] No [ ]

5 ACCEPTANCE

5.1 TESTING OUTCOMES

- The brakes are operable by the rear driver
- Force needed to keep the rickshaw stationary: <u>7.8 lbf to stop with a max possible of 12.7 applied</u>
- The parking brake strap did keep the rickshaw stationary

5.2 ENGINEERING TEAM CERTIFICATION

5.2.1 Confirm that testing is complete, that testing results are appropriately documented herein, and that the testing was executed according to this procedure, inclusive of any variations or additions documented via red-line changes.

Engineer:	Austin Neuner		05/02/2018
	Printed Name	Signature	Date
Engineer:	Tyler Mitchell		05/02/2018
	Printed Name	Signature	Date

6 REFERENCES

[1] Requirement Contract

Rickshaw Senior Design Capstone Project Reflective Writing

Marcus Doc Cronin

Adventure is one of my favorite words. I always find a way to make whatever I am doing more of an adventure. This was no different when it came time for me to choose a senior design project in my engineering capstone class. The professors sent out a survey with 15 different project options and I initially went with a project my study buddies wanted to do. However, there was a project that called to me and the way things worked out I ended up on that project: coming up with ideas for creating a rickshaw for Common Ground, a local non-profit organization. The mission of Common Ground is to provide outdoor adventures for people with disabilities. My senior project was to help make this mission possible in the way of helping people with disabilities be able to go on and enjoy hiking trails.

My senior design team consisted me and four other engineering students, Professor Graham, and our TA Tate. At the onset of the project Nate and Abby, representatives of Common Ground, and the team had a meeting about what exactly Common Ground wanted the rickshaw to be able to do. In that first meeting Nate showed us a previous rickshaw Common Ground had acquired and used but had ultimately broke. Being engineers we were curious as to why the rickshaw broke and thought of ways of making the design better. In talking with Nate and Abby we found out what Common Ground wanted us as engineers to include in the rickshaw we would build and came up with a list of requirements. These requirements were the foundation to the rickshaw project.

With the requirements in mind my fellow engineering students and I decided that the best way to come up with solutions to fix the previous rickshaw and incorporate the new requirements was to test the previous rickshaw on the Wind Cave trail in Logan Canyon. In our

engineering coursework we have learned field testing is invaluable to addressing problems and being able to think of ways to overcome those problems. Additionally, field testing allowed us to see other improvements that could be made. We loaded up the rickshaw and drove to the Wind Cave Trail.

Going along the trail we had someone sit in the bucket seat and ride in the rickshaw while the front driver pulled and a rear driver pushed. We quickly found out with a two-wheeled design like the rickshaw had made it impossible to keep the rickshaw from tilting over. I especially noticed as I was the one riding in the rickshaw most of the time. We also determined several other improvements that could be implemented into creating a better design including having adjustable handles, making the seat more comfortable, having the rickshaw have rear handles, and incorporating adjustable foot supports to help make the rickshaw rider more comfortable. We updated the requirements and had several ideas of what the rickshaw design should include and what it should not include.

The next part in the design phase was to come up with several designs and as a team ultimately select a design that would meet the requirements we made with the customer Common Ground and would overcome the problems of the previous rickshaw. At this point in the senior design course our team had to present a Preliminary Design Review. This presentation consisted of explaining several designs we were considering and what we would do to determine which design would work best. Our team at this point was divided into two main designs: a two-wheeled rickshaw and a one-wheeled rickshaw. As we had done at the first of the semester we decided to conduct more tests and we found a way to conduct a test that would determine which design to move forward with.

Our team found out that an existing rickshaw design existed and Antelope Island State Park had this rickshaw onsite. We were able to schedule a time and with Abby went and conducted tests on this existing rickshaw. If I learned one thing from this project it was how important testing models similar to what we wanted to design was to coming up with the best design. From this testing on Antelope Island with the one-wheeled rickshaw we had no doubt that a one-wheeled rickshaw was the best design for this project. Abby the customer agreed and we moved forward with the one-wheeled rickshaw design.

As my team and I moved into the critical design phase when we presented a final design I learned how important communication is to the success of a project. One part of this phase is to present the finalized design before moving forward into building the actual product. A misunderstanding between us engineering students and our faculty mentor left us presenting requirements that were not met. From this presentation my team and I learned when using engineering requirements it is okay to change a requirement as long as the customer agrees and signs a new contract document. We learned the hard way that through not communicating this with our faculty mentor that we ended up with a not up to par presentation.

After changing several of the requirements to fit with the updated rickshaw frame specifications and test results the project once again moved forward this time into the manufacture phase. As a team we ordered the metal, bolts, nuts, and other supplies to build the rickshaw frame. This was my favorite part of the project. We spent hours in the USU Student Prototype Lab putting together the frame and finding out the challenges that come into building and manufacturing products. One of the biggest challenges was getting precise cuts and bends into the metal. A few times we got stuck and had no idea what to do. Another important lesson learned from this project was to ask people with experience such Professor Graham, what

problem we had and ask what he would recommend. With Professor Graham's experience and suggestions, we were able to overcome each problem and move forward.

As of this past week my team and I completed the rickshaw and presented our final presentation. Remembering how much communication is to the success of the project from our critical design review, we made sure to communicate with our customer and Professor Graham and go into our final design review making sure we had met all the requirements and cleared up any questions and concerns.

The presentation was a success! My team and I were able to communicate effectively we had met each of the requirements and how we met the requirements. With preparation and practicing the presentation and attention to detail we delivered what Professor Graham and Professor Wendel called one of the best Senior Design Presentations of their time here at USU. I knew we had done our best and from learning from our shortcomings in the past and overcoming these shortcomings we had progressed so much during our time in our senior design capstone project. It meant a lot to me to know that we had progressed and achieved our goal.

All things considered, my senior design capstone project of working with an outstanding team of engineers was the capstone of my time here at USU. All that I have been learning in my classes, both engineering as well as all others, helped me in some way to help complete the rickshaw project. I am grateful to Professor Graham for all his help and support. I am grateful to our TA Tate who was there to help us. I am also grateful to the USU Honor's program for supporting me in completing this project and have given me tools and experience to overcome and solve problems. This rickshaw senior design capstone project has been an adventure; every week I learned something new and ventured into new territory. If I learned nothing else from this capstone project it is to enjoy the ride and all the new things you learn along the way.

Author Biography

Marcus Cronin, more commonly known as Doc, completed his Mechanical Engineering Bachelor's Degree at Utah State University. He achieved this degree in 4 years. Doc served a full-time two-year LDS mission to Asuncion, Paraguay and learned Spanish and the native language of Guarani. He was an Honors Intern at the Federal Bureau of Investigation (FBI) working from June 2017 to May 2018 at the Salt Lake FBI Field Office with Special Agents on cases ranging from National Security to International Terrorism to helping out with the FBI Evidence Response Team. Doc considers his greatest accomplishment at USU to be designing and building a rickshaw, an all-terrain device which will enable disabled individuals to experience outdoor hiking trails, made for his senior design project.

After graduation Doc spending time pursuing his love of the outdoors and be a Backcountry Ranger in the National Park Service and then become a U.S. Navy Officer to serve his country and travel the world. He also plans to get married and have a family.

Doc loves USU, the USA, the outdoors, his family, nerf gun fights, tennis, American and military history, and going on any fun adventure