Mobility Cart for Monoskiers

Final Design Review

December 7th, 2018

Sponsor

Disabled Sports Eastern Sierra

Josh Pighetti jpighetti11@gmail.com

Team

Aaron Kan amkan@calpoly.edu

Tyler Meskin tmeskin@calpoly.edu

Craig Miller cmille78@calpoly.edu

Bryce Petersen bpeter12@calpoly.edu

Advisor

Brian P. Self bself@calpoly.edu

California Polytechnic State University, San Luis Obispo

Department of Mechanical Engineering

Statement of Disclaimer

Since this project is a result of a class assignment, it has been graded and accepted as fulfillment of the course requirements. Acceptance does not imply technical accuracy or reliability. Any use of information in this report is done at the risk of the user. These risks may include catastrophic failure of the device or infringement of patent or copyright laws. California Polytechnic State University at San Luis Obispo and its staff cannot be held liable for any use or misuse of the project.

Abstract

This document represents the culmination of the senior design project of Team *Monoski M.E.* This project was in partnership with Disabled Sports Eastern Sierra (DSES), a volunteer-based, non-profit organization focused on providing people with disabilities opportunities to participate in outdoor activities. Our first objective was to perform background research and speak with DSES in order to fully understand the scope of the project. Through this, we developed the following problem statement.

Currently monoskiers, athletes with disabilities limiting their ability to stand or balance, require the assistance of up to 3 or 4 lift operators to load on and off the gondola at Mammoth Mountain using a modified utility cart. Monoskiers need a safe, American Disabilities Act (ADA) compliant device that gives them the freedom to access the entire mountain by allowing them to transport themselves through the gondola building and load on and off the gondola with little to no assistance.

After fully defining the problem, our team researched related assistive devices and further narrowed our scope of design. Next, we started to develop design concepts for each individual function of our design. We narrowed down these concepts to the most feasible concepts using decision matrices and combined them into full system concepts. All these designs incorporated a custom wheelchair frame and some type of integrated system to raise and lower the user. The wheelchair aspect was critical in order to allow the user to propel themselves and remain independent while using this device. After presenting each of these designs to DSES, we agreed to move forward with the hydraulic scissor lift design. However, further ideation proved that the scissor lift was not feasible. After going back to the drawing board, we developed our final design concept, consisting of a wheelchair with an integrated hydraulic lift. This design consists of a swinging platform that is raised and lowered via a hydraulic cylinder and parallel linkage system, which is powered by a manual hand pump.

The manufacturing phase was performed almost entirely in the Mustang ’60 Machine Shop. We welded the entire frame out of aluminum square tubing. The hydraulic cylinder was attached using clevis pins and custom-made brackets. The swiveling linkage arms were connected using shoulder bolts and oil-embedded bronze bushings, or “sleeve bearings”. All welds were heat treated and all aluminum components were finished with primer and paint for additional corrosion resistance. We performed weld break tests, hydraulic load tests, brake tests, static and dynamic load tests, and ergonomics tests to verify the integrity of our design and final product.

Over the span of three quarters at Cal Poly, our team was able to design and build a fully functional product that will be delivered to and used by DSES at Mammoth Mountain. Our process, iterations, analyses, and final design and product will be explained in this report.

Table of Contents

List of Figures

List of Tables

1 Introduction

Disabled Sports Eastern Sierra, or DSES for short, is a volunteer-based, non-profit organization focused on providing people with disabilities opportunities to participate in outdoor activities. Based in Mammoth Mountain, DSES supplies people with disabilities with equipment and instruction for a variety of outdoor sports. During their winter program, when Mammoth Mountain receives sufficient snow cover, DSES accommodates athletes with disabilities. One of their most common types of students are those with lower body mobility impairments, or other disabilities limiting their ability to stand or balance. In order to ski, these students use a device called a monoski. While monoskis come in a variety of forms and have been a proven way for people with disabilities to enjoy skiing, the problems with loading monoskiers onto the gondolas at Mammoth remain. The resulting challenge involves giving monoskiers the freedom to navigate themselves through the gondola building while already in their monoskis, and being able to load, ride, and unload from the gondola so that they can ski down from the top of the mountain. DSES approached the Cal Poly San Luis Obispo Mechanical Engineering Department with this challenge as a senior project proposal. Cal Poly Mechanical engineering seniors Aaron Kan, Tyler Meskin, Craig Miller, and Bryce Petersen were chosen, along with advisor Dr. Brian Self, to develop a solution for the monoskiers. The primary contact throughout this project will be Josh Pighetti, a ski and snowboard instructor with DSES.

2 Background

Before delving into possible designs or ideas of how to help the monoskiers transport themselves to the gondolas in order to get to the slopes, research needed to be conducted in order to obtain as much information on the topic as possible.

To gain a better understanding of how to solve the problem at hand, background research on the sport of monoskiing was compiled. The first objective was to find out what monoskis were and how they work. This objective was met initially with researching relevant patents, product research of current monoski brands and types, and articles outlining the way athletes interacted with them. After gaining a better understanding of monoskis and how they work, the next step in the research process was to study the area where the potential device would be operating. Most of this information was garnered in phone interviews with Josh Pighetti in which he explained the current process used to move the monoskiers from one place to another. In these interviews, many of the base dimensions in which the monoskiers had to navigate were defined. With this information in hand, research shifted to studying the previous attempts at transporting monoskiers. Here it was discovered that the search for a solution to the monoskiers' problems was well under way. Many devices were found, with some being more applicable than others. Nonetheless, significant information was found and applied to an improved understanding on the sport of monoskiing and the dilemma in transporting the skiers when not on snow.

2.1 Customer Interactions

As stated in the introduction, our main point of contact is Josh Pighetti. Our first interaction with Josh was a conference call on January 19th, 2018. We had Josh talk us through the exact path of a typical monoskier, from outside the gondola building to getting out of the top gondola building. We then discussed the specifications and function of the current modified mobility cart that is in use, as well as information and dimensions regarding monoskis. Josh also gave us insight on the range of experience of monoskiers he has seen, as well as his vision for the project [1]. The last topic talked about was travel, and specific weekends that would be beneficial to come to Mammoth when many monoskiers would be present.

Our next conversation with Josh was a conference call on Tuesday, January 30th. We went over our problem statement and specifications table to ensure that we were in agreement with Josh and his vision for the project. Previously, our team had discussed going to Mammoth in the near future, because we felt the need to see, firsthand, the process of using the cart. Since we were nearing the brainstorming and concept generation phase, we felt this was necessary to fully understand what we were the challenge at hand. With this is mind, we asked Josh his thoughts, and we talked about traveling the weekend of February 10-11th. During this trip, our main goal was to observe the process of loading the monoskiers on and off the cart, as well as the entire time while they are on the cart.

When we visited the Mammoth Mountain facility, a handful of monoskiers were present. Josh and many of the DSES ski instructors were available to discuss the project and answer our questions about the process. Although no monoskiers were using the gondola that day, Josh walked us through the route to the gondola and the process of loading the cart on and off the gondola. We were also able to obtain measurements of the various dimensions of the cart, gondola, and other parts of the facility along the path to the gondola. The trip to Mammoth proved to be invaluable to our design process and we would like to thank DSES for allowing us to visit.

2.2 Relevant Products

First, the function of a monoski must be understood before moving forward with researching adaptive devices. A monoski consists of the seat, frame, binding, and the ski itself. An example is shown in Figure 1. The seat is usually plastic and can be at a variety of angles based on the skill of the user and his or her level of spinal lesion. The frame is usually aluminum, making it lightweight, so the user has maximum control. There is a shock absorber system within the frame which can be a mechanical, hydraulic, or air shock to increase ride comfort. A simple foot rest is found at the front of the frame. At the bottom of the frame there are bindings that fit into a standard ski. The frame is usually adjustable so that the center of gravity can be adjusted and optimized for each user. Usually a monoskier has two handheld outriggers that they use like ski poles to maneuver around on the snow. A typical outrigger is shown below in Figure 2.

Figure 1. An example monoski [2].

According to Josh Pighetti, the seat height (off the ground) of monoskiers at Mammoth ranges from roughly 8-10 inches for beginners to 20-30 inches for more experienced monoskiers, and on average is typically around 18 inches [1].

Figure 2. An example of outriggers [2].

After these devices were researched, relevant products to our design challenge were explored. The products we found are described below.

1. Current Mobility Cart at Mammoth

    a. The modified utility cart currently used at Mammoth is shown in Figure 3. The cart is taken to the base of the building where the monoskier is loaded on with their ski still attached. They are then carted through the building, taken up the elevator, and the gondola is stopped, a ramp is placed at the gondola door and the cart is rolled on. Upon arrival at the upper gondola building, the gondola is stopped, a ramp is placed again, and the cart is rolled out. The cart is taken down an elevator and the monoskier is helped off the cart. Once off the cart, the monoskier is free to move on the mountain. This device requires the aid of 1-4 people based on the weight and ability of the user. The cart itself weighs between 10 and 15 pounds. There is only one of these carts currently, meaning the people involved must be in constant communication so that the cart is in the right place at the right time.

Figure 3. Modified utility cart currently in use.
Picture courtesy of Josh Pighetti

2. Snowheel Gondola Ski Cart [3]

    a. The Snowheel Gondola Ski Cart is a device that was designed specifically for monoskiers, and is shown in Figure 4. We believe this design is the best solution currently available to monoskiers who want to ride the gondola. The product is similar in nature to a wheelchair, where the user can sit comfortably while their ski remains attached to their binding. The users can propel themselves using normal wheelchair operation by pushing on the large back wheels. The device weighs 44 pounds. However, this device does not solve the problem of elevating the monoskier to gondola height. We were unable to find any other information on this design, and it does not have a patent.

Figure 4. Snowheel Gondola Ski Cart.

3. Mono-Scooter [4]

    a. The Mono-Scooter device is shown in Figure 5. This product has the user remove his ski, and the binding fits into the rolling cart. The webpage said this is available at some ski resorts (assumed to be in Europe), and the carts are stationed at each gondola stop. No other information could be found about this product.

Figure 5. Mono-Scooter gondola device.

4. TeamHOC Monohauler [5]

    a. This device is for transporting a monoski, with the most common use being from the car to the slopes. The ski itself is not attached and the user is not in their monoski while using this device. This device is a good example of a transport vessel that is lightweight, durable, and highly maneuverable. The Monohauler is shown in Figure 6.

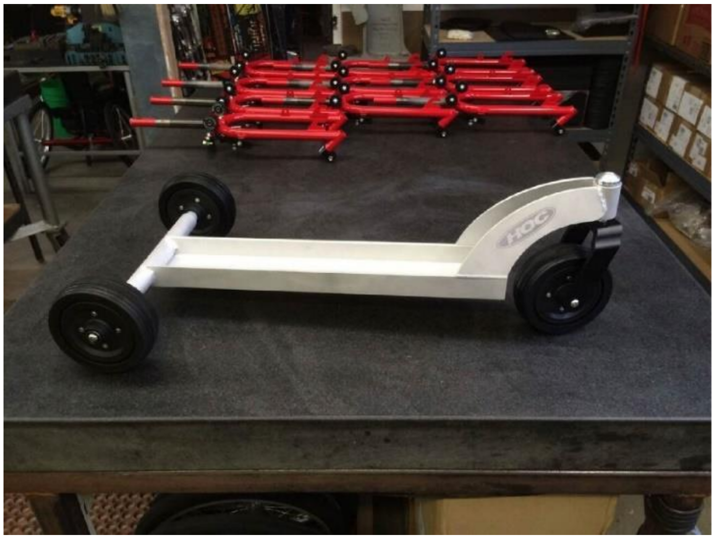


Figure 6. TeamHOC Monohauler.

5. Electric Luggie Scooter [6]

    a. This is an example of a self-propelled device that one could use to move around. Since we will be considering making our design self-propelled or motorized, this product is useful to observe. This type of design is heavier, more complex, and requires higher maintenance due to the electronics. An example is shown in Figure 7.

Figure 7. Electric Luggie Scooter.

6. Teton – Nordic, Mono-ski cart [7]

    a. This product seems similar to the Mono-Scooter in that the monoski is not fixed in the binding of the monoski while using it. This product has an interesting layout of larger fixed-angle wheels in front with smaller swivel wheels for steering in the rear, as shown in Figure 8. This appears to suit itself well to maneuverability and may even feel more similar to the way monoskiers shift their weight in the rear while skiing. The product has the definition "*actually a transportation device which the sitskier can remain in while being used! See photo below...*" which might lend itself to the argument that it can be used with the ski attached as well. No other information could be found on this product.

Figure 8. Teton Nordic Mono-ski cart.

2.3 Patents

Part of the background research involved a search of all relevant product patents. Surprisingly, there were no products that solved our exact problem. However, looking at some relevant patents gave us insight on monoski size, dimensions and functionality [9-11]. One important dimension was the length of the mono ski. The maximum length of the ski is around 185 centimeters or 6 feet. This was used to help determine maneuverability and turning radius. It also gave us information on current powered and unpowered wheelchairs [14-17].

2.4 Technical Research

In developing an idea of how monoskiers move in their sport, numerous medical journals and kinematic studies were compiled. These medical journals provided information on how the body moved and which positions gave the skier an advantage. This was valuable information in grasping how an athlete was positioned in the monoski. Most of these studies contained simulated monoskiing as a method of collecting data. To validate this, a study was also found in comparing the effectiveness in simulated skiing as a substitute for real monoskiing. Another subject the team desired to find was the output an athlete's shoulder and arms could output as this would be the main mode of propulsion. In particular, *Shoulder Strength and Physical Activity Predictors of Shoulder Pain in People With Paraplegia From Spinal Injury* contained data on peak shoulder torque for paraplegic persons with shoulder pain and those without shoulder pain. With this information, it was noted that the lower limits of these peak torque outputs was to be used in order to accommodate for all users. Kinematic and kinetic studies were found in order to answer these questions as well as a reference on human factors and outputs [9]. While this data gave the team much of its needed required dimensions, research was still required to better understand the standards of designing devices for people with disabilities.

2.5 Relevant Standards

Naturally, the design of a system for people with disabilities requires the accommodation of different standards. The most notable are the American Disabilities Act (ADA) Standards for Accessible Design. While the scope of the project is not to reshape the facilities at Mammoth, the project is responsible for being able to accommodate for the facilities at the resort. According to Josh Pighetti, all of the elevators and doors are ADA compliant. This allows the design constraints to become quantitative specifications as there are a number of dimensions available courtesy of the ADA standards. Unfortunately, these dimensions are not the strictest in the development of the overall size of the device. The gondola doors have a door width of approximately 30 to 32 inches which was confirmed on a visit to the Mammoth Mountain facility. While the upper limit of the gondola is in agreement with the ADA standard for doors, the device must be able to account for a variety of situations and, as a result, must be restricted to the lower limit of width. The width requirement is a telling example of how the standards will be used in the design of the device. With this accumulation of information, along with the other research discussed in this section, initial device dimensions and requirements are now understood.

3 Objectives

After performing extensive research on the topic of monoskiers and the challenge ahead, goals and objectives for the project became clearer. In drafting a problem statement, care was taken to inform the issue while not confining the design team to certain pathways toward a solution. The problem statement was then proposed to peers as well as Josh Pighetti himself for review. With the problem statement in mind, a list of the customer's needs and wants was created. This list, in addition to the research done previously, was used as the basis for developing a House of Quality chart using the quality functional deployment process and engineering specifications were drafted in order to apply the background research done into concrete obtainable objectives. The steps taken to carry each of these procedures, as well as discussions on the meanings behind them, are outlined below.

3.1 Problem Statement

Currently monoskiers, athletes with disabilities limiting their ability to stand or balance, require the assistance of up to 3 or 4 lift operators to load on and off the gondola at Mammoth Mountain using a modified utility cart. Monoskiers need a safe, ADA compliant device that gives them the freedom to access the entire mountain by allowing them to transport themselves through the gondola building and load on and off of the gondola with little to no assistance.

As with any project in its early development stages, the problem statement only provides a wide perspective of the issue at hand. To visualize the scope of the project, a boundary diagram was sketched depicting the situation that monoskiers are in, shown in Figure 9.

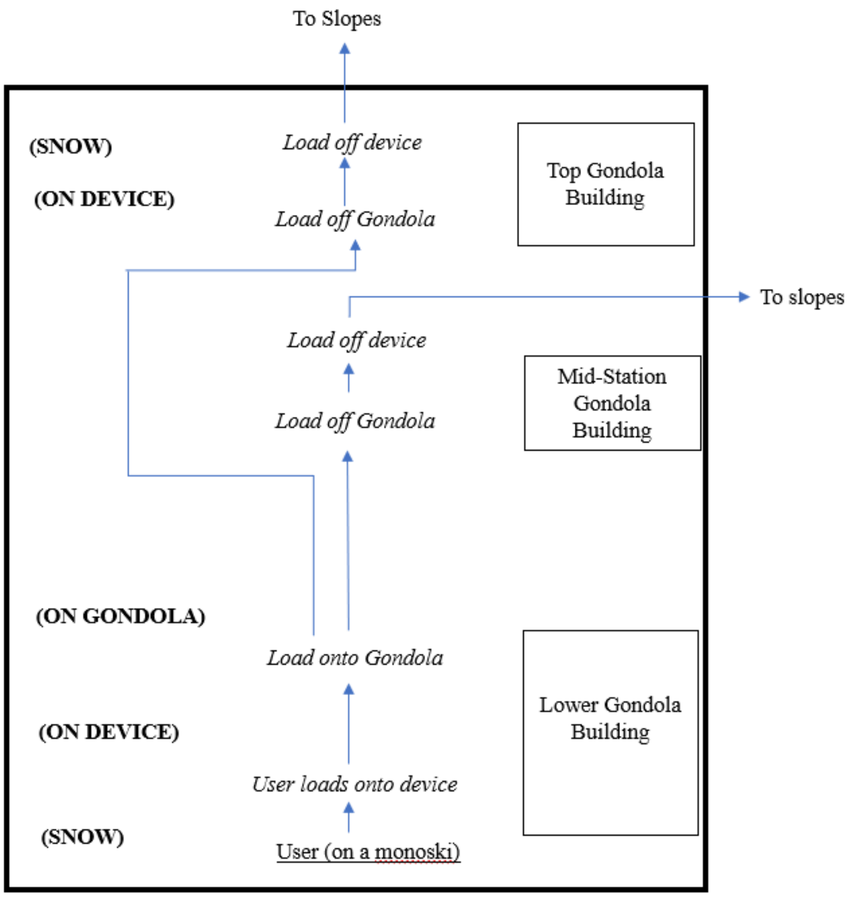


Figure 9. Project scope boundary sketch.

The boundary of this problem is between the monoskier's ski and the ground, elevator floor, and gondola, from the entrance to the gondola building at the bottom of the mountain to when they get back on the slopes at the top of the mountain. Therefore, the scope of this problem requires designing a device that will allow monoskiers to travel through the gondola buildings, elevators, and gondolas themselves.

3.2 Project Goals

Now that we understand the scope of the problem, the goals for the project were considered. During the first customer interview, Josh expressed his desire to make the gondola loading process independent for the monoskiers. To accomplish this, the primary goal for the project was decided to be giving monoskiers as much independence as possible. The ideal solution would allow monoskiers of any experience to easily travel through the gondola buildings to and from the slopes, as well as load and unload from the gondola, without any assistance from others.

3.2.1 Customer Needs and Wants

To assess how the project goals will be accomplished, a complete list of the customer's needs and wants was formed. This was done using information and insights gained through our first customer interview and background research on the problem. The needs were chosen to successfully and explicitly meet our customer's expectations. The wants were items that would be nice to have as part of the solution, but not essential to the device design. The list is summarized and discussed below.

Paramount to a designing a successful end product is meeting ADA specifications. This is essential in ensuring monoskiers are able to enter through the various building, elevator, and gondola doors on their path to the slopes at the top of the mountain. Some needs were determined based on physical constraints and requirements of the device to be designed. Important examples of these include supporting the weight of a monoskier with their monoski, traveling over various surfaces, the ability to maneuver the device around turns and obstacles, the ability to stop and control themselves while on the device, and the device being safe to operate. Other needs were determined based on what it would take to give monoskiers a functional device that increases their independence on the mountain. Important examples of these include the device being easy and intuitive to use, requiring little to no assistance from others, working for a variety of different monoskis and monoskiers, and accounting for their outriggers (poles) in some type of way. The wants on the list are items that are not essential to the device design but would be good things to accomplish with our design if possible. Some of these include allowing the user to be entirely self-propelled and load/unload the gondola with no assistance from others, the device being aesthetically pleasing, and the device requiring low overall maintenance.

3.3 Quality Function Deployment Process

With the scope of the problem and project goals well-defined, our team set forth to follow the Quality Function Deployment (QFD) process in order to develop appropriate specifications for our future design. This was done by creating a House of Quality chart, which is included in Appendix A. Developing the House of Quality chart allowed us to determine what specifications would be necessary to meet our primary customer's desires. In addition, comparisons with benchmarked products gave insights to what seems to have worked or not in terms of meeting the customer's desires.

3.3.1 Customer Identification

Beyond Josh and Disabled Sports Eastern Sierra, it is important to look at the other “customers” who will be influenced by this product, so that considerations can be made accordingly to account for their needs as well. The primary other customers for this product are monoskiers, as they are the ones who will be using the device in the end. Thus, it is crucial that the assessment of monoskiers’ needs are factored into the choosing of specifications for this device. In addition, gondola/lift operators and monoski instructors were also included as they will likely be the next closest individuals interacting with the device.

3.3.2 Customer Requirements

With DSES, monoskiers, gondola operators, and monoski instructors in mind, the original list of customer needs and wants was condensed into a list of 16 distinct requirements. These requirements were chosen to reflect the most important end goals needed to satisfy all of the customers. These requirements are late used in the development of the design specifications.

3.3.3 Requirement Weighting

With the customers and customer requirements both determined, the relative importance of the requirements was assessed. By rating on a 1-10 scale, each customer requirement was weighted based on its importance to each of the affected customers. Performing this on the entire list of requirements revealed the relative importance of meeting each of the customer requirements. This is important to see what requirements should be prioritized over others when making design decisions later on in the project.

3.3.4 Competition Benchmarking

Another valuable practice for giving insights on future design decisions is seeing how well previous products have met the customer requirements for our problem. The previous products considered for the House of Quality were the current modified utility cart, the Snowheel Gondola Ski Cat, the Mono-Scooter, the Monohauler, and the Electric Luggie Scooter. To accomplish this, each existing product was rated on a 1-5 scale as to how well they seemed to meet each of the customer requirements. Because limited information was available on some of the existing products, some imagination had to be used based on the appearance of product designs from available pictures online. With this complete, the team was able to see what requirements the existing products met well and look into what aspects of the existing designs allowed those products to be successful at satisfying the customer requirement. Conversely, the team was also able to look at what customer requirements weren’t met well and what design aspects prevented the existing products from satisfying those requirements. These insights were crucial later in the process when assessing what the product design should encompass to satisfy the customers’ requirements.

3.3.5 Specifications Selection

The next step in following the QFD process was generating a list of engineering requirements, or specifications. Most of the specifications were chosen with one or more of the customer requirements in mind. Specifically, specifications were chosen that would provide a way to measure or verify that the customer requirements are being met. For example, to meet the requirement of being ADA compliant, a specification on the outer width of the device was chosen to ensure that the device is within the acceptable range and able to pass through ADA compliant doors. With these specifications, quantities were also set as end targets for the design. Each specification was also designated a direction of improvement, either increasing, decreasing, or on target. For example, the total weight of the device was desired to be decreased as much as possible within reasonable means.

At the center of the House of Quality is the intersection of the customer requirements and the specifications chosen to measure and verify them. Within this area, the relationship between each customer requirement and specification is considered and weighted based on how strong of a relationship exists between the two. Performing the assessment of all the requirement-specification relationships in the chart allows for the determination of the relative technical importance of each of the specifications to meeting the customers' needs. As we did for the requirements, the same existing products were benchmarked as to how well they satisfied each of the specifications. Finally, the correlations between all of the specifications were assigned, filling the top "roof" part of the House of Quality. This related different specifications to each other to show how each affects the rest. For example, a positive correlation was set between product dimensions and weight because the larger the device is, the more material would be required, and thus the weight would be greater as well. A negative correlation was set between athlete-device integration and the user's fatigue, because the better or more integrated the monoskier is to the product, the less energy he or she will expend, and thus will become less fatigued.

3.4 Specifications

The end result of following the QFD process and building the House of Quality is a quantifiable list of specifications. The specifications and their respective requirements/targets for our product were compiled into Table 1 on the following page. These were accompanied by the type of tolerance on the specification, as well as the risk of completion (L=low risk, M=medium risk, H=high risk), and method of assessing compliance with the specified target.

Table 1. Monoskier Mobility Cart Design Specifications

Spec. #	Parameter Description	Requirement or Target (units)	Tolerance	Risk	Compliance
1	Height of Device Components	36 in	Max	L	I
2	Outer device Width	30 in	Max	L	I
3	Device Length	48 in	Max	L	I
4	Center of Gravity Height (w/ Mono Skier)	30 in	± 12	M	A, T
5	Turn Radius	35 in	Max	M	A, T
6	Ability to Roll Over Bumps/Gaps	2 in	Min	M	A, T, S
7	Supports Load (Weight)	300 lb_f	Max	M	T
8	Weight of Device	50 lb_f	Max	M	I
9	Applied Brake Force	10 lb_f	± 5	L	A, T, S
10	Applied Force Required	25 lb_f	± 5	H	A, T, S
11	Time Taken to Understand Device	1 min	Max	L	I, T
12	Time to Gondola	5 min	Max	M	I, T
13	Number of Assistants Required	0 Assistants	± 1	H	T, S
14	User's or Assistant's Fatigue (1-10 scale)	3	Max	M	I, T
15	Lifespan	15 years	Min	M	A, S
16	Maintenance Frequency	Once per season	± 1	M	I, S

KEY:	
A	Analysis
I	Inspection
T	Test
S	Similarity to Existing Designs

The specifications will each be discussed below in detail, referred to according to the specification numbers assigned in Table 1.

1-3. The length, width, and height specifications of the device are based on ADA guidelines and research of the existing problem solutions. These were designated as the upper limits of the overall device dimensions with the goal being to minimize the device size and weight to improve its maneuverability. Their compliance to the specifications were evaluated by inspection, directly measuring the final distances.

4. A reasonable center of gravity height was desired to keep the tipping potential of the monoskier on the device low to ensure safe and effective maneuverability. The specification target was set at the average height of the bottom of the monoski seat plus one foot to account for the monoskiers mass above the seat. This is a mere approximation, but intuitively makes sense and gives insight to potential device heights. Because of the large variation in monoski heights, and each athlete’s unique body mass, the center of gravity will vary greatly between individuals. Having a low center of gravity will allow the monoskiers to balance easier and put them at less risk for tipping over on the cart. We attempted to estimate the center of gravity of the device and monoskier based on

human index data and will test to ensure safe operation of the device. We will also be looking into CAD "dummies" that you can place into models to simulate a person. The center of gravity height was weighted on the lower end of technical importance and poses a high risk for accurately determining its average or range of values, so efforts will be focused more elsewhere on specifications that have a higher relative importance.

5. The turn radius was chosen as a specification to satisfy the maneuverability requirement. We want the monoskiers to be able to move around different obstacles, make U-turns if needed, and have good control over the device. A turn radius of 30 inches was set, as that is the set specification for the max outer width of the device. This would allow the monoskier to use one side of the device as a pivot point and rotate around it with the other side at a distance of 30 inches (the width of the cart.) This will be evaluated by a geometric analysis as well as testing to validate the actual turn radius in the end.

6. The ability to roll over bumps/gaps is very important, as there may be small obstacles to avoid while traveling through the gondola building, such as the small gap when entering/exiting the elevator. This could also refer to rolling over something protruding like a rock. The height of 2 inches was chosen as the target minimum obstruction measurement needed to overcome. This will be checked for compliance through an initial analysis, then testing, and or possibly by comparing it to similar devices with other wheels.

7. Supporting the load (weight) of the monoskier is essential to the functionality of the mobility cart. With the average monoskier weighing between 100-200 lb_f and the average monoski weighing 30-40 lb_f, we chose 300 lb_f as our desired max load capacity so as to leave a bit of a cushion in case of a heavier athlete-monoski combination. This load capacity will be verified through a force analysis as well as validation testing.

8. The overall weight of the device is desired to be as low as possible so as to make handling and transporting it easier on the monoskiers and gondola workers. Initially set to 50 lb_f, this specification has been reduced to a maximum value of 40 lb_f, after discussing it with Josh. However, efforts will be made to reduce the overall weight of the device as much as possible below this upper limit. This specification will be validated through CAD analysis as well as inspection of the device on a scale to measure the weight.

9-10. The initial estimates for the required applied forces are estimated based on the force taken to move a wheelchair. These will largely depend on the final design but as a start are set to 10 ± 5 lb_f, which is relatively low and should not excessively wear out the athletes. This specification will be revisited once further in the design process to ensure its validity. The required forces will likely be determined through a force analysis, testing, and comparisons of similar devices. These specifications are at a higher risk as a more complex analysis that accounts for human capabilities will be required for an accurate understanding of the force required to operate the device while still attached to a monoski.

11. The time taken to understand the device is desired to be kept low as a way to validate that the device is intuitive and easy to use. We decided that this means it should take no longer than 1 minute for a monoskier to understand how to use the device for the first time. This will be verified through inspection or testing of monoskiers or other individuals trying to use the device for the first time.

12. Another goal was to maximize the athlete-device integration so that monoskiers would be able to interact and operate the device effectively. This requires the design taking ergonomics into consideration. This will be verified by inspection or testing to see how well monoskiers interface with the design chosen. The goal or target for this specification is for the device to be non-hindering to the athlete. This means the device should not hold the athlete back or restrict them in any way.

13. The specification of the number of assistants required to help the monoskier stems from the little to no assistance requirement. The target for this is to design a device that requires zero assistants. If this is not possible, the design will ideally not require the assistance of more than one other person. This will be verified by testing and inspection.

14. It is desirable that user and any assistant do not become fatigued while operating this device. This will be evaluated on a 1-10 scale, with the target of the user's fatigue not exceeding a rating of 3. This will require testing different monoskiers on the device and surveying them to see how much operating it tires them out.

15-16. The device lifespan and maintenance frequency will be considered as background goals when compared to the more essential functional requirements of the device. The targets for these are a life of at least 15 years, and a maintenance interval of once or perhaps twice per season. These will be examined with analyses, inspection, and possibly similarity to existing products.

4 Concept Design Development

In this stage of the project, we use several strategies to generate many design ideas and solutions. It was important to generate as many ideas as possible to solve several different functions that the device needs to accomplish. Our three main functions are loading and unloading on and off the device, propulsion while on the device, and loading and unloading on and off the gondola. A selection of our top solutions for each function was then made using decision matrices and a method called controlled convergence. Next, we moved to building a concept prototype. In this, we looked at the effect and functionality of a pivot ramp for loading onto the device. Finally, several Computer-Aided Design (better known as CAD) models were developed in SolidWorks to combine our top design picks from each function along with the insight we gained from our prototype and trip to Mammoth.

4.1 Concept Development

When generating concepts to solve different functions, the most difficult part is often the beginning. In order to overcome this, the process starts with a quantity over quality approach. At this point, we considered every idea to be possible with no concerns of time, money or difficulty. Our goal in these initial steps was to generate as many ideas as we could, as new ideas have the potential to form from the inspiration of others. Only after we generated a substantial amount of ideas did our team proceed in narrowing down our choices.

4.1.1 Functional Decomposition

Approaching the entire project as a whole would have been a difficult task. Not only would ideas be more difficult to generate, but feasible ideas for sub-functions could be overlooked. To allow for the most ideas to be recorded, we used a process called functional decomposition. We began by decomposing the primary function of allowing monoskiers to use the gondola into three main sub-functions: loading the skier on and off the device, loading the device and/or skier on and off the gondola, and propulsion of the monoskier while on the device. From here we used different methods to develop ideas for each of the main sub-functions. Additional sub-functions that were considered throughout were providing independence, fitting a variety of monoskiers, and maneuverability – such as the ability to go around obstacles and over bumps and gaps.

4.1.2 Brainstorming

Brainstorming is an ideation process in which all group members generate as many ideas as possible in a short period. To get the most ideas possible, it is important to withhold judgment on all ideas, as well as to help build off of each other's ideas in search of other ideas that would otherwise not have come into fruition. Our team used "Post-it notes" and a free wall to generate and actively visualize as many ideas to solve each function (separately) as possible. Some examples of the ideas that came from brainstorming include wheelchair wheels and powered tank tracks for propulsion, an ambulance stretcher system to load on and off the gondola, and different styles of ramps to load on and off the device.

4.1.3 Brainwriting

Brainwriting is an ideation process in which each individual in the group takes several minutes to both write and draw ideas. These writings are then shuffled amongst the group and ideas are then expanded. Some benefits to this technique include the ability for everyone's ideas to be recorded without judgement, and the ability for collaborative team ideation. During this process we expanded on our pivot ramp by thinking of new ways to implement it in our concepts. Using brainwriting did not compare to brainstorming sessions in the sheer number of ideas generated, but rather it gave us an opportunity to start drawing and visualizing feasible ideas with each other.

4.1.4 Concept Modeling

Concept models are intended to be quick, simple models. The idea is to build as many as possible in a small amount of time. The goals for concept modeling were to communicate our ideas to each other, check for basic feasibility, and inspire new ideas. The day we set aside for concept modeling, we chose to model only two of the sub-functions to maximize the number of ideas to test. The two we chose to model were loading the skier on and off the device and loading the skier on and off the gondola. We decided against modeling for propulsion as most of the ideas for that sub-function were too complex for simple and quick models to convey. To build these models, we used foam core boards, popsicle sticks, a hot glue gun and other easily obtainable materials. Once the models were completed, we began to see which ones were reasonable, and which ones did not fit our objectives. The top ideas for the two sub-functions we made models for are shown in Figures 10 and 11.

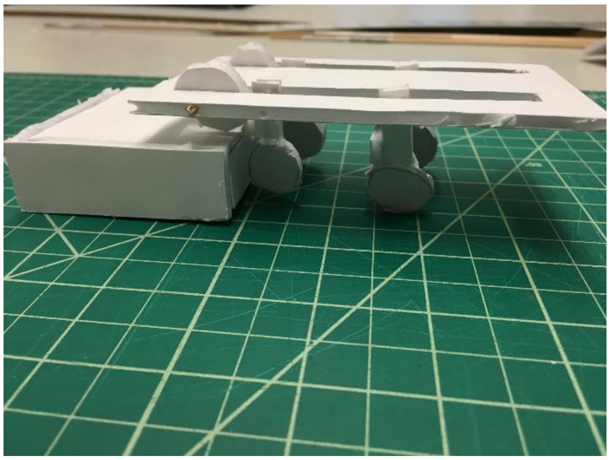


Figure 10. Concept model for loading onto the gondola. This model was inspired by ambulance stretchers in the way the wheels fold up into the cart as they are pushed into the ambulance.

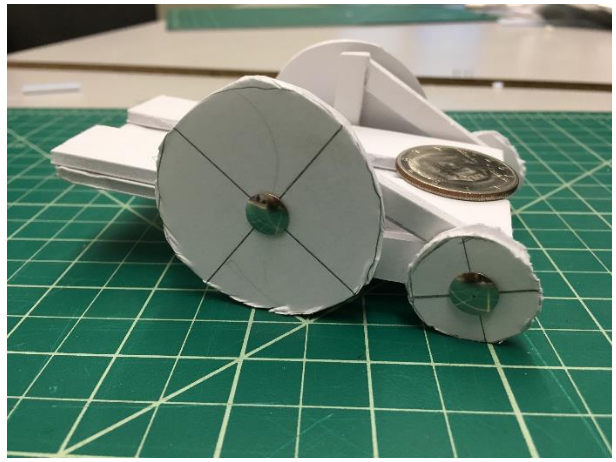


Figure 11. Concept model for loading the monoskier onto the device. This model contains a pivot point that tips when the monoskier is far enough on the ramp in order to lock the ramp into the device.

These ideas for individual sub-functions are a good example of why it is best to ideate for the device in separate categories. Not only can these ideas be potentially combined together, but they both also inspired new ideas, such as a taller pivoting ramp that would bring monoskiers directly to gondola height, allowing them to transfer onto a non-damaging material put down in the gondola during loading. This idea is discussed further in Section 4.3 regarding our concept prototype.

4.1.5 Results

The concept development process led us to a number of promising ideas worthy of exploring further. The brainstorming and brainwriting methods generated many ideas while the functional decomposition kept each idea in its respective category. Concept modeling then proved helpful in identifying the shortfalls in ideas that sounded good but were not feasible in reality.

4.2 Concept Selection

In order to narrow down the large quantity of ideas that we had generated, we used the method of controlled convergence. This is a method to thoroughly evaluate each concept by making sure it stands up to all parameters. This method also creates an opportunity to generate new concepts that stem from analysis of the original concepts. The different steps of this method are outlined in the following sections.

4.2.1 Sub-Function Concept Evaluation

First, our list of ideas was narrowed down by removing those that were simply unfeasible based on our judgement. Next, we set up a Pugh Matrix for each sub-function, shown in Appendix B. This is similar to a decision matrix but involves comparing all new concepts back to a single datum concept; in our case this is the current cart. Several criteria were weighted, and each concept was scored accordingly. These criteria included time taken, user energy required, difficulty of use (how intuitive the user interface is), complexity, mobility, cost, and size. Our thought process for each of these Pugh Matrices are outlined below.

1. Device Loading: For the Pugh Matrix for device loading, the highest scoring concepts were a ramp on a pivot point, an external ramp, and a ramp connected to the cart. The ramp on a pivot point would be built into the device and would allow the user to seamlessly load onto the device from the ground. An external ramp could take the form of a deployable ramp or even a ramp made of snow. Both kinds of ramps would require maintenance and/or attention at opening and at closing each day. A ramp could be attached to the cart in various ways but would allow the user to access it without the aid of others.

2. Propulsion: For the Pugh Matrix for propulsion methods, the highest scoring concepts were a wheelchair device, tank tracks, a bike crank, and electric assist. A wheelchair device seems most feasible, since we observed that most Mammoth monoskiers are already familiar and comfortable with using a wheelchair to move around. Tank tracks initially seemed promising to go over a variety of surfaces and potentially even straight into the gondola, but we determined that they would likely need an unjustifiable electric system to power it, which we felt would be over-solving the problem. The same logic applied to the electric assist. The bike crank would involve the user turning a crank with their hands that would be connected to the wheel drive of the cart, similar to the propulsion of a recumbent bicycle.

3. Gondola Loading: For the Pugh Matrix for gondola loading, the highest scoring concepts were using a ramp into the gondola, triangle wheels that turn over each other to climb stairs, and directly transferring into the gondola. A ramp like the existing one in use is a straightforward solution that requires nothing built into the cart. We eliminated triangle wheels due to its complexity and seeming unfeasibility to overcome the 10-inch height difference between the gondola and the floor. The direct transfer method involves sliding the monoskier straight into the gondola from the device. This would involve setting a low friction material such as artificial turf in the gondola car first. Transferring directly into the gondola could also take form in the monoskier bringing the device into the gondola with them, while somehow bypassing the existing ramp.

4.2.2 Full System Concept Evaluation

By taking our top three concepts from each Pugh Matrix, we began combining these concepts into full system designs. We came up with five complete designs that we deemed the most feasible and put each of these into a weighted design matrix, as shown in Appendix B with the rest of our decision matrices. Each criterion was weighted (0-5) based on significance, and each design was scored based on these weighted criteria. The cart with a bike crank scored the lowest, and we decided to not move forward with this design. Each of the remaining four designs scored relatively high, and we decided to continue developing each one in some way.

4.3 Concept Prototype

After seeing the scores of our top designs in our weighted decision matrix, we decided that the wheelchair with the large pivot point ramp would be the most useful to prototype for. By building the ramp to scale at gondola height (approximately 10 inches), we hoped to determine if it would be feasible for a monoskier to overcome this pivot height when loading onto the device. If so, this design would be very promising, as it would solve the problem of loading on and off the device, as well as loading on and off the gondola all in one step.

4.3.1 Build Plans

We decided to build a ramp on a 10-inch-tall pivot point attached to a frame. We did not see a need to attach it to wheelchair wheels at this point, as the frame would act as the locked wheels. The frame was built out of two by fours with a ¾-inch metal pipe for the pivot. The ramp was made of plywood cut to a length of roughly 42 inches. We bought these materials at Home Depot and constructed the design at the Aero Hangar Shop at Cal Poly.

4.3.2 Proof-of-Concept

During the construction of the ramp, the team decided that the ability to test different angles of the ramp would be beneficial in assessing its feasibility. Three sets of attachment points were drilled into the plywood to allow the ramp to be mounted at different points. The concept prototype can be seen in Figure 12.

Figure 12. Concept prototype built to correct gondola height (10 inches), shown with the ramp down (left) for loading and up (right) for transportation and transferring into the gondola.

4.3.3 Observations

Once the proof of concept model was constructed, the most significant observation made was that the angle to raise a monoskier ten inches was very steep. Even at the ramp's lowest setting (with the pivot point closest to the front of the board), the ramp had little material left in front of the pivot. This would require the monoskier to be much closer to the front of the device than desired. A major drawback of this setting was the added length of the ramp that would make navigating the device through the gondola building difficult. Another observation was that the ramp fell abruptly when enough weight was shifted forward. This pointed us toward a need for either a ramp at a lower height or some kind of linkage system to slow the sudden falling action.

4.4 Overall Design Concepts

After our brainstorming, controlled convergence of ideas, and concept prototypes, our team progressed to developing our overall design concepts. During this stage, three main concepts were focused on and preliminary CAD models were developed. Compliance with ADA wheelchair standards was taken into consideration in the development of all designs. Additionally, the specifications we developed previously were accounted for to ensure that these concepts were all reasonably feasible.

4.4.1 Wheelchair with Pivot Ramp

Our first concept was inspired by a basic wheelchair and can be seen in Figures 13 and 14. In this design, a monoskier is free to maneuver how he or she would as if they were on a standard wheelchair. This device adequately satisfies our first two functions, loading on and off device and propulsion. It does not improve on the third function of loading and unloading on and off the gondola, as this concept would still use the ramp currently in use at the gondola buildings.

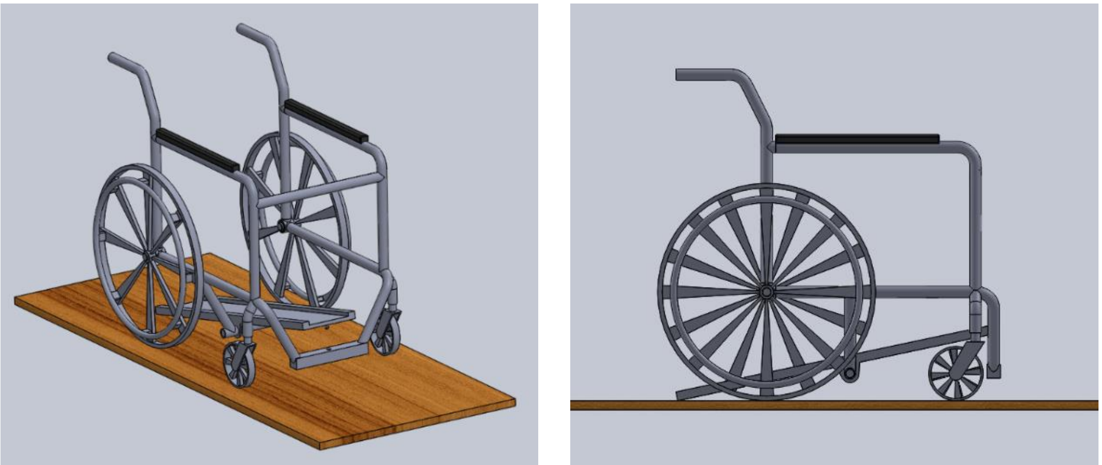


Figure 13. Isometric and side views of wheelchair with pivot ramp concept, with ramp in down position for loading.

To load into this device, wheelchair wheel locks/brakes are set, and the ramp is lowered to the ground. The monoskier can then use their outriggers to propel themselves onto the device. As they move forward the ramp then tilts forward and locks into place. The user would then be able to maneuver and propel themselves using the rear wheels. This configuration is shown in Figure 14. To enter the gondola, the current ramp is still needed as well as a push from a lift operator.

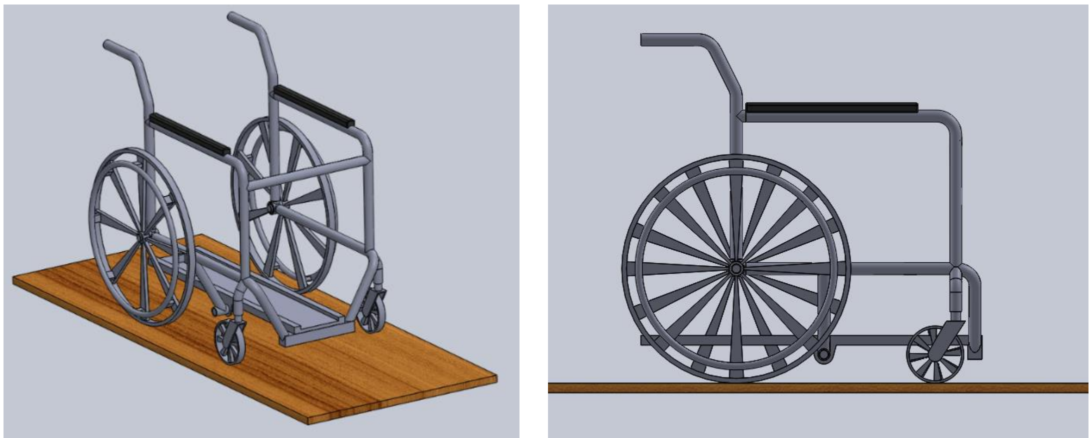


Figure 14. Isometric and side views of wheelchair with pivot ramp concept, with ramp locked in level position for transportation while monoskier is on the device.

The advantages to this concept are its maneuverability and loading process. This device allows the monoskier the ability to independently load themselves onto and off the device. It also gives them the freedom to transport themselves from the slope to the gondola doors without assistance. Additionally, this design benefits from being fairly simple overall and completely self-contained. A simpler design will make for the lowest weight and cost in the end and will make repeatability feasible for manufacturing. Being self-contained means monoskiers have the freedom to load and unload the device anywhere that is convenient, rather than at specific spots. There could theoretically be just one or multiple of these devices in circulation. Some disadvantages of this design are its low ride height and lift operators having to set up the heavy ramp to enter the gondola. During days of high snow fall, the bottom as well as the wheels may drag through the snow.

4.4.2 Wheelchair Device with Detachable Cart

Our second overall design concept was developed through controlled convergence, as discussed in Section 4.2, and is shown below in Figures 15 and 16. This concept originated from wanting to combine the mobility of a wheelchair-style device with easy and quick gondola loading that foregoes the current need for pulling out and setting up a ramp. To accomplish this, the device includes an outer frame with wheelchair wheels, similar to that explained in the previous device description, and an inner cart that becomes completely independent from the outer frame. The inner cart would be used by the monoskier to directly load and unload the gondola by rolling in and out of outer frames located at the different gondola buildings. External ramps or loading stations would need to be designated at the gondola buildings for monoskiers to load on and off the device as they would be transporting themselves at gondola floor height while fixed in the outer frame.

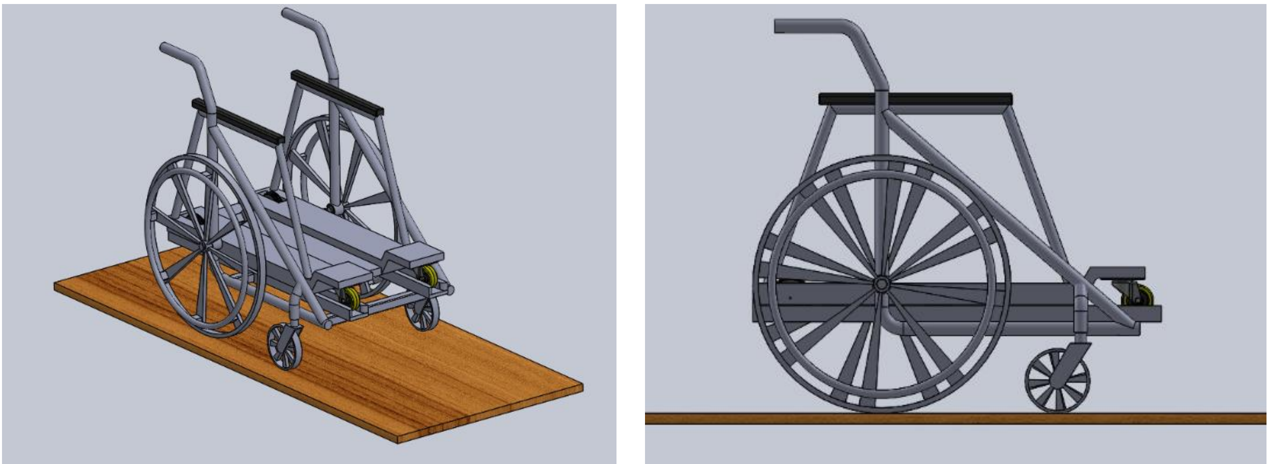


Figure 15. Isometric and side views of wheelchair and detachable cart concept locked together, as if the device was being used for transportation to or from the gondola.

The method of loading monoskiers onto this device is flexible but was envisioned using an external ramp or loading station as stated above. We believe the best way to accomplish this would be having a level loading ramp or platform with a non-damaging surface that monoskiers could slide directly from the slopes and onto the device. This platform would be placed on a small incline so that the side they first slide on would be directly at snow level, and the side they slide off and onto the device would be at the height of the cart. This would allow the device to be stationed at the edge of the platform allowing monoskiers to load onto the device while the wheelchair wheels are locked, keeping the device from moving during the loading process. After loading the device, monoskiers would be locked or secured in some manner to the inner detachable cart, and the detachable cart would initially remain locked in the outer frame. Once loaded and secured to the device, monoskiers would unlock the wheelchair wheels and be able to travel through the gondola building similar to a regular wheelchair. Once the monoskier reaches the gondola, the operator will stop the gondola as usual, and the monoskier will wheel themselves directly up to the open gondola doors. When in position, the monoskier will lock the wheelchair wheels and unlock the inner device from the outer frame, allowing them to roll off of the tracks on the outer frame onto the gondola floor with the smaller wheels of the detachable cart. A push from the lift operator may be required to assist the monoskier in loading the gondola. This transfer could be made smoother with very small pivoting ramps on the end of the tracks (not pictured) that would eliminate any gaps between the device and gondola, similar to the pivot on the current large ramp used to load the monoskiers. The inner cart can be seen independent of the outer frame in Figure 16.

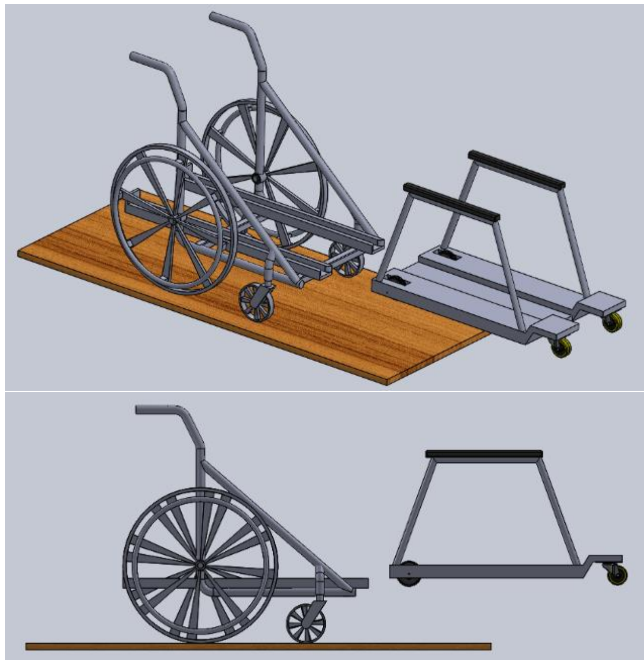


Figure 16. Isometric and side views of wheelchair and detachable cart concept separated, as if the monoskier were to be riding the gondola to the top of the mountain on solely the detached cart.

The rear wheels are fixed while the front wheels are caster wheels, to allow the monoskier to angle themselves inside the gondola. Once in the gondola, the outer frame could be taken back to the loading station with another detachable cart for the next user. After riding the gondola, the monoskier would be met by another outer frame at the top of the mountain, which the lift operator would position in front of the open gondola doors and lock the wheels to ensure a safe transfer. The monoskier would roll from the gondola onto the tracks of the outer frame, lock the cart in place, unlock the wheelchair wheels, and move to an unloading station similar to the loading station following a reverse process from loading.

The advantage of this design lies in the near complete independence of the monoskier through the entire process. They would be able to load on and off the device alone, propel themselves easily, and load on and off gondola very quickly with little assistance from the lift operators. Eliminating the need for a ramp into the gondola will save the lift operators the time and effort of pulling out, setting up, and putting away the current ramp which is fairly cumbersome. While this design would theoretically work very well functionally, there are also a fair amount of challenges and disadvantages that lie within it. Being more complex, this device would require more materials and would thus weigh and cost more than the first design. There would also need to be an absolute minimum of two outer frames for the top and bottom of the mountain, and one inner cart. Additional inner carts would need to be built to allow multiple monoskiers to take the gondola without waiting for a single cart to come all the way around. A third outer frame would be required if unloading at the mid station is desired. The complexity of this design would thus require more manufacturing time per device than a simpler design. This device would require several locking mechanisms, which also increases the overall complexity of the design. The monoskier would need to be locked to the inner cart, the inner cart locked to the outer frame, and the wheelchair wheels locked in place.

4.4.3 Stretcher Wheelchair Device

Our last overall concept combines the use of wheelchair wheels and a mechanism similar to those on ambulance stretchers. The device is shown with wheelchair wheels down and wheels up to fold into the gondola in Figures 17 and 18, respectively. The idea, explained in the earlier concept model, is that the wheels will fold into the cart as the device comes into contact with the gondola. The imagined process is the monoskier will use the wheelchair wheels to propel themselves from a loading station, through the elevator, and to the gondola.

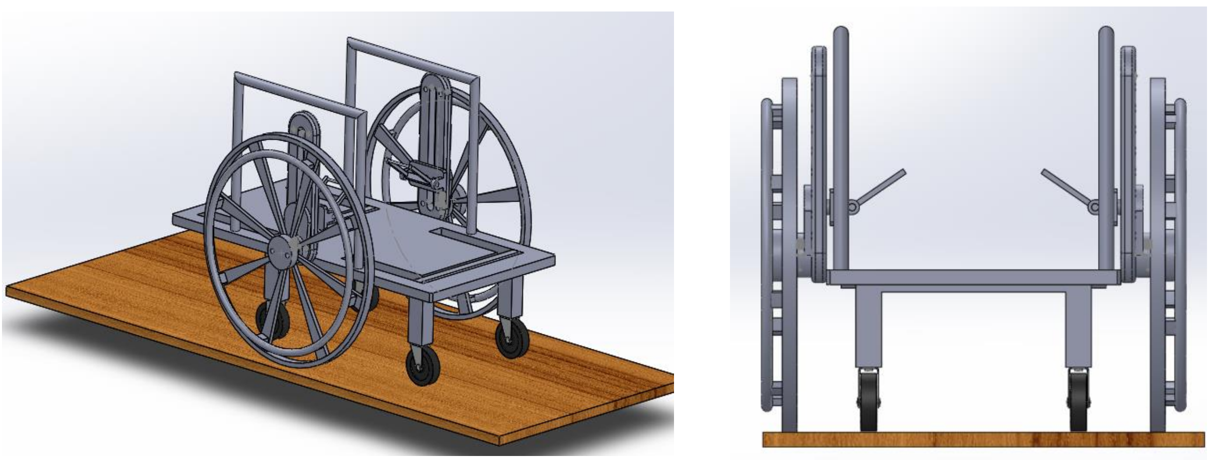


Figure 17. Isometric and front views of stretcher concept with wheels down.

As the monoskier approaches the gondola, he or she squeezes the handles in order to release a locking mechanism holding the wheelchair wheels in place. The monoskier then lifts the wheels, which are free to move along the slots they are attached to, into the upper position to prevent the wheelchair wheels from impeding on the loading process. The monoskier will then reengage the locking mechanism to hold the wheels in place. Next, the monoskier could use the doors of the gondola to pull themselves in, or a lift operator could assist in pushing the cart in. The hinges attached to the cart wheels would be pushed into the cart by the gondola floor as the entire device moves into the gondola. The concept is shown in this configuration in Figure 18. In reverse, a lift operator would pull the device out of the gondola and the cart wheels would then release to engage with the ground. The monoskier would then be able to lower wheelchair wheels to the ground and move themselves back to the snow.

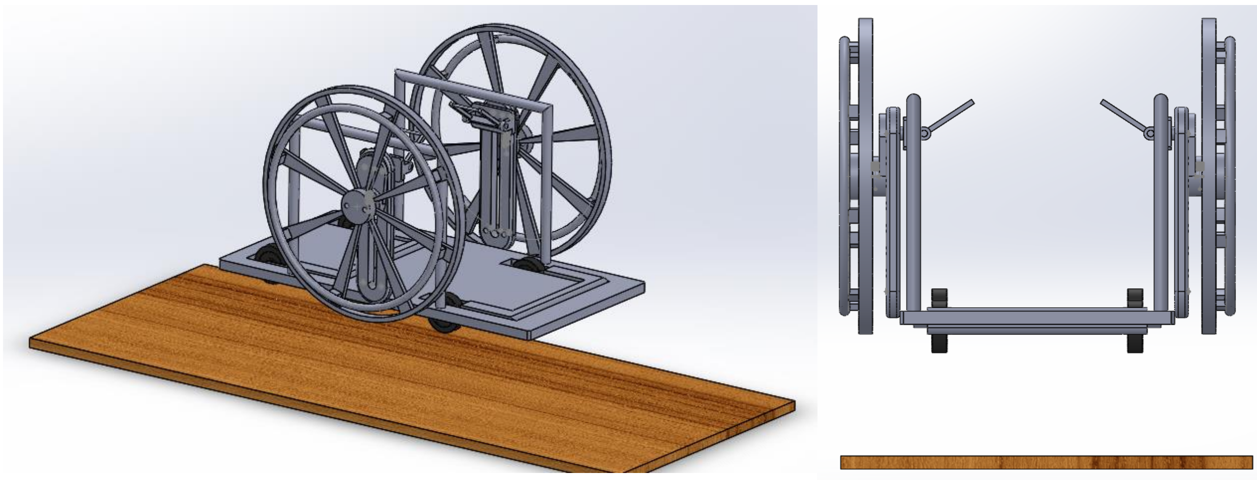


Figure 18. Isometric and front views of stretcher concept with wheels up, as if in a gondola.

While the SolidWorks model does not show a way of loading the monoskier onto the device, a couple of options are available. This device could use the same type of external loading station as described for the detachable cart concept. Another option is to mimic the ambulance stretchers again. A locking mechanism for the rotating wheels would be implemented in order for the cart to be lowered for the monoskier to slide onto the device. The same mechanism would be used to lift the monoskier to gondola height and to lower the monoskier down to the snow. While the lowering function could be made to be operated by the monoskier independently, the lifting function would require the assistance of another person and would thus not be fully independent. However, raising the device and exiting the gondola would be the only time outside assistance would be needed, which is fairly minimal. While this may rightfully be seen as the most complicated device, it does merit significant freedom for the monoskier and reduces the amount of time needed to stop the gondola. This design would require more manufacturing time and precision to ensure functionality of all moving parts, but otherwise ease of manufacturing was taken into consideration when drafting the SolidWorks model as the geometries of the parts are relatively simple. Similar to the first concept, one or multiple of these devices could be in circulation at once.

4.5 Revised Design Concepts

Through presentation of the overall design concepts to DSES, the absolute necessity of the ability for the platform to raise to gondola height was confirmed. As a result, we decided to generate new concepts for a lifting mechanism to be incorporated with a wheelchair frame. The results of this new concept generation are presented in the following sections.

4.5.1 Hydraulic Scissor Lift

We began researching scissor lift mechanisms due to their advantage of giving us the mechanical advantage by inputting a smaller horizontal displacement and outputting a larger vertical displacement. We found that they also have high structural integrity for raising large loads and can be compacted down to a small size. Due to our space constraints, a scissor lift mechanism seemed like a good choice. The drawback to this mechanism is that a much larger force is required than if we had an actuation method pushing straight up on the platform. However, hydraulics could provide these large forces.

We developed a design that utilized a hydraulic cylinder pushing on the crossbar of the scissor lift. As seen in Figure 19 below, some of the legs are on sliders, which allow the top platform to remain flat as it raises. The entire platform compacts so that the pivot ramp can still be integrated and initially used to load the user onto the device. This mechanism will be integrated into a wheelchair frame, similar to the design that we have developed previously. The cylinder will be attached to a rubber hose, which attaches to a hand pump that will be mounted on the wheelchair frame. This design would allow the skier to easily raise themselves up to gondola height simply by pumping the hydraulic pump, which would not require too much energy. This model was developed to show function, and no stress analysis was performed at this point to determine if the members would be able to bear the required loads.

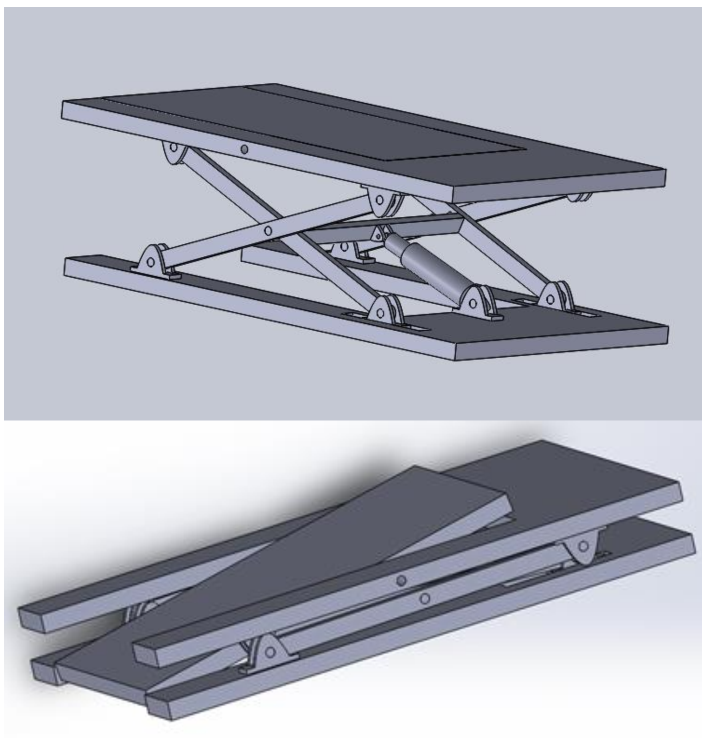


Figure 19. Scissor lift mechanism extended (left) and compacted (right).

4.5.2 Linear Actuators

Another idea generated for lifting the monoskier to gondola height was through the use of electrically powered linear actuators. Linear actuators are self-contained devices which operate using a small motor and internal power screw. This design would require fixing a 12V power source (battery) to the frame to power the actuators, as well as wiring a switch to the two actuators to allow monoskiers to raise and lower themselves between the ground and gondola height.

Pictures of our concept device integrated with linear actuators to provide the vertical lift to gondola height are shown in Figure 20.

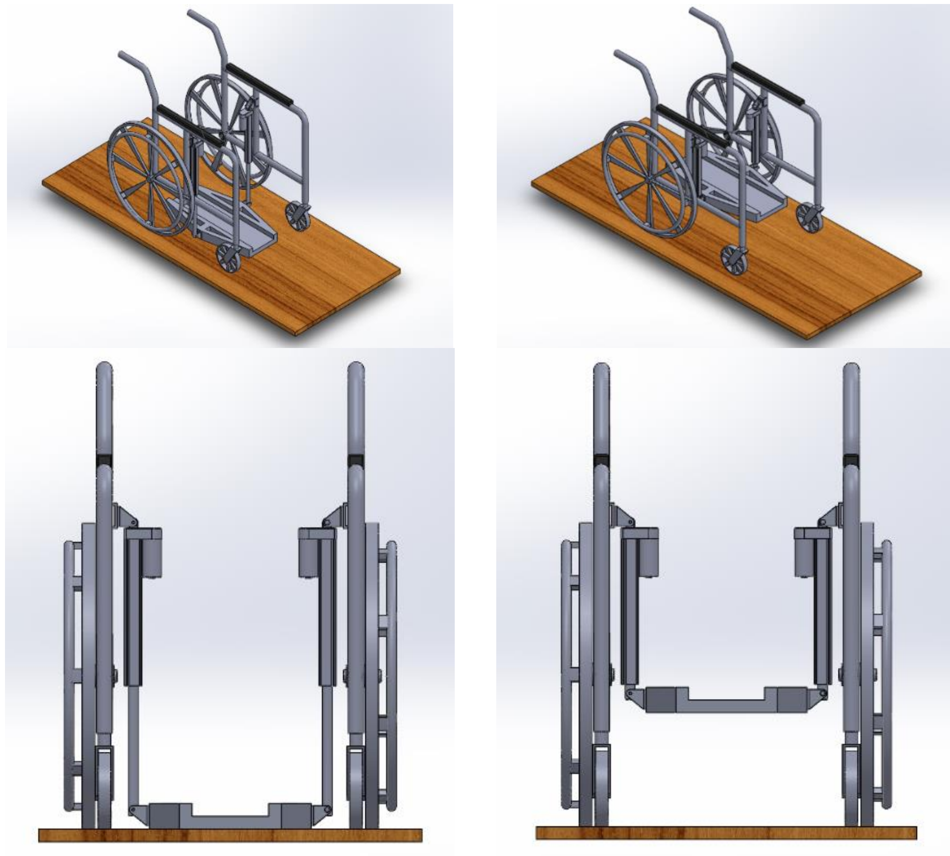


Figure 20. Mobility cart with linear actuators to lift platform shown in lowered (left) and raised (right) positions.

This device concept had pros and cons and was ultimately eliminated moving forward. To begin, the cold weather in Mammoth as well as the wet conditions during the winter were not preferable for the battery and electrical components. Additionally, reliance on a charged battery for device operation was unfavorable, as a dead battery would render the device useless. Another concern came from the space requirements of the linear actuators. To lift the platform to gondola height, the actuators needed to be mounted on the inside of the device. This took away from the space available to monoskiers and would limit the variation in overall width of monoskiers who could use our device. This was extremely undesirable as designing a device that can be used by the large variety of monoskiers out there was fundamental to our design goals. Finally, the development of this model showed us that the lateral structural stability for our device would need to be assessed. As shown, the device would collapse due to the lack of lateral bracing and the pinned joints of the actuators. An open front end was first designed to allow monoskiers to load the device from the back and exit the device from the front. Unfortunately, this functionality could not be achieved as a lateral brace was determined to be required at the front of the device. For this reason, we began looking at more concepts where monoskiers would load from the rear of the device, then back the device up to the gondola, raise up to gondola height, and slide backwards to load the gondola. At the top of the mountain, this would then allow them to exit the gondola comfortably facing forward.

4.5.3 Air Shocks

Another alternative to linear actuators is air shocks. One type of air shock is made of a piston cylinder assembly with a light internal spring. The cylinder has a valve that allows air to flow into and out of the cylinder. While the valve is shut, the assembly acts like a shock compressing the air. Because the cylinder only lifts due to a light internal spring (when the valve is open,) the user would have to press themselves up to gondola height.

The second type of air shock resembles the previous. It is, however, connected to a pressure vessel and uses the stored energy to lift the shock. With this design, an onboard compressed air tank would need to be replaced frequently and is thus impractical for our design.

4.5.4 Ratchet & Pawl Mechanism

Because batteries and electronics are less efficient in cold weather and more prone to failure in wet conditions, we wanted to develop a purely mechanical system. To meet this constraint, we proposed the use of springs in combination with a ratchet and pawl mechanism. A ratchet and pawl mechanism consists of a specially toothed gear (ratchet) connected to a spring and a lever (pawl) for controlling the spring. The way these two components work together can be seen in Figure 21.

Figure 21. Ratchet and pawl mechanism (top) and torsion spring (bottom).

This assembly would deliver the desired, pure mechanical system. Incorporating the system into a wheelchair-like device would then provide mobility for the user to be able to wheel to the gondola. The proposed design for this lifting mechanism is shown in Figure 22. While this concept did provide the mechanical device we were looking for, there were a number of drawbacks that prevented us from continuing with this design. First, due to the nature of torsion springs, much less lifting force is provided when compared to traditional springs. Not only would the springs need to lift the monoskier and his or her ski, but also the weight of the platform. Another design using traditional linear springs was also considered. However, the linear springs added to the overall height off the ground of the device. This would affect the pivot ramp's ability to provide the monoskier a reasonable angle to climb.

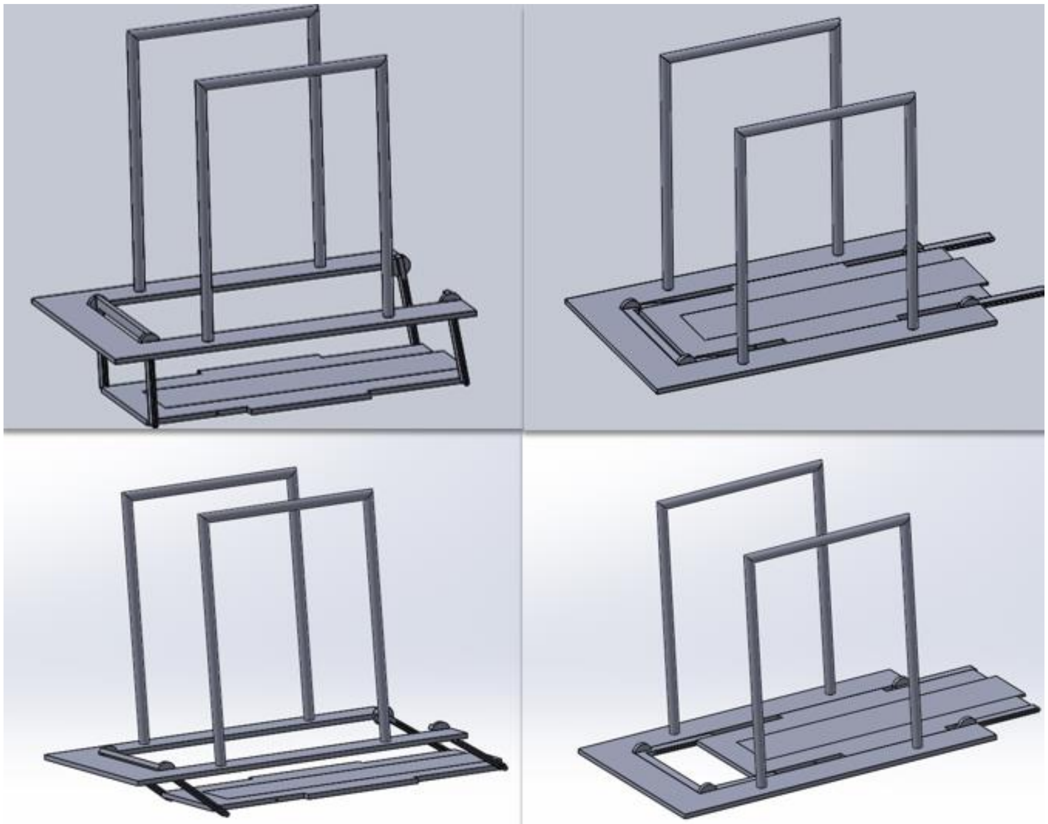


Figure 22. Parallel linkage ratchet and pawl device. Starting at the top left and moving counter-clockwise, the device rotates the monoskier up to gondola height.

To supplement the forces provided by the torsion springs, the use of a tricep dip by the monoskier was suggested. As most monoskiers are able to lift the weight of themselves and their monoski, a tricep dip would be a reasonable method of reducing the force required by the springs. A reason against this was brought up during our Interim Design Review (IDR) presentation to DSES. The reason was that the tricep dip would also induce an impact load to the platform. This impact load would require us to design for a thicker and heavier lifting platform. This would push the weight over what the springs could carry and make for an ineffective device.

Part of this design stemmed from an earlier concept involving a parallel linkage system to somehow swing the monoskier up to gondola height. The advantage of a parallel linkage system is that with all four members being equal lengths, a platform could remain level while being raised through a lifting motion. This idea stuck with us and eventually resurfaced during our final re-design, becoming a critical feature as part of our final design.

4.6 Secondary Revised Design

After presenting these lifting mechanism concepts to DSES via a Skype presentation on April 13th, 2018, the following design was agreed upon, consisting of a hydraulic scissor lift incorporated into a wheelchair-based frame. Another decision matrix assessing various lifting mechanisms was developed, which helped lead to this design. This can be found with the other decision matrices in Appendix B. DSES informed us that hydraulic components were favorable as they were confident in their ability to hold up to the elements like the hydraulic shocks found on standard monoskis.

4.6.1 Design Description

The monoski mobility cart design consists of two main assemblies: the wheelchair frame and hydraulic lift system. Our design incorporates the maneuverability of a wheel chair to give the user a way to navigate from the snow through the gondola stations and get to the gondola lift. Once at the gondola lift, the user can operate the hydraulic hand pump to raise the scissor lift to gondola height and slide into the gondola. A picture of our overall final CAD model is shown in Figure 23, with major components labeled.

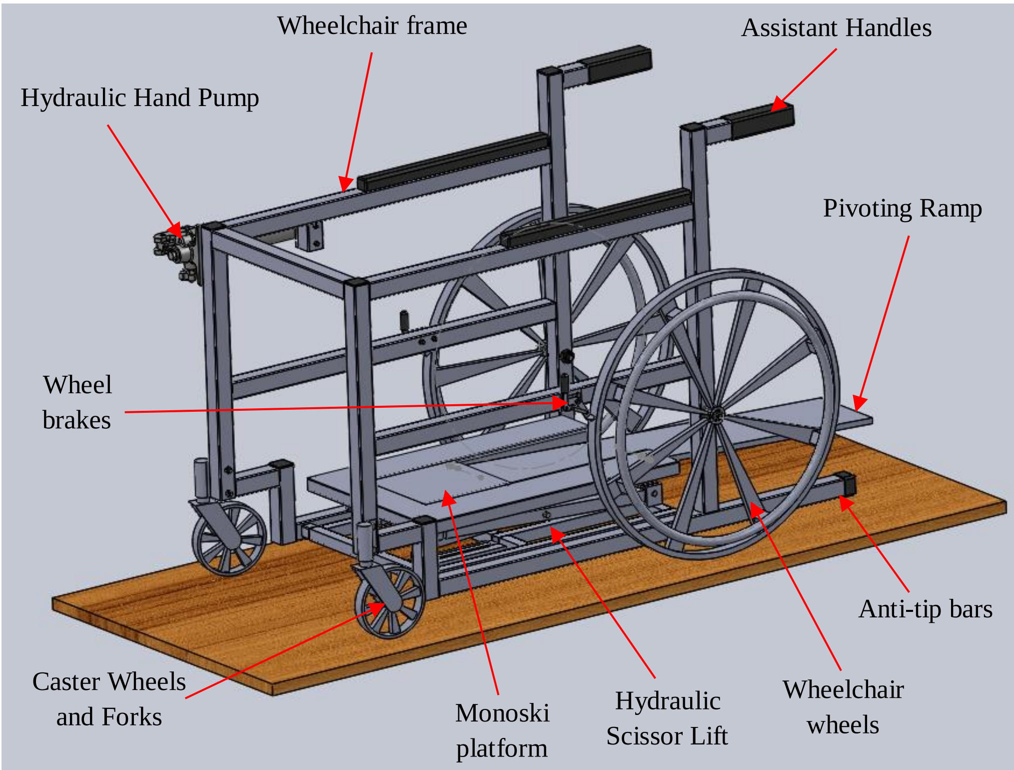


Figure 23. Secondary revised design layout.

Several other components will be described in more detail below. Additionally, Figure 24 shows the overall maximum dimensions of the proposed device, which were derived from ADA specified wheelchair dimensions.

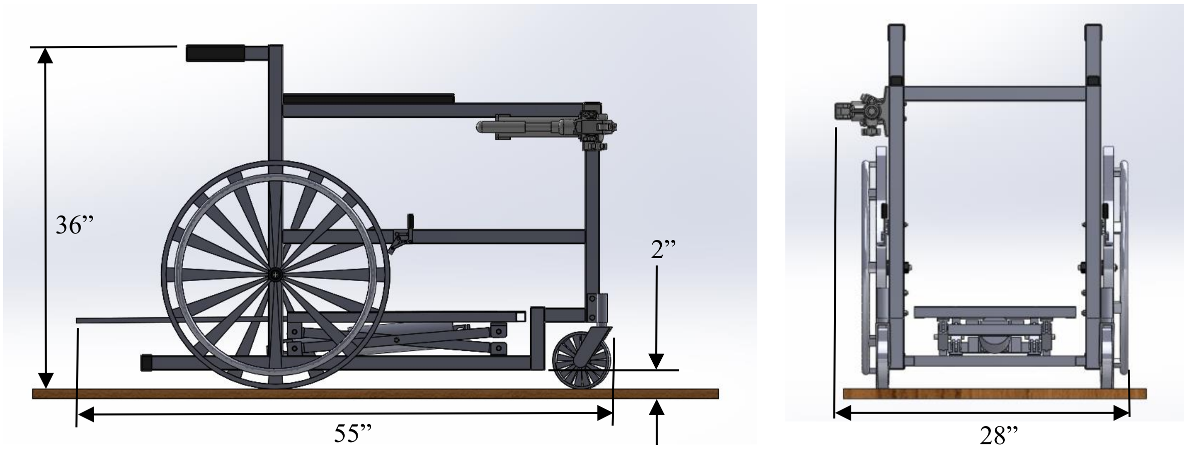


Figure 24. Overall dimensions of the secondary revised proposed design.

4.6.2 Hydraulic Scissor Lift Design

Located at the center bottom of the device and frame will be the hydraulic scissor lift assembly. A picture of our scissor lift assembly model is shown with major components labeled in Figure 25.

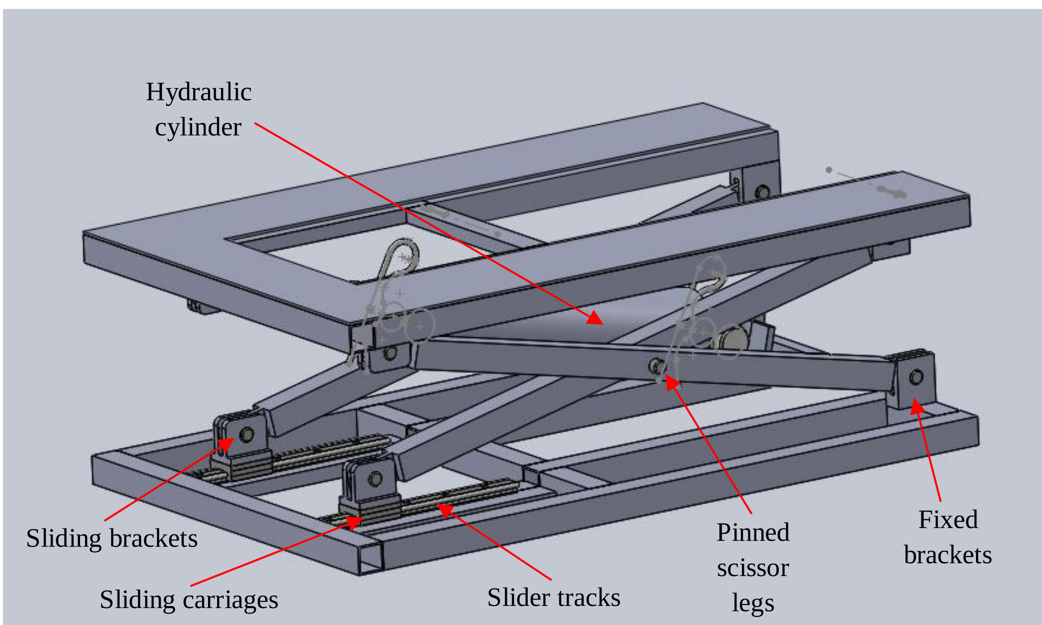


Figure 25. Mobility cart scissor lift assembly.

The scissor lift consists of two pairs of legs mounted on each side of the platform. Each leg is pinned at the middle point. The end of each leg will have a tab with a hole for a pin. The pin will go through the tab and be fixed to the frame with a bracket, allowing rotation. The top and bottom platform will both be made of aluminum square tubing that will be welded together. The top platform will have a piece of sheet metal fastened to the top of it, with a cutout for the pivot ramp. The ramp will be a narrower, but thicker piece of sheet metal that is located within the cutout on the top platform. It will be attached with a metal axle that will fit into the frame (not pictured), allowing the ramp to pivot.

Each of the front facing leg brackets is mounted to a slider sleeve bearing. This sleeve will slide along a rail, which is mounted with screws to the frame. These sliders allow the scissor lift to stay level as it moves up and down. The remaining leg brackets will be welded to the frame, allowing the legs to rotate but not slide.

A hydraulic cylinder provides linear motion to raise the scissor lift. The cylinder has a short circular tube welded on each end for mounting as shown in Figure 26 below. Pins are inserted through these tubes, which allow rotation. The pins are then attached to brackets on each side, which will be welded to two crossbars that are mounted between the legs of the lift. The cylinder is hooked up to a rubber hose, which will run along the frame and attach to the hand pump that is mounted at the top of the wheelchair frame.

Figure 26. Hydraulic cylinder with welded end joints.

4.6.3 Structural Prototype

To assess the feasibility of our final design, we set out to build a structural prototype of the scissor lift mechanism we plan to incorporate to lift monoskiers to gondola height. This was accomplished by purchasing materials from Home Depot to build a cost-effective, proof-of concept prototype. Aluminum square tubing was purchased to be used for the frame and legs of the scissor lift. We chose to go this route so that we could gain early practice at TIG welding thin-walled aluminum tubing, which is a notoriously difficult process. In addition, flat aluminum bars were purchased to be cut and drilled to make the fixed brackets for the scissor legs. For the sliding end of the legs, we used inexpensive wheels fastened to the free end of the legs in order to simulate the effect of a roller or pinned slider. All pinned points were created using standard ¼-20 fasteners for demonstration, as this would still allow free rotation of the legs as if they were pinned. Pictures of our structural prototype are shown in Figure 27 on the following page.

We acquired valuable knowledge through the process of manufacturing our structural prototype. The most valuable part of building this scissor lift prototype was the welding practice. At the start of the process, we spent time solely practicing weld beads on the tubing and then moved onto practicing welding various joints to join two pieces of tubing together. By the end of the process, we found that properly preparing every weld by first cleaning and wire brushing the surfaces and filler rod, sharpening the electrode, and fixing everything into place using clamps and magnets produced the best and most consistent welds.

Figure 27. Structural Prototype in raised (left) and lowered (right) positions.

Once we began getting a feel for welding the thin tubing, we began manufacturing the prototype itself. This was done by first welding together the top and bottom rectangular frames that the rest of the lift components would be fixed to. This was accomplished using welding clamps/vices to hold the joints together in place while welding. After this, the required spacing between adjacent scissor legs was examined in order to determine where the inner members needed to be welded for attaching the inner legs. This showed us that it will be critical to space components, and particularly the scissor legs, to avoid causing any part interferences. To make sure the inner frame members were welded into place with proper alignment, spacers were inserted between the outer and inner frame members to keep the distance between them constant across the full length of the device. Again, welding clamps and magnets were used to secure the pieces being welded to assist in the process. Even with these measures taken, we still found that it is easy for the tube stock to deform due to the heat applied during the welding process. Minimizing the deformations in the tube stock will be crucial to maintaining the alignment of our final device. We plan to continue using the techniques we began developing making this prototype to manufacture our final design prototype, as well as other techniques that will be discussed in the following sections.

Other than welding, there were several other important takeaways from building this prototype. Through the drilling of the numerous holes in the device, we learned that achieving the tolerances specified will be crucial to build a functional and reliable device. The center-to-center distance of mounting holes will be critical dimensions. Locating drill points will need to be done accurately and will be initiated using a center punch to prevent the drill bit from "walking" and drilling a hole away from its intended location. As stated before, locating the side-to-side members for the scissor legs will also be critical to avoid part interferences. Finally, we found that symmetry between the fixed brackets and sliding brackets will also be critical in our design. This can be seen in Figure 27 above, as the top platform is not parallel to the bottom platform. The reason for this is because the wheels used to demonstrate the sliders are significantly taller than the fixed brackets. This causes the device to become lopsided, inducing an angle on the top surface. To create a scissor lift with parallel platforms as desired, we learned that the distance from the tubing of the frame and the mounting pin for the fixed and sliding brackets needs to be equal. This will be achieved through the manufacturing of our own brackets for the scissor lift mechanism as discussed in the following section.

4.6.4 Design Pivot

Unfortunately, while continuing to develop this design, it was realized that that the scissor lift had a major flaw. We found that the top of the platform would only be able to lower to a height of 7 inches off the ground when fully compacted to a minimum vertical dimension of 5 inches. This would make the mounting of the cart nearly impossible for the monoskier to accomplish. The proposed ramp also would require too steep of an angle and posed serious strength and deflection concerns. Therefore, it was decided to move away from the scissor lift, as it was not feasible to make it compact enough for the user to load onto the device from the ground. DSES was most comfortable using a hydraulic system to perform any lifting actions, so we began to consider how we could alter our existing design concept while still using hydraulics as planned. The final design is explained in the next section.

5 Final Design

Due to the unsolved issues from the previous concepts, the team spent large amounts of time brainstorming to find a possible miscue or discarded idea that could solve all of the design constraints. After long hours of deliberation, a combination of the parallel linkage system and hydraulic components was decided on. The following section describes the thought process of the final design.

5.1 Design Description

The hydraulic system was determined to be the best lifting force as it held a number of pros for the system's use in cold weather, high loads, and product familiarity for DSES. The parallel linkage system solved the system's issue of mounting the cylinder in order to lift the user, as well as allowing the platform to lower fully to the ground for the easiest possible device loading and a lower ride height, reducing the center of gravity and giving more stability. Additionally, the parallel linkage system ensures that the platform will remain level throughout its full range of motion. A complete model of the final iteration of our design is shown in Figure 28 on the following page.

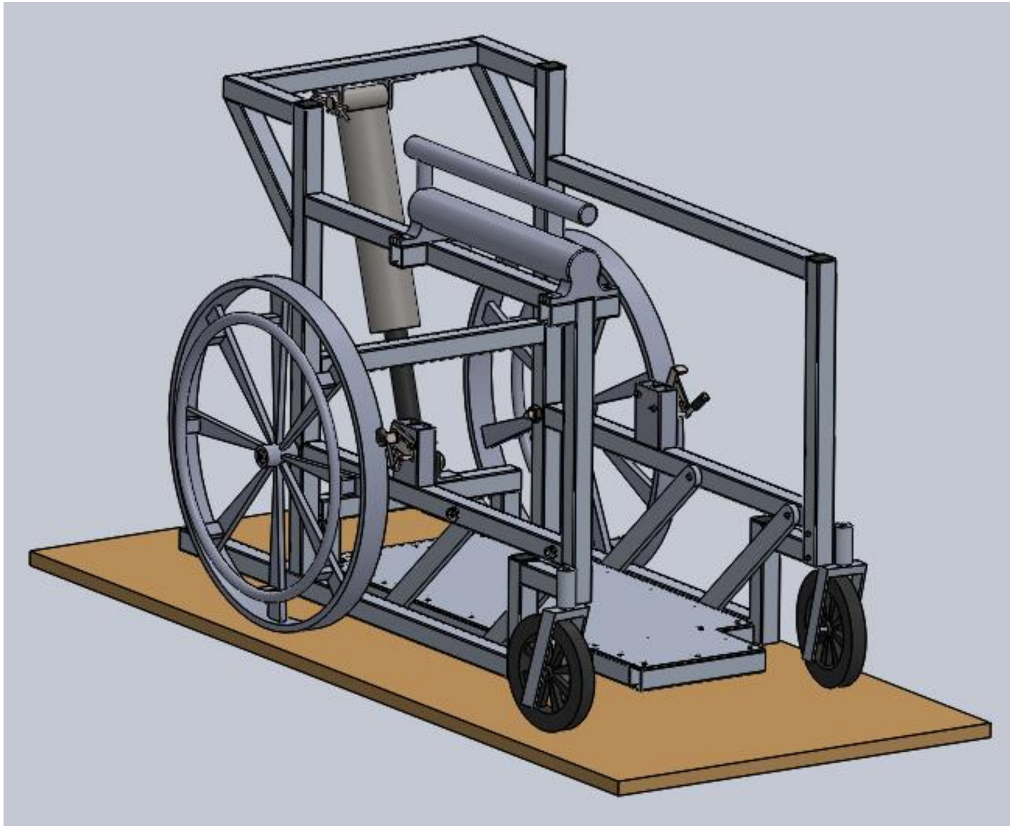


Figure 28. Final design combining parallel linkage system and hydraulics.

This new system is powered by the hydraulic cylinder, which retracts and pulls the ramp of the cart up and towards the rear in a swinging motion. To maintain a level ramp for the monoskier, the four parallel linkage arms serve as supports that balance and keep the platform level. This system allows for much of the wheelchair frame to remain intact while also providing a fully functioning device for monoskiers to raise up and down to gondola height.

5.1.1 Wheelchair Frame

The main frame of the mobility device ties all of the individual components together. The frame will resemble a standard wheelchair frame on the sides but will differ in the center region of the device. The center space will be occupied by the monoskier, hydraulic cylinder, cross braces, and platform mechanism. The frame will be constructed as two sides that are joined by two lateral members, with all of the aluminum square tubing welded at the joints. Both of the lateral members will support the ramp and hydraulics at the base of the frame (not shown) while stabilizing the frame. The lateral members are placed in these locations to provide the maximum possible space for the variation in size of monoskiers who will use the device. The wheelchair and caster wheels will be mounted to the two sides of the frame, which will also incorporate anti-tip bars, support handles for assistance, and mounting for the wheel locks, hydraulic pump and lines, and outrigger clips. The wheelchair frame of the mobility cart is shown in Figure 29.

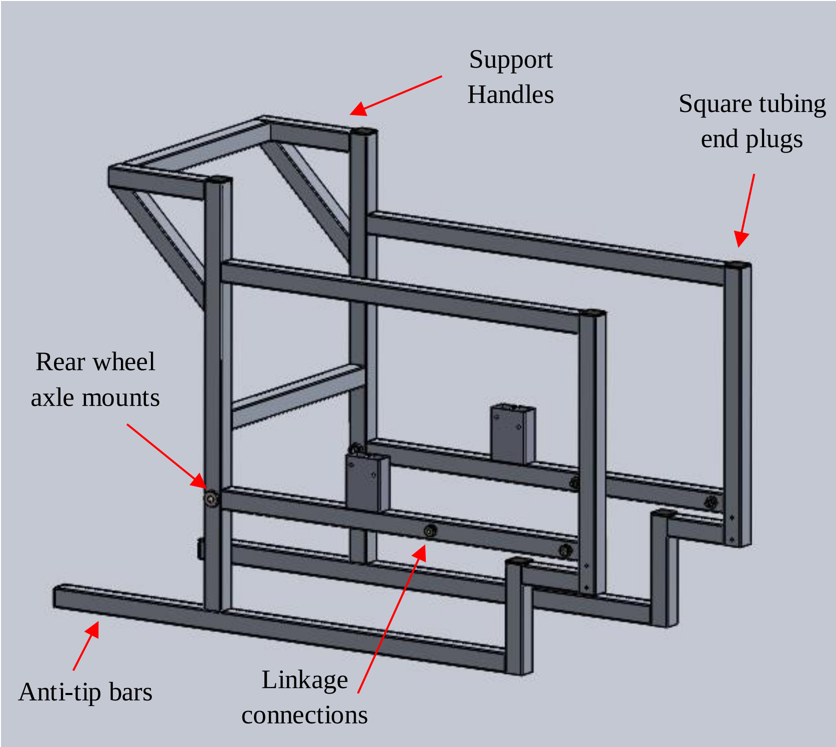


Figure 29. Wheelchair-inspired frame for the mobility cart.

5.2 Design Analysis

The following summarizes the analyses we deemed necessary to evaluate our design and confirm its strength. All the following subsections summarize hand calculations that were performed, and can be viewed in Appendix C.

5.2.1 Hydraulic Lift Power

The main considerations for the hydraulics were to ensure that we chose components that would provide us with the required power to raise the monoskier. Based on the specifications and dimensions of the Maxim 6FWX2 double acting hydraulic cylinder, we calculated the maximum force the cylinder could produce to be 9400 pounds. Given the load of the monoskier was to be conservatively estimated at 750 pounds, this was more than enough. A double-acting cylinder was required in order to provide lifting force while the cylinder retracts, as opposed to a single-acting cylinder which can only provide force while extending. Using data given for the hand pump we selected, we found that the cylinder extends 0.141 inches per stroke. Further calculations showed that raising the weight of the monoskier would require about 60 pumps. While 60 pumps seems like an excessive number, it was noted that the user could find time to pump while waiting in the elevator or in line for the gondola. In addition, the user would also need to pump up 2 inches to ride height in order to provide clearance for the bottom of the platform while in transit, which takes roughly an initial 20 out of the 60 pumps. The hydraulic cylinder will be secured to the frame and platform by ¾” clevis pins secured by the hydraulic brackets.

5.2.2 Critical Loads on Frame

One location of critical stress on the frame is on the crossbar, where the cylinder is actuating. To check the maximum deflection on these crossbars, the moment of inertia of the hollow square tubing was calculated. Using the modulus of elasticity for 6061 aluminum, the length of the bar, and the force exerted from the cylinder, the maximum deflection was found to be 0.0042 inches. After checking deflection, the stresses on the crossbar were analyzed. The hydraulic cylinder load was used to specify 6061 aluminum square tubing of 1.5” x 1/8” thick to withstand the shear force and induced bending moment on the crossbar. The final iteration of this calculation resulted in a factor of safety of 3.4, which we considered satisfactory for our human-interfaced device. These calculations can be found in Appendix C.

Another area of concern was the new brackets that would be needed to allow the hydraulic cylinder to rotate and provide lifting force to the ramp. In order to ensure the bracket design would withstand the loading, hand calculations and a Finite Element Analysis (FEA) were conducted. Both of these methods used a point load of 375 lbf to estimate the load and fixed boundary conditions where the bracket would be welded to the ramp and frame. Figure 30 shows the FEA study at the finest mesh.

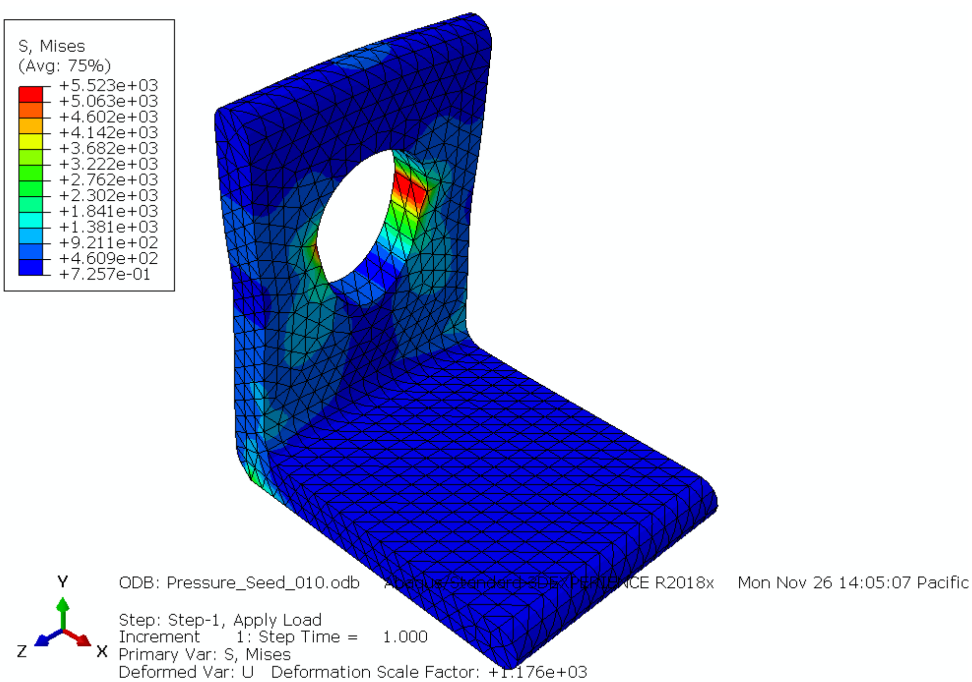


Figure 30. FEA study completed on bracket showing Mises stress concentration.

In order to check the validity of the point load assumption, the FEA model was also run using a pressure load. This load produced similar results, but only after plotting the maximum values for stress instead. The values for maximum stress and strain from these studies were 7500 psi and 0.000750, respectively. As the yield strength for aluminum is 35000 psi and the strain calculated were both deemed safe, the component could then be assumed to satisfy the requirements.

Additional analyses performed included a static analysis of the platform and linkage system while in its critical loading condition of being fully raised. The static analysis was used with our maximum load case to determine the load conditions of the linkage member and platform. The linkage members are two force members and were specified far from the verge of failure as they act as critical supports for the monoskier along with the hydraulic cylinder. The critical stress location on the platform was determined to be at the center linkage mounting location, and a stress concentration was determined for the hole in the tubing at this location, which led to a calculated stress of roughly half the material yield strength. These calculations are also included as a part of Appendix C.

5.2.3 Fasteners and Weld Strengths

At the base level of our design, welded joints and fasteners will be holding our device together. These will be two critical features for our device, as a failure of a weld or fastener could render the cart immobile. In terms of welds, it is generally acknowledged that a good weld is as strong or stronger than the base material it is joining. For this reason, we will model the joints in our analysis as rigidly connected and will be looking at cross sections of the tubing just next to the welds where the bending moments and torsion are often greatest. For aluminum the rule of thumb for welded joints/areas is not as true as with steel. Strength near welds can be reduced to half in worst cases. In order to recover as much of the lost strength as possible, all welded components would be heat treated in an attempt to bring them back to T6. To make sure that our frame is as strong as we design it to be, we will also be practicing welding and performing weld break tests to confirm the integrity of our welds. This will be discussed in later sections.

The fasteners used for our device would need to withstand cyclic loading of the hydraulics as well as provide free rotation. After help from shop technicians and some of the team's own knowledge, an assembly of flanged oil-embedded bronze bushings, shoulder bolt (with machined surface), and threaded insert was decided on. The shoulder bolts would provide a shaft like surface and the bushings would act like bearings to allow rotation in the aluminum tubing. The threaded insert would then provide the connection between the shoulder bolt and arm. An insert was chosen so that aluminum threads in the linkage arms could be seized with the outside of the insert, while providing better, stainless steel threads for the shoulder bolt to thread into. Figure 31 illustrates this assembly.

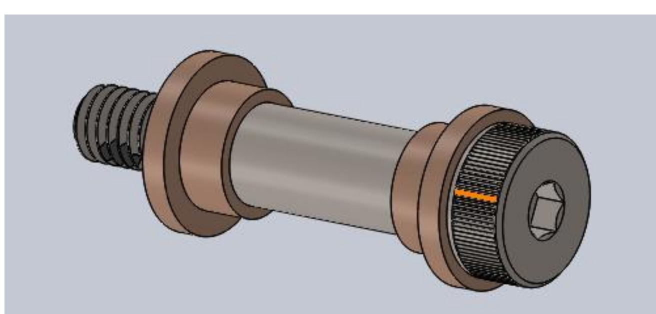


Figure 31. Shoulder bolt and bushing assembly. Oil-embedded bronze bushings act as a bearing surface for the shoulder bolt, which is connected to a threaded insert embedded in the linkage arm (not shown).

Tolerances of the bushings were transferred to the members of the frame that would support them in order to ensure a proper fit. Inner diameters of the bushings and outer diameters of the shoulder bolts are controlled closely by the researched manufacturer to ensure a clearance fit. The shoulder bolt's head also allows the DSES team to disassemble the system with a standard hex key if necessary. This configuration also allows for a point of adjustment in aligning the linkage arms and platform, by adjusting how far the shoulder bolt is threaded into the insert.

5.3 Material, Geometry, & Component Choices

A summary of the material, geometry, and component choices that will be incorporated into the design of the mobility cart are outlined in the following sections.

5.3.1 Material

Aluminum is the main material used in this design. Billet T6 6061 aluminum square tubing will make up the frame and ramp due to its high strength, light weight, corrosive resistant, weldable, and heat-treatable properties. The yield strength for this material is 40 kpsi, the ultimate strength is 45 kpsi, and the modulus of elasticity is $10x10^3$ kpsi. These values were used in our analyses performed in Appendix C. T6 was selected for the best strength and heat-treatability for after welding.

5.3.2 Geometry

In designing the monoski mobility cart, the geometries of the various components of the device had to be kept in close consideration during all decisions. All overall dimensions of the device had to meet the ADA wheelchair size requirements of 46L x 28W x 36H inches. All other component geometries were designed to accommodate the variation in monoskiers that may use this device, maximizing the space which they can occupy on the device.

5.3.2.1 Frame geometry

As stated before, the frame of the device is constructed as two sides that are joined by two lateral members. The lowest members of the frame are elevated 2 inches from the ground in order to provide adequate clearance while the cart moves over various surfaces. The sides of the frame will have long longitudinal members at its base that extend out from the back of the device to act as anti-tip bars, while stabilizing the frame sides from racking out of square longitudinally. From these members, the primary vertical members of the sides run up to the max height of 36 inches off the ground, where the assistant handles are located. The wheelchair wheels will be mounted 12 inches from the ground on these members to account for the wheel size of 24 inches. From this primary vertical member on the sides, two horizontal members will run longitudinally to the front of the device where they will be joined by another vertical member. The vertical member in the front of the device will be connected to the longitudinal base member via two smaller tube members to provide clearance and mounting for the caster wheels. The two upper longitudinal members provide mounting for the wheel locks, linkage arms, hydraulic pump, and outrigger clips. The most constraining dimension on the frame is the device width requirement. After accounting for the width of the wheelchair wheels and frame sides, the maximum allowable inner distance between the two sides of the frame was determined to be 18 inches. From the information on monoski dimensions available, 18 inches is wide enough to fit the widest monoskis that we could find.

5.3.2.2 Linkage Arm Considerations

In order to allow the hydraulic cylinder to apply force in a vertical direction, the linkage arms had to support the platform while the cylinder pulled at the rear. The internal width as well as clearance for the arms had to be accounted for to ensure ample assembly room and smooth rotation. To accomplish much of this task, the length of the linkage arm was calculated by determining the useful radius in which it would rotate. This length became the center to center distance of the two holes in the arm. The edges of the arm were also designed to be rounded to allow the ramp to come into complete contact with the ground.

5.3.3 Component Choices

Several components will be purchased including rear wheels, caster wheel assembly, rear axle housing, hydraulic components, wheel locks, and miscellaneous smaller parts. The rest will be manufactured, such as the hydraulic brackets. The rear wheels are fiber enforced composite plastic to save weight with urethane tires. The tires are tubeless to ensure no tube failures and no pressure loss while traveling over snow and ice. The rear axle was sized and selected to accommodate the rear wheels and axle receivers. The wheel locks were purchased after a cost analysis confirmed manufacturing would cost more.

The hydraulic system components were chosen for the following reasons:

- Cylinder – Smallest/cheapest double-acting cylinder for required 10” stroke
- Pump – Cheapest double-acting manual hand pump with reasonable fluid displ.
- Fittings choices – 90-degree angled and rotating (swivel) on both ends

5.4 Cost Analysis

The total estimated cost for our final prototype is approximately $3000. A large portion of this cost was filled by the hydraulic components. Together, they made up about 40% of the total cost. The reasoning for selecting such heavy-duty equipment laid in the *capabilities*, not the ratings, of the selected pump and cylinder. Due to the use of both retraction and extension of the cylinder, the pump needed to be double acting and carry enough fluid for both sides of the cylinder to be filled. This is because we needed to use the retracting motion to lift the platform. The cylinder also needed to meet the bore and stroke requirements in order to provide enough force and to lift the user high enough. These capabilities proved to be expensive as well as heavy. As previously mentioned, the pump was the cheapest option that had a fluid displacement that would allow full range of the cylinder in under 100 pumps. This pump, the Enerpac P-84, is over $1000 new. We chose to buy a used one on Ebay for under $700. The rest of the hydraulic cost came from the cylinder, hoses, fittings, oil, and pins.

The next most expensive components were the wheel assembly, which made up about 30% of the total cost. This consisted of the caster assembly, rears wheels, axles, and axle receivers. None of these components would be feasible to manufacture on our own, so they were purchased.

The aluminum frame components made up about 20% of the total cost. Due to the complexity of the wheelchair frame and platform, we needed roughly 60 feet of this tubing. We determined that we cannot use a cheaper material, because we needed the previously mentioned properties of aluminum to fulfill our requirements.

All fasteners were purchased in quantities to benefit the team's budget. A full cost breakdown by component and assembly can be viewed in Appendix D.

5.5 Safety, Maintenance, and Repair Considerations

To ensure the safety of the user, we completed several assessments of potential dangers associated with our device. We first completed a design hazard checklist and came up with plans to deal with the potential hazards. The design hazard checklist is included in Appendix E. We also performed a risk assessment using a program called designsafe. The report from our risk assessment is included as Appendix F. Finally, a Failure Modes and Effects Analysis (FMEA) was conducted. This approach is a step-by-step process to identify all potential failures and examine them individually and then collectively. One mode that was analyzed was the potential tipping hazard.

To ensure the monoski would not tip backwards while on high incline surfaces or during loading and unloading the gondola, anti-tip bars were incorporated into the wheelchair frame. In the unlikely case of a tip, the bars will prevent the user from falling all the way back. Note that these bars are not designed to support a vertical load from someone standing on them, and should never be used to stand on by an assistant from the rear. The lower portion of the mobility cart frame is shown in Figure 32.

Our design was also built with maintenance and repair considerations in mind. There will be little maintenance needed for the mobility cart. When the wheelchair wheel tires wear down or crack, new tires or wheels can easily be swapped through quick-release axle and receiver assembly. The receivers (sleeve bearings with external threads for a jam nut) may wear down over time and need to be replaced, although this is unlikely. These can simply be unscrewed from their corresponding bracket, and a new one can be installed. Oil-embedded bronze bushings were chosen for linkage mounting points because they will never require lubrication, and thus provide a maintenance-free method of rotation. Similar internal bushings (without the external flange) are used within the cylinder mounts in order to allow free rotation without requiring lubrication at the pinned joints. The linkage arms may become misaligned if the shoulder bolts move from their initial threaded positions over time. Red Loctite will be used on the outside of the inserts to fix them in the linkages, while blue Loctite will be used on the inner threads of the insert and shoulder bolt in order to fix the threads while allowing later adjustment if necessary. In order to adjust alignment of the linkage arms, use a hex hey on the heads of the shoulder bolts to thread them further in or out of the inserts and bring the arms into alignment and clearance with the frame. Care should be taken to ensure that the linkage arms are maintained in clearance with the lower frame rails. Misalignment and an interference of moving and stationary parts along with an applied hydraulic force could result in deformation and eventual failure of the longitudinal frame rails.

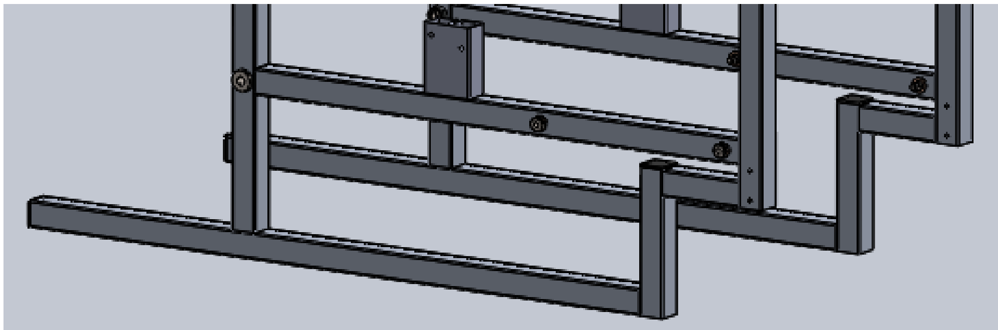


Figure 32. Wheelchair frame anti-tip bars and rear wheel axle mounts.

Some maintenance may need to be done to keep debris out of all the moving components. We are most worried about moisture, where snow will melt and water may get into the bushings, tubing, and fasteners. This could cause extra friction and cause fatigue over time of these components. If moisture gets into these parts and then refreezes, this could cause the device to stop working completely. Drainage holes were drilled on the bottom of the frame and platform members in order to allow moisture from snow or condensation to escape from the tubing. The device should not be left outside when not in use, and it should be wiped down at night to ensure minimal moisture gets in. Our full FMEA analysis is included as Appendix G.

6 Manufacturing

The manufacturing phase took place throughout the entirety of the 2018 Fall quarter. It concluded just prior to the Project showcase on November 30, 2018. The majority of the manufacturing took place at the Cal Poly Mustang ’60 Machine Shop and was performed entirely by our senior project team members.

6.1 Procurement

The majority of the materials and components for the monoski mobility cart were purchased online and shipped to Cal Poly. The vendors we used the most were McMaster-Carr, Grainger, and OnlineMetals. See the Bill of Materials in Appendix H and the Procurement list in Appendix D for further details on all purchased components.

Funding for this project was provided partially through Cal Poly MESFAC ($1500) and was roughly matched through a Cal Poly senior project grant in order to purchase all materials and components. Part and material ordering began at the end of the 2nd quarter in May when MESFAC funding was granted and proceeded throughout the 3rd quarter manufacturing phase.

6.2 Manufacturing

This section will cover the various manufacturing processes that were performed in order to construct our device. All manufacturing was done in-house by the senior project team, but could also be outsourced to a competent manufacturing company if needed. Engineering drawings were created for all parts being manufactured by the senior project team in house, and are available at all part, sub-assembly, and full assembly levels in our drawing package in Appendix I.

6.2.1 Tube Frame

The frame consists of aluminum 6061 T6 square tubing, with 1.5inch sides and 1/8 inch thickness. First, all tubing was cut to its desired length using the aluminum chop saw in the machine shop. Each member was measured again after cutting to ensure the length was correct and finished on the belt sander to the ensure the desired length was achieved. Excess aluminum and burrs were removed using the belt sander and deburring tools as necessary. We were able to cut almost all the tubing early in the quarter, within two shop sessions.

Next, all necessary holes were drilled in the frame members. For all holes, a center punch was first used to make an indent on the tubing at the exact hole location. The small holes (caster mount and pump mount holes) were made using a drill press. A center drill bit was used to start the hole, and then standard drill bits were used. The holes were then deburred using a deburring tool. For the larger and more precise holes for the rear wheel shaft, a mill was used as shown in Figure 33. This was done to ensure the hole location was accurate with our tolerance of ±0.005 inches. A center drill was also used on the mill to help start the hole accurately. Next, a small drill bit was used to continue the hole, and drill sizes were gradually stepped up until we reached our specified hole size.

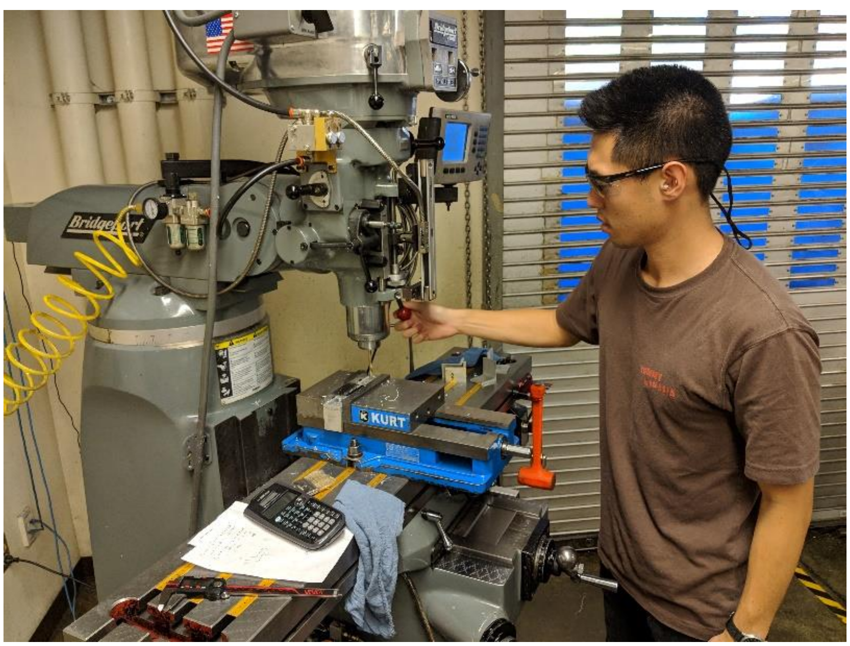


Figure 33. Milling precision holes on the tubing and brackets.

Next, we welded the left and right sides of the main frame, as well as the platform frame. All aluminum was first thoroughly cleaned and wire brushed in order to minimize possible contamination of welds. The electrode was started with a sharpened tip with the end blunted in order to maximize weld efficiency and penetration, allowing the characteristic shiny mirror ball to form at the end of the electrode to form after several welds, as shown in Figure 34.

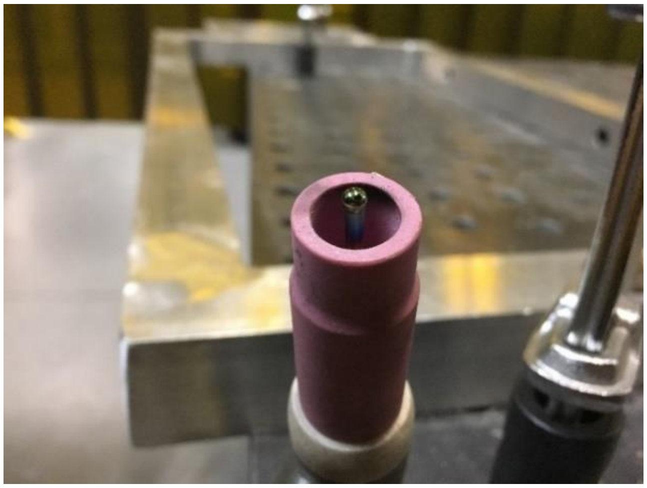


Figure 34. Balled TIG electrode tip.

All joints were TIG welded all around using a 3/32" electrode and filler rod, an appropriate size for the 1/8" square tubing wall thickness. The frame was first laid out and jigged to the welding table using a framing square and clamps to ensure alignment was maintained during the welding process. This can be seen in Figure 35. The two frame sides were first welded as upper and lower sections and then joined due to welding table size constraints. To minimize possible deflections from the heat of welding, all joints were first tack welded in order to locate all members before any significant deflections occurred. After all joints were tack welded, they were be fully welded around on all four sides to maximize the strength of the joints. Welds were performed on the opposite sides of the direction any members are deflecting in order to deflect the members back into alignment as necessary.

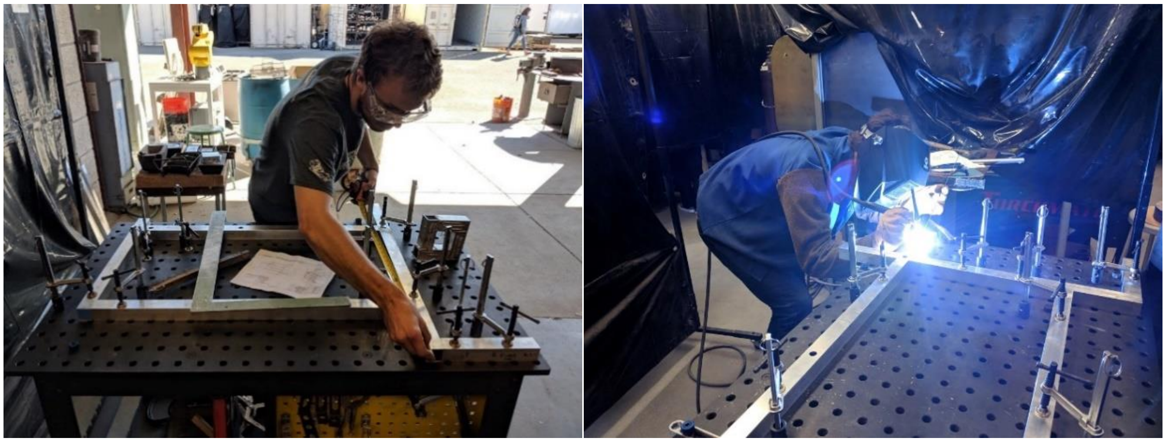


Figure 35. Jigging side of frame to welding table (left) and starting to weld (right).

Next, we welded the brackets to the upper and lower cross frame members, and these weldments were heat treated individually at 350ºF for 8 hours. Both sides of the frame were next clamped down on a welding table, and the cross members were welded to join the frame together as shown in Figure 36. We took several measures to ensure that each member intersection and weld was precisely square using several framing squares, clamps, and shims.

Figure 36. Welding the cross members to join the two sides of the frame together.

6.2.2 Linkage Arms

The linkage arms are made of aluminum 6061 T6 rectangular bar, 1.5 inches by 0.75 inches. We first cut each arm to size using the same aluminum chop saw as previously mentioned. Next, we made the holes at each end on the mill, using the same milling procedures as before. The arms were then taken to the belt sander, and the ends were rounded on the sander in order to give the required clearance. All holes were threaded using a hand tap tool. Linkage arms were later milled down to the length of the inserts, 33/64" or 0.5165" to allow for easier installation and better clearance between the frame sides and platform. This was allowable because the arms were originally specified very conservatively, knowing that we could take them down to a thinner thickness during final assembly if required. The four linkage arms are shown in Figure 37.

Figure 37. Linkage arms during paint preparation.

6.2.3 Platform

The platform is constructed of a 1.5” x 1/8” thick square tube frame with a sheet metal top surface. The platform tube frame was welded using the exact same methods as discussed previously for the main frame. The platform frame was the first part of the device that was welded together, as we wanted to start small in case any parts needed to be re-made through the manufacturing process. Thankfully all welding went smoothly, and no parts needed to be re-made during the duration of the welding process. The completed platform tube frame, including hydraulic cylinder mounting brackets, is shown in Figure 38.

Figure 38. Fully welded platform tube frame.

The platform top surface was made from an 1/8” thick sheet of 6061 T6 aluminum. In order to cut it to our desired shape and size, we used the water jet at the machine shop, as shown below in Figure 39. The water jet also located all of the mounting screw holes, which saved us valuable time compared to drilling them by hand. These holes were later countersunk using a countersinking drill bit, so that the sheet metal surface could be mounted to the square tube platform frame with countersunk flathead sheet metal screws, so that the screws would lay flush with the top surface and not risk damaging the user’s ski.

Figure 39. Waterjet cutting the sheet metal platform surface.

During final assembly, the platform was attached using the countersunk sheet metal screws after complete installation to the frame through the connecting linkage arms. The shoulder bolts for the platform can be accessed from the inside of the tube frame, underneath where the sheet metal will go. The platform was finished off with a piece of artificial turf cut to fit in order to provide a smooth, non-damaging surface for the monoskier to slide on and off of. Additionally, a long rubber latch will be attached to the platform that pivots down over the user's ski as a method of holding them in place while using the device.

6.2.4 Brackets

The brackets were made of 6061 T6 aluminum extruded angle, 2 inches by 2 inches with ¼ inch thickness. We first cut the angled aluminum to the specified 1.5 inch width for the four brackets. We made the holes for the hydraulic cylinder pins on the mill, with the same milling procedure as the previous tubing holes. The brackets were then welded to the cross members and heat treated for 8 hours at 350ºF as previously mentioned, prior to being welded to the frame/platform. The bracket and cross brace weldments are shown in the oven heat treating in Figure 40.

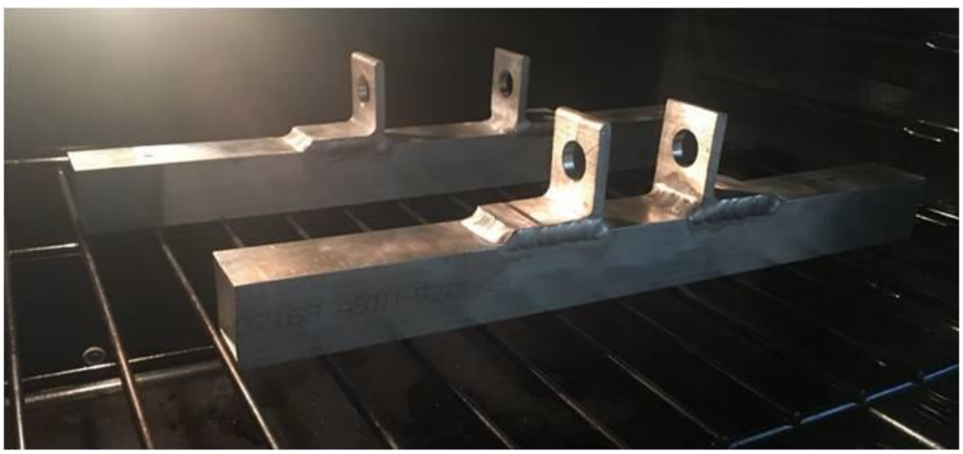


Figure 40. Hydraulic bracket weldments during initial heat treatment.

6.2.5 Brake Mounts

We purchased the brakes online as a whole assembly. In order to mount them in the appropriate location to clamp down on the wheel, some modifications were necessary. We first modified the mounting surface to allow mounting to our flat tubing, as they were intended for use with round tubing. We then milled down the total thickness of the brake mount to properly locate the brakes on the wheel tires. To mount the brakes, we welded two short aluminum square tubes together, lengthwise. This was ground down to smooth, and then the drill press was used to drill the appropriate holes for the brake mount. The welded tubing member was then welded to each side of the frame, on the longitudinal linkage mounting member on the frame sides, in front of the wheels. This provides the most convenient and ergonomic location for the brakes while using the device.

6.3 Heat Treatment

Due to the heat of welding, some strength is lost in the aluminum. The process of heat treatment can help reverse this and return the aluminum to T6. We first heat treated the hydraulic bracket weldments for 8 hours at 350ºF as these are the principle load bearing locations on the device. This is shown on the previous page in Figure 40. After all welding was completed, we took our entire frame and platform to the large oven in the composites lab. We heat treated our welds for 12 hours at 250ºF to regain as much of the lost strength as possible.

6.4 Assembly

This section covers the processes followed in order to successfully assemble our device. The order of assembly operations was important to maximize simplicity and efficiency of assembly. This section will cover assembly of all procured and manufactured parts. Assembly drawings for this are included as a part of our full drawing package in Appendix I.

6.4.1 Prepping and Painting

We decided to paint the frame in order to improve corrosion resistance even further, and to give it a more finished appearance. Critical load bearing welds were left unground, while butt welds, that don't support the frame as much as the interior fillet welds, were often ground flat for several reasons such as preparation for further welding, flat mounting surfaces being required, eliminating protrusions, and the like. To prep all the aluminum components (main frame, platform frame, platform sheet, and linkage arms) for painting, we used an angle grinder and a compressed air-powered sanding disc. We smoothed all sharp edges and uneven surfaces and gave the aluminum some "etching" to help the paint hold better using scotch bright pads on a pneumatic grinder. This can be seen in Figure 41.

Figure 41. Completed frame and platform during paint preparation.

All bushing and threaded surfaces were taped off prior to painting. Next, we applied two coats aluminum spray primer, allowing for dry time in between coats as specified by the can directions.

Finally, we finished with two coats of black aluminum spray paint, again allowing for specified dry time in between coats. Pictures from the painting process are shown in Figure 42.

Figure 42. Painting all manufactured aluminum components with aluminum primer and paint.

6.4.2 Hydraulic Assembly

As discussed in section 5.4.3, we chose clevis pins with hairpin cotter pins to mount the cylinder. We used oil-embedded sleeve bearings to go over the pin and through the cylinder pin hole. Due to the pin diameter and length of the longer cylinder hole, we had to use two sleeve bearings in series for the upper cylinder mount. These components are shown in Figure 43.

Figure 43. Hydraulic bracket assembly including clevis pins, cotter pins, and sleeve bearings.

We used liquid thread sealant on all threads for each hydraulic fitting. After initially assembling the hydraulic sub-system with all fittings and hoses for fit check as shown in Figure 44, we noticed that there seemed to be some air in the system as the cylinder was not moving quickly or smoothly. We then purchased more hydraulic fluid and filled the pump further until full. This fixed this problem and increased the pumping efficiency significantly.

Figure 44. Hydraulic sub-assembly.

6.4.3 Final Assembly

The final assembly process was performed as follows:

1. Install wheelchair wheel axle receivers in frame with jam nuts
2. Install rear wheelchair wheels and front caster wheels on frame
    a. Adjust quick release wheelchair axles to proper length for wheel hubs and receivers during installation
    b. Use appropriate nuts and bolts for caster assemblies
3. Install brakes using appropriate nuts and bolts
    a. Use socket or crescent wrenches
    b. Lock brakes for further assembly
4. Install shouldered sleeve bearings in tubing on frame and platform
    a. Press fit using rubber mallet
    b. Note: Platform shoulder bolts installed prior to attaching sheet metal to platform
5. Install inserts into linkage arms using red Loctite and let dry according to manufacturer's specifications
6. Install shoulder bolts through sleeves and thread into linkage arm holes

   a. Begin by installing the shoulder bolts in the platform with the heads on the inside of the platform, attaching them in a cross (X) pattern to balance during installation
   b. Apply blue Loctite to secure threaded locations prior to installation, and allow to dry according to manufacturer's specifications after installation is completed
   c. Use allen wrench to thread shoulder bolts into inserts (perform in cross X pattern)
      i. Repeat for shoulder bolts attaching frame to linkage arms, installing with the heads of the shoulder bolts on the outside of the frame
      ii. Take care to bring the platform and linkage arms into alignment with the frame at this point in order to balance the linkage system properly and avoid any interference issues
7. Install hydraulic cylinder using cotter pins, washers, and clevis pins
   a. Pin top of cylinder to frame and let hang
   b. Pump the cylinder to the appropriate length to mount inside the platform brackets
   c. Pin the bottom of the cylinder to the platform hydraulic brackets
   d. Adjust platform alignment as necessary while attaching hydraulic cylinder
8. Install pump using appropriate nuts and bolts
   a. Use socket set and/or box/crescent wrenches
9. Zip tie excess hydraulic hoses in optimal position away from user, wheels, handles, etc.
10. Install sheet metal platform surface onto platform frame using appropriate screws
    a. Pre-drill specified hole size for sheet metal screws in platform tube frame
    b. Use driver to install flathead countersunk sheet metal screws
11. Install artificial turf onto sheet metal
    a. Apply carpet tape to platform sheet metal surface and place artificial turf onto tape, taking care to properly align the artificial turf with the platform
12. Install rubber latch onto platform using appropriate screws
    a. Pre-drill specified hole size for sheet metal screws
    b. Use driver to install sheet metal screws
13. Install outrigger clips onto frame using appropriate screws
    a. Pre-drill specified hole size for sheet metal screws
    b. Use driver to install sheet metal screws
14. Install grip tape on support handles and armrest locations
    a. Maintain tension during installation and secure on finishing end with electrical tape
15. Insert tubing end caps in all upwards or side facing open tube ends
16. Inflate tires to approximately 50 psi

The final, fully assembled device is shown in Figure 45. It is important that users familiarize themselves with the device and how to operate it prior to fully using the device. Additional pictures of the final device accompanied by a detailed operator's manual are located in Appendix J.

Figure 45. Fully assembled final device at the senior project expo.

7 Design Verification

A crucial component of the design process is verifying that the design decisions and calculations that were made on paper will be effective in the real world. Many times, issues will arise when going from theoretical calculations based on assumptions to actual use and loading. The following sections discuss the tests performed to ensure the validity of our design.

7.1 Weld Break Tests

To ensure adequate strength of our frame is achieved through welding, we performed several weld break tests after a long time practicing TIG welding aluminum, before moving on to welding the final product. This was done on short corner welded joints, which include the 3 most common types of fillet and butt welds that are found on our frame. To perform the break test, we used a large hydraulic press to break the welds on our test pieces. During these break tests we looked for proper penetration to both sides of the joint and imperfections such as spatter and pockets within the weld. An example of a weld test piece is shown in Figure 46.

Figure 46. Sample weld test piece in hydraulic press.

While this weld looks effective on the exterior, it is difficult to know whether or not proper penetration was achieved. Performing weld break tests allowed the team welder to attain a better feel for the quality of welds produced, and how to adjust his technique to achieve better results. These tests were performed until adequate welds were reliably performed by the team welder to ensure the structural integrity of the device, which took two rounds of tests to achieve. Advice from the Cal Poly Welding Professor, Kevin Williams, was used to alter welding technique for better penetration, and after the second round of tests (doing two test pieces per test round) he gave approval that we were achieving adequate penetration and strength in our welds. A sample of a test piece after being broken from the first and second rounds is shown in Figure 47. In the first round, deformation was observed before the weld fractured and broke. The welds from this round were determined to have poor penetration, as can be seen when looking at the weld material in the first-round picture. It appears that the weld material is simply sitting on top of the base material, not penetrating past the surface. The team welder compensated these results by turning up the amperage and using more pedal to increase the current sent through the weld, and as a result the amount of metal melting and penetrating beneath the surface. Flatter welds that protruded less from the surface were aimed for, as the first round had tall beads, a sign that the metal was not getting hot enough. The second round of break testing showed much better results than the first. The tubing deformed much more significantly before weld fracture than during the first round, a sign of a stronger weld. Additionally, observing the weld metal after breaking the test pieces in the second round showed weld metal penetrating significantly into the base material.

Figure 47. Weld break test pieces from 1st (top) and 2nd (bottom) rounds.

Final results from the weld break test were significant deformation of the aluminum tubing prior to weld fracture/breaking under high hydraulic loads. Unfortunately, no force read-outs were available to determine the point of failure of the welds. Further investigation showed significant penetration along weld beads on both sides of weld joints, and the welds from the second round were deemed strong enough to proceed on to welding the final frame.

7.2 Hydraulic Load Test

After receiving our hydraulic components, we performed initial testing on them in order to ensure functionality of the sub-system. The cylinder and pump were connected with the fittings and hoses, then filled with hydraulic fluid via the pump. For our test, we hung the cylinder from one end and then hung weights from its other end. A load of 160lbs was used due to availability at this time, and was deemed sufficient to assess the system's capability. Before hanging the weights, we began by pumping the pump and cycling the system to get the cylinder moving smooth and consistent. We determined there was too much air in the system and that more hydraulic fluid would need to be added to the system during this testing, which would reduce the number of pumps required to actuate the cylinder. The hydraulic system was able to lift and lower the load through its full range of motion without issue, and we determined that the system should adequately work for our device. The testing apparatus used for this procedure is shown in Figure 48.

Figure 48. Hydraulic load test set-up.

7.3 Wheelchair Brake Tests

A crucial aspect of our device design is that it remains stationary while monoskiers load onto and off the device to and from the slopes and gondola. In order to ensure functionality of device loading, we performed a braking test to confirm that the wheel brakes adequately lock the wheelchair wheels and prevent rotation and thus movement of the device. Pictures of the wheel locking/breaking mechanism in both open and locked positions are shown in Figure 49.

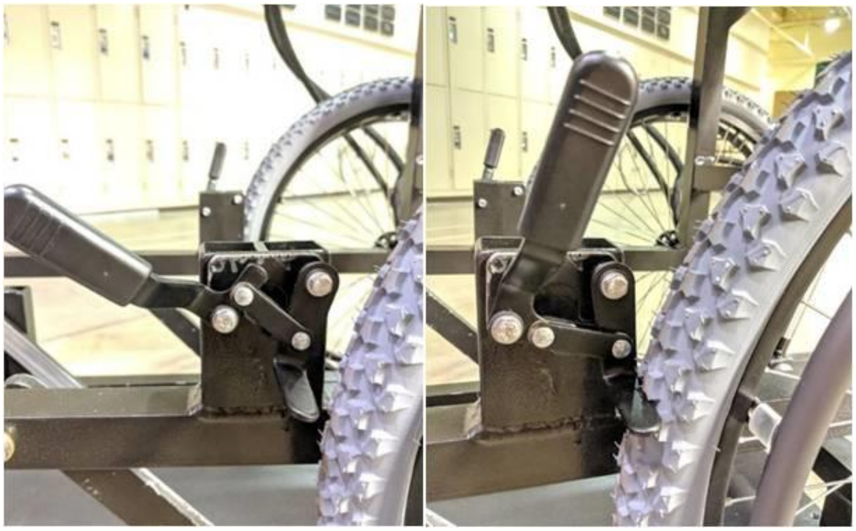


Figure 49. Wheel locks in open (left) and locked (right) positions.

This was done by applying a moderate vertical load on the device of 150lb (one group member) and then applying a more significant horizontal force to simulate a monoskier pulling or pushing themselves on or off the device. The friction between the wheels and ground will be greater as the vertical load is increased, so we used a load on the lower side of our anticipated loads to ensure the brakes would work for a lighter weight monoskier. The brakes lock the wheels firmly in place, and the device remains stably planted when pushed from the front or rear. If pushed from the side in the front of the device, the casters allow the device to swivel. This load is not expected to be seen under normal use. A feature included when designing the device was to allow the caster wheels to come in contact with the front of the platform when the platform is fully lowered on the ground. This limits the amount the device can be pushed around before the casters contact the platform. When the platform is raised, the casters clear it in the wheel cutouts. This feature proved to be effective along with the brakes in limiting the ability of the device to move during loading.

During later ergonomic testing, a test was performed where both brakes were applied while the device was in motion to simulate an emergency stop situation. When this was done, the device quickly came to a full stop as the tires were seized by the wheel locks and prevented from rotating.

7.4 Static Load Test

The purpose of this test is to confirm the structural integrity of the frame, the platform, the linkage arms, and the cylinder. The entire prototype is required for this test, as well as weights up to 400 pounds. Two team members were used for weights, and the platform was set to different positions through its range of motion to ensure it could support the load statically at all positions. The device was able to hold the load steadily at all positions. A small decrease in platform height of approximately 1/2” was observed when the load was applied. This is due to the nature of the pinned linkage system, and is acceptable as our device was designed to lift an extra inch above the maximum required lift height. This aspect of the design acts as a slight suspension system for the device, which makes for a smoother ride while traveling over bumps and rough surfaces.

7.5 Dynamic Load Test

In addition to testing the frame under the static load of the monoskier, we also needed to ensure the frame could withstand the forces applied by the hydraulic cylinder when raising the monoskier. The same load applied in the static load test was used for this test while the hydraulic pump was used to raise the load from the ground to gondola height. The device was able to effectively raise and then lower two team members through the entire range of motion of the device. We found that the hydraulic system still felt somewhat slow going through this process, taking 60 pumps to raise or lower the device. While somewhat slow, the system felt steady and reliable. It was observed that slow and steady pumps are more effective than rapid pumps, as the full pump stroke is not utilized if pumped too quickly. Our recommendation is to perform about 20 pumps to reach ride height of the device, perhaps some more while in the gondola building elevator, and then the remaining amount while in line for or approaching the gondola.

7.6 Ergonomic Testing

In order to assess the general use and functionality of the device, several additional ergonomics and functionality tests were performed using the device. After ensuring the device could safely support the user through the previous tests, we could finally unlock the brakes and take the device out for a spin. We began by raising the platform to ride height and kneeling on the platform to simulate being at the location of where a monoskier's torso would be. In this position we tested the ability of the user to self-propel the device, lock the brakes, and pump the hand pump to raise and lower the platform through its full range of motion. The device was very easy to self-propel and handled surprisingly well given its sheer size. The cart turns on a dime if the rear wheels are spun in opposite directions, allowing the used to do a 180-degree (or more) spin essentially in place. The turn radius is thus the distance between the rear wheel axle and the front of the cart, approximately 35 inches. The ergonomics of the assistant(s) was also tested. The support handles are at the right height for an assistant to help push a monoskier while on the cart if needed, and one can comfortably push the cart around from behind as needed. In practice, the assistant should be careful if the monoskier's ski protrudes far out of the rear of the device where they will be walking. Additionally, it was determined that two assistants could easily lift the device together (one on either side) and roll it forward into or out of a gondola for transport. Due to the size and weight of the device, it was determined that a single person should not attempt to lift the device by themselves. A few of these tests are shown in Figure 50.

Figure 50. Ergonomic tests for assistants and users.

One observation of a negative characteristic of the device was that when pushed from behind by an assistant at *high* speeds, the two frame sides began to resonate at the front of the device, developing a wobble back and forth. This occurred whether or not the device was loaded by a user. This occurs because the only lateral braces on the device are located in the rear due to the nature of the device. This concern was addressed during the design phase and the linkage arms and platform help provide fairly decent lateral support at the front of the device. Resonance developed at high speeds on smooth ground in a long open stretch, and although looking concerning, stability and control were maintained overall. It is important to note that the speeds at which resonance occurred are not likely reachable by a user self-propelling the device, especially when considering the nature of the route they will be traveling through - consisting of rough terrain, tight corners, and short stretches. Considering this information, we determined the issue of resonance to be improbable during normal use of the device, but wanted to make note of its potential. Repeated exposure to such resonance could result in fatigue at the welded cross braces in the rear of the device due to the repeating oscillations, and is thus advised against.

Overall, our device met nearly all of our specifications and functional requirements. The two slight downfalls of the device are its weight, being over 50lbs, and the time required to move the platform through its full range of motion. Although somewhat slow, the time required to pump through the full motion (60 pumps) meets our specification and overall time requirements. The system is at least consistent and reliable if not fast. Although the weight is larger than our initial specification, we believe it will not largely affect the principal users experience as the device is still easy for them to propel under their own power.

7.7 Design Verification Test Results

Table 2 below shows the summary of our test results. We assigned a "pass" grade to all but one test result. The total weight of the device was over 50 pounds, which was higher than we originally planned for. This discrepancy came from our misjudgment of the weight of the hydraulics. The pump and cylinder combined weighed nearly 50 pounds. Our failure to meet our weight requirement stemmed for our limitations in hydraulic pump and cylinder selection. We were not able to obtain a large enough scale to accurately weigh the device, but we estimate that it weighs roughly 75 pounds.

Table 2. Summary of Design Verification Test Results

Test	Result	Pass/Fail
Overall Dimensions	L42" x W28" x H36"	Pass
Turning Radius	35"	Pass
Weight	>50 lb	Fail
Platform Height	0" to 11"	Pass
Hydraulic Loading	Lift & hold 300 lb	Pass
Weld Break Test	Proper weld penetration	Pass
Wheel Brake Test	No slip while locked	Pass
Tip Test	No tip in any direction	Pass

8 Project Management

This project began in January 2018 and culminated with the Project Expo on November 30, 2018. In order to stay on schedule, we used a Gantt chart which can be seen in Appendix K. This allowed us to define each task and assign it a timeline. Mapping out all the tasks together allowed us to efficiently and effectively move towards our end goal.

8.1 Project Timeline

The following list shows all major stages of the project in chronological order.

1. Problem Definition………………………………………………………1/16/18
2. Background Research……………………………………………………1/18/18
3. Technical Requirements…………………………………………………1/25/18
4. **Scope of Work**………………………………………………………2/1/18
5. Brainstorming and Ideation………………………………………………2/8/18
6. Concept Modeling…………………………………………………………2/13/18
7. Concept Prototype & CAD Model…………………………………………3/1/18
8. **Preliminary Design Review**………………………………………………3/10/18
9. **Interim Design Review**..4/10/18
10. Build Structural Prototype..4/17/18
11. **Critical Design Review Presentation**...5/1/18
12. Begin Manufacturing..5/24/18
13. **Manufacturing & Test Review**...6/5/18
14. **Hardware/ Safety Demo**..10/18/18
15. Testing..10/25/18
16. **Expo**..11/30/18

Bold indicates presentation date with DSES

8.2 Process Evaluation

Overall, our team was satisfied with the project process. As expected, the final few weeks before Expo were hectic in getting everything completed. It would have been beneficial to start the manufacturing process earlier, especially for our project, which required significant time and effort in the manufacturing phase. After completing what we thought was our final design in the middle of Spring (2nd) quarter, we discovered a major flaw in the scissor lift design (see section 4.6.3). We were forced to abandon this design and develop a new lifting mechanism and perform a major design overhaul going into the end of May. This took away from time that we could have moved forward and started manufacturing. This was an error on our part, but it could have been minimized by having earlier deadlines and moving the design work and design iterations up to an earlier time in the quarter. The other main factor that slowed us down was the machine shop being closed for the first two weeks of our Fall (3rd) quarter. This was prime manufacturing time that we lost.

We did enjoy the iterative process of this project. There was a lot of focus on brainstorming and developing a wide range of design concepts. This process allowed us to generate many ideas that we wouldn't have come up with otherwise, and eventually culminated in our final design. We were able to take aspects from several design concepts and incorporate them into our final design, which we believe to be a very effective solution to the problem we were given to solve.

9 Conclusion

Over the course of three quarters, the Cal Poly Monoski M.E. Senior Project team worked to develop a solution to a problem presented by Disabled Sports Eastern Sierra (DSES) at Mammoth Mountain. The team set out to design, build, test, and deliver a functional mobility device that would give monoskiers at Mammoth the ability to independently transport themselves through the gondola building and load on and off of the gondola.

The culmination of this project was at the Fall 2018 Cal Poly College of Engineering Student Project Expo. The team was able to successfully complete manufacturing and testing of the mobility cart prior to the expo. After being granted permission to operate the device during the expo, the team revealed the finished mobility cart and demonstrated its capabilities to fellow students, faculty, and project sponsors.

9.1 Accomplishments and Shortcomings

The team was excited to unveil the final result of this design project – a fully functional device that solves the problem at hand and will successfully give monoskiers independence in using the gondola at Mammoth Mountain. The final design and device are the product of a carefully executed design process. Multiple iterations resulted in a design encompassing the best features from all previous concepts. A wheelchair-inspired frame will give monoskiers a familiar platform for transporting themselves through the gondola building. Wheelchair wheels allow the user to easily self-propel the device and wheel locks keep the device stable in position and offer an emergency braking mechanism located ergonomically and conveniently in front of the users hands while propelling themselves with the hand rims. The parallel linkage system allows the platform to lower completely to the ground, offering the easiest possible device loading. When combined with the hydraulic cylinder connecting the frame to the platform, the platform can successfully lift to anywhere between the ground and 11 inches off the ground – 1 inch above the maximum gondola floor height. The manual hand pump allows the user to raise and lower themselves to various heights under their own power. The artificial turf is a lightweight non-damaging material that will allow users to controllably slide on and off of the device and gondola. The outrigger clips offer a straight forward way to hold the user's outriggers during transit. Bicycle handlebar tape successfully cushions the rear support handles and the arm rest locations on the frame where the user's arms may contact the frame during propulsion. The carefully thought-out design was manufactured methodically by the team, 100% in house at the Cal Poly Machine Shops. Tolerances were maintained and resulted in a functional final product that works as it was intended to. The device meets all of the team's original specifications other than the weight limit. The mobility cart passed all testing with flying colors and was easy and enjoyable to propel and maneuver.

After completing the project, the team felt the biggest shortcoming of the final product was the mobility cart's hydraulic system. The hydraulics proved to be heavier than we initially expected or accounted for – roughly 50 pounds for all hydraulic components. Although this made our device heavier than our specified weight limit, no major adversities are noticed as a result of the additional weight, and the mobility cart is still easy to use and effective in transporting its user. Another shortcoming of the hydraulic system is the hand pump being relatively slow to extend and retract the cylinder, translating to more time spent lowering and raising the platform. Although the system is slow, our testing proved it to be consistent and reliable. The hydraulic system can handle our expected loads with no issues, but suffers from insufficient fluid displacement generated by the hand pump, resulting in the slow speeds. For future iterations, we would focus on re-evaluating our current hydraulic system. We would recommend investigating whether an electric hydraulic pump could generate sufficient fluid displacement to efficiently reduce the actuation time of the cylinder. This could potentially reduce the time spent pumping and the weight of the pump, and would eliminate the input force required by the user. Another potential option could be removing the hydraulic system all together and using a linear actuator with a battery instead. Linear actuators contain motors that drive a mechanical lead screw, which in effect extends and retracts a cylinder linearly like a hydraulic cylinder. A viable solution may lay in replacing the hydraulics with a linear actuator, while maintaining the majority of the existing design. This would decrease the weight of the lift system and would remove all safety concerns associated with hydraulics. Although electronics would have to be introduced to the system for these options, a more efficient and user-friendly product would result if successfully achieved. Water and weather-proofing capabilities exist, and it would be feasible to develop an electronic system that could withstand the cold and wet conditions in snowy Mammoth.

Another shortcoming between the device and system proposed is that the mobility cart needs to be transported between the lower and upper gondola stations for monoskiers to use it. The design of the mobility cart is such that it would be more beneficial and effective to have a cart at both the bottom and top stations, so that it would not have to be sent up and down on the gondola. Having two mobility carts would also allow multiple monoskiers to use the gondola in succession rather than having to wait for the cart to come back down the mountain from the previous user. Having a second device for the top station would also give more freedom for a different design. A gas spring, or air shock (similar to in an office chair), could potentially be used to allow users to quickly lower themselves from gondola height down to ride height and the ground. This would be faster than the current device, which requires pumping the hand pump to lower the platform. This will be discussed further in "Next Steps" below.

9.2 Next Steps

Snow has begun to fall and the slopes are open for the Winter season at Mammoth Mountain. The volunteers at DSES are back in the office and on the slopes, and the team is planning to deliver the mobility cart following Fall quarter finals. The team members will personally drive the device to Mammoth, and will give Josh and the other volunteers, monoskiers, and lift operators a walkthrough using the device, explaining its intended features and usage. The team will also deliver several copies of the operator's manual, which also includes maintenance instructions for the device. The operator's manual is shown in Appendix J. After demonstrating and confirming the device's use in the conditions at Mammoth, monoskiers will be able to start using the device to take the gondola to the top of the mountain.

This project would not be what it is without the collaboration between the Cal Poly Monoski M.E. team and the volunteers at DSES. The team hopes to maintain contact with DSES and answer any questions that arise during the initial use of the device. Additionally, the team will help consult with DSES with regards to any damage sustained to the device or maintenance and repairs that need to be performed.

As mentioned previously, having a second device that stays at the top gondola station would make for a more efficient system to transport monoskiers using the gondola. With a device at either station, multiple monoskiers could use the gondola in much quicker succession. If DSES would like to have a second device made according to the same specifications as the first, they could bring the documentation provided by the senior project team in this report to a fabrication shop which would be willing to take on the project. The fabrication shop could also make alterations to the design as discussed in the previous section. Alternatively, DSES could reach back out to the Cal Poly Mechanical Engineering Department if they would like to propose a subsequent senior project to design a device for unloading monoskiers at the top gondola station.

9.3 Final Thoughts

Our team is proud of the outcome of the final product developed. We believe the overall concept and design is practical and will satisfy both DSES and the monoskiers who will use the device in the future. Comprehensive testing and careful consideration during manufacturing and assembly ensured proper function of the device and the meeting of DSES's requirements. Evident by the numerous brainstorming concepts and design iterations, the resulting mobility cart not only carries this group's creativity and attention to detail, but also the determination to provide the best solution possible to the challenge proposed one year ago. We hope that DSES and monoskiers at Mammoth Mountain will be able to enjoy the use of the monoski mobility cart for many years to come.

Acknowledgements

We would like to thank DSES for their cooperation, support, and allowing us to visit Mammoth Mountain. The staff of the organization were very welcoming, and the information gathered on the trip proved to be invaluable to our intuition in developing our designs. We would especially like to thank Josh Pighetti and Maggie Palchak of DSES. Their insight and feedback were instrumental in guiding our design process. We look forward to the delivery of the product and the use of it by monoskiers for many seasons to come.

The team would like to express their gratitude to Kevin Williams, the Cal Poly IME Department welding instructor, for his consultations regarding TIG welding the aluminum frame and for allowing the team to use his jigging table and welding facilities during the manufacturing of the device. Additionally, the team would like to extend their appreciation to Eric Pulse, the Mustang '60 Machine Shop Manager, along with all of the student technicians who supervise and keep our students working safely.

Finally, we would like to thank our senior project advisor, Dr. Brian Self. His mentorship and guidance were extremely beneficial towards each step of the design process, from beginning to end.

References

[1] Phone interview with Josh Pighetti, Mammoth Mountain Snowboard and Ski Instructor

[2] Kraisser, Andreas. *Monoski » Alois Praschberger - No Limits for Disabled People*, www.praschberger.com/en/bilder-gallery-seiten/monoski/.

[3] Borgetto, Marc. "Snowheel Gondola Ski Cart." *AdaptiveSkiing.net*,adaptiveskiing.net/ adaptive-skiing-equipment/lift-snow-access/item/snowheel-gondola-ski-cart.

[4] "Sommeraktivitäten." *Monoskikurs - Gondel*, www.monoskikurs.de/liftfahren/gondel/.

[5] "Snow Skiing Accessories: Monohauler." *HOC*, www.teamhoc.com/snow-skiing-accessories-monohauler.php.

[6] "2018 Luggie Standard Scooter." *Luggie Scooters*, www.luggie-scooters.com/luggie-standard-scooter/?gclid=CjwKCAiAqIHTBRAVEiwA6TgJw-Ct7a10VBN3LQAHVWf7bK7WAVngIQB0ibFw-H4zj1BIb0jcL0w8GRoCgLgQAvD_BwE.

[7] "Sit-Ski." *DisabledGear.com*, disabledgear.com/pages/sit-ski.

[8] Professional Ski Instructors of America and American Association of Snowboard Instructors. *PSIA-Rocky Mountain-AASI ADAPTIVE EXAM GUIDE for MONO-SKI*. October 25th, 2013.

[9] Mulroy, Sarah J., Hatchett, Valerie, Eberly, Valerie J., Haubert, Lisa L., Conners, Sandy, Requejo, Phillip S.. Shoulder Strength and Physical Activity Predictors of Shoulder Pain in People With Paraplegia From Spinal Injury: Prospective Cohort Study. American Physical Therapy Association. Volume 95, Number 7. and February 17, 2015. Page 9.

[10] Valeria, Rosso, Lindinger, Stefan, Linnamo, Vesa, Vanlandewijck, Yves, Rapp, Walter, Gastaldi, Laura. *Trunk kinematics during cross country sit-skiing ergometry*. Journal of Electromyography and Kinesiology.

[11] Valeria, Rosso, Lindinger, Stefan, Linnamo, Vesa, Vanlandewijck, Yves, Rapp, Walter, Gastaldi, Laura. *Biomechanics of simulated versus natural cross-country sit skiing*. Journal of Electromyography and Kinesiology. November 5, 2016.

[12] Niku, Saeed. *Creative Design of Products and Systems*. John Wiley & Sons, Inc., 2009

[13] Department of Justice. *2010 ADA Standards for Accessible Design*. Department of Justice, September, 15, 2010.

[14] US Patent No. 6,036,202, March 14, 2000

[15] US Patent No. US2016/0144882 A1, May 26, 2016

[16] US Patent No. Des. 380,991, July 15, 1997

[17] US Patent No. 5,156,226, October 20, 1992

List of Appendices

Appendix A – QFD House of Quality

Appendix B – Decision Matrices

Decision Matrix 1a: Concepts for Loading onto the Gondola

Criteria:	Time	Energy Required	Difficulty (UI)	Complexity	Mobility	Cost	Size	
Weights:	3	4	4	3	5	2	2	**Total Weighted Score**
Existing: Utility Cart w/ Ramp	0	0	0	0	0	0	0	**0**
Ramp into gondola	0	1	1	0	1	0	0	**12**
Device rolls directly into gondola (like Stretcher)	1	1	0	-1	0	-1	0	**1**
Platform Raised to Gondola w/ Wheels	1	0	-1	-1	1	-1	-1	**-3**
Air Suspension	1	0	1	-1	0	-1	-1	**0**
Scissor lift (Hydraulic Pump)	0	0	1	-1	0	-1	-1	**-3**
Car Jack	0	0	-1	-1	0	-1	-1	**-11**
Bike Crank	-1	0	-1	0	0	0	0	**-7**
Ratchet Lifting Device	-1	0	0	0	0	0	0	**-3**
Triangle wheels (Tri-wheel)	1	1	0	-1	1	-1	0	**6**
Direct Transfer from platform into gondola	0	1	-1	1	0	1	0	**4**

Decision Matrix 1b: Concepts for Propulsion

Criteria:	Time	Energy Required	Difficulty (UI)	Complexity	Mobility	Cost	Size	
Weights:	3	4	4	3	5	2	2	**Total Weighted Score**
Existing: Utility Cart w/ Ramp	0	0	0	0	0	0	0	**0**
Wheelchair Device	0	1	1	0	1	0	0	**12**
Electric Motor	1	1	1	-1	1	-1	-1	**8**
Outriggers	-1	-1	-1	0	-1	1	0	**-13**
Bike Crank	1	0	1	-1	1	0	0	**9**
Regular Tank Tracks with motor	1	1	1	-1	1	-1	0	**10**
Gas Motor	1	1	0	-1	1	-1	-1	**4**
Electric Assist	1	1	1	-1	1	-1	0	**10**

Decision Matrix 1c: Concepts for Device Loading

Criteria:	Time	Energy Required	Difficulty (UI)	Complexity	Mobility	Cost	Size	
Weights:	3	4	4	3	5	2	2	**Total Weighted Score**
Existing: Utility Cart (manually lift them on)	0	0	0	0	0	0	0	**0**
Ramp on Pivot Point	1	1	1	-1	1	-1	0	**10**
Permanent ramp on cart	1	0	1	1	-1	1	-1	**5**
External ramp for loading to device height	1	1	1	1	-1	1	1	**12**
Device that lowers to ground height	0	0	0	-1	0	-1	0	**-5**
Ramp that pulls out from device and folds down	0	0	-1	-1	1	-1	1	**-2**

Decision Matrix 2: Overall Designs

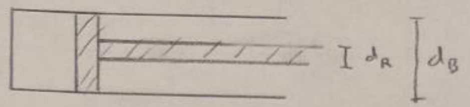
Criteria:	Device Loading Time	Gondola Loading Time	User Energy Required	Required Assistance	Difficulty (UI)	Complexity	Mobility	Cost	Size	
Weights:	4	3	4	3	4	3	5	2	3	**Total Weighted Score**
Wheelchair w/ small pivot point ramp	5	2	4	3	5	4	4	4	4	**114**
Wheelchair w/ large pivot point ramp	4	3	2	4	1	3	2	4	3	**73**
Wheelchair + detachable cart	4	4	3	4	3	2	3	3	3	**88**
Stretcher w/ Wheelchair wheels	4	4	3	4	2	1	3	2	3	**79**
Cart w/ Bike Crank	4	3	3	2	1	1	1	2	3	**62**

Decision Matrix 3: Concepts for Lifting Mechanism

Criteria:	Time	User Energy Required	Difficulty (UI)	Manufacturing Complexity	Mobility	Cost	Reliability/Maintenance	
Weights:	2	5	4	3	3	2	4	**Total Weighted Score**
Linkage system with ratchet & pawl, torsion spring, and user doing tricep dip	5	1	2	2	5	5	5	74
Air shocks ("gas springs") with user doing tricep dip	5	1	2	4	5	4	4	74
Hydraulic scissor lift, hand pump actuated	4	4	4	2	2	1	5	78
Linear actuators vertical lift (battery powered)	3	5	5	4	4	2	1	83
Pneumatic scissor lift w/ air compressor/tank	3	4	2	1	1	1	1	46
Pneumatic Cylinder vertical lift w/ hand pump	1	2	4	3	4	3	4	71

Appendix C – Hand Calculations

HYDRAULIC CALCS

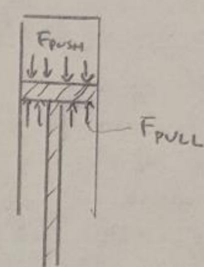


MAXIM CYLINDER 6FWX2

10" STROKE
BORE Ø: $d_B = 3''$
ROD Ø: $d_R = 1.5''$
MAX PRESSURE: 3000 PSI

MAX PUSH FORCE:

$$F_{PUSH} = PA$$
$$= \left(3000 \frac{lb_f}{in^2}\right) \frac{\pi}{4} (3\ in)^2$$
$$\boxed{F_{PUSH} = 21{,}200\ lb_f}$$



MAX PULL FORCE:

$$F_{PULL} = PA$$
$$= \left(3000 \frac{lb_f}{in^2}\right) \frac{\pi}{4} \left(3 in^2 - 1.5 in^2\right)$$
$$\boxed{F_{PULL} = 15{,}900\ lb_f}$$

ENERPAC P-84 HAND PUMP:

DISP./STROKE (1ST STAGE) = 1.00 IN^3

CYLIDER EXTENSION (PUSH) PER STROKE:

$$\text{DISPLACEMENT} = \frac{\text{VOLUME DISP.}}{\text{AREA}} = \frac{1\ in^3}{\frac{\pi}{4}(3\ in)^2} = 0.141\ in$$

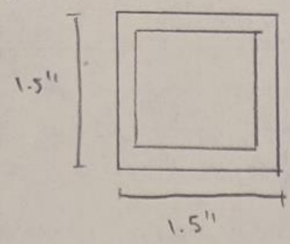
∴ TO REACH FULL EXTENSION (10 in): $\frac{10\ in}{0.141\ in} = 71$ pumps

CYLINDER RETRACTION (PULL) PER STROKE:

$$\text{DISP.} = \frac{\text{VOLUME DISP.}}{\text{AREA}} = \frac{1\ in^3}{\frac{\pi}{4}(3 in^2 - 1.5 in^2)} = 0.189\ in$$

∴ TO FULLY RETRACT (10 in): $\frac{10\ in}{0.189\ in} = 53$ pumps

ALUMINUM SQUARE TUBING



$\frac{1}{8}$" thickness

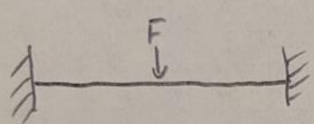
$E = 10{,}000$ ksi

$$I = \frac{bh^3 - (b-2t)(h-2t)^3}{12}$$

$$\boxed{I = 0.2184 \text{ in}^4}$$

LOOKING AT CROSSBAR DEFLECTION.

MODEL AS FIXED BEAM



$F = 300$ lbf
(ASSUMED MAX LOAD)

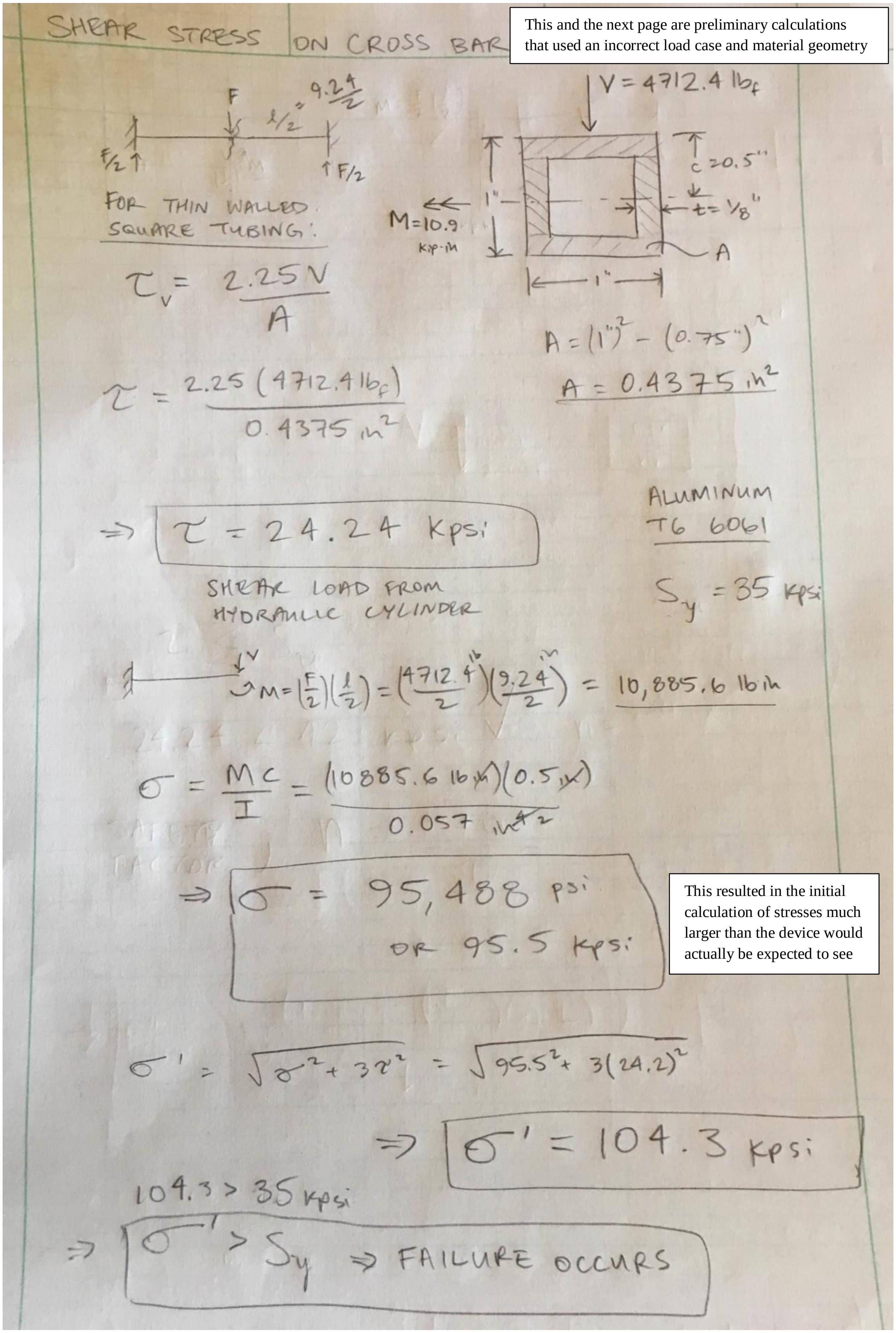
$$y_{max} = \frac{FL^3}{192EI}$$

$$= \frac{(300 \text{ lbf})(18 \text{ in})^3}{192\left(10\times10^6 \frac{\text{lbf}}{\text{in}^2}\right)(0.2184 \text{ in}^4)}$$

$$\boxed{y_{max} = 0.0042 \text{ in}}$$

SMALL DEFLECTION ACCEPTABLE

This and the next page are preliminary calculations that used an incorrect load case and material geometry



SHEAR STRESS ON CROSS BAR

FOR THIN WALLED SQUARE TUBING:

$$\tau_v = \frac{2.25V}{A}$$

$$A = (1")^2 - (0.75")^2$$

$$A = 0.4375\ in^2$$

$$\tau = \frac{2.25(4712.4\ lb_f)}{0.4375\ in^2}$$

$$\Rightarrow \tau = 24.24\ Kpsi$$

SHEAR LOAD FROM HYDRAULIC CYLINDER

ALUMINUM T6 6061

$$S_y = 35\ Kpsi$$

$$M = \left(\frac{F}{2}\right)\left(\frac{\ell}{2}\right) = \left(\frac{4712.4\ lb}{2}\right)\left(\frac{9.24\ in}{2}\right) = 10{,}885.6\ lb\ in$$

$$\sigma = \frac{Mc}{I} = \frac{(10885.6\ lb\ in)(0.5\ in)}{0.057\ in^4}$$

$$\Rightarrow \sigma = 95{,}488\ psi \text{ OR } 95.5\ Kpsi$$

This resulted in the initial calculation of stresses much larger than the device would actually be expected to see

$$\sigma' = \sqrt{\sigma^2 + 3\tau^2} = \sqrt{95.5^2 + 3(24.2)^2}$$

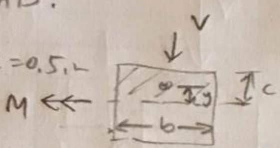
$$\Rightarrow \sigma' = 104.3\ Kpsi$$

104.3 > 35 Kpsi

$$\Rightarrow \sigma' > S_y \Rightarrow \text{FAILURE OCCURS}$$

USE SOLID 1" BAR INSTEAD.

$A = 1\ in^2,\ b = 1\ in,\ c = 0.5\ in$



$\tau_v = \frac{VQ}{Ib}$

$I = \frac{1^4}{12} = 0.083\ in^4$

$\tau = \frac{(4712.4\ lb_f)(0.125\ in^3)}{(0.083\ in^4)(1\ in)}$

$Q = \Sigma yA$
$= \left(\frac{c}{2}\right)(0.5)(1)\ in^3$
$= (0.25)(0.5)\ in^3$
$Q = 0.125\ in^3$

$\tau = 7097\ psi$

$\sigma = \frac{Mc}{I} = \frac{(10{,}885.6\ lb \cdot in)(0.5\ in)}{0.083}$

$\sigma = 65{,}576\ psi$ OR $65.6\ kpsi$

STILL FAILS. TRY 1.25".

$\tau = \frac{(4712.4)\overbrace{\left(\frac{1.25}{4}\right)}^{y}\overbrace{(1.25)\left(\frac{1.25}{2}\right)}^{A}}{\underbrace{\left(\frac{1.25^4}{12}\right)}_{I}\underbrace{(1.25)}_{b}} = 4524\ psi$

$\sigma = \frac{\overbrace{(10885.6)}^{M}\overbrace{\left(\frac{1.25}{2}\right)}^{c}}{\left(\frac{1.25^4}{12}\right)} = 33440.6\ psi$

$\sigma' = \sqrt{33.4^2 + 3(4.52^2)} = 34.3\ kpsi$

$34.3 < 35\ kpsi \Rightarrow \sigma' < S_y$ DOESN'T FAIL

SAFETY FACTOR, $n = \frac{S_y}{\sigma'} = \frac{35}{34.3}$

Again, incorrect due to previously mentioned reasons. 1.25” solid bar NOT necessary, and a safety factor of 3.4 was achieved, as will be shown, in order to protect our users

$n = 1.02$ → OK, HYD. CYLINDER MAX LOAD IS KNOWN

FRAME STRESS ANALYSIS 1/2

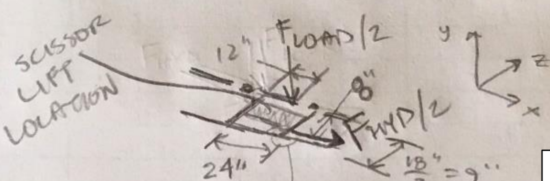
CHECK THAT 1" × 1/8" THICK SQUARE TUBING WILL SUPPORT MAXIMUM ANTICIPATED LOAD.

LOOK AT CRITICAL STRESS LOCATION:

↳ WHERE LATERAL MEMBERS MEET FRAME SIDES AT BASE OF DEVICE (LARGEST BENDING MOMENTS AND TORSION)

$S_U = 42\ kpsi$

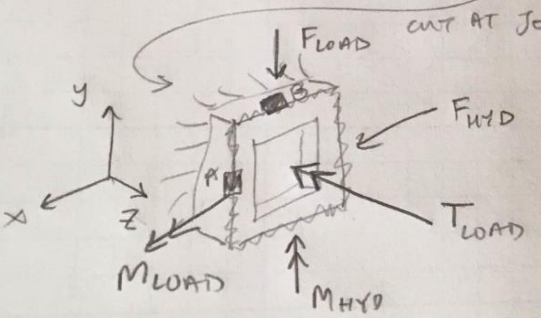
CONSERVATIVE: ASSUME MONOSKIER MAX LOAD ACTING OVER REAR WHEELS, WITH MAX LOAD OF HYD. CYL. ACTING AS POINT LOAD TRANSFERRED TO FRAME. ASSUME LOAD IS TRANSFERRED TO FRONT JOINTS, ONLY SO THAT REAR IS UNLOADED (WORST CASE). ANALYZE ONE OF FRONT JOINTS WITH HALF OF LOADS APPLIED. HYD. LOAD TRANSFERRED TO 1" FROM SIDE.



$F_{LOAD} = 300\ lb_f$

$F_{HYD} = 4712\ lb_f$

Proper load (F_{load}) now being used



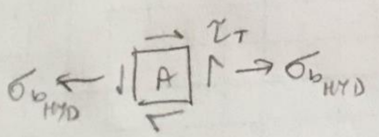
$T_{LOAD} = F_{LOAD}/2\ (12") = \frac{300\ lb}{2}(12") = 1800\ lb\cdot in$

$M_{LOAD} = \frac{F_L}{2}(9") = \frac{300}{2}\ lb(9") = 1350\ lb\cdot in$

$M_{HYD} = \frac{F_{HYD}}{2}(1") = \frac{4712\ lb_f(1")}{2} = 2356\ lb\cdot in$

NEGLECT SHEAR FORCES COMPARED TO BENDING/TORSION.

$M_{HYD} > M_{LOAD}$ SO LOOK @ [A]



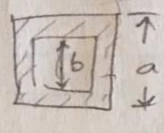
$\sigma_b = \frac{Mc}{I} = \frac{(2356\ lb\cdot in)(0.5\ in)}{0.057\ in^4}$ ← FROM PREV CALCS

$\Rightarrow \sigma_b = 20,666.73\ lb/in^2$

OR $\boxed{\sigma_b = 20.7\ kpsi}$

2/2

$$\tau = \frac{Tr}{J}$$



$$J = \frac{(a^4 - b^4)}{6} = \frac{(1^4 - 0.75^4)\ in^4}{6}$$

$$J = 0.114\ in^4$$

$$\tau = \frac{(1800\ in \cdot lb)(0.5\ in)}{0.114\ in^4} \Rightarrow \tau = 7894.7\ lb/in^2$$

$$\tau_T = 7.89\ kpsi$$

COMBINED LOADING

$$\sigma' = \sqrt{\sigma^2 + 3\tau^2} = \sqrt{(20.7)^2 + 3(7.89)^2}\ kpsi$$

$$\Rightarrow \sigma' = 24.8\ kpsi$$

$\sigma' < S_y$ ✓

NO FAILURE

$$n = \frac{S_y}{\sigma'} = \frac{35\ kpsi}{24.8\ kpsi}$$

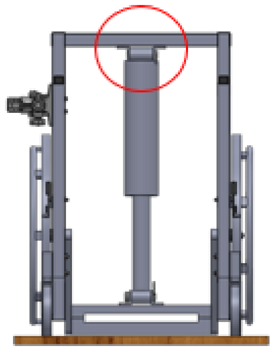
$$\Rightarrow S.F.,\ n = 1.41$$

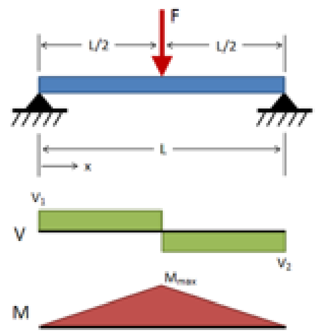
Procured material properties have S_y = 40ksi, thus n = 1.61

The previous calculations were revised for 1.5" x 1/8" thick square aluminum tubing with a maximum applied force of 750 lbf by the hydraulic cylinder. These calculations are summarized by the critical stress analysis shown on our project expo poster below. The pages following consider the loading of several other critical components including the hydraulic brackets, linkage arms, and platform.

Critical Stress Analysis

Critical stress location is at center of cross brace supporting hydraulic cylinder





Beam conservatively assumed to be simply supported (pinned-pinned) to account for any deflections within frame.

Maximum applied force is 750 lb_f with selected hydraulic cylinder and pump.

For 1.5" x 1/8" thick 6061-T6 Aluminum square tubing (S_y = 40 kpsi):

$$M_{max} = \frac{FL}{4} = \frac{(750\,\mathrm{lb_f})(18in)}{4} = 3375\ \mathrm{lb \cdot in}$$

$$\tau_v = \frac{2.25 \times V}{A_c} = \frac{2.25 \times 375\mathrm{lb_f}}{(1.5\mathrm{in}^2 - 1.25\mathrm{in}^2)} = 1227\ \mathrm{psi}$$

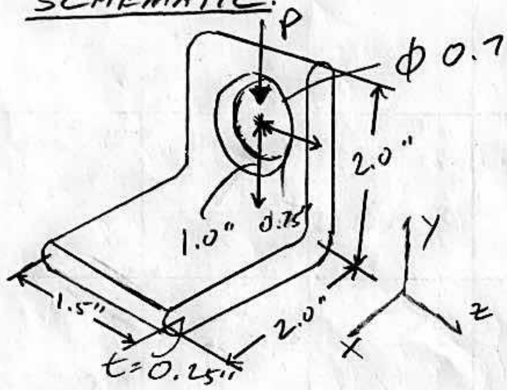
$$\sigma_b = \frac{Mc}{I} = \frac{3375\mathrm{lb \cdot in} \times 0.75\mathrm{in}}{\left(\frac{1.5\mathrm{in}^4 - 1.25\mathrm{in}^4}{12}\right)} = 11{,}589\ \mathrm{psi}$$

$$\sigma' = \sqrt{\sigma_b{}^2 + 3\tau_v{}^2} = \sqrt{(11{,}589\mathrm{psi})^2 + 3(1227\mathrm{psi})^2} = 11{,}782\ \mathrm{psi}$$

Safety Factor: $$n = \frac{S_y}{\sigma'} = \frac{40{,}000\mathrm{psi}}{11{,}782\mathrm{psi}} = 3.4$$

ME404	PROJECT HAND CALCULATIONS	AARON KAN

SCHEMATIC:



MATERIAL: 6061-T6

ADDITIONAL CONCERNS:

- DEFLECTION FROM ΔT

GIVEN:

$P = 750\ lbf/2 = 375\ lbf$ +/- FOR DIFFERENT CASES

$E = 10000\ ksi$ $G = 3770\ ksi$ → ASM inc.

$\sigma_{yr} = 45000\ psi$

$\nu = 0.33$

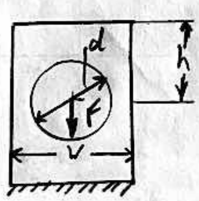
FIND:

σ_{max}, ε_{max}

ASSUME:

PIN LOADING FIG. A-15-12 IN SHIGLEY'S
WELDS ARE STRONGER THAN ALUMINUM
(FIXED AT BOTTOM END)

SKETCH W/ ASSUMPTIONS



W/ t, THICKNESS

FROM SHIGLEY'S

$\sigma_0 = F/A$

WHERE $A = (w-d)t$

CONT'D

$\sigma_{MAX} = \sigma_0 K_t$

LOOK UP K_t @

$\frac{h}{w} = \frac{1.0}{1.5} = 0.6667$

$\frac{d}{w} = \frac{0.75}{1.5} = 0.50$

$K_t \approx 2.5$ DUE TO CLEARANCE + 50% $K_t = 3.75$

$A = (w - d)t$

$= (1.5 - 0.75)(0.25)$

$= 0.1875\ in^2$

$\sigma_0 = \frac{375\ lbf}{0.1875\ in^2}$

$= 2000\ psi$

$\sigma_{MAX} = 3.75(2000\ psi)$

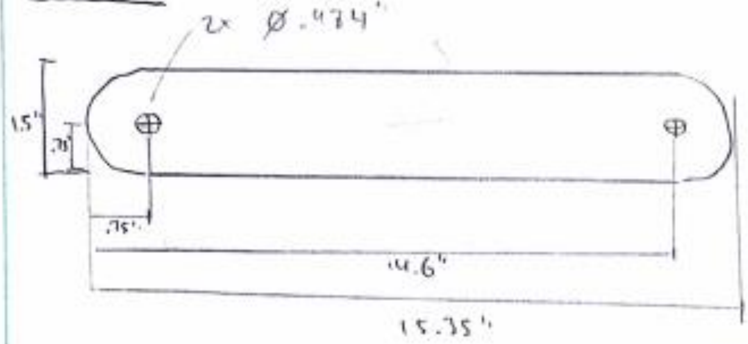
$\sigma_{MAX} = 7500\ psi < \sigma_{y_{AL}} = 45000\ psi$

$\varepsilon_{MAX} = \frac{\sigma_{MAX}}{E_{AL}}$

$\varepsilon_1 = \frac{7500\ psi}{10000\ ksi}$

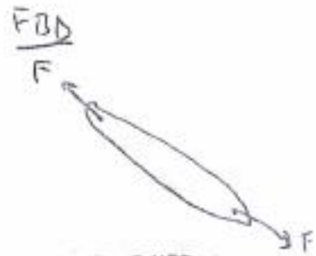
$\varepsilon_{MAX} = 750 \times 10^{-6}$

LINKAGE



6061 T6 Aluminum
0.75" thickness

$E = 10 \times 10^3$ ksi
$\nu = 0.33$
$\sigma_{yield} = 45{,}000$ psi



F = 2435 lb_f
(from previous hand calc for static load)

For stress concentration factor K_t
Shigleys Fig A-15-12

$\sigma_{max} = K_t \sigma_0$

d = 0.484"
w = 1.5"

$A = (w-d)t$
$= (1.5 - .484)(1.5)$
$= 1.524\ in^2$

$\sigma_0 = \frac{F}{A}$
$= \frac{2435\ lb_f}{1.524\ in^2}$
$\sigma_0 = 1598$ psi

$\frac{h}{w} = \frac{0.75}{1.5} = 0.5$

$\frac{d}{w} = \frac{0.484}{1.5} = 0.323$

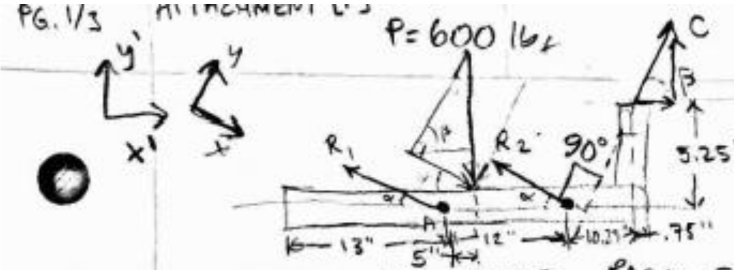
$\rightarrow K_t = 3.9$

$\sigma_{max} = (3.9)(1598\ psi)$
$= 6231$ psi $< \sigma_{yield}$

F = 2435 comes from the static analysis on the following page, and is the maximum load experienced in an individual linkage member:
F = R_1/2 = 4870/2 = 2435 lb

PG. 1/3 ATTACHMENT C-3

PLATFORM HAND CALCS CRAIG MILLER

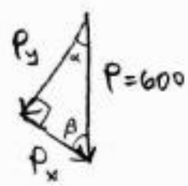


$\alpha + \beta = 90°$ $(\perp)$

$\alpha = 9.52°$

$\beta = 80.48°$

SET UP AXES PARALLEL TO REACTIONS R_1, R_2, C — ALL 2-FORCE MEMBERS



$P \sin\alpha = P_x = 600 \sin(9.52°) = 99.24$ lbf

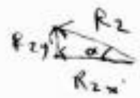
$P \cos\alpha = P_y = 600 \cos(9.52°) = 591.74$ lbf

$\Sigma F_x = 0: \quad R_1 + R_2 = 99.24$ lbf

$\Sigma F_y = 0; \quad$ **$C = 591.74$ lbf**

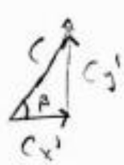
$\Sigma M_A = 0: \quad -600\,\text{lbf}(5") + 0.1654 R_2 (12") - 97.87(5.25") + 583.57(22.25") = 0$

$(-3000) \qquad (-513.82) \qquad (12984.43)$



$R_{2y'} = R_2 \sin\alpha = 0.1654 R_2$

ONLY VERT. COMPONENT IN y' DIRECTION CREATES MOMENT



$C_{x'} = C \cos\beta = .1654\, C = 97.87$ lbf

$C_{y'} = C \sin\beta = .9862\, C = 583.57$ lbf

$-3000 + 1.985 R_2 - 513.82 + 12984.43 = 0$

$R_2 = \dfrac{3000 - 12984.43 + 513.82}{1.985} = \dfrac{-9470.61}{1.985}$

$R_2 = -4771.1$ lb

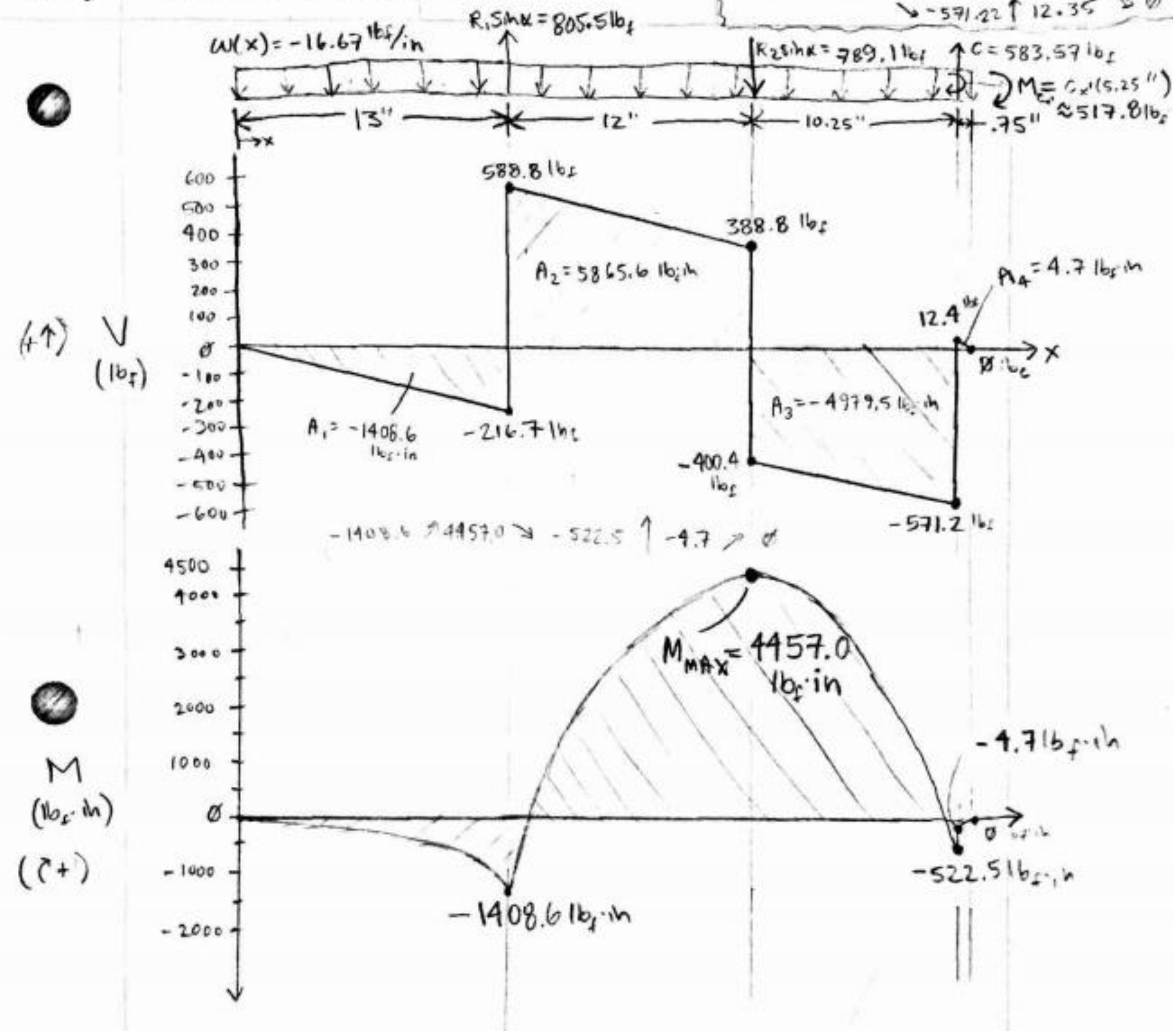
$R_1 = 99.24 + 4771.1$ lb

$R_1 = 4870.3$ lbf

R1 & R2 are split between two linkage members on either side, so these values are divided in half to analyze an individual member under the worst load case

PG. 2/3 PLATFORM HAND CALCS

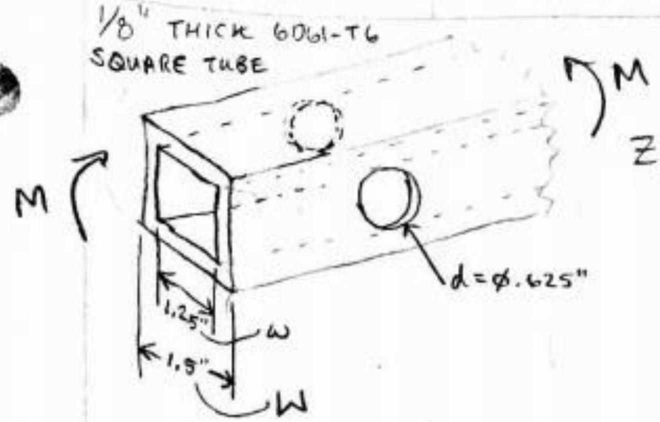
Ø ↘ -216.71 ↑ 588.79 ↘ 388.75 ↓ -400.35 ↘ -571.22 ↑ 12.35 ↘ Ø



SO, MAX MOMENT IS AT PINNED HOLE OF R_2.

∴ LOOK AT STRESS @ R_2 @ x = 25"

PG. 3/3 PLATFORM HAND CALCS



SECTION MODULUS

$$Z_{NET} = \frac{1}{6W}(W^4 - \omega^4)$$

$$= \frac{1}{6(1.5")}(1.5"^4 - 1.25"^4)$$

$$\Rightarrow Z_{NET} = 0.291 \text{ in}^3$$

CLOSEST STRESS CONCENTRATION FACTOR CHART IS SHIGLEY'S TABLE A-16 FOR APPROX. STRESS-CONC. FACTOR K_t FOR BENDING OF A ROUND TUBE W/ A TRANSVERSE ROUND HOLE.

↳ GOING TO USE THIS AND ATTEMP TO ADJUST FOR SQUARE TUBE W/ TRANSVERSE HOLE

NOMINAL BENDING STRESS IS $\sigma_0 = \frac{M}{Z_{NET}}$

FOR $\frac{a}{D} = \frac{d}{W} = \frac{0.625}{1.5} = 0.4167$

↳ OFF CHART → TRY EXTRAPOLATING

& $\frac{d}{D} = \frac{\omega}{W} = \frac{1.25}{1.5} = 0.833$

↳ B/W 0.6 & 0.9 → INTERPOLATE

USING MODIFIED TABLE & CREATING A CHART TO INTERPOLATE & EXTRAPOLATE ON EXCEL, I APPROXIMATED THE STRESS CONCENTRATION FACTOR TO BE $K_t = 2.8$

FOR $M_{MAX} = 4457.0$ lb$_f$·in APPLIED AT X=25", SHEAR & MOMENT LOADING IS SPLIT EVENLY BETWEEN THE LEFT & RIGHT SIDES OF THE PLATFORM.

∴ USE $M = 2228.5$ lb$_f$·in

$$\text{SO, } \sigma_0 = \frac{M}{Z_{NET}} = \frac{2228.5 \text{ lb}_f\cdot\text{in}}{0.291 \text{ in}^{3}} = 7658.1 \text{ psi}$$

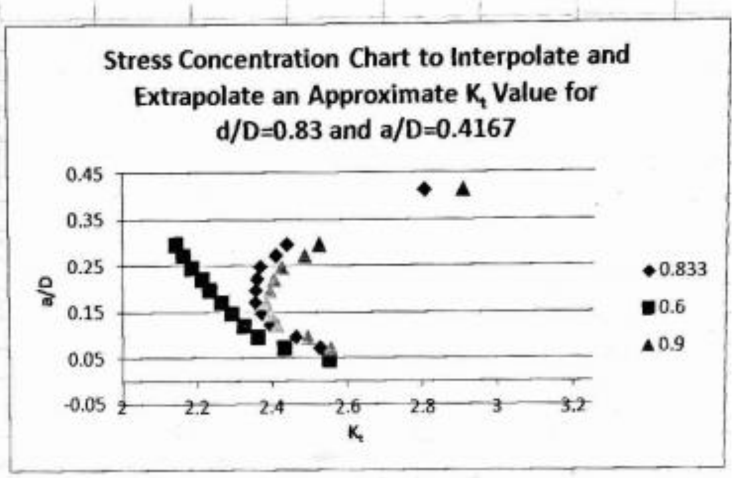
$$\text{THEN: } \sigma_{MAX} = K_t \sigma_0 = 2.8(7658.1 \text{ psi})$$

$$\Rightarrow \boxed{\sigma_{MAX} = 21.44 \text{ ksi}}$$

$\sigma_{MAX} < S_y$

21.44 ksi < 40 ksi ✓

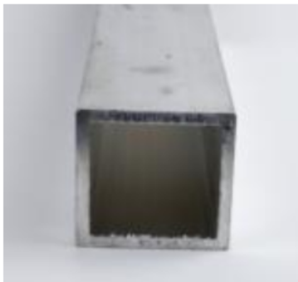
	A	B	C	D
1	d/D	0.9	0.6	0.833
2	a/D	Kt	Kt	Kt (interp)
3	0.05	2.63	2.55	2.612133
4	0.075	2.55	2.43	2.5232
5	0.1	2.49	2.36	2.460967
6	0.125	2.41	2.32	2.3899
7	0.15	2.39	2.29	2.367667
8	0.175	2.38	2.26	2.3532
9	0.2	2.39	2.23	2.354267
10	0.225	2.4	2.21	2.357567
11	0.25	2.42	2.18	2.3664
12	0.275	2.48	2.16	2.408533
13	0.3	2.52	2.14	2.435133
14	0.4167	2.9		2.8
15				
16				
17				
18				



Appendix D – Procurement Summary & Vendor Specification Sheets

Assembly	Part Number	Item	Vendor	Cost
Frame	F-001 - F-012 R-001 - R-007	Aluminum square tube	Online metals	$299.60
	B-001	Aluminum brackets	Online metals	$122.53
	R-004	Aluminum sheet metal	Online metals	
	M-001	Aluminum bar (linkages)	Online metals	
	J-002	--Shoulder bolts (8)	McMaster-Carr	$60.32
	M-002	--Threaded Inserts (8)	McMaster-Carr	$79.36
	n/a	--Threaded Install Tool	McMaster-Carr	$9.26
	J-001	Flanged sleeve bearings (16)	McMaster-Carr	$71.52
	J-003	Sheet metal screws	McMaster-Carr	$6.67
Wheels	W-002	Rear wheels (2)	Melrose Wheelchairs	$269.00
	W-001	--Axles (2)	DMEHub	$55.00
	W-003	--Axle receivers (2)	Melrose Wheelchairs	$45.00
	W-004	--Axle receiver jam nuts (2)	WingTactical	$23.90
	D-001	--Brake assembly (2)	Vitality Medical	$38.59
	J-005	----Brake bolts	McMaster-Carr	$7.11
	C-001	Caster wheel assembly (2)	Quickie Wheelchairs	$280.00
	J-004	--Caster Bolts	McMaster-Carr	$5.88
Hydraulics	H-003	Hydraulic cylinder	Grainger	$233.00
	B-002	--Clevis pin - long	McMaster-Carr	$5.16
	B-004	----Sleeve Bearings (2)	McMaster-Carr	$10.06
	B-005	--Clevis pin - short	Mcmaster-Carr	$14.50
	B-007	----Sleeve Bearing	McMaster-Carr	$5.65
	n/a	--Clevis pin washers	Miners Ace	$9.52
	H-001	Hydraulic hand pump	Ebay	$579.99
	J-006	Pump Bolts	McMaster-Carr	$4.52
	J-007	Pump Nuts	McMaster-Carr	$7.44

	H-007	Short hose	Grainger	$53.75
	H-006	Long hose	Grainger	$56.50
	n/a	Hose adapters - cylinder a (2)	Grainger	$10.80
	H-004	Hose adapters - cylinder_b (2)	McMaster-Carr	$11.76
	H-005	Hose adapters - cylinder_c (2)	Hydraulics Direct	$4.22
	H-002	Hose adapters -pump (2)	Grainger	$35.10
	n/a	Hydraulic Oil	Grainger	$51.00
	n/a	Thread sealant	Amazon	$8.43
Misc.	n/a	Tube end caps	McMaster-Carr	$9.98
	R-008	Turf for platform/gondola	Amazon	$15.67
	n/a	Carpet tape	Amazon	$4.96
	n/a	Hand grip tape	Amazon	$19.98
	J-008	Outrigger holder clips	McMaster-Carr	$10.14
	n/a	Outrigger clip screws	McMaster-Carr	$6.91
	n/a	Rubber strap for platform	McMaster-Carr	$26.87
	n/a	Primer and paint	Home Depot	$55.45
			Total tax & shipping	425.75
			TOTAL COST	**$3,050.85**



EXTRUDED ALUMINUM SQUARE TUBE 6061 T6

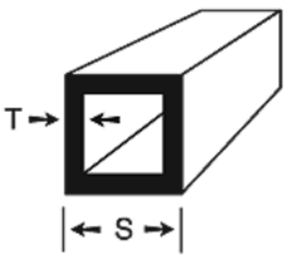
Part #: 14466

Aluminum Square Tube 6061-T6 (1.5" x 0.125") is frequently found in aircraft construction. Alloy 6061-T6 has a high strength-to-weight ratio, making it ideal for large parts that need to be very light, such as the plane's wings and fuselage.

View our "Guide to Aluminum" for available grades, shapes and additional information.

Mill Test Reports are available on this item and can be selected during the checkout process.

Material Meets These Standard(s): AMS- 4150, AMS-QQ-A 200/8, ASME-SB- 221, ASTM B-221, ASTM B221-14



DIMENSIONS	Weight/Lineal Foot: 0.8064 lbs
Dimension Name	Value
Height	1.5"
Wall	0.125"
Internal Height	1.25
	View Other Sizes

EXTRUDED STRUCTURAL ALUMINUM BARE ANGLE 6061 T6

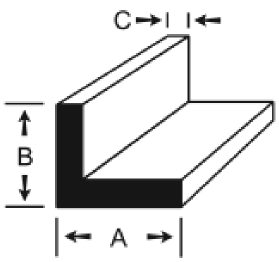
Part #: 989

Aluminum Angle 6061-T6 (2" x 2" x .25") is the most commonly used aluminum for structural applications. It has above average corrosion resistance, good machinability, and is excellent for welding.

View our "Guide to Aluminum" for available grades, shapes and additional information.

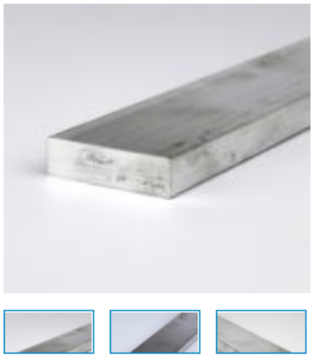
Mill Test Reports are available on this item and can be selected during the checkout process.

Material Meets These Standard(s): AMS-QQ-A 200/8, ASTM B-221, ASTM B308



DIMENSIONS	Weight/Lineal Foot: 1.13 lbs
Dimension Name	Value
Leg 1	2"
Leg 2	2"
Wall	0.25"
Inside Radius	0.25
Leg Radius	0.125
	View Other Sizes

⚠ **WARNING:** Cancer and Reproductive Harm - www.P65Warnings.ca.gov



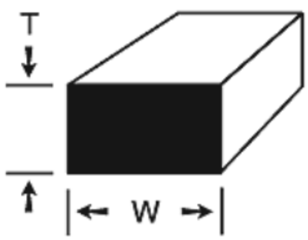
EXTRUDED ALUMINUM BARE RECTANGLE 6061 T6511

Part #: 1178

Aluminum Rectangle Bar 6061 (0.75" x 1.5") is the most commonly used aluminum for structural applications. 6061 has above average corrosion reisistance, good machinability, and is excellent for welding.

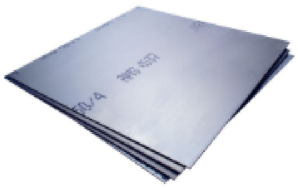
View our "Guide to Aluminum" for available grades, shapes and additional information.

Mill Test Reports are available on this item and can be selected during the checkout process.



Material Meets These Standard(s): ASTM B221

DIMENSIONS	Weight/Lineal Foot: 1.323 lbs
Dimension Name	Value
Thickness	0.75"
Width	1.5"
	View Other Sizes



ALUMINUM BARE SHEET 6061 T6

Part #: 1246

Aluminum Sheet 6061 T6 Bare 0.125", also referred to as structural aluminum, is the most versatile of heat treatable aluminum alloys and an excellent choice for its good corrosion resistance, strength, machinability and weldability. This aluminum 6061 sheet has a T6 temper, is artificially aged and heat treated for increased strength, and is a general-purpose material used in a variety of applications.

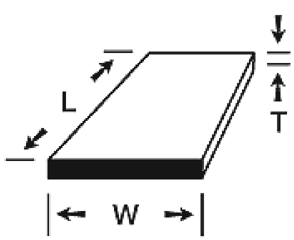
Properties: good formability, good weldability, good machinability, superior corrosion resistance, heat treatable, medium-high strength
Common Uses: structural siding, fabrication, aerospace parts, welding, machining
Environments / Industries: manufacturing, aerospace, outdoor, transportation, automotive

PVC 1 SIDE?" That refers to a PVC coating the mill adds for protective purposes. It peels off after you get everything in place.

View our "Guide to Aluminum" for available grades, shapes and additional information.

Mill Test Reports are available on this item and can be selected during the checkout process.

Material Meets These Standard(s): AMS 4027, AMS-QQ-A 250/11, ASTM B209



DIMENSIONS	Weight/Square Foot: 1.77 lbs
Dimension Name	Value
Thickness	0.125"
	View Other Sizes

Phillips Flat Head Screws for Sheet Metal

Super-Corrosion-Resistant 316 Stainless Steel, Number 10 Size, 1/2" Long

Packs of 50

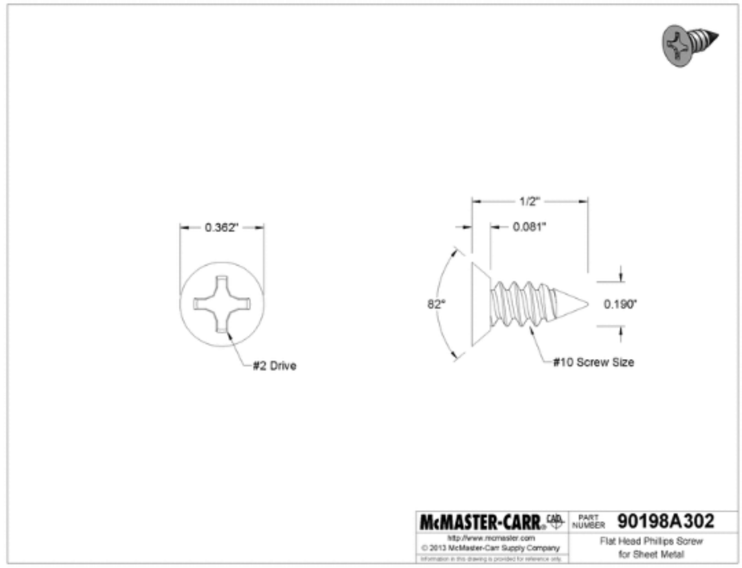
ADD TO ORDER

In stock
$8.67 per pack of 50
90198A302

Material	316 Stainless Steel
Screw Size	No. 10
Screw Size Decimal Equivalent	0.190"
Length	1/2"
Flat Head Profile	Undercut
Head	
Diameter	0.362"
Height	0.081"
Drive Size	No. 2
Drive Style	Phillips
Drill Bit Size	No. 21
Drill Bit Size Decimal Equivalent	0.159"
Maximum Drilling Thickness	0.025"
Approximate Threads per Inch	12
Thread Direction	Right Hand
Threading	Fully Threaded
Tapping Method	Thread Forming
Tapping Screw Type	A/AB
Head Type	Flat
Countersink Angle	82°
Tip Type	Pointed
Shank Cross Section	Round
System of Measurement	Inch
For Use In	Sheet Metal
RoHS	Compliant

More corrosion resistant than 18-8 stainless steel screws, these have excellent resistance to chemicals and salt water and may be mildly magnetic. They're beveled under the head for use in countersunk holes. Screws penetrate 0.025" and thinner sheet metal. Length is measured from the top of the head.

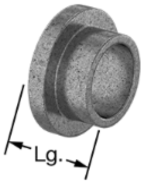
Undercut screws allow for more threading.



The information in this 3-D model is provided for reference only. Details

Oil-Embedded Sleeve Bearing with Certification

Flanged for 1/2" Shaft Diameter & 5/8" Housing ID, 3/8" Long



Each

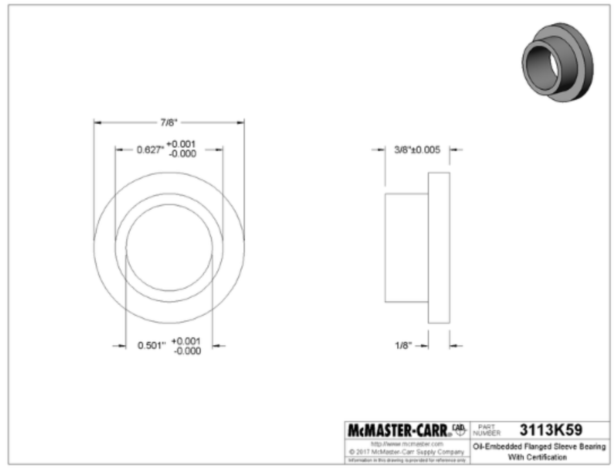
ADD TO ORDER

In stock
$4.47 Each
3113K59

Bearing Type	Plain
Plain Bearing Type	Flanged
For Load Direction	Combined Radial and Thrust
Material	SAE 841 Bronze
For Shaft Diameter	1/2"
ID	0.501"
ID Tolerance	0" to 0.001"
For Housing ID	5/8"
OD	0.627"
OD Tolerance	0" to 0.001"
Length	3/8"
Length Tolerance	-0.005" to 0.005"
Flange OD	7/8"
Flange Thickness	1/8"
Dynamic Radial Load Capacity	370 lbs. @ 120 rpm
Dynamic Thrust Load Capacity	730 lbs. @ 120 rpm
Lubrication	Lubricated
Lubrication Method	Embedded
Lubricant	SAE 30 Oil
For Shaft Type	Round
Shaft Mount Type	Slip Fit
Temperature Range	-35° to 300° F
Certification	Material Certificate with Traceable Lot Number and Test Report
RoHS	Compliant

These bearings come with a traceable lot number and material test report. They are also known as Oilite® bearings; startup friction causes them to release a thin layer of oil on the bearing's surface.

Note: Dynamic load capacity is the maximum load a bearing can withstand at a given shaft speed. If your application's load and speed requirements are below the values listed, the bearing will work.



The information in this 3-D model is provided for reference only. Details

316 Stainless Steel Thread-Locking Shoulder Screw

1/2" Shoulder Diameter, 1-3/4" Shoulder Length, 3/8"-16 Thread

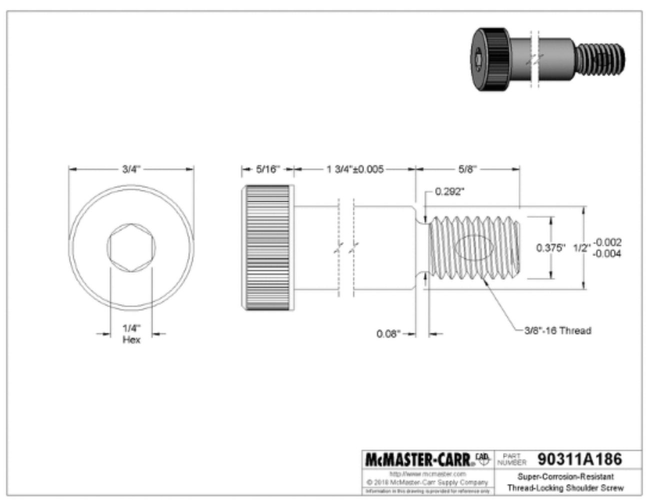
Each

ADD TO ORDER

In stock
1-4 Each $8.86
5 or more $7.54
90311A186

Shoulder Fit	Standard
Shoulder Diameter	1/2"
Shoulder Diameter Tolerance	-0.004" to -0.002"
Shoulder Length	1 3/4"
Shoulder Length Tolerance	-0.005" to 0.005"
Thread Size	3/8"-16
Screw Size Decimal Equivalent	0.375"
Thread Type	UNC
Thread Spacing	Coarse
Thread Fit	Class 3A
Thread Direction	Right Hand
Thread Length	5/8"
Head Diameter	3/4"
Head Height	5/16"
Material	316 Stainless Steel
Hardness	Rockwell B79
Tensile Strength	70,000 psi
Minimum Shear Strength	35,000 psi
Locking Type	Thread Locker
Thread Locker	
Type	Nylon Patch
Temperature Range	-50° to 250° F
Head Type	Socket
Socket Head Profile	Standard
Head Texture	Knurled
Drive Style	Hex
Drive Size	1/4"
Specifications Met	ASME B18.3
System of Measurement	Inch
RoHS	Compliant

A locking element on the threads adds friction to resist loosening. More corrosion resistant than 18-8 stainless steel shoulder screws, these have excellent resistance to chemicals and salt water. They may be mildly magnetic. A standard shoulder with an undersized tolerance allows them to fit most machinery and equipment. They're often used to guide or align components, and as an axle or pivot point.



The information in this 3-D model is provided for reference only. Details

316 Stainless Steel Easy-to-Install Thread-Locking Insert

3/8"-16 Thread Size

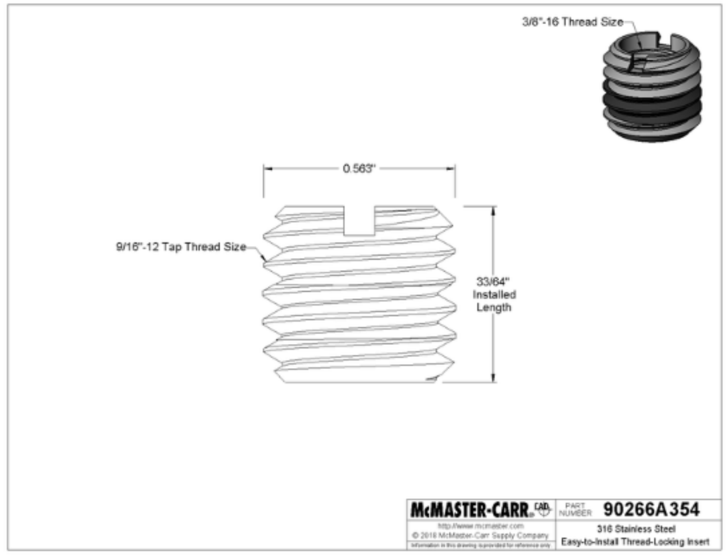
Each

ADD TO ORDER

In stock
$9.92 Each
90266A354

For Use In	Metal
Threaded Insert Type	Thread Locking
Material	316 Stainless Steel
Passivation	Not Passivated
System of Measurement	Inch
Thread Direction	Right Hand
Thread Size	3/8"-16
Thread Type	UNC
Thread Spacing	Coarse
Thread Fit	Class 2B
Thread-Locking Insert Wall Style	Thick
For Tap Type	Standard (UN)
For Tap Thread Size	9/16"-12
Installed Length	33/64"
For Min. Material Thickness	33/64"
Drill Bit Size	31/64"
For Maximum Hole Diameter	31/64"
End Type	Open
External Locking Type	Thread Locker
External Thread Locker Type	Loctite® Adhesive
Thread Locker Temperature Range	-65° to 300° F
Begins to Harden	10 min.
Reaches Full Strength	72 hrs.
Drive Style	Slotted
Tensile Strength	30,000 psi
RoHS	Compliant
Related Product	Installation Bits

These inserts are the most corrosion-resistant thread-locking inserts we offer. Also known as E-Z Lok, they use Loctite® adhesive to keep them in place. The adhesive reaches full strength after 72 hours. All have thick walls for strength and can be used to fill a large hole with stripped threads. They may be mildly magnetic. Installation requires a drill bit and a standard tap. Then set the insert with an installation bit, a slotted screwdriver, or a bolt with two nuts.



The information in this 3-D model is provided for reference only. Details

Installation Bit

for 3/8, M10, & 7/16 Thread Size Slotted-Drive Insert

Each

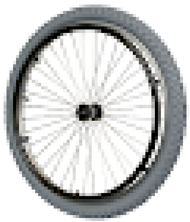
ADD TO ORDER

In stock
$9.26 Each
94110A160

For Threaded Insert Type	Tapping, Thread Locking
For System of Measurement	Inch, Metric
For Thread Direction	Right Hand
For Thread Size	3/8"-16, 3/8"-24, M10
For Drive Style	Slotted
Shank Type	Hex for Power Tools
Hex Shank Size	3/8"
RoHS	Not Compliant

For fast installation, use these installation bits with power drills and drill presses.

Home > Parts & Accessories > Wheels > PACKAGE DEAL - 24" Off Road Wheels with Tires and Hand Rims



PACKAGE DEAL - 24" Off Road Wheels with Tires and Hand Rims

Starting at: $269.00

24" x 1.95" Off road alloy wheel with alloy hub and steel spokes. This wheel has a radial spoke pattern for good sideways rigidity and light weight.

They come with off road tires and hard anodized hand rims. Black vinyl hand rims are available for an extra $55.

These wheels are light and strong and are ideal for off road use.

Price is for a pair of wheels. Axles are not included.

- Shipping Weight: 9.4lbs

Options:

Hand Rim Anodized Hand Rim

Add to Cart
Write a Review

Dome Button Quick Release Axle

Larger Photo

Like 0 Share

Dome Button Quick Release Axle

★★★★★ 4 Reviews

Dome Button Quick Release Axle

Low Overhead = Low Prices. That's how we roll!

~~Retail Price: $36.00 /Each~~

Our Price: $27.50 /Each

You Save: $8.50

Helpful Tip: Click on the Technical Specs tab for help with selection

Need Advice? Wheelchair Experts on Staff (855) 339.5155

Free Shipping on orders of $99+

Availability:: Usually Ships in 24 Hours

Product Code: NES-DBQRA

Size*:

4" (min usable length) ▾

Product Summary | Technical Specs | Warranty Info

The Dome Button Stainless Steel Quick Release Axle utilizes the big button style release for ease of use and it also acts as a "hub cap" to reduce water and debris from entering the wheel hub. Not to mention, it's pretty convenient to have extra axles if you have more than one set of wheels. Plus, you're always covered by the Limited Lifetime warranty offered on all quick release axles purchased through DME Hub.

Product Details:

- **Stylish Dome Release Button Design**
- Stainless steel won't rust or corrode
- Fits chairs with 1/2" diameter axles
- Silver anodized button
- Offered in 5 lengths
- Limited lifetime warranty

Home > Parts & Accessories > Axles > Receiver 1/2" with Flange

Receiver 1/2" with Flange

$22.50

Receiver with Flange for the 1/2" axle, 2" length, 5/8 - 18 thread. This fits into the camber-bar or axle plate and the 1/2" axle goes through the wheel (bearings) and fits into the receiver. 2" is our standard receiver length.

Price is for a single (1) Receiver only, the nut and washer are not included. You can order multiple Receivers when viewing your shopping cart.

- Product Code: 30242
- Shipping Weight: 0.09lbs

Add to Cart
Write a Review

JP ENTERPRISES, INC.

JP Enterprises 5/8-24 Jam Nut

★★★★★ (1 product review)

Product Code: JPE-JPJN-58S-750-SS
Shipping: CALCULATED AT CHECKOUT

$11.95 LOW STOCK

* Finish:

Stainless Steel

1 ADD TO CART SAVE TO WISHLIST

MPN: JPJN-58B.750 / JPJN-58S.750

FEATURES:

- Re-usable
- Easier to timing your muzzle device

SPECIFICATIONS:

- **Material:** Steel
- **Weight:** 0.2 oz.
- **Finish:** Black (Phosphate) or Raw Stainless Steel
- **Thread:** 5/8"-24

COMPATIBILITY:

- Any barrel with 0.750" outer diameter with 5/8"-24 TPI (Threads Per Inch)

Wheelchair Wheel Lock and Brake Assembly

By MedLine

Wheelchair Wheel Lock and Brake Assembly is a replacement part for the **Excel 2000 Wheelchair**. Made of metal, it is strong and durable for repeated use. It is also compatible with other Medline wheelchairs, including bariatric wheelchairs. It comes as a pair, one for each side and is easy to use. Simply pull to lock the brakes and push to release. Easy to install, this brake replacement is a more affordable option than buying a whole new wheelchair.

Product Features and Benefits

- Universal for MedLine Wheelchairs
- Durable
- Made of Metal
- Pull Lock System

Product Specifications

- Manufacturer: MedLine
- Weight: 1.5 lbs
- Dimensions: 5.5 x 6 x 4.4 In (L x W x H)

316 Stainless Steel Hex Head Screw

Super-Corrosion-Resistant, M6 x 1 mm Thread, 70 mm Long

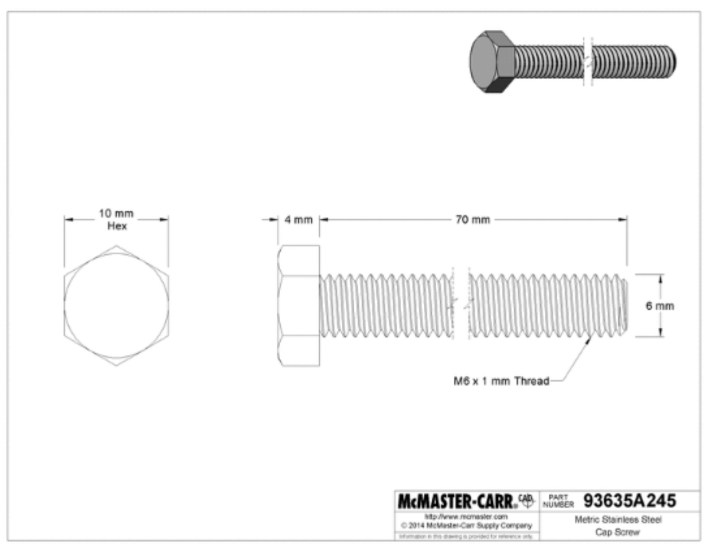
Packs of 10

ADD TO ORDER

In stock
$7.11 per pack of 10
93635A245

Thread Size	M6
Thread Pitch	1 mm
Length	70 mm
Threading	Fully Threaded
Head Width	10 mm
Head Height	4 mm
Material	316 Stainless Steel
Hardness	Not Rated
Tensile Strength	100,000 psi
Thread Type	Metric
Thread Spacing	Coarse
Thread Fit	Class 6g
Thread Direction	Right Hand
Head Type	Hex
Hex Head Profile	Standard
Drive Style	External Hex
Specifications Met	DIN 933
System of Measurement	Metric
RoHS	Compliant

More corrosion resistant than 18-8 stainless steel screws, these screws have excellent resistance to chemicals and salt water. They may be mildly magnetic. Length is measured from under the head.

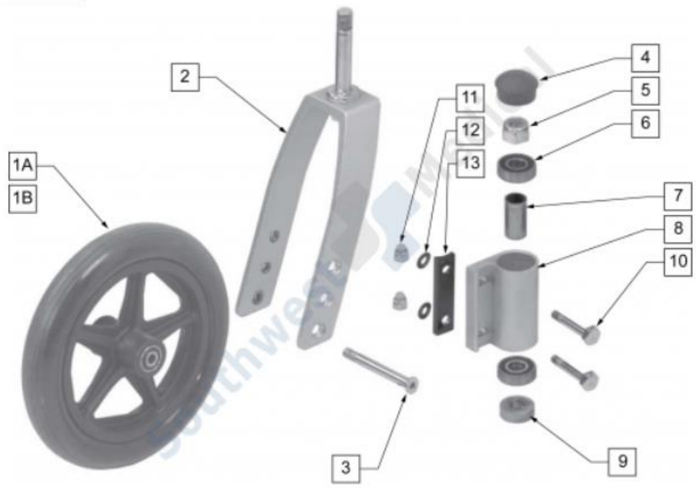


The information in this 3-D model is provided for reference only. Details

Caster Fork Assembly 8"x1" Wheel Black 1/2" Bearing Invacare Style Package of 2

HRP

Name: Breezy Ultra 4: 8" Caster, Fork And Hardware
Manufacturer: Sunrise Medical



4, 6 – 8, 10 – 13	BZU6051	CASTER HOUSING ASSM W/BEARINGS	KT	$50.00

316 Stainless Steel Hex Head Screw

Super-Corrosion-Resistant, M6 x 1 mm Thread, 50 mm Long

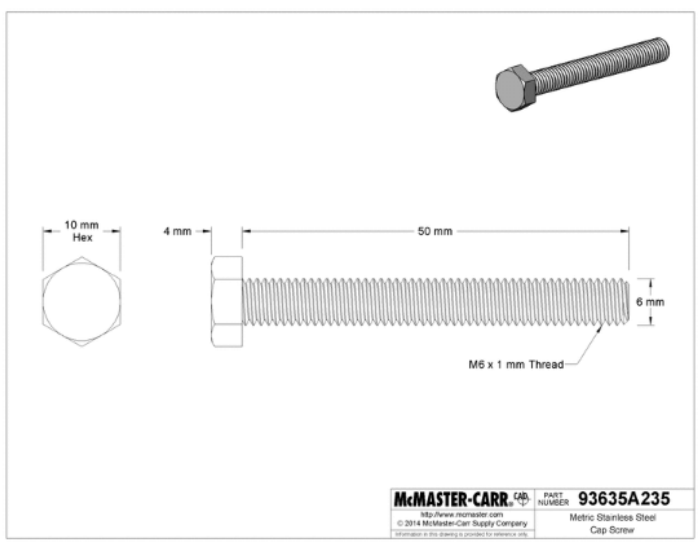
Packs of 10

ADD TO ORDER

In stock
$5.88 per pack of 10
93635A235

Thread Size	M6
Thread Pitch	1 mm
Length	50 mm
Threading	Fully Threaded
Head Width	10 mm
Head Height	4 mm
Material	316 Stainless Steel
Hardness	Not Rated
Tensile Strength	100,000 psi
Thread Type	Metric
Thread Spacing	Coarse
Thread Fit	Class 6g
Thread Direction	Right Hand
Head Type	Hex
Hex Head Profile	Standard
Drive Style	External Hex
Specifications Met	DIN 933
System of Measurement	Metric
RoHS	Compliant

More corrosion resistant than 18-8 stainless steel screws, these screws have excellent resistance to chemicals and salt water. They may be mildly magnetic. Length is measured from under the head.



The information in this 3-D model is provided for reference only. Details

MAXIM

Double Acting Welded Style Hydraulic Cylinder; 3 Bore Dia. (In.), 10 Stroke (In.)

Item # **6FWX2** Mfr. Model # **288-336** Catalog Page # **2477** UNSPSC # **27121602**

Technical Specs

Item	**Hydraulic Cylinder**	Temp. Range	**-20 to 220**
Type	**Double Acting Welded Style**	Piston Material	**Ductile Iron**
Bore Dia. (In.)	**3**	Piston Rod	**High Tensile Strength**
Stroke (In.)	**10**	Tubes	**Precision Honed Steel**
Rod Dia. (In.)	**1-1/2**	Rod Seal	**Polypak**
Retract (In.)	**18**	Tie Rods	**High Tensile**
Port Size (SAE)	**#8**	Finish	**Black**
Max. Pressure (PSI)	**3000**	Pin Dia.	**1"**

Zinc-Plated Steel Clevis Pin

3/4" Diameter, 4-3/4" Usable Length

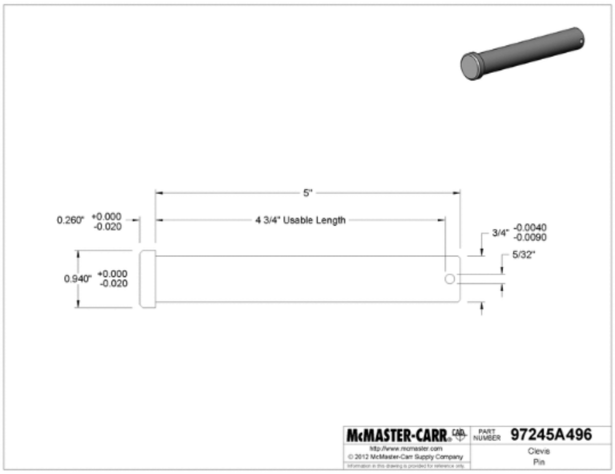
Packs of 1

ADD TO ORDER

In stock
$5.16 per pack of 1
97245A496

Diameter	3/4"
Usable Length	4 3/4"
Length	5"
Head Diameter	15/16"
Head Height	1/4"
Through Hole Diameter	5/32"
For Maximum Cotter Pin Diameter	1/8"
Diameter Tolerance	-0.009" to -0.004"
Head Diameter Tolerance	-0.02" to 0"
Head Height Tolerance	-0.02" to 0"
Material	Zinc-Plated Steel
Min. Hardness	Rockwell B80
Pin Type	Clevis
System of Measurement	Inch
RoHS	Compliant

The zinc-plated finish gives these pins good rust resistance. Steel pins are an economical choice with good strength. With a head on one end and a through-hole for locking on the other, they offer all the advantages of bolts and rivets, plus quick installation and removal. A cotter pin (sold separately) is required to lock them in place.



The information in this 3-D model is provided for reference only. Details

High-Load Oil-Embedded SAE 863 Bronze Sleeve Bearing

for 3/4" Shaft Diameter and 1" Housing ID, 1-3/4" Long

Each

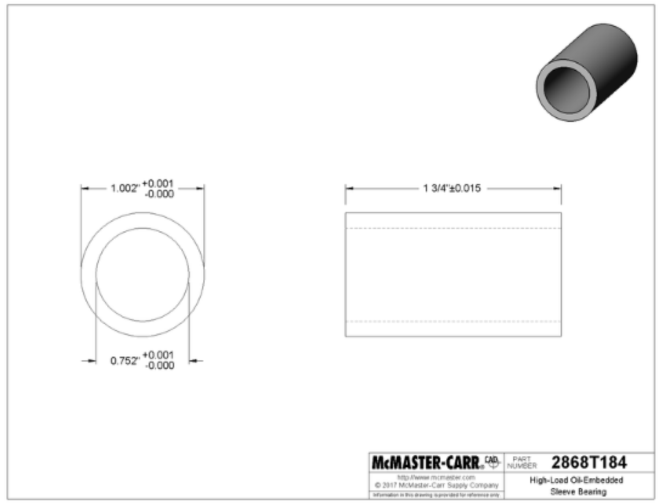
ADD TO ORDER

In stock
$5.03 Each
2868T184

Bearing Type	Plain
Plain Bearing Type	Sleeve
For Load Direction	Radial
Material	SAE 863 Bronze
For Shaft Diameter	3/4"
ID	0.752"
ID Tolerance	0" to 0.001"
For Housing ID	1"
OD	1.002"
OD Tolerance	0" to 0.001"
Length	1 3/4"
Length Tolerance	-0.015" to 0.015"
Dynamic Radial Load Capacity	3,850 lbs. @ 60 rpm
Lubrication	Lubricated
Lubrication Method	Embedded
Lubricant	SAE 90 Oil
For Shaft Type	Round
Shaft Mount Type	Slip Fit
Temperature Range	-15° to 300° F
RoHS	Compliant

Increased iron content makes these bearings stronger and more resistant to shock loads than standard oil-embedded bearings; however they operate at lower speeds. Startup friction causes them to release a thin layer of oil on the bearing's surface. Color is silver because of the iron.

Note: Dynamic load capacity is the maximum load a bearing can withstand at a given shaft speed. If your application's load and speed requirements are below the values listed, the bearing will work.



The information in this 3-D model is provided for reference only. Details

18-8 Stainless Steel Clevis Pin

with Hairpin Cotter Pin, 3/4" Diameter, 2-3/4" Usable Length

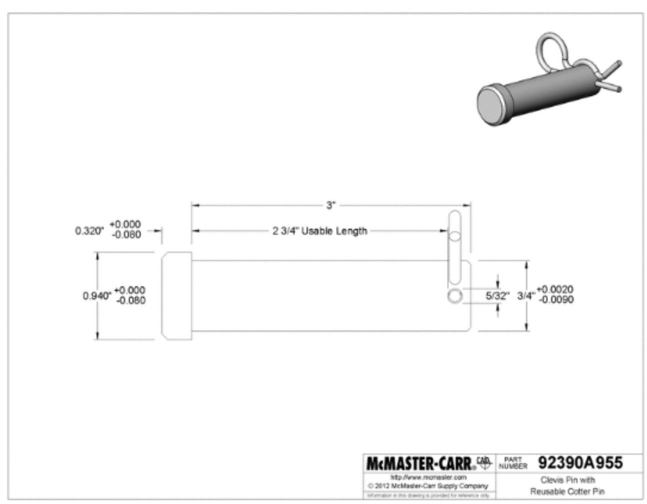
Packs of 1

ADD TO ORDER

In stock
$13.75 per pack of 1
92390A955

Diameter	3/4"
Usable Length	2 3/4"
Length	3"
Head Diameter	15/16"
Head Height	5/16"
Through Hole Diameter	5/32"
For Maximum Cotter Pin Diameter	1/8"
Diameter Tolerance	-0.009" to 0.002"
Head Diameter Tolerance	-0.08" to 0"
Head Height Tolerance	-0.08" to 0"
Material	18-8 Stainless Steel
Min. Hardness	Rockwell B80
Hairpin Cotter Pin Material	Stainless Steel
Pin Type	Clevis
System of Measurement	Inch
RoHS	Compliant

These pins are more corrosion resistant than steel pins. An alternative to bolts and rivets, they have a head on one end, a through-hole for locking on the other, and a reusable hairpin cotter pin for quick installation and removal. Pins may be mildly magnetic.



The information in this 3-D model is provided for reference only. Details

High-Load Oil-Embedded SAE 863 Bronze Sleeve Bearing

for 3/4" Shaft Diameter and 1" Housing ID, 2" Long

Each

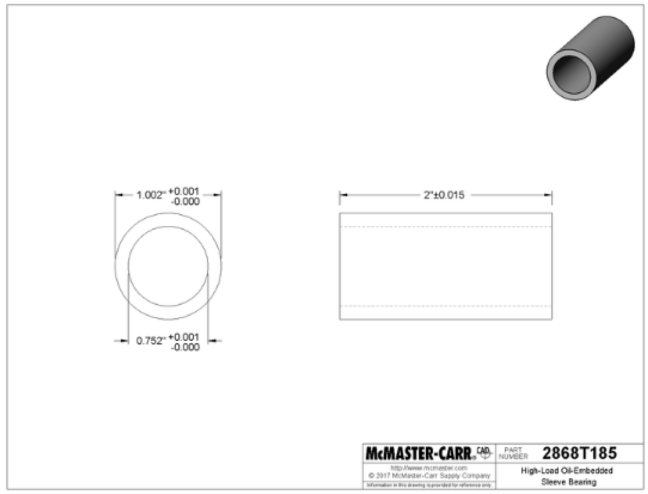
ADD TO ORDER

In stock
$5.65 Each
2868T185

Bearing Type	Plain
Plain Bearing Type	Sleeve
For Load Direction	Radial
Material	SAE 863 Bronze
For Shaft Diameter	3/4"
ID	0.752"
ID Tolerance	0" to 0.001"
For Housing ID	1"
OD	1.002"
OD Tolerance	0" to 0.001"
Length	2"
Length Tolerance	-0.015" to 0.015"
Dynamic Radial Load Capacity	4,450 lbs. @ 60 rpm
Lubrication	Lubricated
Lubrication Method	Embedded
Lubricant	SAE 90 Oil
For Shaft Type	Round
Shaft Mount Type	Slip Fit
Temperature Range	-15° to 300° F
RoHS	Compliant

Increased iron content makes these bearings stronger and more resistant to shock loads than standard oil-embedded bearings; however they operate at lower speeds. Startup friction causes them to release a thin layer of oil on the bearing's surface. Color is silver because of the iron.

Note: Dynamic load capacity is the maximum load a bearing can withstand at a given shaft speed. If your application's load and speed requirements are below the values listed, the bearing will work.



The information in this 3-D model is provided for reference only. Details

ENERPAC P84 Hydraulic Hand Pump NICE! Double acting 2 Speed US Made!

Condition: **Used**
"*Excellent used condition, tested and the pump quickly built PSI to 10,000 PSI and checked, both*"
… Read more

Sold for: **US $579.99**
$53 for 12 months *

Already paid? Go to your eBay Bucks - Activity View to see your Bucks.

Shipping: **$82.07** Standard Shipping | See details
Item location: Verdunville, West Virginia, United States
Ships to: United States and many other countries | See details

Delivery: Estimated on or before **Wed. Dec. 05** to 93401

Payments: PayPal, VISA, MasterCard, American Express, Discover

PayPal CREDIT
*$53 for 12 months. Minimum purchase required. Apply Now | See terms

ENERPAC P84 Hand Pump, 2 Speed, 10, 000 psi, 134 cu in

ENERPAC

Item Specifics

Height (In.)7-5/8

ItemHydraulic Hand Pump

Length (In.)20-1/16

NPT Port (In.)3/8

Number of Stages2

Reservoir Capacity134 cu. in.

Reservoir Capacity (Cu.-In.)134

Width (In.)5-15/16

Overall Height7-5/8"

Overall Length20-1/16"

Overall Width5-15/16"

SpeedTwo

Displacement/Stroke 1st Stage (Cu.-In.)1.00

Displacement/Stroke 2nd Stage (Cu.-In.)0.15

Max. PSI 1st Stage500

Max. PSI 2nd Stage10,000

Handle MaterialFiberglass

Pump MaterialSteel

Port Size3/8" NPT

Reservoir MaterialSteel

Max. Handle Effort (Lbs.)77

Reservoir Capacity (Gal.)0.5801

Max. Handle Effort77 lb.

Max. Pressure 1st Stage500 psi

Max. Pressure 2nd Stage10,000 psi

Displacement per Stroke 1st Stage1.00 cu. in.

Displacement per Stroke 2nd Stage0.15 cu. in.

Oil IncludedYes

316 Stainless Steel Hex Head Screw

Super-Corrosion-Resistant, M8 x 1.25 mm Thread, 70 mm Long

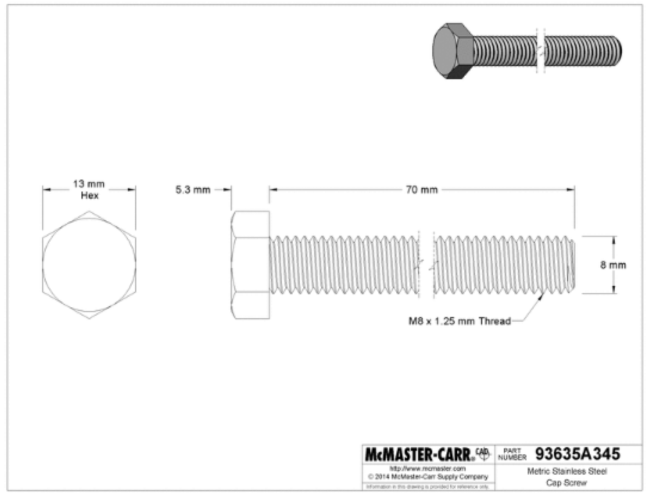
Packs of 1

ADD TO ORDER

In stock
$1.13 per pack of 1
93635A345

Thread Size	M8
Thread Pitch	1.25 mm
Length	70 mm
Threading	Fully Threaded
Head Width	13 mm
Head Height	5.3 mm
Material	316 Stainless Steel
Hardness	Not Rated
Tensile Strength	100,000 psi
Thread Type	Metric
Thread Spacing	Coarse
Thread Fit	Class 6g
Thread Direction	Right Hand
Head Type	Hex
Hex Head Profile	Standard
Drive Style	External Hex
Specifications Met	DIN 933
System of Measurement	Metric
RoHS	Compliant

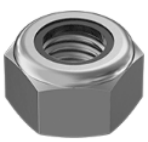
More corrosion resistant than 18-8 stainless steel screws, these screws have excellent resistance to chemicals and salt water. They may be mildly magnetic. Length is measured from under the head.



The information in this 3-D model is provided for reference only. Details

316 Stainless Steel Nylon-Insert Locknut

Super-Corrosion-Resistant, M8 x 1.25 mm Thread



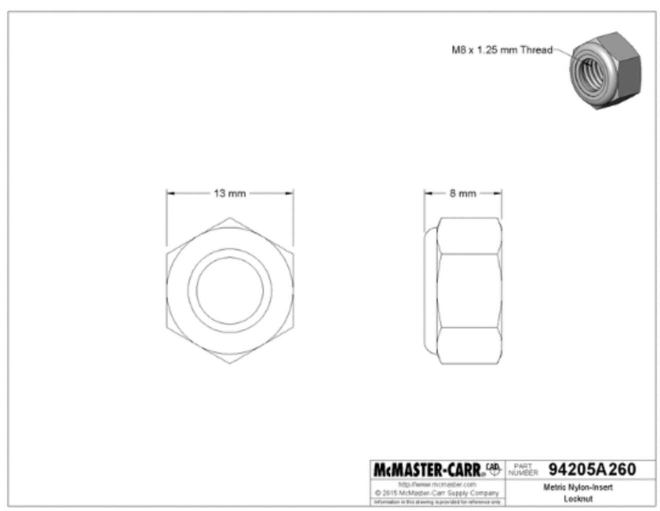
Packs of 25

ADD TO ORDER

In stock
$7.44 per pack of 25
94205A260

Material	316 Stainless Steel
Thread	
Size	M8
Pitch	1.25 mm
Type	Metric
Spacing	Coarse
Fit	Class 6H
Direction	Right Hand
Width	13 mm
Height	8 mm
Insert Maximum Temperature	220° F
Specifications Met	DIN 985
Drive Style	External Hex
Nut Type	Locknut
Hex Nut Profile	Standard
Locking Type	Nylon Insert
System of Measurement	Metric
RoHS	Compliant

Made from 316 stainless steel, these locknuts have excellent resistance to chemicals and salt water. The nylon insert grips the bolt to resist loosening without damaging threads. They're reusable, but their holding power lessens with each use. Metric 316 stainless steel is also known as A4 stainless steel. Nuts may be mildly magnetic.



The information in this 3-D model is provided for reference only. Details

EATON AEROQUIP

60" Synthetic Rubber High Pressure Hydraulic Hose Assembly

Item # **4Z217** Mfr. Model # **3/8 FC410 60** Catalog Page # **2479** UNSPSC # **40142005**

Web Price
$53.75 / each

One Time Delivery
Auto Reorder

1 **Add to Cart**
+ Add to List |

Shipping Pickup
Expected to arrive **Wed. Nov 28**.
Ship To **93401** (Change)

Be the first to write a review

Shipping Weight **1.5 lbs.**

How can we improve our Product Images?

Country of Origin **USA** | *Country of Origin is subject to change.*
Note: Product availability is real-time updated and adjusted continuously. The product will be reserved for you when you complete your order. More

Technical Specs

Item	**Hydraulic Hose Assembly**	Tube	**Synthetic Rubber**
Type	**High Pressure**	Cover	**Synthetic Rubber**
Hose Inside Dia. (In.)	**3/8"**	Reinforcement	**Braided Carbon Steel**
Hose Length	**60"**	Min. Bend Radius (In.)	**2.50**
NPT (In.)	**3/8-18**	Weight/Ft. (Lb.)	**0.27**
Dash Size	**6**	Safety Factor	**4:1**
Hose Outside Dia. (In.)	**0.68**	Standards	**SAE J517C 100R2**
Max. Operating PSI	**4000**	Compatible With	**Petroleum and Water Based Fluids**
Temp. Range (F)	**-40 to 212**		

EATON AEROQUIP

72" Synthetic Rubber High Pressure Hydraulic Hose Assembly

Item # **2F765** Mfr. Model # **R2-8-72M** Catalog Page # **2479** UNSPSC # **40142005**

Web Price
$56.50 / each

One Time Delivery
Auto Reorder

1 **Add to Cart**
+ Add to List |

Shipping Pickup
Expected to arrive **Wed. Nov 28**.
Ship To **93401** (Change)

Be the first to write a review

Shipping Weight **2.35 lbs.**

How can we improve our Product Images?

Country of Origin **USA** | *Country of Origin is subject to change.*
Note: Product availability is real-time updated and adjusted continuously. The product will be reserved for you when you complete your order. More

Compare

Technical Specs

Item	**Hydraulic Hose Assembly**	Tube	**Synthetic Rubber**
Type	**High Pressure**	Cover	**Synthetic Rubber**
Hose Inside Dia. (In.)	**1/2"**	Reinforcement	**Braided Carbon Steel**
Hose Length	**72"**	Min. Bend Radius (In.)	**3.50**
NPT (In.)	**3/8-18**	Weight/Ft. (Lb.)	**0.34**
Dash Size	**6**	Safety Factor	**4:1**
Hose Outside Dia. (In.)	**0.79**	Standards	**SAE J517C 100R2**
Max. Operating PSI	**3500**	Compatible With	**Petroleum and Water Based Fluids**
Temp. Range (F)	**-40 to 212**		

EATON AEROQUIP

MNPT to FNPT Swivel Street Elbow Pipe Thread Hydraulic Hose Adapter

Item # **38YN62** Mfr. Model # **2252-6-6S** Catalog Page # **N/A** UNSPSC # **40141734**

How can we **improve our Product Images?**

Compare

Web Price
$17.55 / each

One Time Delivery
Auto Reorder

1 **Add to Cart**

+ Add to List |

Shipping Pickup

Expected to arrive **Wed. Nov 28.**

Ship To **93401** (Change)

☆☆☆☆☆ **Be the first to write a review**

Shipping Weight **0.31 lbs.**

Country of Origin **USA** | *Country of Origin is subject to change.*

Note: Product availability is real-time updated and adjusted continuously. The product will be reserved for you when you complete your order. More

Technical Specs

Item	**Pipe Thread Hydraulic Hose Adapter**	Max. Working Pressure (PSI)	**4000**
Fitting Shape	**90 Degrees Street Elbow**	Hose Adapter Material	**Carbon Steel**
Fitting Thread Type 1	**Male NPT**	Length (In.)	**1.69**
Fitting Thread Size 1	**3/8"-18**	Finish	**Trivalent Chromate Zinc**
Fitting Thread Type 2	**Female NPT**	Standards	**SAE J514, J513, J512, J1926, J1453**
Fitting Thread Size 2	**3/8"-18**		

6900 -SAE O-RING BOSS ORB MALE X NPTF PIPE FEMALE SWIVEL ADAPTER

(1) ORB Male (2) NPTF Female Swivel

Like 0 Share

Alternative Views: 

SAE O-Ring Boss ORB Male x NPTF Pipe Female Swivel Adapter

6900 ORB steel adapters are equivalent to the following:

* SAE 140157
* Parker 0507
* Weatherhead 9315
* Aeroquip 2066

6900-08-08	6900-08-08 - 1/2" ORB Male x 1/2" NPSM Female Swivel	**$2.11**	1	☐

Zinc-Plated Steel Hydraulic Hose Fitting

90 Degree Elbow, 3/8 NPSM Female x 1/2 NPTF Male

Each

ADD TO ORDER

In stock
$5.73 Each
5340K91

Pipe Size	3/8 × 1/2
Connection Type	Pipe × Pipe
Connections	Threaded NPSM Female End (Swivels Until Tightened) with Threaded NPTF Male 90° Elbow End
Maximum Pressure	3,000 psi @ 72° F
Temperature Range	Not Rated
Maximum Vacuum	Not Rated
For Hose Type	Hydraulic
Material	Zinc-Plated Steel
Specifications Met	SAE J514
For Use With	Hydraulic Fluid
Type	Reducing Adapter
RoHS	Compliant

These elbows swivel until tightened for easy installation.

Zinc-plated steel elbows have fair corrosion resistance and high wear resistance.

NPTF (Dryseal) threads are compatible with NPT threads. Female NPSM (National Pipe Straight Mechanical) threads are compatible with male NPT threads.

ENERPAC

Hydraulic Oil, 1 gal. Jug, ISO Viscosity Grade : 15

Item # **2RV21** Mfr. Model # **LX101** Catalog Page # **2466** UNSPSC # **15121504**

How can we improve our Product Images?

Compare

Web Price
$51.00 / each

One Time Delivery

Auto Reorder

1 Add to Cart

+ Add to List |

Be the first to write a review

Shipping Weight **7.55 lbs.**

Country of Origin **USA** | *Country of Origin is subject to change.*

Note: Product availability is real-time updated and adjusted continuously. The product will be reserved for you when you complete your order. More

Product Details

Medium viscosity index improves flow properties, especially in lower temperatures. Not for use in power pumps. Includes antisludge and antirust additives. Formulated specifically for use with Enerpac pumps.

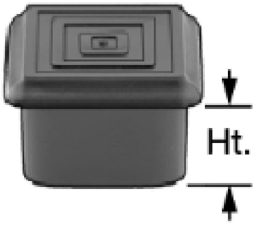
View Less

Technical Specs

Item - Hydraulic Oils	**Hydraulic Oil**
ISO Viscosity Grade	**15**
SAE Grade	**Not Specified**
Container Size	**1 gal.**
Lubricant NSF Rating	**Not Rated**
Lubricant Additives	**Zinc**
Viscosity Index	**105**
Flash Point	**375 Degrees F**
Pour Point	**-45 Degrees F**
Container Style	**Jug**
Color	**Amber**
Timken OK Load	**Not Specified**
Application	**Specially Formulated for Hand Pumps. Reduced Handle Effort Over HF oil**
Four-Ball Wear	**Not Specified**
Specific Gravity	**0.848**

Square Plugs

Push-In, for 1.260" x 1.260" Inside



Packs of 50 | In stock
$9.98 per pack of 50
9565K29

ADD TO ORDER

Plug Type	Push In
For Shape	Square
For Surface Type	Unthreaded
For Inside	
Length	1.26"
Width	1.26"
Head	
Length	1 1/2"
Width	1 1/2"
Height	1/2"
Material	Polyethylene Plastic
Hardness	Durometer 50D
Maximum Temperature	150° F
Color	Black
RoHS	Compliant

Push these plugs into an opening and friction holds them in place.

Weather-Resistant Draw Latch

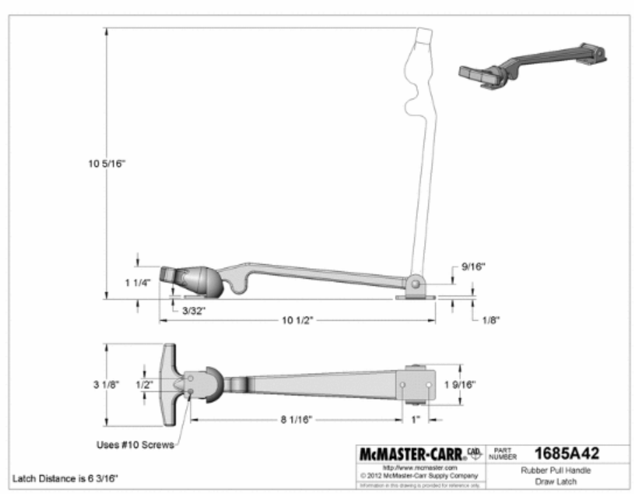
304 Stainless Steel Strike Plate, 10-1/2" Long x 3-1/8" Wide

Each | In stock
$26.87 Each
1685A42

ADD TO ORDER

Material	Black Rubber
Strike Plate Material	304 Stainless Steel
Latching Distance	6 3/16"
Overall	
Length	10 1/2"
Width	3 1/8"
Projection	1 1/4"
Capacity	Not Rated
Temperature Range	0° to 200° F
Mount Type	Screw On
Mounting	
Style	Surface
Fasteners Included	No
Screw Size	No. 10
Draw Latch Type	Nonlocking
Latching Distance Adjustability	Fixed
RoHS	Not Compliant

These latches have a rubber body that absorbs vibration and stretches to compensate for slight misalignment. Capacity is the maximum amount of force the latch can withstand. The overall length listed includes the strike plate.



The information in this 3-D model is provided for reference only. Details

Ottomanson Evergreen Collection Indoor/Outdoor Green Artificial Grass Turf Solid Design Runner Rug, 3'0" x 7'3", 3

by Ottomanson

259 customer reviews | 76 answered questions

Amazon's Choice for "cheap outdoor rug"

Price: $15.67 ✓prime

Your cost could be $5.67. Eligible customers get a $10 bonus when reloading $100.

Size: **3' x 7'3"**

2' X 5' | 2'7" x 8' | 2'7" x 9'10" | 3' x 7'3" | 3'11" x 6'6" | 6'6" x 9'3" | 6' x 7'3" | 16" x 48" | 20" X 59"

- 100% Polypropylene
- Imported
- Size: (3'0x 7'3)
- Color: Green
- Rubber backed with drainage hole
- Use virtually anywhere, indoors or out
- Safe for pets and children's playground

Compare with similar items

New (6) from $15.67 ✓prime

Report incorrect product information.

Share

$15.67
✓prime

FREE Delivery by **Thursday**
if you order within 10 hrs 23 mins.
Details

In Stock.
Ships from and sold by Amazon.com.

Qty: 1

Add to Cart

Buy Now

Turn on 1-Click ordering for this browser

Deliver to Bryce - San Luis Obispo 93401

Add to List

Product description

Size:3' x 7'3"

Evergreen Collection Artificial Solid Grass Design Rug

Product information

Size:**3' x 7'3"**

Product Dimensions	10 x 12 x 40 inches
Item Weight	3.55 pounds
Shipping Weight	4.01 pounds (View shipping rates and policies)
Manufacturer	Ottomanson
ASIN	B01JN9C3SU
Item model number	R250-3X7

Warranty & Support

Manufacturer's warranty can be requested from customer service. Click here to make a request to customer service.

Feedback

If you are a seller for this product, would you like to **suggest updates through seller support**?
Would you like to **tell us about a lower price**?

Duck Brand 392907 Indoor/Outdoor Carpet Tape, 1.41-Inch x 42 Feet, Single Roll

by Duck

221 customer reviews | 36 answered questions

List Price: $8.99
Price: $4.96 **Free shipping** for Prime members when buying this Add-on Item. Details
You Save: $4.03 (45%)

Your cost could be $0.00. Eligible customers get a $10 bonus when reloading $100.

Arrives before Christmas.

Size: **1.41 Inch x 42 Feet**

1.41 Inch x 42 Feet $4.96 Add-on Item | 1.88 in. x 75 ft. (48mm wide) $13.26 ✓prime

- Durable carpet tape for permanent carpet installation
- Excellent adhesion to smooth and rough surfaces
- Fiberglass reinforced for extra durability
- For use with a variety of indoor, outdoor carpet materials
- 1.41-inch x 42-foot roll

› See more product details

Compare with similar items

Add-on Item

This item is available because of the Add-on program

The Add-on program allows Amazon to offer thousands of low-priced items that would be cost-prohibitive to ship on their own. These items ship with qualifying orders over $25. Details

New (18) from $4.96 & FREE shipping.

Waiting for www.amazon.com...

BV EVA Road Bike Handlebar Tapes, Bicycle Bar Tape, Cycling Handle Wraps – 2 Rolls

by BV

172 customer reviews | 4 answered questions

Price: $9.99 prime

Your cost could be $0.00. Eligible customers get a $10 bonus when reloading $100.

Color: **Black**

- EVA Foam material with embossed "BV" logo provides comfortable and anti-slip grip.
- Ultra-light and durable quality absorbs shock and vibration during cycling.
- Fade, water, and UV-radiation resistant.
- 3M adhesive backing is easy to install.
- Includes 2 handlebar end plugs and 2 finishing tapes

New (2) from $9.99 prime

Report incorrect product information.

Holiday Toy List
Our favorite toys for everyone on your list Shop now

Share

$9.99
prime

FREE Delivery by **Thursday**
if you order within 10 hrs 22 mins, or

Get it **Wednesday** if you order within 14 hrs 37 mins and choose paid One-Day Shipping at checkout Details

In Stock.
Sold by BikepakUSA and Fulfilled by Amazon. Gift-wrap available.

Qty: 1

Add to Cart

Buy Now

Turn on 1-Click ordering for this browser

Deliver to Bryce - San Luis Obispo 93401

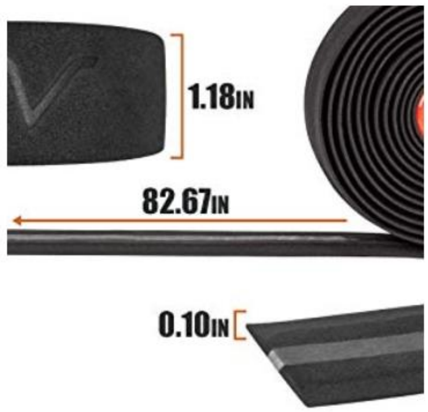
Add to List

Add to your Dash Buttons

Dimensions and Weight

Diameter: 2100mm (Length) x 30mm (Width) x 2.5mm (Thickness).

Weight: 1.6 OZ (45g).



Product description

EVA Foam Material

Ultra-light EVA foam material limits the weight of your bike.
Durable, anti-slip, fade and water resistant properties provide comfortable and safe grip during cycling in the rain or wet environment.

Easy to Install

3M adhesive backing helps to install easily without any extra tool and make you easy to wrap to the correct position.
Handlebar end Plugs and finishing tapes make your handlebar look decent and perfect.

High Quality

EVA material is soft enough to isolate your hands from shock and vibration.
Relieve your fatigue and hands pressure for long rides.

Package Includes

- 2 x Handlebar Tapes
- 2 x Handlebar End Plugs
- 2 x Handlebar Finishing Tapes

Features

- Material: EVA Foam
- Color: Black or White
- Diameter: 2100mm (Length) x 30mm (Width) x 2.5mm (Thickness)
- Weight: 1.6 OZ (45g)

BV is continuously improving and evolving for our customer needs. Our goal is your 100% satisfaction..
We offer every customer a limited one-year product warranty on every item purchased

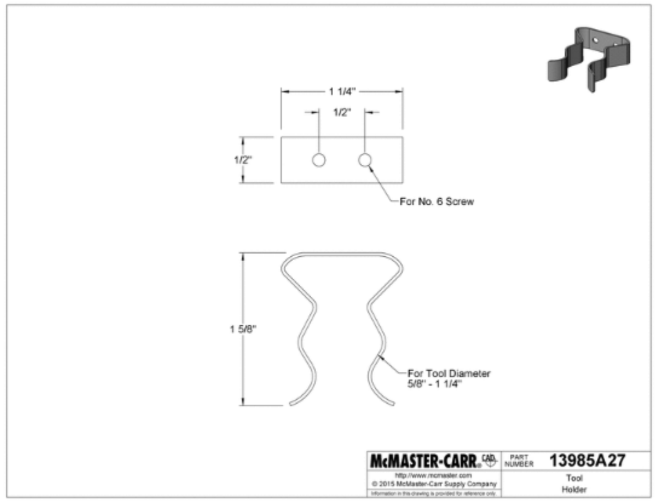
Stainless Steel Clip for 5/8"-1-1/4" Tool Diameter

Packs of 5

ADD TO ORDER

In stock
$10.14 per pack of 5
13985A27

Mounting Location	Wall
Mount Type	Screw Mount
Material	Stainless Steel
Appearance	Dull
Holding Mechanism	Clip
For Item Diameter	5/8"-1 1/4"
Overall	
Width	1 1/4"
Height	1/2"
Depth	1 5/8"
Overall Capacity	Not Rated
Number of Holders	1
Mounting Fasteners Included	Yes
Number of Mounting Holes	2
Screw Size	No. 6
RoHS	Compliant



Phillips Rounded Head Screws for Sheet Metal

Super-Corrosion-Resistant 316 Stainless Steel, Number 6 Size, 3/8" Long

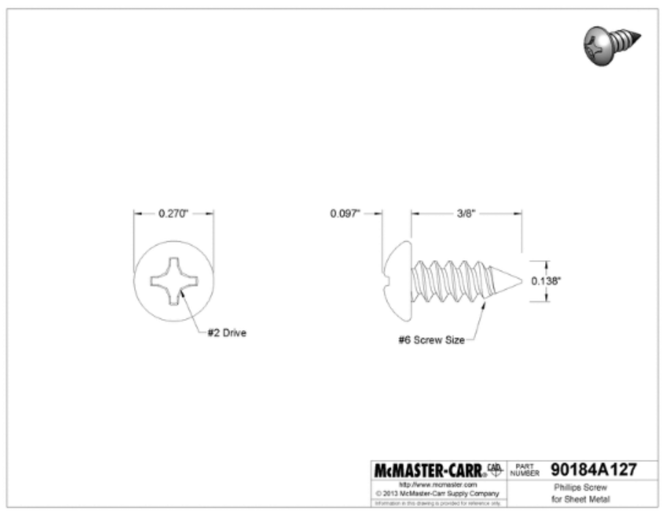
Packs of 100

ADD TO ORDER

In stock
$6.91 per pack of 100
90184A127

Material	316 Stainless Steel
Screw Size	No. 6
Screw Size Decimal Equivalent	0.138"
Length	3/8"
Head	
Diameter	0.27"
Height	0.097"
Drive Size	No. 2
Drive Style	Phillips
Drill Bit Size	No. 32
Drill Bit Size Decimal Equivalent	0.116"
Maximum Drilling Thickness	0.025"
Approximate Threads per Inch	18
Thread Direction	Right Hand
Threading	Fully Threaded
Tapping Method	Thread Forming
Tapping Screw Type	A/AB
Type	Rounded
Rounded Head Profile	Standard
Rounded Head Style	Pan
Tip Type	Pointed
Shank Cross Section	Round
System of Measurement	Inch
For Use In	Sheet Metal
RoHS	Compliant

More corrosion resistant than 18-8 stainless steel screws, these have excellent resistance to chemicals and salt water and may be mildly magnetic. They penetrate 0.025" and thinner sheet metal. Length is measured from under the head.



The information in this 3-D model is provided for reference only. Details

Appendix E – Design Hazard Checklist

Y	N	
✔	☐	1. Will the system include hazardous revolving, running, rolling, or mixing actions?
✔	☐	2. Will the system include hazardous reciprocating, shearing, punching, pressing, squeezing, drawing, or cutting actions?
☐	×	3. Will any part of the design undergo high accelerations/decelerations?
✔	☐	4. Will the system have any large (>5 kg) moving masses or large (>250 N) forces?
☐	×	5. Could the system produce a projectile?
✔	☐	6. Could the system fall (due to gravity), creating injury?
☐	×	7. Will a user be exposed to overhanging weights as part of the design?
✔	☐	8. Will the system have any burrs, sharp edges, shear points, or pinch points?
☐	×	9. Will any part of the electrical systems not be grounded?
☐	×	10. Will there be any large batteries (over 30 V)?
☐	×	11. Will there be any exposed electrical connections in the system (over 40 V)?
☐	×	12. Will there be any stored energy in the system such as flywheels, hanging weights or pressurized fluids/gases?
☐	×	13. Will there be any explosive or flammable liquids, gases, or small particle fuel as part of the system?
☐	×	14. Will the user be required to exert any abnormal effort or experience any abnormal physical posture during the use of the design?
☐	×	15. Will there be any materials known to be hazardous to humans involved in either the design or its manufacturing?
☐	×	16. Could the system generate high levels (>90 dBA) of noise?
✔	☐	17. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, or cold/high temperatures, during normal use?
✔	☐	18. Is it possible for the system to be used in an unsafe manner?
☐	☐	19. For powered systems, is there an emergency stop button?
☐	×	20. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

For any "Y" responses, included below is (1) a complete description, (2) a list of corrective actions to be taken, and (3) date to be completed.

Description of Hazard	Planned Corrective Action	Planned Date	Actual Date
1: Large wheelchair wheels will be used to propel the device.	Minimize potential of user's hands becoming caught in wheelchair wheels by using simple geometry and adequate clearances	05/11/18	11/13/18
2: Device may incorporate pivot point, squeeze handles, or other dynamic mechanism	Minimize potential of user interference with any mechanisms. Packaging and location of mechanisms will be carefully considered. We will attempt to make all motions smooth and not abrupt or sudden so that the device behaves predictably.	05/11/18	11/20/18
4: The system must transport a person, which inherently will exceed a mass of 5 kg and force of 250 N	This is an unavoidable aspect of our device. To minimize these effects, we will try to make our device as lightweight as possible so that users can still propel themselves easily. Analyses will be done to see that the device will support the expected loads on the device.	05/04/18	05/10/18
6: The system could potentially fall (tip) over, fall out of the gondola when loading/unloading, or user could fall off device	Keep center of gravity as low as is feasible and wheels as wide as possible in order to minimize tipping potential. Incorporate wheelchair wheel locks/brakes to keep device stationary when needed in loading and unloading processes. Locks or restraints will be incorporated to secure the monoskier to the device to prevent them from falling off.	05/04/18	11/27/18
8: The device will be composed of a metal frame and thus could have burrs and sharp edges, and may include a pivoting ramp and other potential pinch points	Care will be taken during the manufacturing process to remove all burrs and sharp edges from the device. This will be done with deburring tools and grinders when necessary. The pinch points will be limited as much as possible and adequate clearances will be provided.	10/18/18	11/28/18
17: The device will inherently be exposed to low temperatures and humid/snowy/wet conditions.	To account for the conditions at Mammoth, we will try to reduce the potential for corrosion as much as possible. Aluminum may be used over steel to avoid corrosion if it is financially feasible. The final product will be coated with paint in order to protect it. Bearings would be sealed to prevent corrosion and excess wear.	10/18/18	11/28/18
18: The device will have some danger inherent to transporting a person	We will take care to design the device to be as safe as possible. We will create an operator's manual that will explain the intended use of the device, and will explain any hazards associated with the device.	05/22/18	11/28/18

Appendix F - Risk Assessment

designsafe Report

Application:	Sample Machine / Product	Analyst Name(s):	Joe Maintenance, Jane Engineer, John Doe
Description:	This example analysis shows some of the basics of a risk assessment.	Company:	Acme Products
Product Identifier:		Facility Location:	Ann Arbor, Michigan, USA
Assessment Type:	Detailed		
Limits:	sample analysis only!!		
Sources:	personnel experiences, ANSI B11 standards, assembly drawings W-Z		
Risk Scoring System:	ANSI B11.0 (TR3) Two Factor		

Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1-1-1	operator normal operation	mechanical : cutting / severing Hands near Scissor lift	Serious Unlikely	Medium	separate hazard / people in time or space, warning label(s), standard procedures, instruction manuals	Serious		
1-1-2	operator normal operation	mechanical : pinch point Hands near Scissor lift	Moderate Unlikely	Low	instruction manuals, warning label(s), standard procedures	Moderate Likely	Medium	
1-1-3	operator normal operation	mechanical : impact Ramp lock failure	Serious Unlikely	Medium	Add larger factor of safety/ redesign, use alternate materials	Serious Likely	High	This risk was mitigated when we eliminated the locking pivot ramp in our design in favor of the hydraulic supported parallel linkage system
1-1-4	operator normal operation	slips / trips / falls : slip Monoskier slips on platform	Moderate Likely	Medium	separate hazard / people in time or space, slow down energy release, safety mats / contact strip, standard procedures, instruction manuals	Moderate Unlikely	Low	

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1-1-5	operator normal operation	slips / trips / falls : fall hazard from elevated work Monoskier falls off platform due to slip or ramp lock failure	Moderate Unlikely	Low	Add larger factor of safety/ redesign, use alternate materials, slow down energy release, safety mats / contact strip	Moderate Unlikely	Low	
1-1-6	operator normal operation	ergonomics / human factors : lifting / bending / twisting some parts weighing >35 lbs	Minor Unlikely	Negligible	standard procedures, instruction manuals	Minor Unlikely	Negligible	
1-1-7	operator normal operation	fluid / pressure : hydraulics rupture Pressure exceeds max piston or line pressure	Serious Unlikely	Medium	warning label(s), standard procedures	Serious Remote	Low	
2-1-1	maintenance technician parts replacement	mechanical : cutting / severing Hands near Scissor lift	Serious Unlikely	Medium	standard procedures, warning label(s), instruction manuals	Serious Unlikely	Medium	
2-1-2	maintenance technician parts replacement	mechanical : pinch point Hands near Scissor lift	Serious Unlikely	Medium	standard procedures, warning label(s), instruction manuals	Serious Unlikely	Medium	
2-1-3	maintenance technician parts replacement	ergonomics / human factors : posture Lifting entire device, working bent over	Moderate Likely	Medium	standard procedures	Minor Unlikely	Negligible	
2-1-4	maintenance technician parts replacement	ergonomics / human factors : lifting / bending / twisting Lifting entire device, working bent over	Moderate Unlikely	Low	standard procedures	Minor Unlikely	Negligible	
2-1-5	maintenance technician parts replacement	fluid / pressure : hydraulics rupture See Above	Serious Unlikely	Medium	See Above	Serious Remote	Low	
2-1-6	maintenance technician parts replacement	fluid / pressure : fluid leakage / ejection Hydraulics failure	Moderate Unlikely	Low	standard procedures	Moderate Remote	Negligible	

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
2-2-1	maintenance technician trouble-shooting / problem solving	mechanical : cutting / severing See Above	Serious Unlikely	Medium	See Above	Serious Unlikely	Medium	
2-2-2	maintenance technician trouble-shooting / problem solving	mechanical : pinch point See Above	Serious Unlikely	Medium	fixed guard, warning sign, standard procedures	Serious Unlikely	Medium	
2-2-3	maintenance technician trouble-shooting / problem solving	ergonomics / human factors : lifting / bending / twisting See Above	Moderate Unlikely	Low	See Above	Minor Unlikely	Negligible	
2-2-4	maintenance technician trouble-shooting / problem solving	fluid / pressure : hydraulics rupture See Above	Serious Unlikely	Medium	See Above	Serious Remote	Low	
2-2-5	maintenance technician trouble-shooting / problem solving	fluid / pressure : fluid leakage / ejection See Above	Moderate Remote	Negligible	See Above	Moderate Remote	Negligible	
3-1-1	Design Team (Testers) Manufacturing & Assembly	mechanical : cutting / severing Sharp edges on machined parts	Moderate Likely	Medium	Sand/grind and deburr	Moderate Unlikely	Low	
3-1-2	Design Team (Testers) Manufacturing & Assembly	mechanical : pinch point See Above	Moderate Unlikely	Low	See Above	Moderate Unlikely	Low	
3-1-3	Design Team (Testers) Manufacturing & Assembly	ergonomics / human factors : posture See Above	Minor Unlikely	Negligible	See Above	Minor Unlikely	Negligible	
3-1-4	Design Team (Testers) Manufacturing & Assembly	ergonomics / human factors : lifting / bending / twisting See Above	Minor Unlikely	Negligible	See Above	Minor Unlikely	Negligible	

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
3-1-5	Design Team (Testers) Manufacturing & Assembly	fire and explosions : hot surfaces From welds milling and cutting	Moderate Likely	Medium	standard procedures	Moderate Likely	Medium	
3-1-6	Design Team (Testers) Manufacturing & Assembly	fluid / pressure : hydraulics rupture See Above	Serious Unlikely	Medium	See Above	Serious Remote	Low	
3-2-1	Design Team (Testers) Testing	mechanical : crushing Failure during load testing	Moderate Unlikely	Low	standard procedures	Moderate Unlikely	Low	
3-2-2	Design Team (Testers) Testing	mechanical : cutting / severing Hands near Scissor lift	Serious Unlikely	Medium	See Above	Moderate Unlikely	Low	
3-2-3	Design Team (Testers) Testing	mechanical : pinch point See Above	Moderate Unlikely	Low	See Above	Moderate Unlikely	Low	
3-2-4	Design Team (Testers) Testing	fluid / pressure : hydraulics rupture See Above	Serious Unlikely	Medium	See Above	Serious Unlikely	Medium	

Appendix G – FMEA

System / Function	Potential Failure Mode	Potential Effects of the Failure Mode	Severity	Potential Causes of the Failure Mode	Current Preventative Activities	Occurrence
Wheelchair Frame/ Move Device	Wheels do not move/moves too slowly	1. Device gets stuck/unusable 2. Device difficult to move	7	1. Interference 2. Bearings seize 3. Debris interferes 4. components too heavy	I. Sealed bearing II. Design for enough clearance III. Aluminum tubing	3
	Wheels do not lock	1. User cannot load	8	1. Locking mechanism broken/worn down	I. Fatigue analysis	2
	Frame breaks	a. frame breaks off from scissor lift b. frame breaks internally	9	1. Improper structural analysis 2. Overloaded 3. Fatigue	I. Fatigue analysis II. Stress Analysis III. Weight limit/Safety Factor	2
	Frame connection Failure		8	1. Pin falls out 2. Pin bores hole in leg/bracket 3. Improper weld penetration 4. Screws unthread	I. Collar on pins II. Thread Lock III. Practice welding	3
	Frame interferes w/ ground or scissor lift	a. components break/wear down	6	1. fatigue 2. Improper assembly	I. Fatigue analysis	4
	Frame tips	a. user falls/is injured b. user unable to load	6	1. weight distribution of user 2. poor cg placement	I. Anti-tip bars II. Design for low cg	
	Frame fatigue	a. components break/wear down	6	1. Rust 2. fatigue cycles	I. Fatigue analysis	2
Hydraulic Scissor Lift/ Raise and lower user	Lift does not move/ moves too slowly	a. device cannot work	8	1. Interference 2. Debris interferes 3. Not enough lift force	I. Design for clearance II. Design for easy removal of debris III. High rated hydraulic cylinder	3
	Lift frame breaks	a. user falls/is injured	8	1. Improper structural analysis 2. Overloaded 3. Fatigue	I. Design Calculations II. Load capacity	2
	Hydraulics rupture/leakage	a. user injured b. device cannot raise	7	1. Lines pinched 2. Cylinder/pump breaks 3. Loose line	I. Line routing II. Highly rated hydraulic components	2
	Frame connection Failure	a. Devise falls apart	8	1. Pin falls out 2. Pin bores hole in leg/bracket 3. Improper weld penetration 4. Screws unthread	I. Collar on pins II. Thread Lock III. Practice welding	4

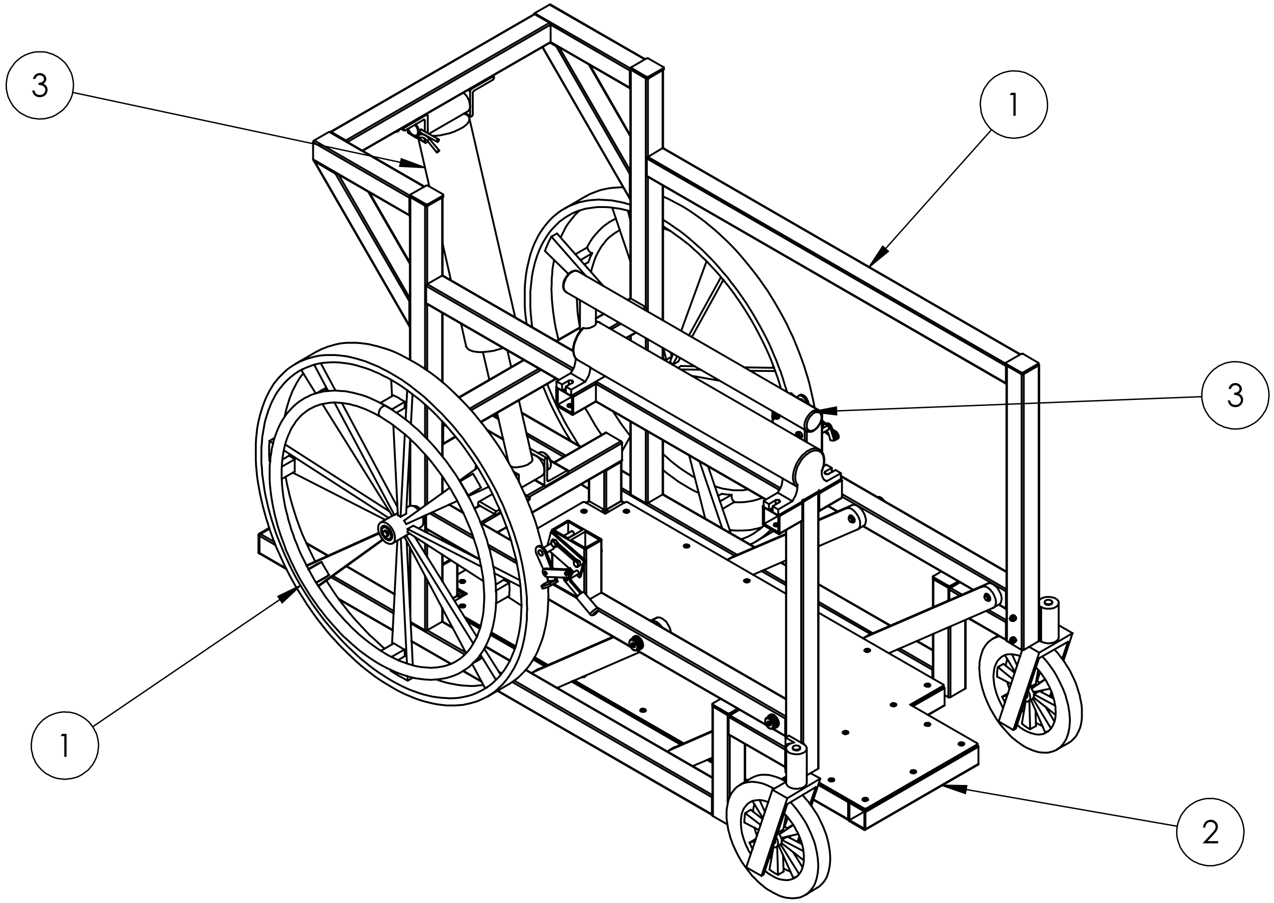
Pivot Ramp/load user on and off device	Ramp does not rotate/rotates too slowly	a. User cannot load	6	1. Interference 2. Debris interferes	I. Design for clearance II. Design for easy removal of debris	3
	Ramp does not lock		6	1. Locking Mechanism broken 2. Locknig mech. Not lined up	I. Fatigue analysis	3
	Ramp too rough	a. damages ski b. slows sliding/loading	5	1. improper material chosen 2. Ramp wears down	I. Material selection II. Ramp Maintenance	2
	Ramp Breaks or deflects too much	a. device is unusable	8	1. Fatigue 2. Not stiff enough material 3. Material too thin or long	I. Stiff material II. Thicker material III. Design analysis	3

Appendix H – Bill of Materials

Level	1	2	3	4	Assembly	Part Number	Part Name	Description	Quantity
1	•				Master		Monoski Mobility Cart	6061 T6 Aluminum, 1.5" square, .125" thickness	1
2		•			Frame	F-001	Vertical Rear Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Frame	F-002	Anti-tip Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Frame	F-003	Handle Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Frame	F-004	High Connector	6061 T6 Aluminum, 1.5" square, .125" thickness	2
3			•		Frame	J-008	Outrigger Clip	SS, screw mount, for 5/8" to 1 1/4" diameter	2
2		•			Frame	F-005	Vertical Front Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Frame	F-006	Horizontal Caster Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Frame	F-007	Vertical Caster Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Frame	F-008	Brake Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Frame	F-009	Cross Brace	6061 T6 Aluminum, 1.5" square, .125" thickness	1
2		•			Frame	F-010	Pump Mount	6061 T6 Aluminum, 1.5" square, .125" thickness	4
2		•			Frame	F-011	Frame Brace	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Frame	H-003	Linkage Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
3			•		Frame	J-001	Oil Bushing	Oil-embedded sleeve bearing	8
3			•		Frame	J-002	Shoulder Bolt	1/2" Shoulder Diameter, 3/8"-16 thread	4
2		•			Linkage	M-001	Linkage Arm	6061 T6 Aluminum, 1.5" x 0.75"	4
3			•		Linkage	M-002	Threaded Insert	316 SS Thread-Locking Insert, 3/8"-16 thread	4
2		•			Ramp	R-001	Long Ramp Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
3			•		Ramp	J-001	Oil Bushing	Oil-embedded sleeve bearing, for 1/2" shaft	8
3			•		Ramp	J-002	Shoulder Bolt	1/2" Shoulder Diameter, 3/8"-16 thread	4
2		•			Ramp	R-002	Horizontal Rear Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Ramp	R-003	Vertical Rear Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Ramp	R-004	Ramp Cover	1/8" 6061 T6 Aluminum sheet metal	1
3			•		Ramp	J-003	Ramp Screw	#10 Phillips, 1/2" length, 316 SS	23
3			•		Ramp	R-008	Turf Cover	Artificial grass turf, fits ramp cover shape	1
2		•			Ramp	R-005	Front Horizontal Member	6061 T6 Aluminum, 1.5" square, .125" thickness	1
2		•			Ramp	R-006	Front Mid Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Ramp	R-007	Front Rear Member	6061 T6 Aluminum, 1.5" square, .125" thickness	2
2		•			Wheel	W-001	Wheel Axle	Quick release, 4" length, 1/2" diameter	2
2		•			Wheel	W-002	Rear Wheel	24" off road wheels w/ hand rims	2
2		•			Wheel	W-003	Axle Receiver	Flanged, 2" length, for 1/2" shaft	2
2		•			Wheel	W-004	Jam Nut	5/8"-24	2
2		•			Caster	C-001	Caster Assembly	Rubber, 8" diameter wheels	2
3			•		Caster	J-004	Caster Bolts	M6 X 1mm, hex head, 50 mm length	4
2		•			Brake	D-001	Brake Assembly	Medline	2
3			•		Brake	J-005	Brake Bolts	M6 X 1mm, hex head, 70 mm length	4
2		•			Bracket	B-001	Bracket	6061 T6 Aluminum angle, 2" x 2" x 1/4" thickness	4
3			•		Bracket	B-002	Clevis Pin L	Zinc plated steel, 3/4" diameter, 4 3/4" usable lengtl	1
4				•	Bracket	B-003	Cotter Pin L	5/32" diameter	1
4				•	Bracket	B-004	Sleeve Bearing L	Oil embedded bronze, for 3/4" diameter, 1 3/4" leng	2
3			•		Bracket	B-005	Clevis Pin S	18-8 SS, 3/4" diameter, 2 3/4" usable length	1
4				•	Bracket	B-006	Cotter Pin S	5/32" diameter	1
4				•	Bracket	B-007	Sleeve Bearing S	Oil embedded bronze, for 3/4" diameter, 2" length	1
2		•			Hydraulic	H-001	Hydraulic Pump	Enerpac P-84 hand pump	1
3			•		Hydraulic	H-002	Pump Fitting	3/8 MNPT - 3/8 FNPT swivel elbow	2
3			•		Hydraulic	J-006	Pump Mount Bolts	M8 X 1.25mm, hex head, 70 mm length	4
3			•		Hydraulic	J-007	Pump Mount Nuts	M8 X 1.25mm locknut	4
2		•			Hydraulic	H-003	Hydraulic Cylinder	Maxim 6FWX2, double acting, 3" bore, 10" stroke	1
3			•		Hydraulic	H-004	Cylinder Adapter	1/2 FNPSM - SAE ORB 8 swivel straight	2
3			•		Hydraulic	H-005	Cylinder Fitting	3/8 FNPS - 1/2 MNPT elbow	2
2		•			Hydraulic	H-006	Hose L	3/8 NPT fittings, 72" length	1
2		•			Hydraulic	H-007	Hose S	3/8 NPT fittings, 60" length	1

Appendix I – Drawing Package

Our complete drawing package follows this page.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	A-002	FRAME ASSEMBLY	1
2	A-003	RAMP ASSEMBLY	1
3	A-006	HYDRAULICS ASSEMBLY	1
4	A-004	WHEEL ASSEMBLY	1

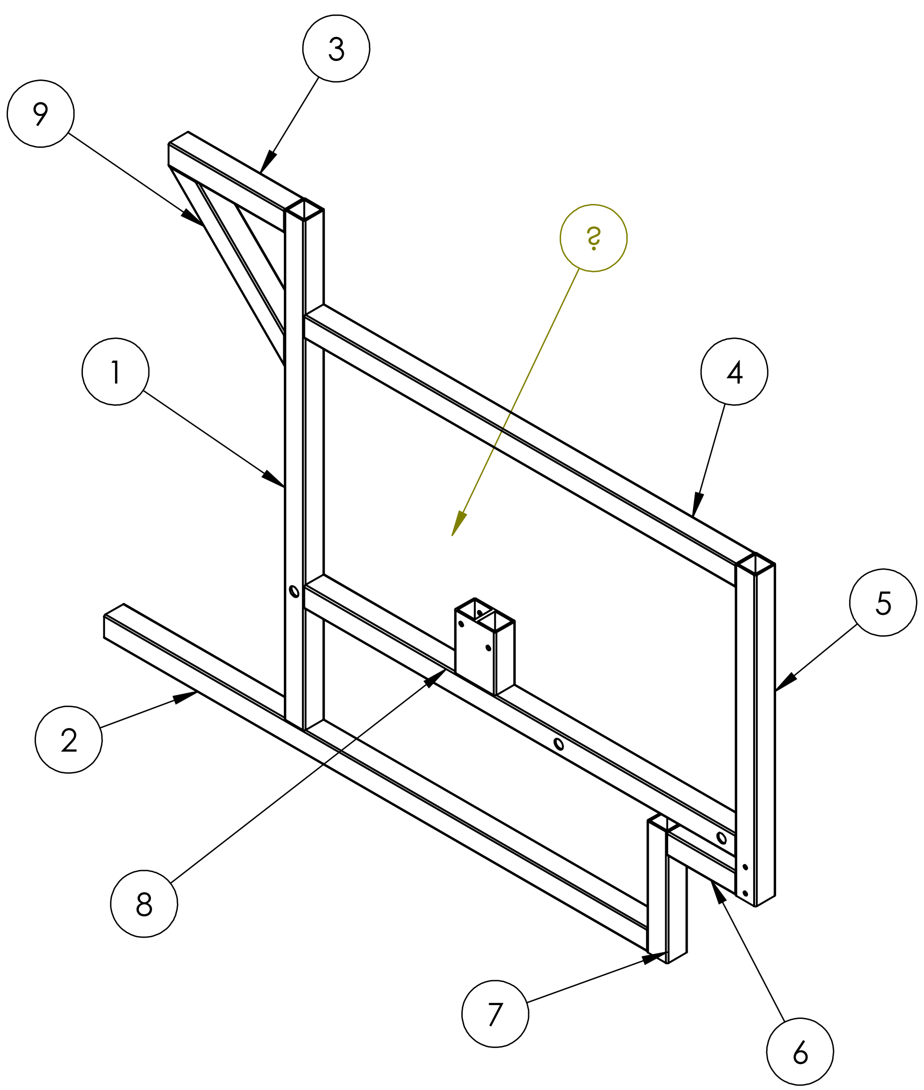
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: TOP LEVEL ASSEMBLY		Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: A-001	Nxt Asb:	Date: 12-06-2018	Scale:	Chkd. By: ME STAFF

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F-001	VERTICAL REAR MEMBER	1
2	F-002	ANTI-TIP MEMBER	1
3	F-003	HANDLE MEMBER	1
4	F-004	HIGH CONNECTOR	1
5	F-005	VERTICAL FRONT MEMBER	1
6	F-006	HORIZONTAL CASTER MEMBER	1
7	F-007	VERTICAL CASTER MEMBER	1
8	F-012	LINKAGE MEMBER	1
9	F-011	FRAME BRACE	1
10	F-008-1		1

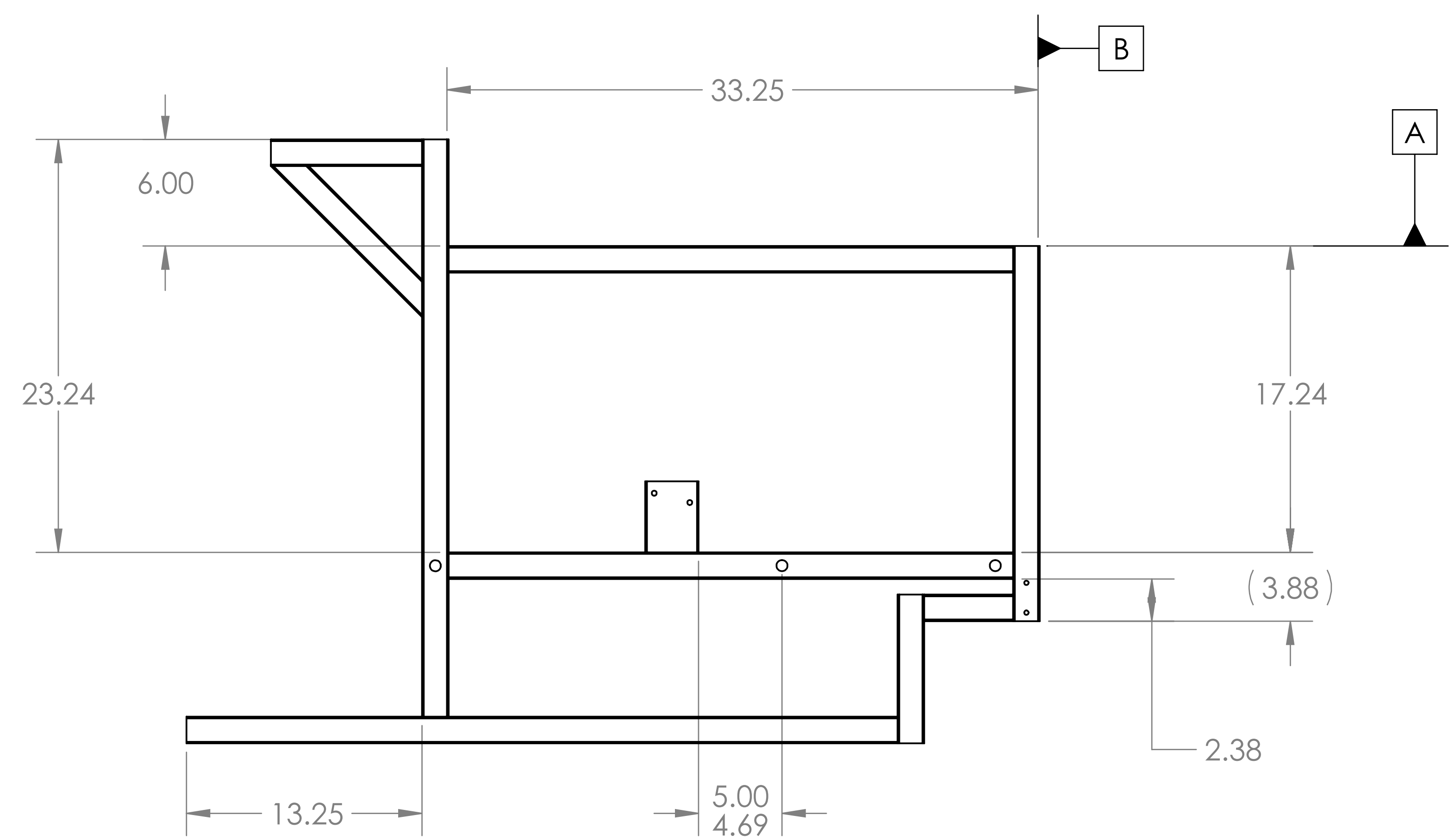
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= ±.01
   X.XXX= ±.005
   ANGLES= ±2°
3. PARTS TO BE WELDED TO AN EDGE ARE TO BE ATTACHED AS SHOWN.
4. USE OF BRAKE MEMBER (F-008) DEPENDENT ON SIZE OF WHEELCHAIR WHEEL. RANGE OF DIMS GIVEN.
5. TWO FRAMES ARE TO BE MADE TO MATCH. DIMENSIONS SHOWN SHOULD BE USED TO VERIFY CORRECT LOCATION.
6. IT IS PERMISSABLE TO IGNORE DIMENSIONS IF MATCHING TO SECOND FRAME IS NECESSARY
7. DRILL OUTRIGGER MOUNTS TO SIDE OPPOSITE OF PUMP. LOCATE APPROX. 8 IN. FROM FRONT AND 6 IN. APART.



ISOMETRIC VIEW
NO SCALE



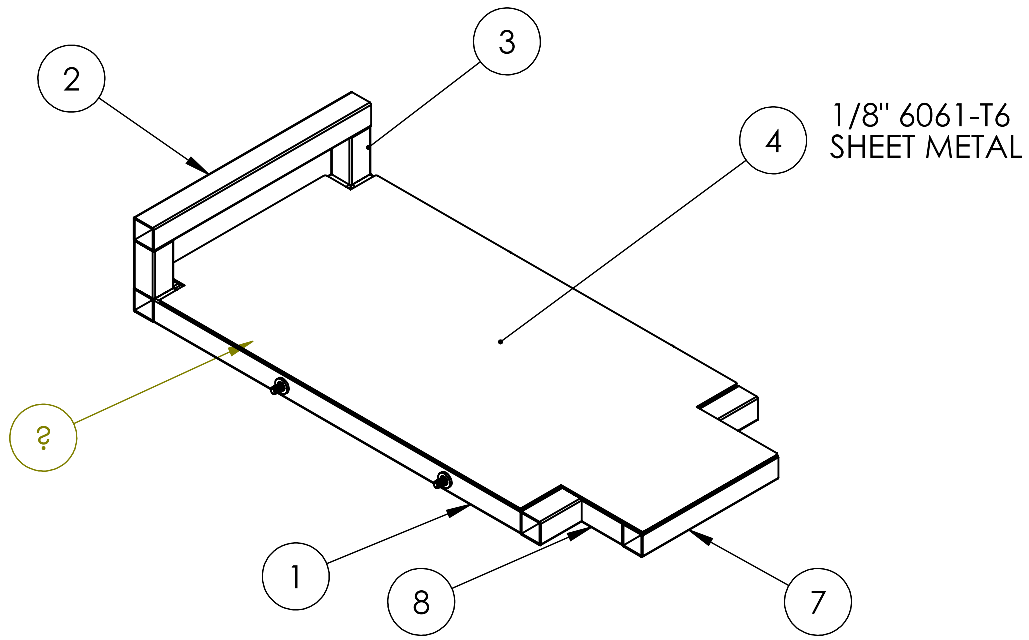
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: FRAME (A-002)		Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: A-002	Nxt Asb: A-001	Date: 10-25-2018	Scale: 1:12	Chkd. By: ME STAFF

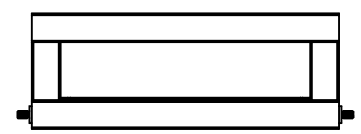
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	R-001	LONG RAMP MEMBER	2
2	R-002	HORIZONTAL REAR MEMBER	2
3	R-003	VERTICAL REAR MATERIAL	2
4	R-004	RAMP COVER	1
5	3113K59	OIL BUSHING	8
6	90311A186	SHOULDER BOLT	4
7	R-005	FRONT HORIZONTAL MEMBER	1
8	R-006	FRONT MID MEMBER	2
9	R-007	FRONT REAR MEMBER	2

NOTES

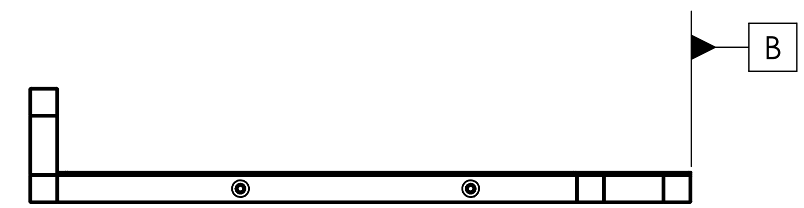
UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX=±.01
   X.XXX=±.005
   ANGLES=±2°
3. ALL PLATFORM MEMBERS TO BE 1.5" X 1/8" THICK 6061-T6 ALUMINUM SQUARE TUBING
4. PARTS TO BE WELDED TO AN EDGE ARE TO BE ATTACHED AS SHOWN.
5. MATCH RAMP FRAME TO RAMP COVER (R-004)
6. PLACE BUSHING ASSEMBLY (3113K59 & 90311A186) INTO RAMP FOR STORAGE

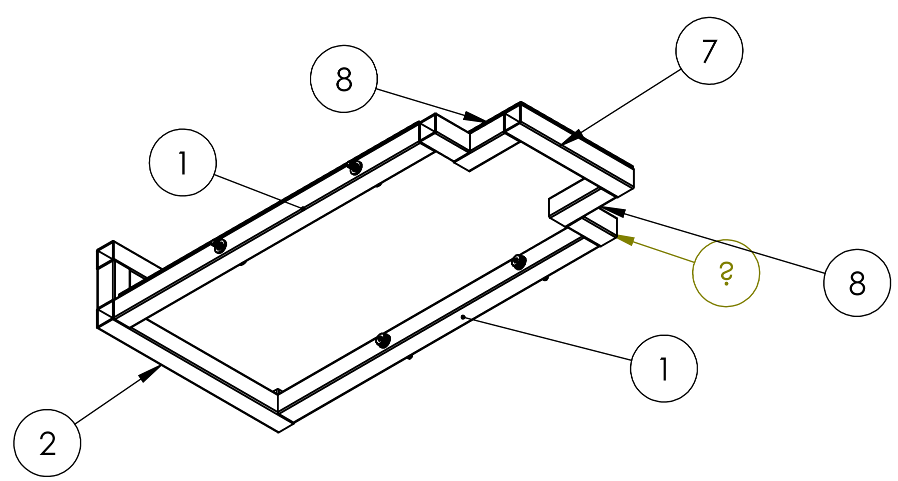




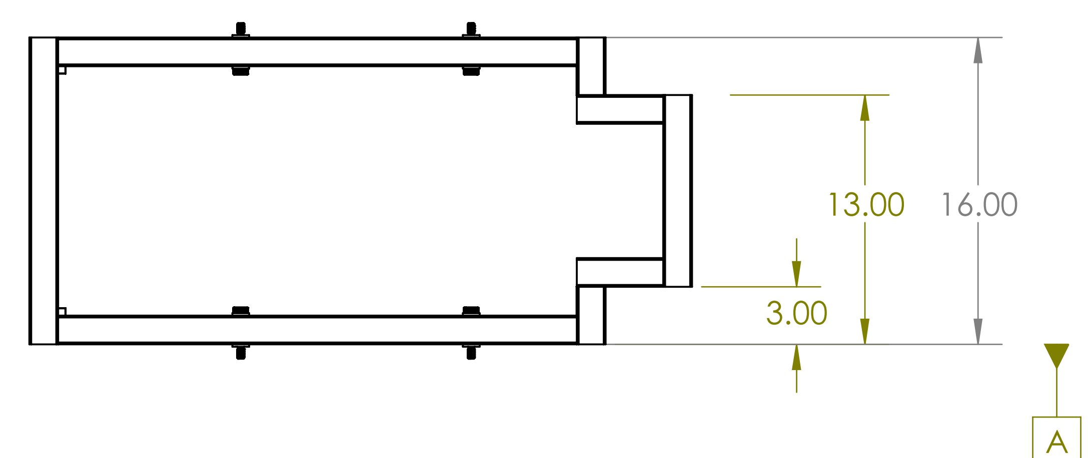
REAR VIEW
FOR REF ONLY



SIDE VIEW

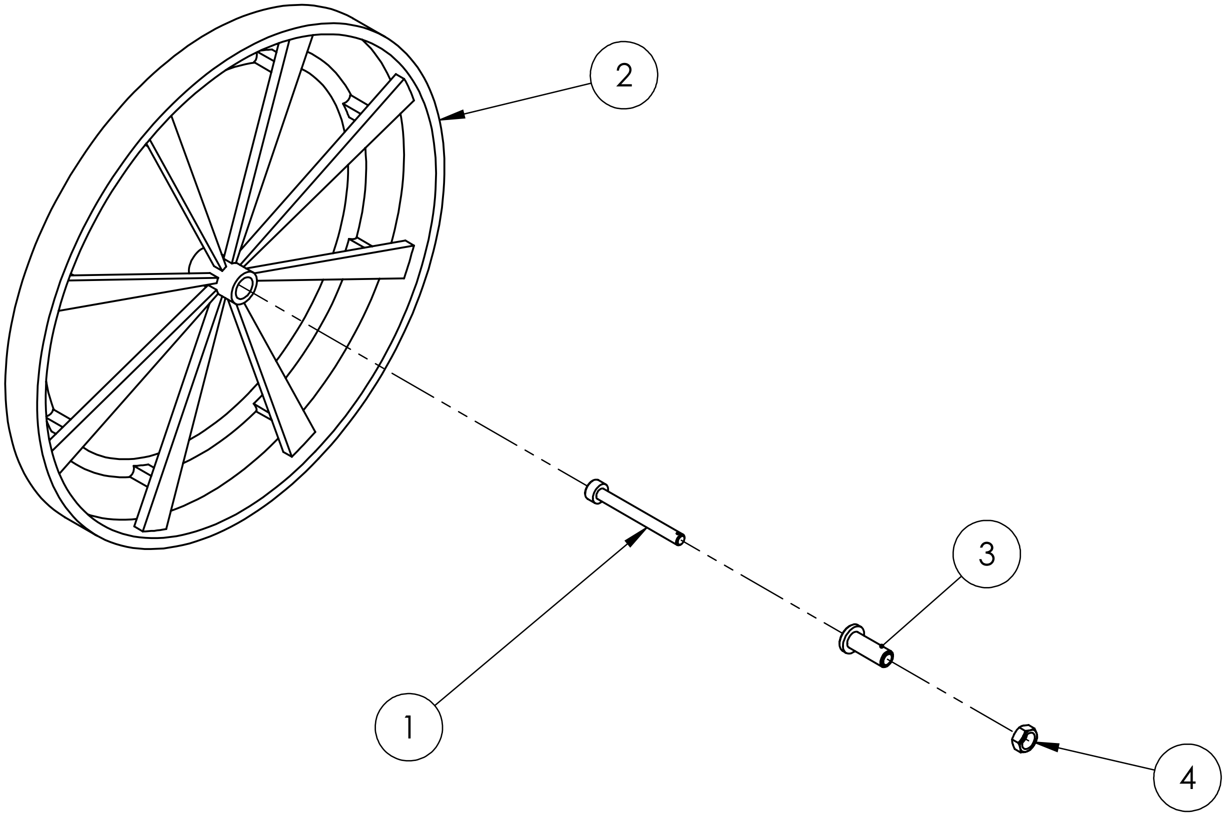


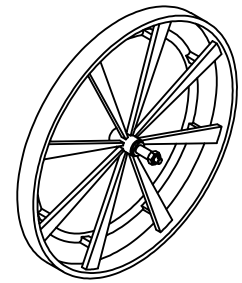
ISOMETRIC VIEWS
NO SCALE



BOTTOM VIEW

Cal Poly Mechanical Engineering ME 430 - FALL 2018	Lab Section: 01	Assignment #	Title: RAMP (A-003)		Drwn. By: AARON KAN
	Dwg. #: A-003	Nxt Asb: A-001	Date: 10-25-2018	Scale: 1:10	Chkd. By: ME STAFF

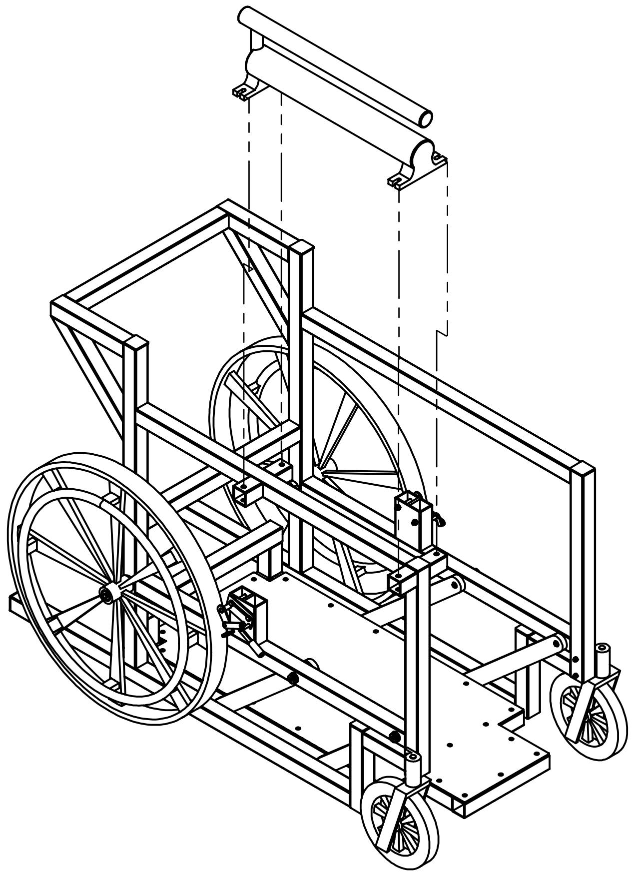




NOT TO SCALE

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	W-001	WHEEL AXLE	1
2	W-002	REAR WHEEL	1
3	W-003	AXLE RECEIVER	1
4	W-004	JAM NUT	1

Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: REAR WHEEL ASSEMBLY		Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: A-004	Nxt Asb: A-001	Date: 12-06-2018	Scale:	Chkd. By: ME STAFF



NOTES

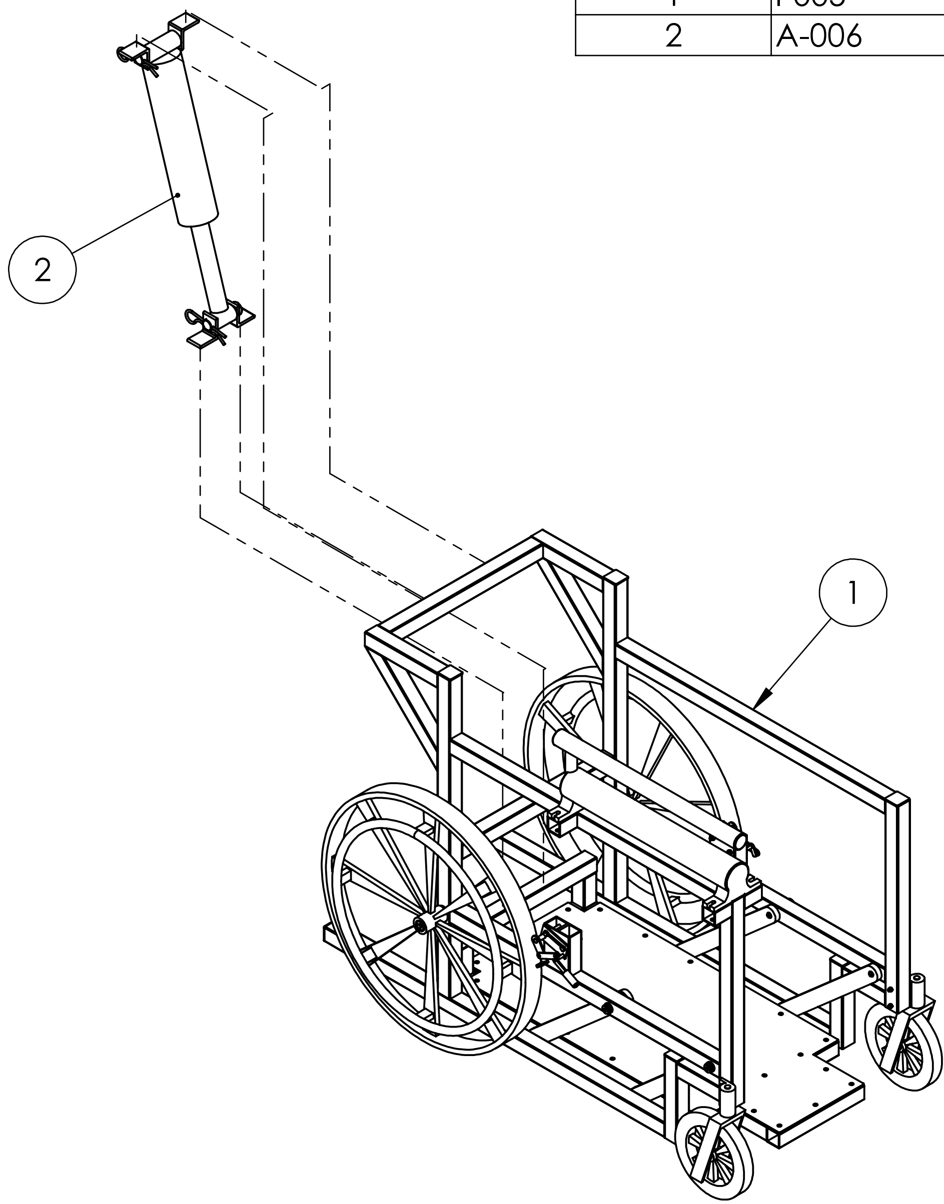
UNLESS OTHERWISE SPECIFIED

1. WELD PUMP MOUNTS (F-010) EQUIVALENT LENGTH OF PUMP MOUNTING BRACKETS. ONE SIDE ONLY (RIGHT SIDE RECOMMENDED)
2. INSTALL WITH M8 BOLTS AND NUTS
3. MOUNT PUMP AS SHOWN
4. ALTERNATIVE PUMP PERMISSIBLE IF RATING MET (750 LB.)

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	I-005	DEVICE	1
2	F-010	PUMP MOUNT	4
6	lilpump		1

Cal Poly Mechanical Engineering ME 430 - FALL 2018	Lab Section: 01	Assignment #	Title: PUMP INSTALLATION	Drwn. By: AARON KAN
	Dwg. #: I-001	Nxt Asb:	Date: 12-06-2018 / Scale:	Chkd. By: ME STAFF

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	I-005	DEVICE	1
2	A-006	HYDRAULICS	1

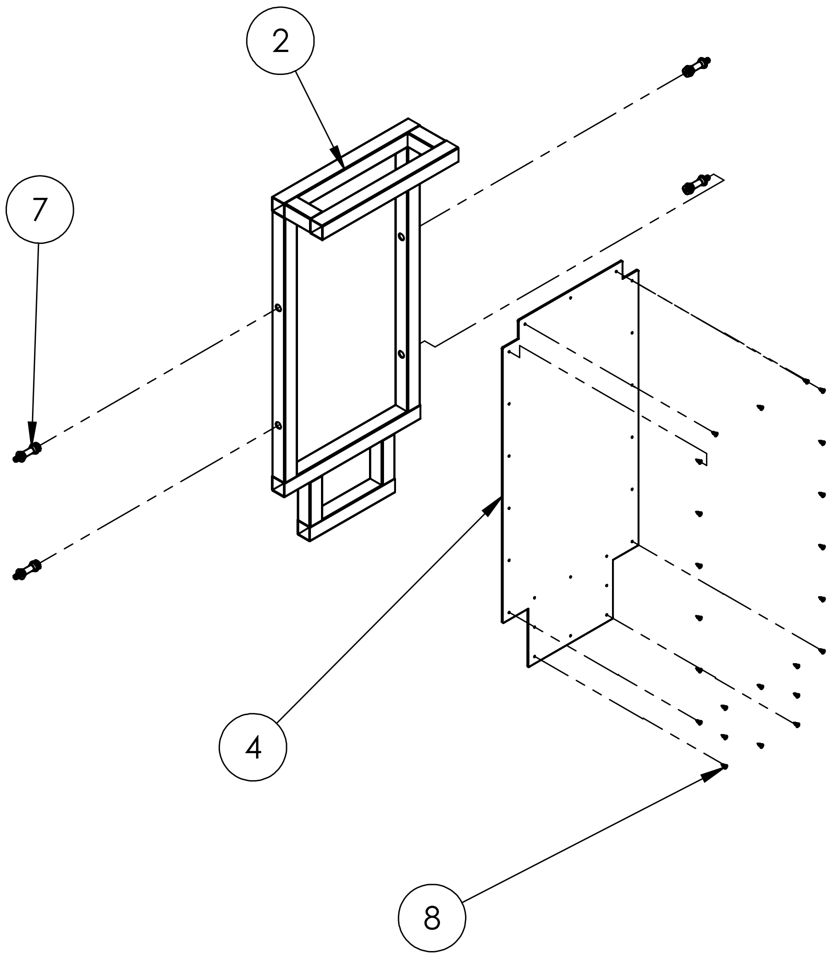


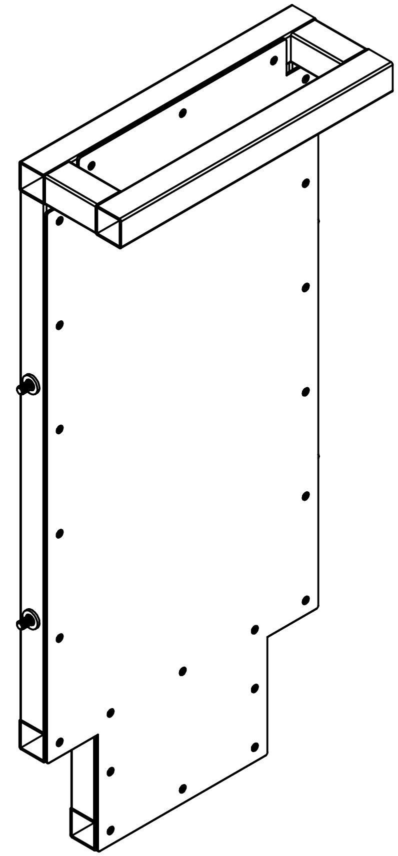
NOTES

UNLESS OTHERWISE SPECIFIED

1. HYDRAULIC BRACKET (B-001) TO BE SPACED ON TUBING MEMBERS F-009 TO ACCOMMODATE CYLINDER MOUNTS
2. INSTALL COMBINATION OF BUSHING AND CLEVIS PIN OR CLEVIS PIN ONLY DEPENDING ON SIZE.
3. MOUNT CYLINDER AS SHOWN

Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: CYLINDER INSTALLATION		Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: I-002	Nxt Asb:	Date: 12-06-2018	Scale:	Chkd. By: ME STAFF



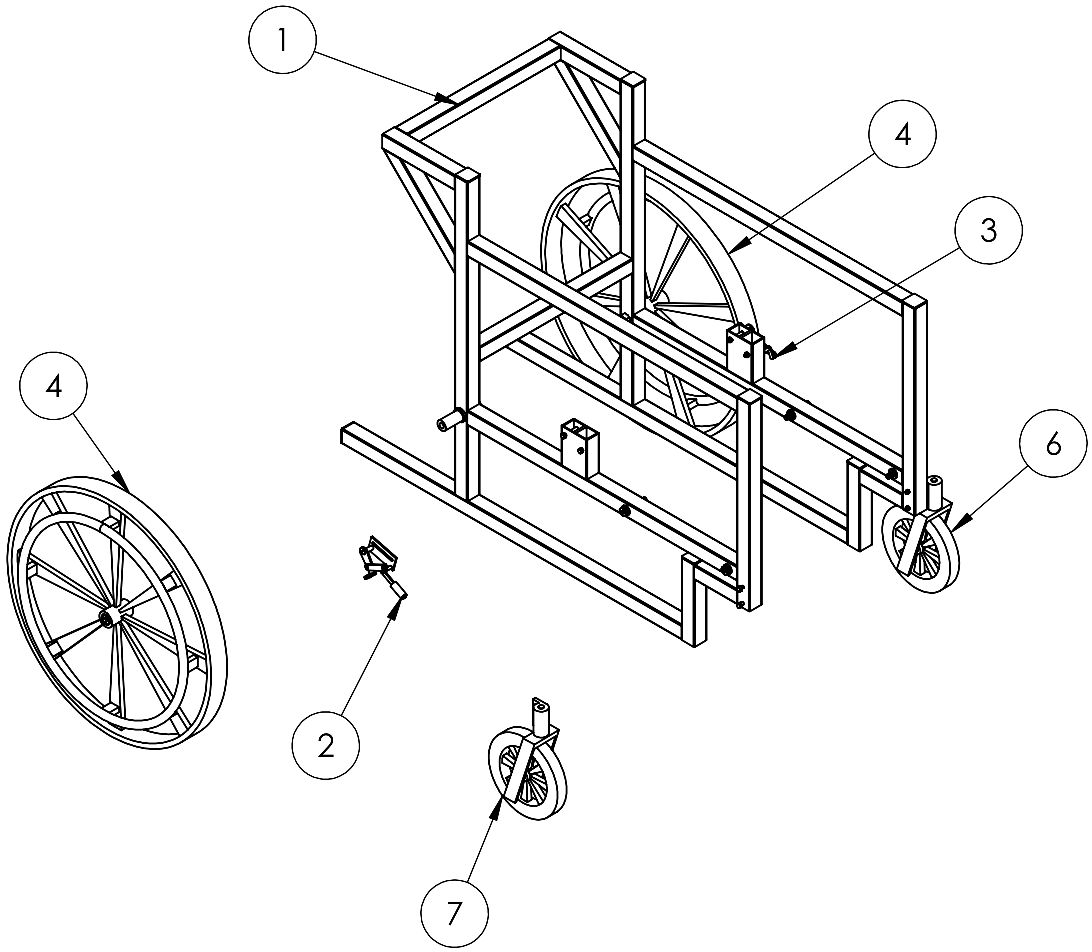


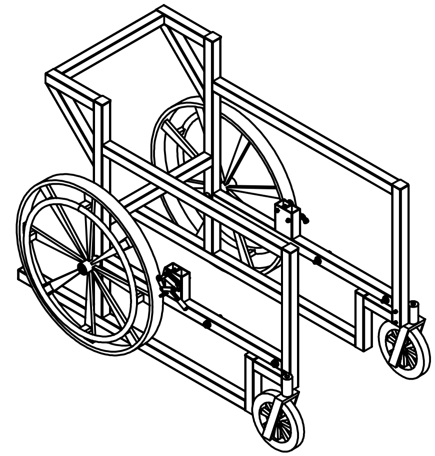
NOT TO SCALE

NOTES
UNLESS OTHERWISE SPECIFIED
1. INSTALL RAMP COVER MATERIAL (R-007) USING CARPET TAPE.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	A-003	RAMP ASSEMBLY	2
4	R-004	SHEET METAL PLATFORM	1
7	A-010	BUSHING ASSEMBLY	4
8	90198A302	#10 SHEET METAL SCREWS	23

Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: RAMP INSTALLATION		Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: I-003	Nxt Asb:	Date: 12-06-2018	Scale:	Chkd. By: ME STAFF

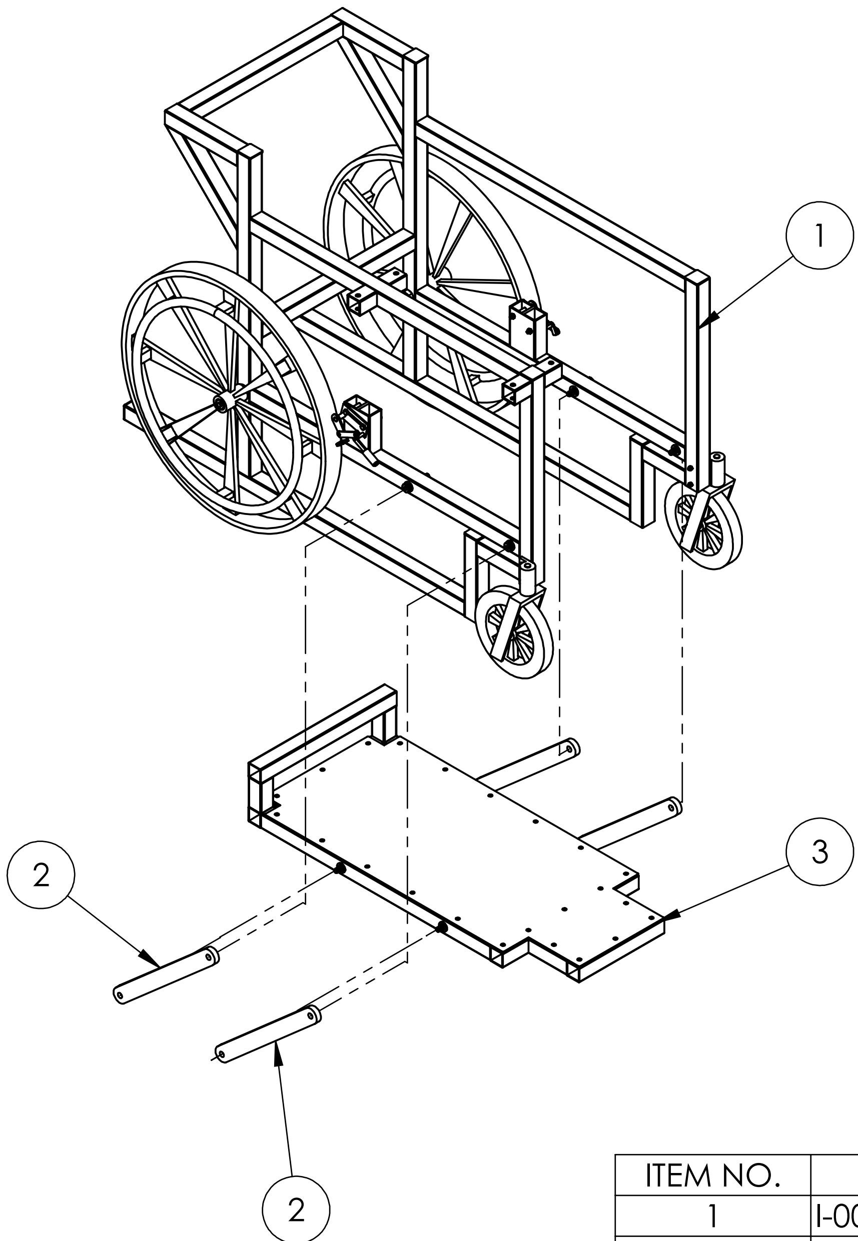




NOT TO SCALE

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	A-002	FRAME	1
2	A-009	BRAKE ASSEMBLY (R)	1
3	A-009	BRAKE ASSEMBLY (L)	1
4	A-004	REAR WHEEL ASSEMBLY (R)	1
5	A-004	REAR WHEEL ASSEMBLY (L)	1
6	A-005	CASTER ASSEMBLY (L)	1
7	A-005	CASTER ASSEMBLY (R)	1

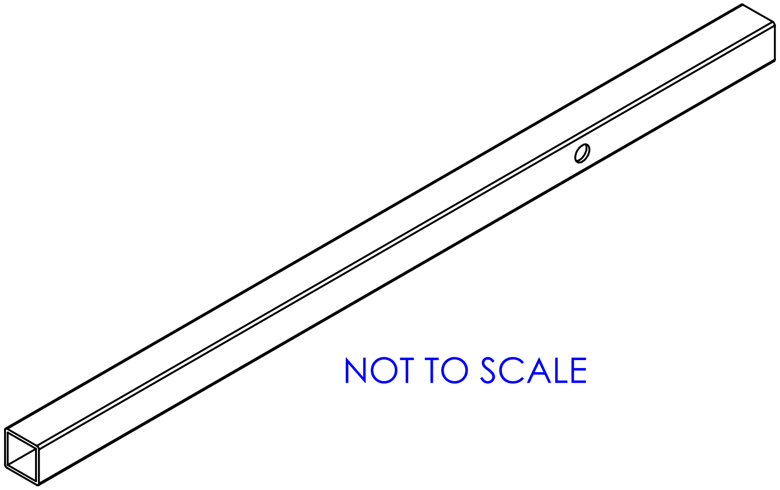
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: FRAME INSTALLATION		Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: I-004	Nxt Asb:	Date: 12-06-2018	Scale:	Chkd. By: ME STAFF



NOTES
UNLESS OTHERWISE SPECIFIED
1. USE BUSHING ASSEMBLY (A-010) TO ATTACH TO RAMP FIRST
2. ATTACH TO FRAME IN CROSS PATTERN TO AVOID FLEX IN THE MEMBERS

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	I-003	FRAME INSTALLATION	1
2	M-001	LINKAGE ARM	4
3	I-004	RAMP INSTALLATION	1

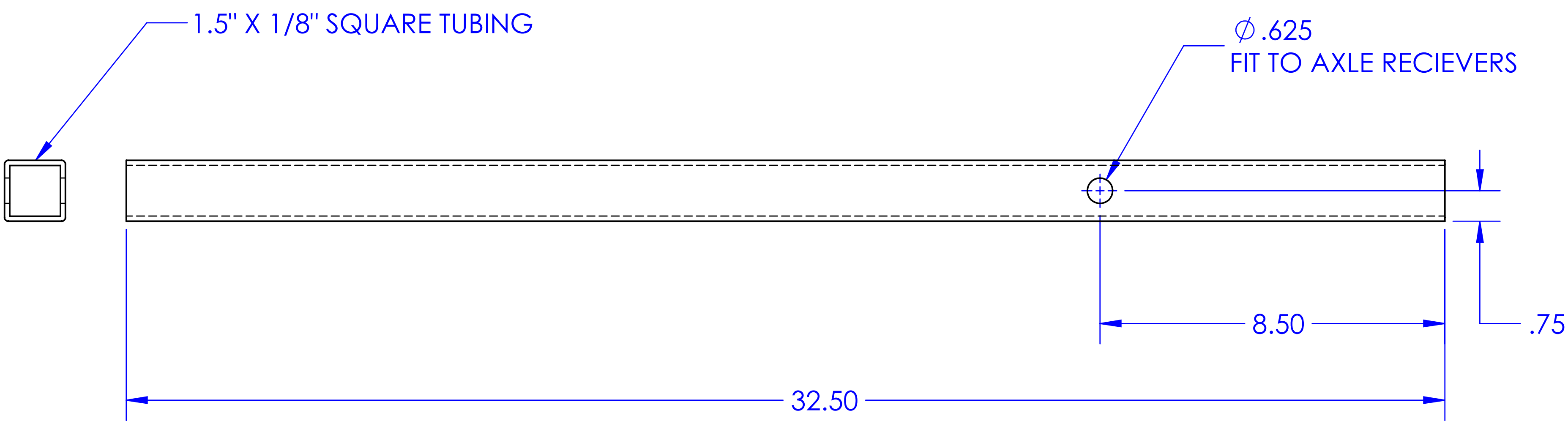
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: DEVICE INSTALLATION	Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: I-005	Nxt Asb:	Date: 12-06-2018 Scale:	Chkd. By: ME STAFF



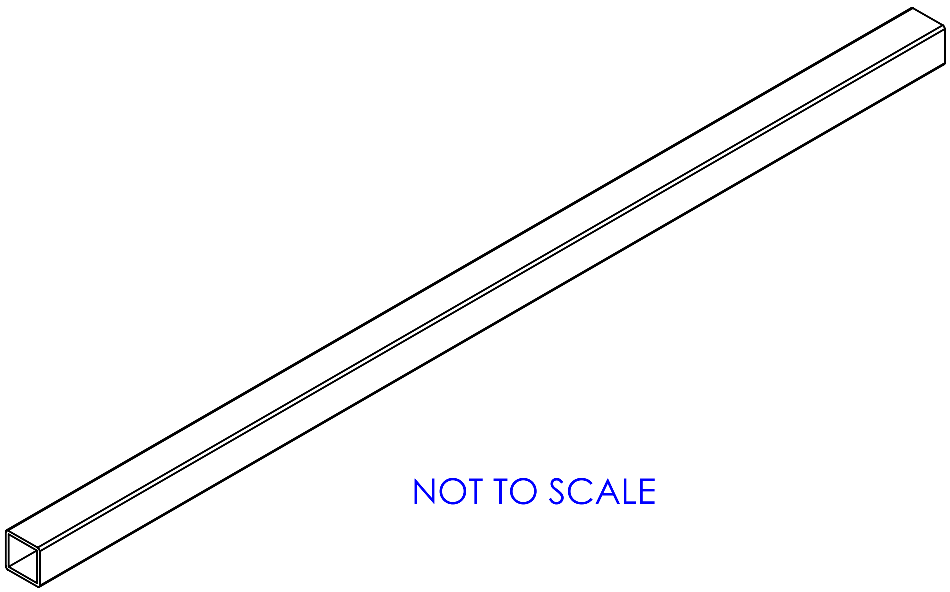
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= ±.01
   X.XXX= ±.005
   ANGLES= ±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1.5 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE

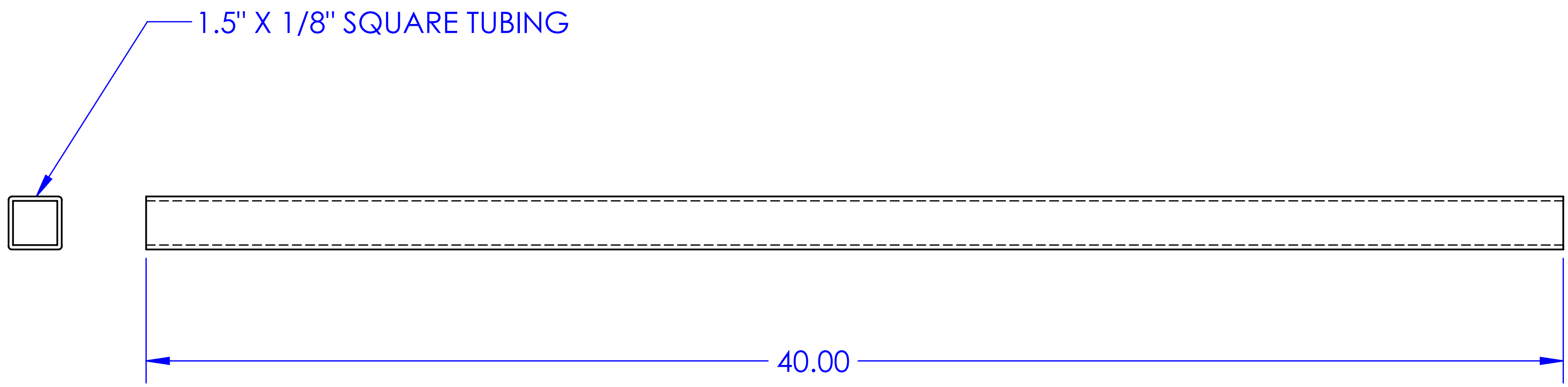


Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: VERTICAL REAR MEMBER F-001		Drwn. By: AARON KAN
ME 429 - SPRING 2018	Dwg. #: D-0201	Nxt Asb: A-002	Date: 10-11-2018	Scale: 1:4	Chkd. By: ME STAFF

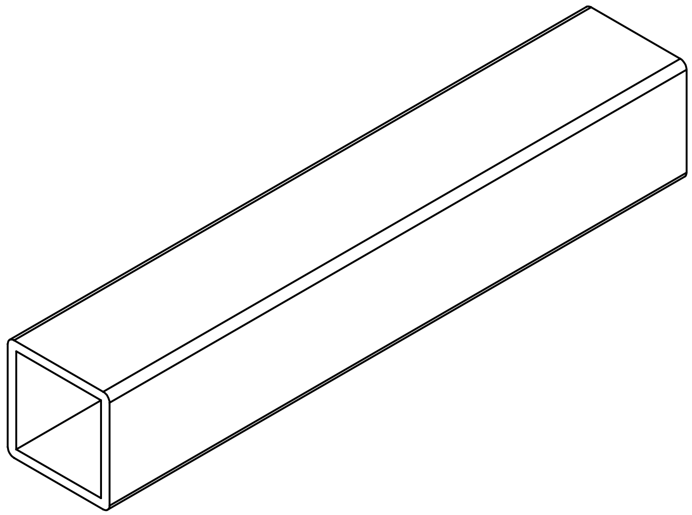


NOT TO SCALE

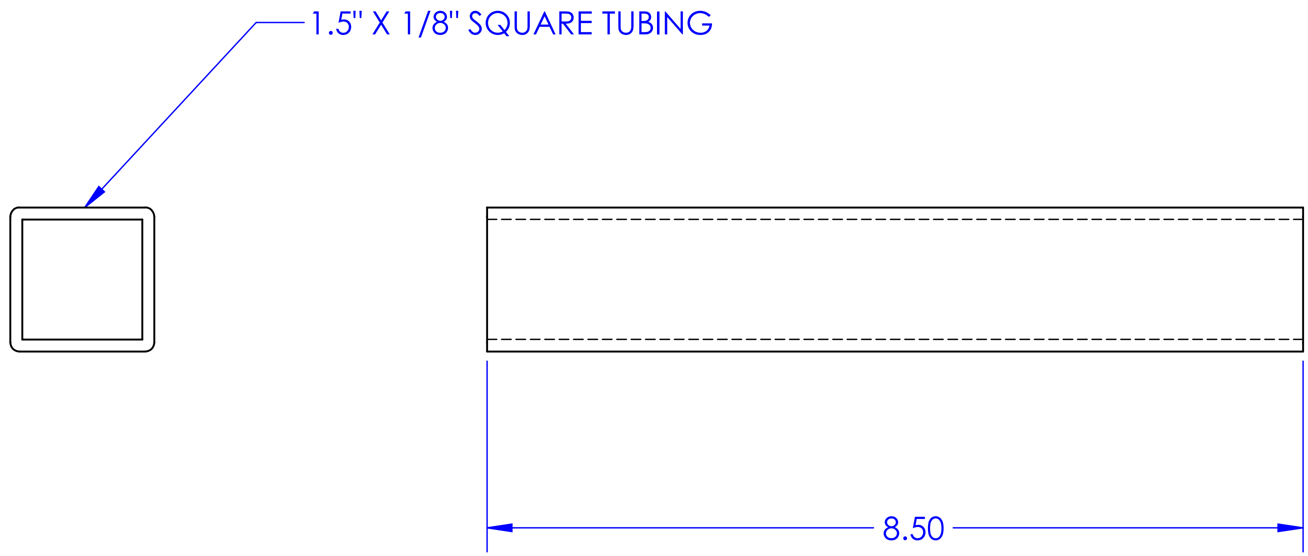
NOTES
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= ±.01
   X.XXX= ±.005
   ANGLES= ±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



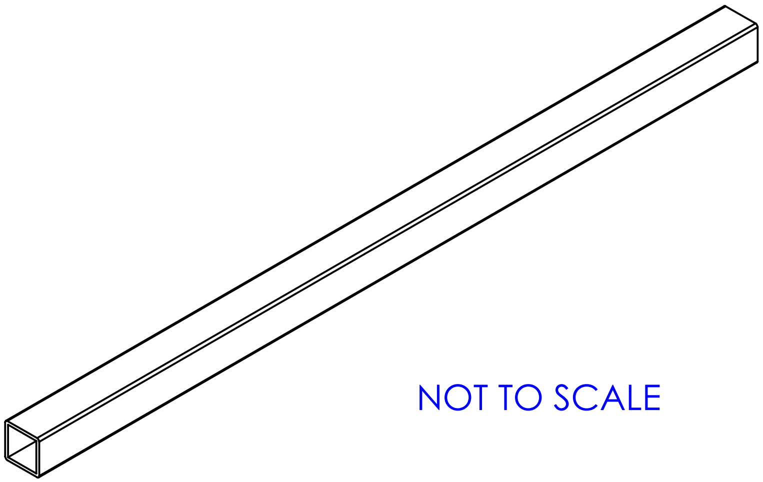
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: ANTI-TIP MEMBER F-002	Drwn. By: AARON KAN
ME 429 - SPRING 2018	Dwg. #: D-0202	Nxt Asb: A-002	Date: 10-11-2018 Scale: 1:5	Chkd. By: ME STAFF



NOTES
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX=±.01
   X.XXX=±.005
   ANGLES=±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: HANDLE MEMBER F-003		Drwn. By: AARON KAN
ME 429 - SPRING 2018	Dwg. #: D-0203	Nxt Asb: A-002	Date: 10-11-2018	Scale: 1:2	Chkd. By: ME STAFF

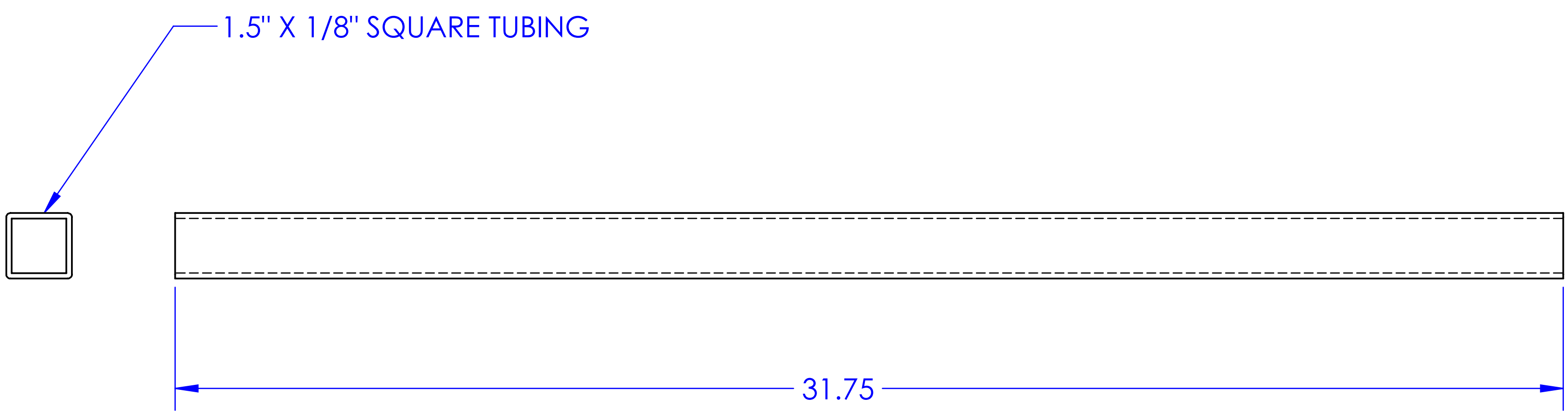


NOT TO SCALE

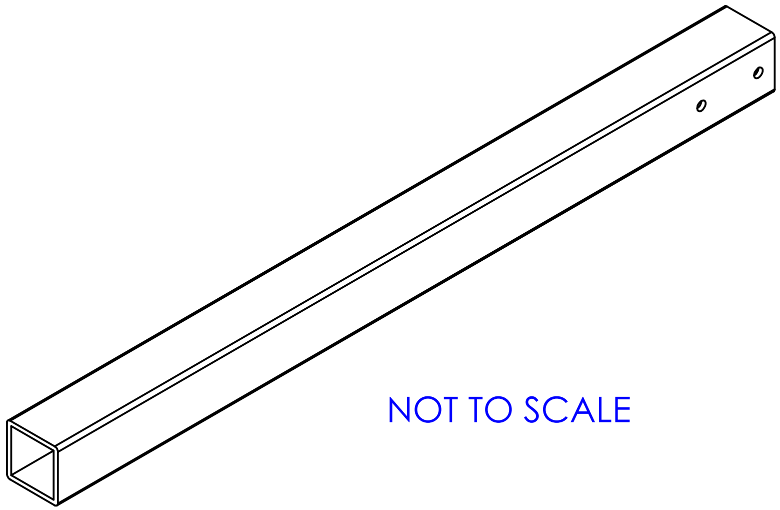
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= ±.01
   X.XXX= ±.005
   ANGLES= ±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: HIGH CONNECTOR F-004	Drwn. By: CRAIG MILLER
ME 429 - SPRING 2018	Dwg. #: D-0204	Nxt Asb: A-002	Date: 10-11-2018 / Scale: 1:4	Chkd. By: ME STAFF

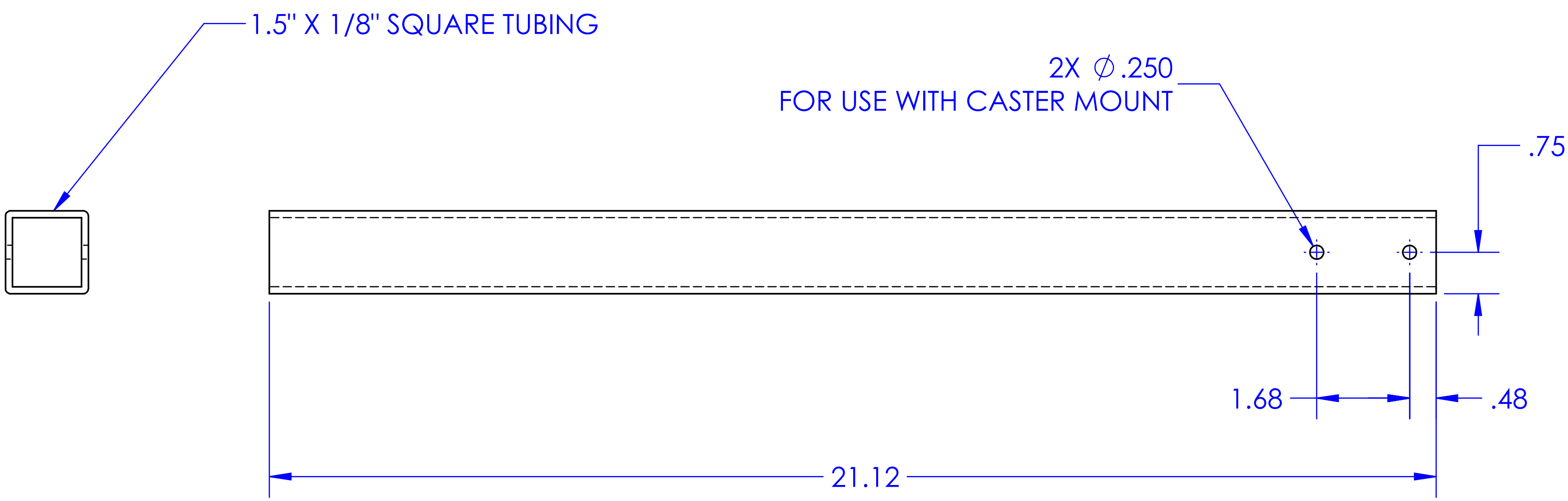


NOT TO SCALE

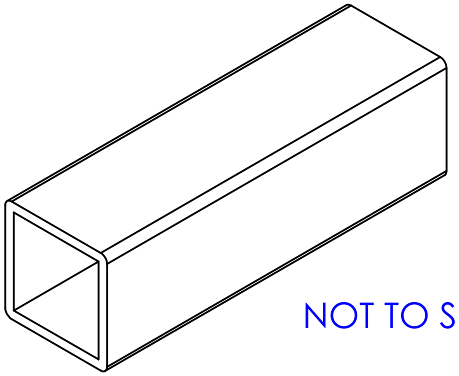
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   - X.XX= ±.01
   - X.XXX= ±.005
   - ANGLES= ±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: VERTICAL FRONT MEMBER F-005	Drwn. By: CRAIG MILLER
ME 429 - SPRING 2018	Dwg. #: D-0205	Nxt Asb: A-002	Date: 10-11-2018 / Scale: 1:3	Chkd. By: ME STAFF

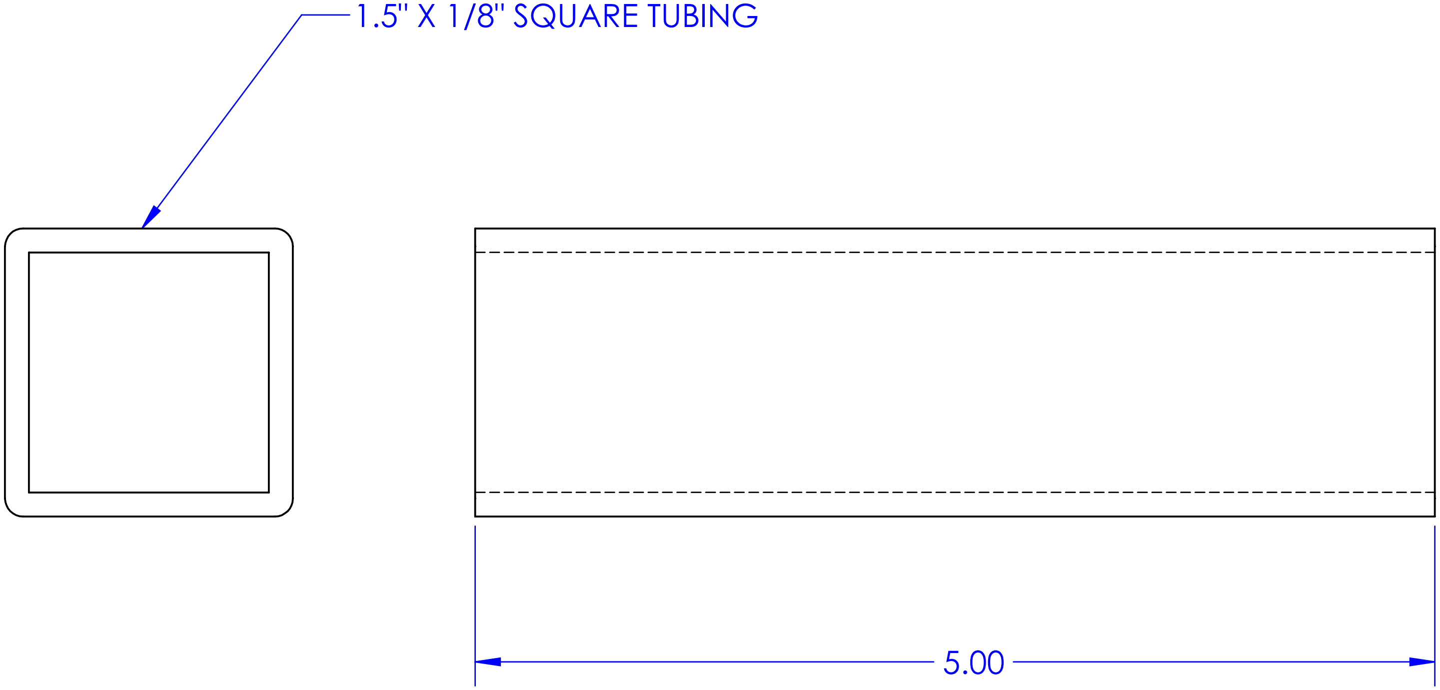


NOT TO SCALE

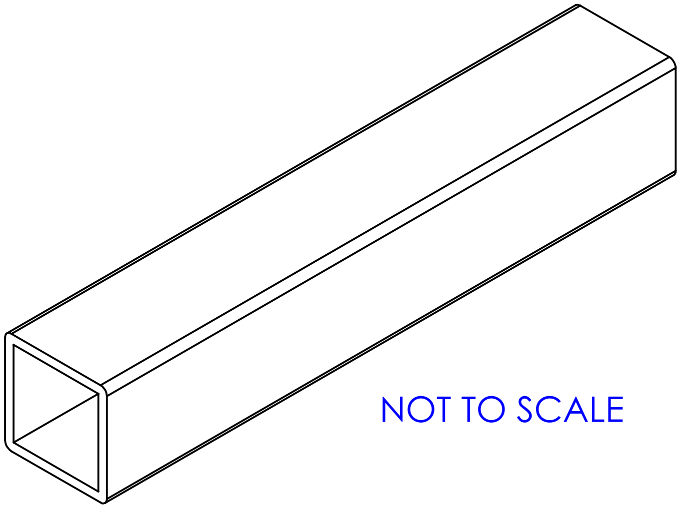
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= ±.01
   X.XXX= ±.005
   ANGLES= ±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: HORIZ. CASTER MEMBER F-006		Drwn. By: CRAIG MILLER
ME 429 - SPRING 2018	Dwg. #: D-0206	Nxt Asb: A-002	Date: 04-26-18	Scale: 1:1	Chkd. By: ME STAFF

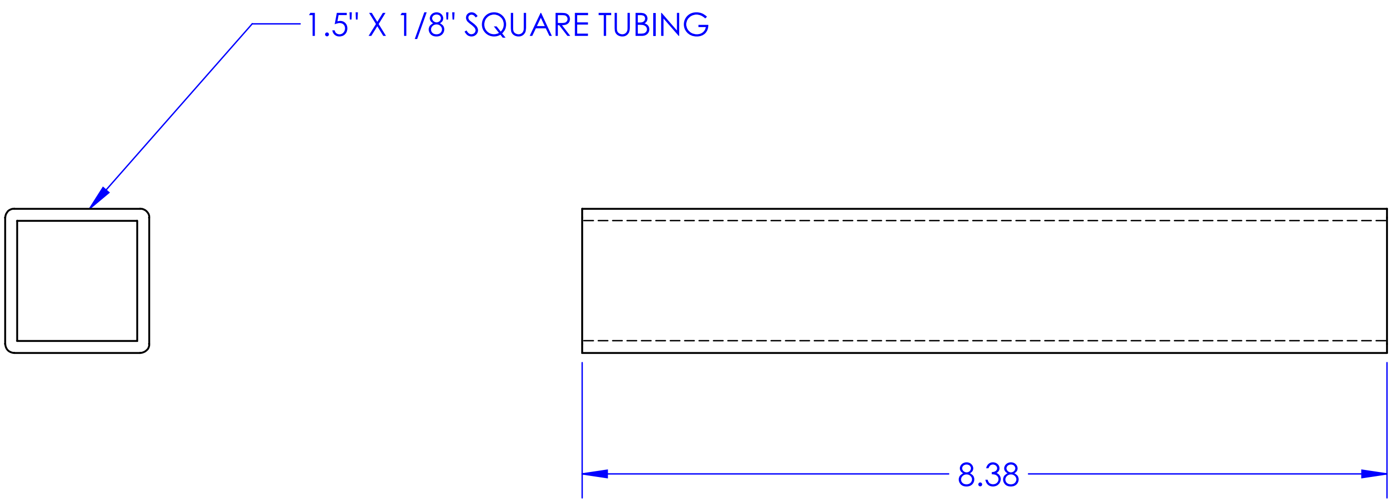


NOT TO SCALE

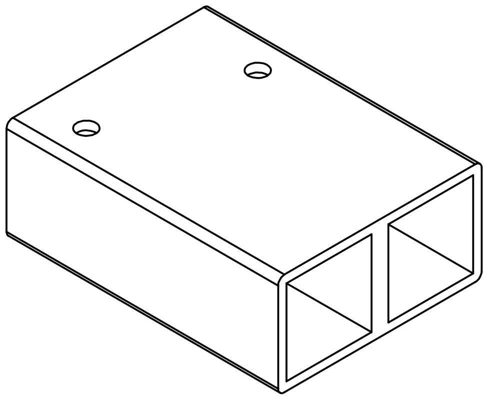
NOTES

UNLESS OTHERWISE SPECIFIED

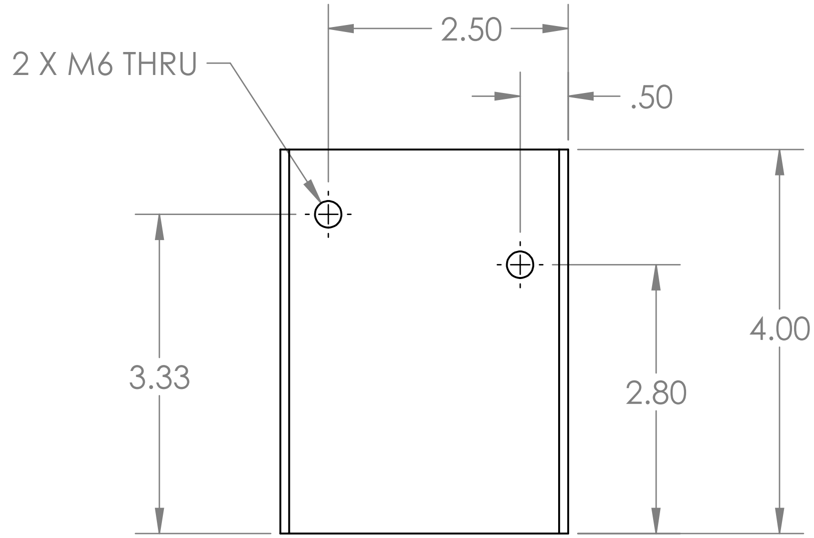
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= $\pm$.01
   X.XXX= $\pm$.005
   ANGLES= $\pm 2°$
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE

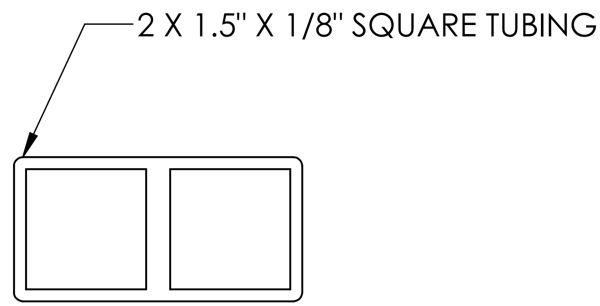


Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: VERT. CASTER MEMBER F-007		Drwn. By: CRAIG MILLER
ME 429 - SPRING 2018	Dwg. #: D-0207	Nxt Asb: A-002	Date: 10-11-2018	Scale: 1:2	Chkd. By: ME STAFF



NOT TO SCALE



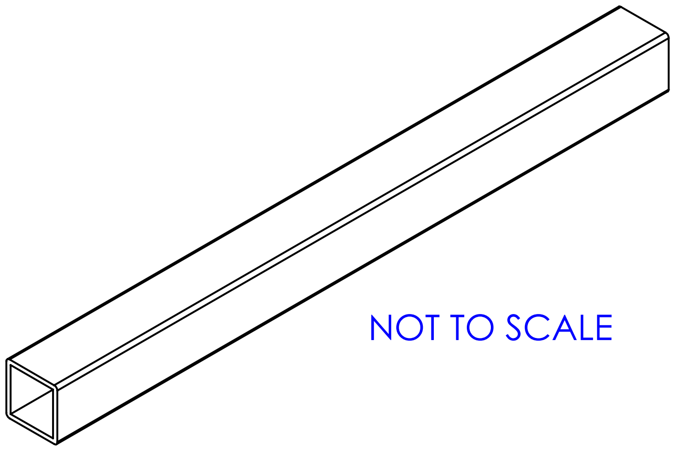


NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= $\pm$.01
   X.XXX= $\pm$.005
   ANGLES= $\pm 2^{\circ}$
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE
8. GRIND WELDS FLAT TO SURFACE
9. HOLES LOCATED APPROX. DUE TO BRAKE MOUNT.

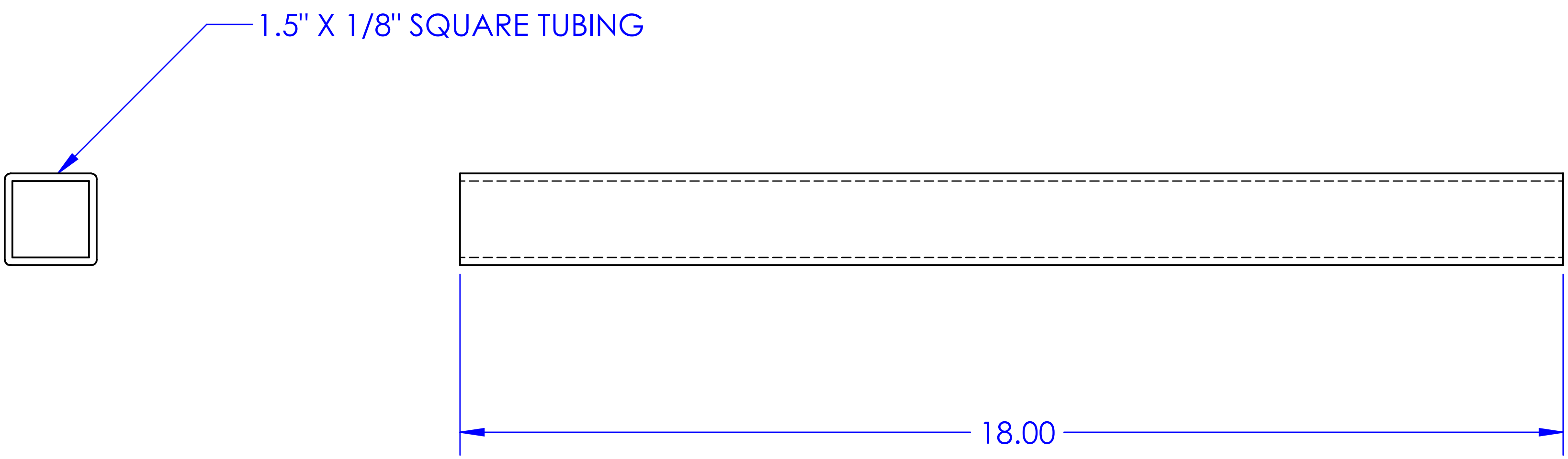
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: BRAKE MEMBER		Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: D-0208-1	Nxt Asb: A-002	Date: 12-04-18	Scale: 1:2	Chkd. By: ME STAFF



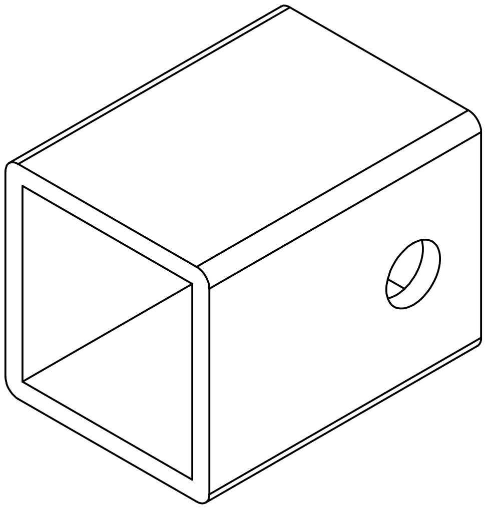
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= ±.01
   X.XXX= ±.005
   ANGLES= ±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: CROSS BRACE F-009		Drwn. By: CRAIG MILLER
ME 429 - SPRING 2018	Dwg. #: D-0209	Nxt Asb: A-002	Date: 10-11-18	Scale: 1:3	Chkd. By: ME STAFF

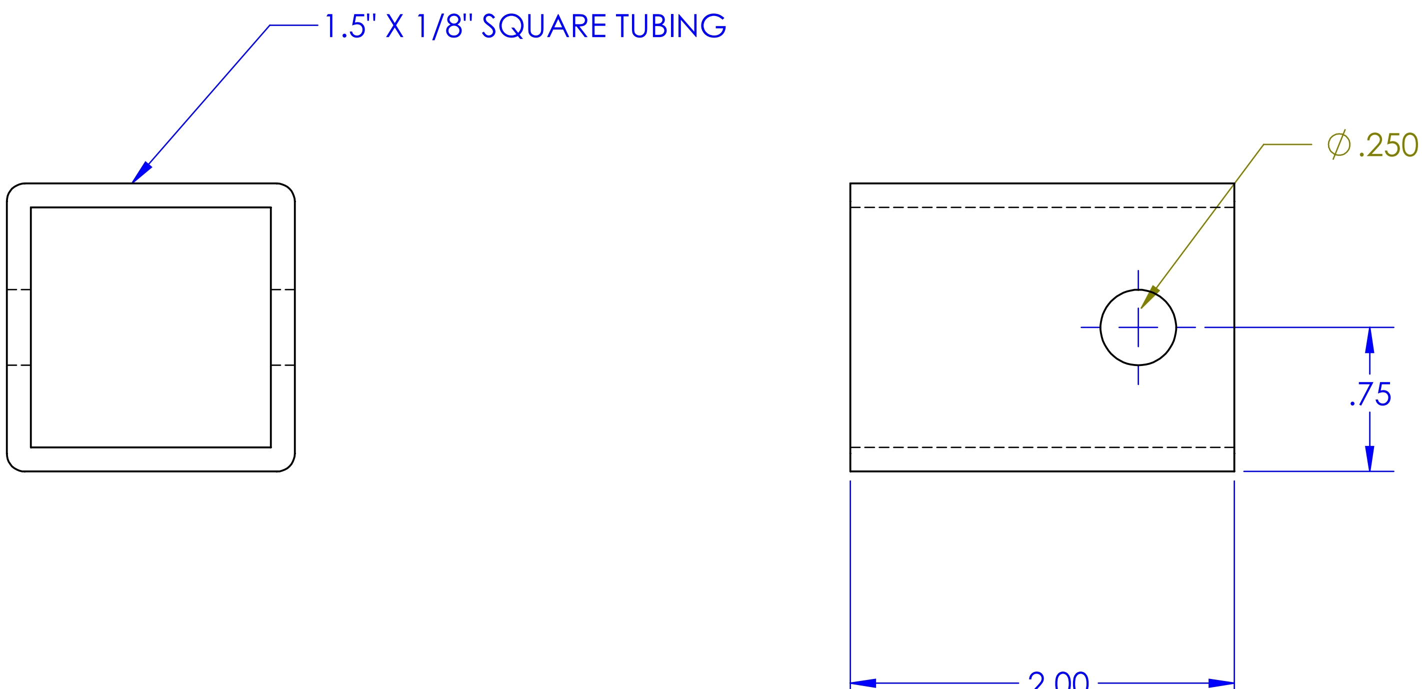


NOT TO SCALE

NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= ±.01
   X.XXX= ±.005
   ANGLES= ±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED

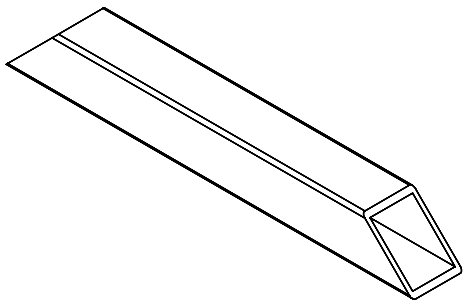


Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: PUMP MOUNT (F-010)	Drwn. By: CRAIG MILLER
ME 429 - SPRING 2018	Dwg. #: D-0210	Nxt Asb: A-002	Date: 10-11-2018 | Scale: 1:1	Chkd. By: ME STAFF

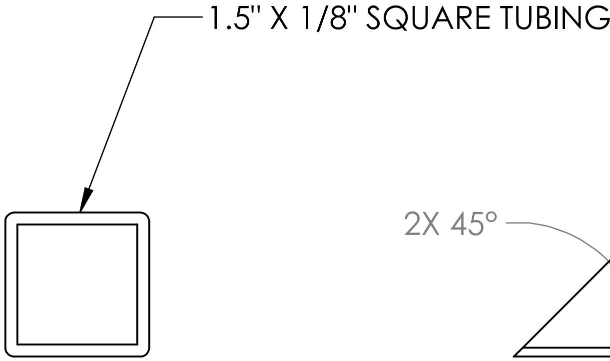
NOTES

UNLESS OTHERWISE SPECIFIED

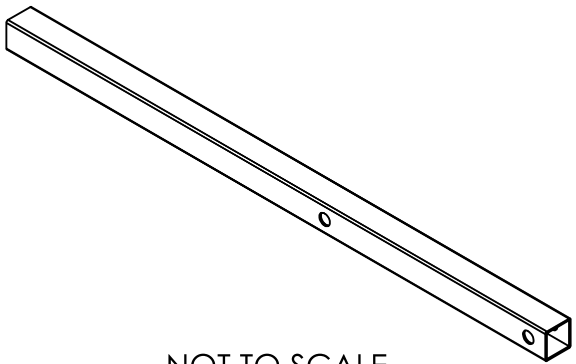
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX=±.01
   X.XXX=±.005
   ANGLES=±1°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



NOT TO SCALE



Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: FRAME BRACE F-011	Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: D-0211	Nxt Asb: A-002	Date: 10-11-18 / Scale: 1:2	Chkd. By: ME STAFF

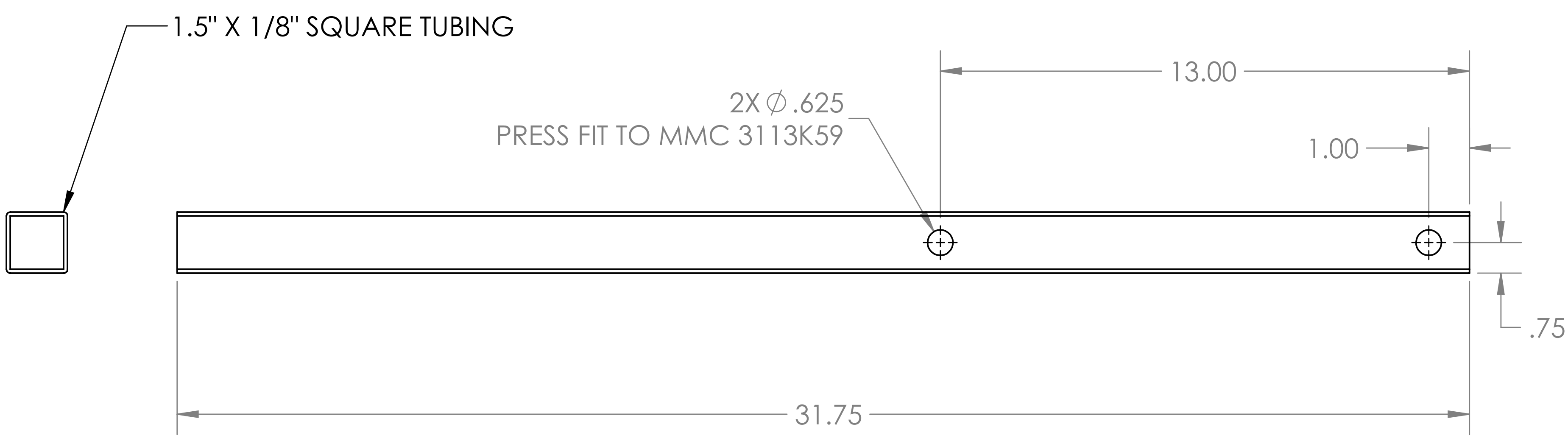


NOT TO SCALE

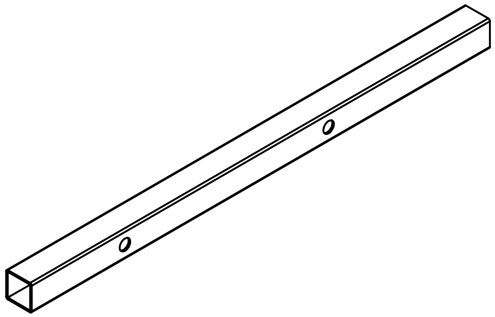
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= ± .01
   X.XXX= ± .005
   ANGLES= ± 2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. ADD WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: LINKAGE MEMBER F-012		Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: D-0212	Nxt Asb: A-002	Date: 10-11-2018	Scale: 1:4	Chkd. By: ME STAFF

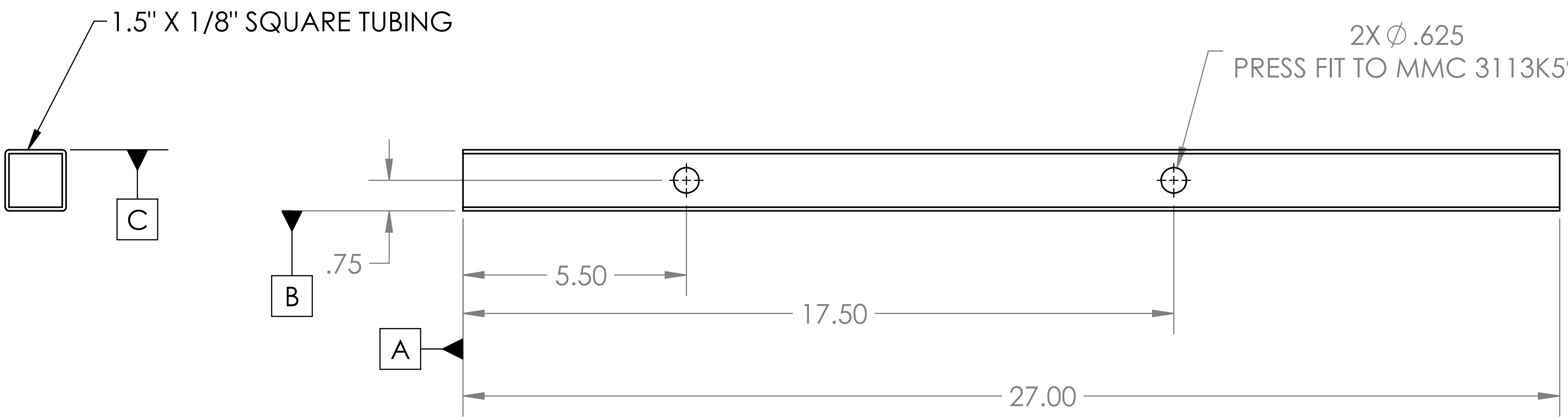


NOT TO SCALE

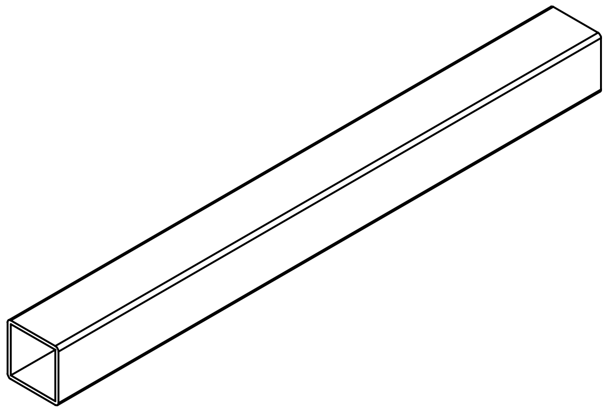
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   - X.XX= ±.01
   - X.XXX= ±.005
   - ANGLES= ±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 T6 ALUMINUM
6. ADD ∅0.25" WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



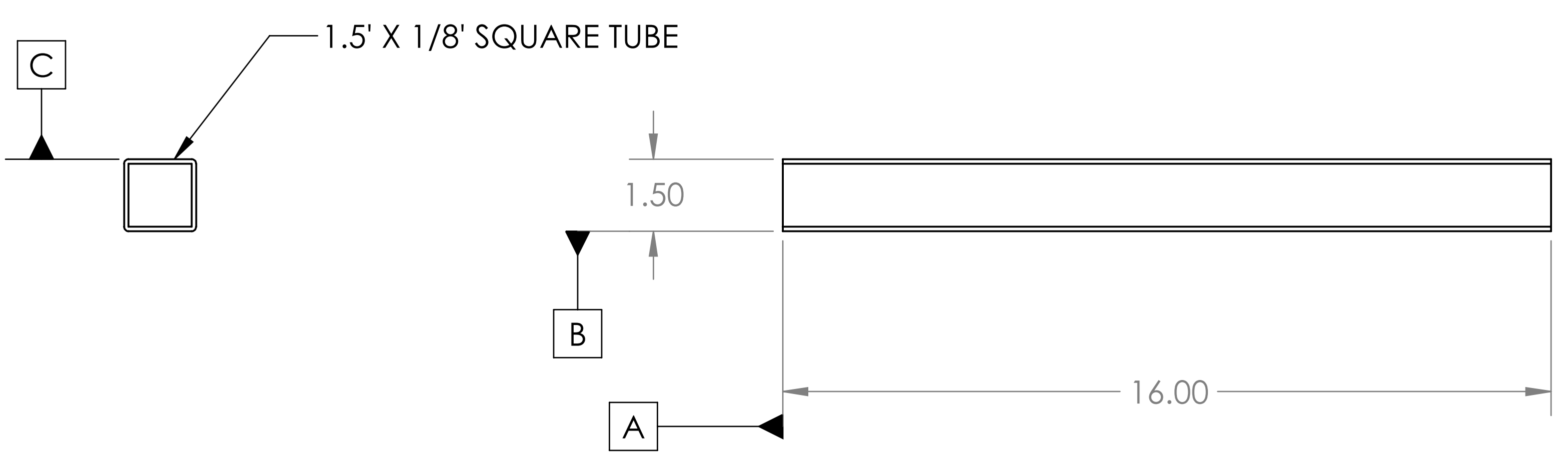
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: LONG RAMP MEMBER (R-001)	Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: D-0301	Nxt Asb: A-003	Date: 10-16-2018 / Scale: 1:4	Chkd. By: ME STAFF



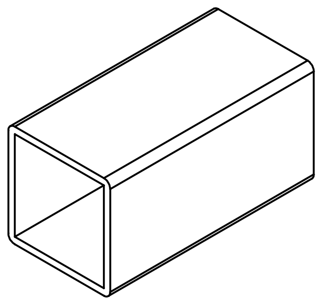
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX=±.01
   X.XXX=±.005
   ANGLES=±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 T6 ALUMINUM
6. ADD ∅0.25" WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



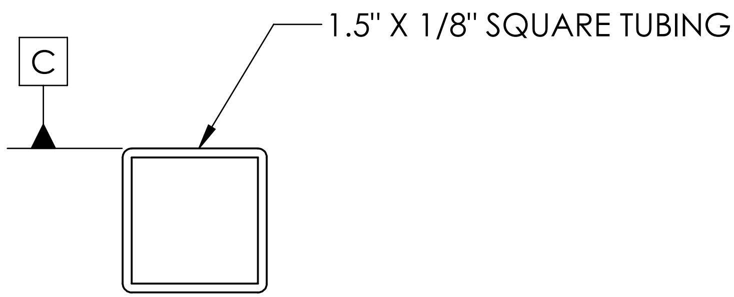
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: HORIZONTAL REAR MEMBER		Drwn. By: BRYCE PETERSEN
ME 430 - FALL 2018	Dwg. #:D-0302	Nxt Asb:003	Date: 10/17/18	Scale: 1:4	Chkd. By: ME STAFF

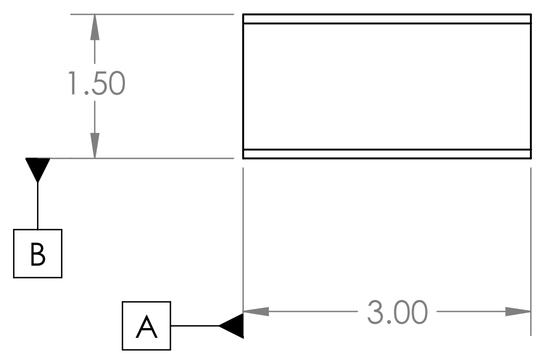


NOTES

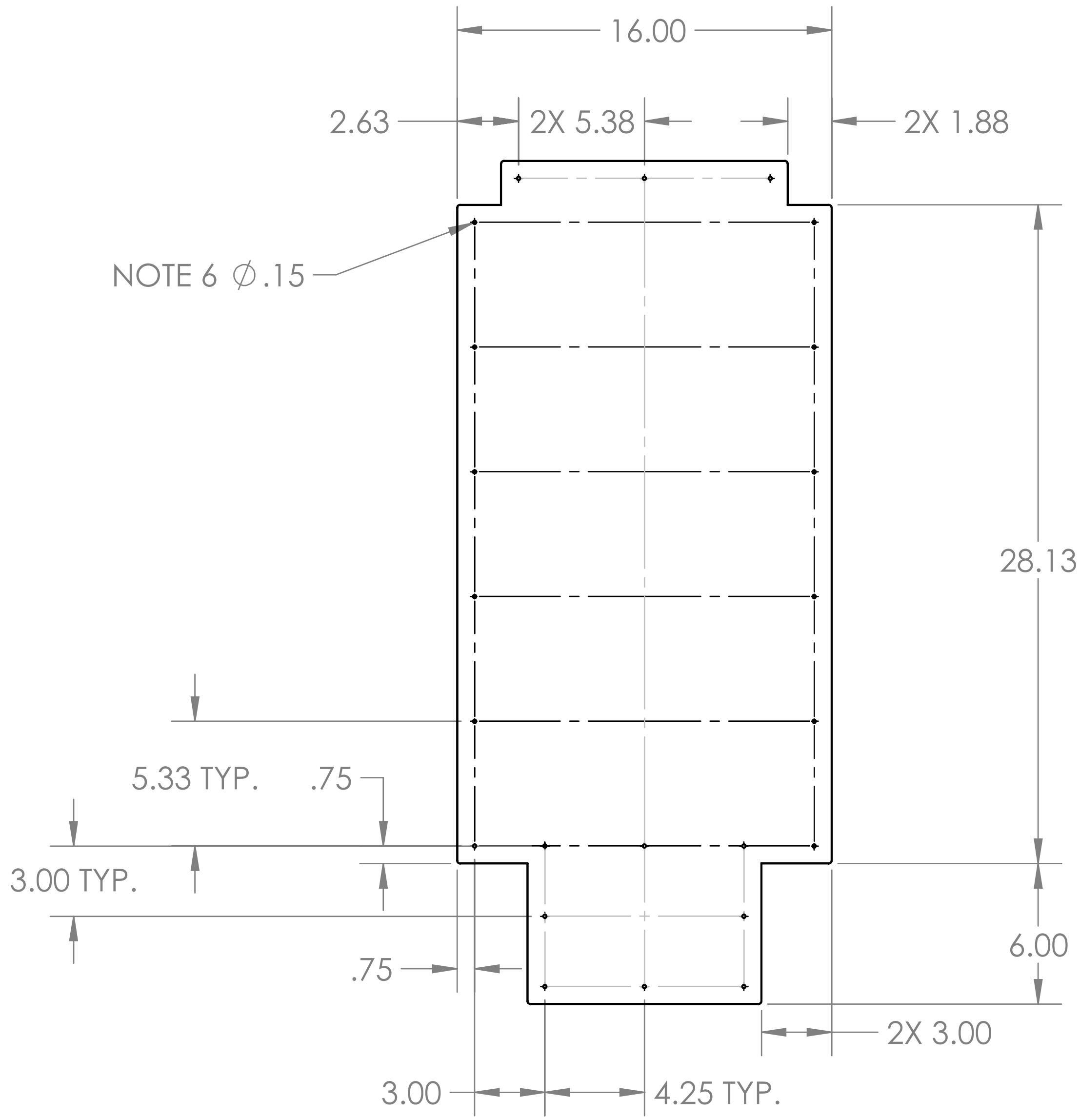
UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX=±.01
   X.XXX=±.005
   ANGLES=±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 T6 ALUMINUM
6. ADD ∅0.25" WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE





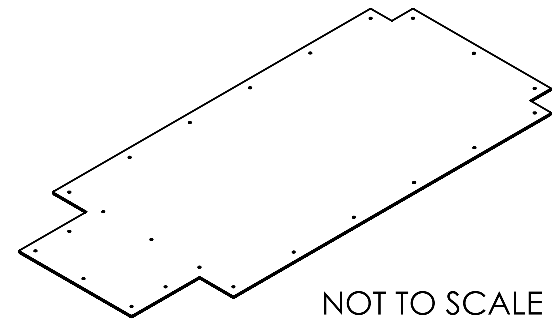
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: VERTICAL REAR MEMBER	Drwn. By: BRYCE PETERSEN
ME 430 - FALL 2018	Dwg. #:D-0303	Nxt Asb: 003	Date: 10/17/18 / Scale: 1:2	Chkd. By: ME STAFF



NOTES

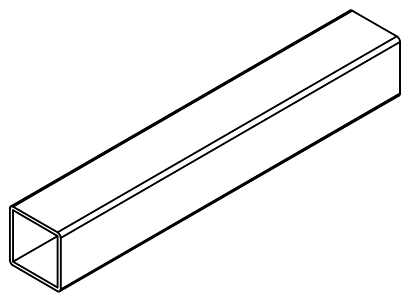
UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX=±.01
   X.XXX=±.005
   ANGLES=±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 1/8" THICK 6061 T6 ALUMINUM
6. HOLE DIAMETER DOWN-SIZED FOR CUTTING ON WATER JET. PRE-DRILL HOLES FOR NO. 10 SHEET METAL SCREWS TO BE INCREASED TO ∅.159 USING NO. 21 DRILL BIT IF NECESSARY.



NOT TO SCALE

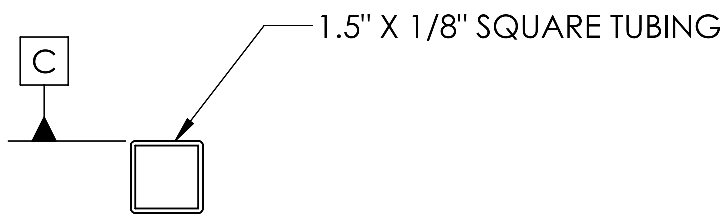
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: SHEET METAL PLATFORM (R-004)		Drwn. By: CRAIG MILLER
ME 430 - FALL 2018	Dwg. #: D-0304	Nxt Asb: A-003	Date: 11-03-2018	Scale: 1:8	Chkd. By: ME STAFF

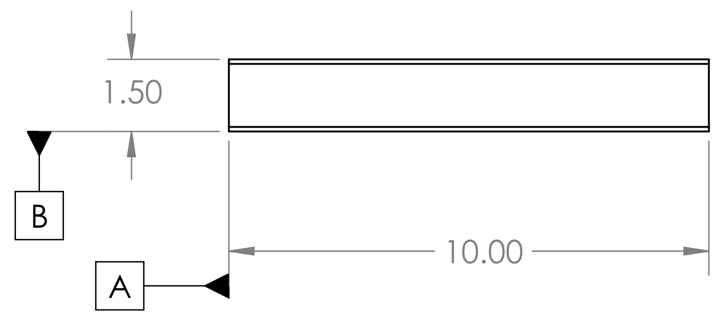


NOTES

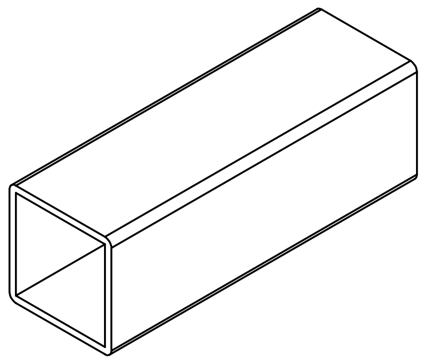
UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   - X.XX= $\pm$.01
   - X.XXX= $\pm$.005
   - ANGLES= $\pm 2^\circ$
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 T6 ALUMINUM
6. ADD ∅0.25" WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE





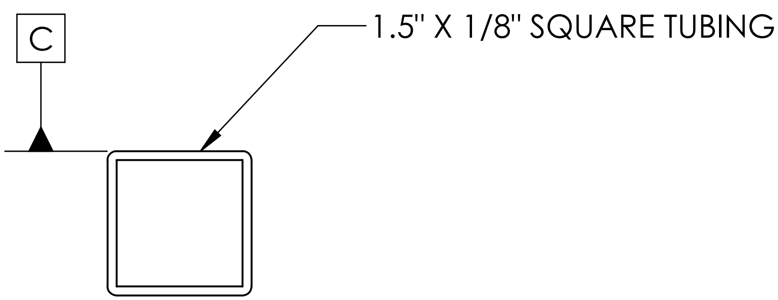
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: FRONT MEMBER		Drwn. By: BRYCE PETERSEN
ME 430 - FALL 2018	Dwg. #: D-0305	Nxt Asb: 003	Date:10/17/18	Scale: 1:4	Chkd. By: ME STAFF

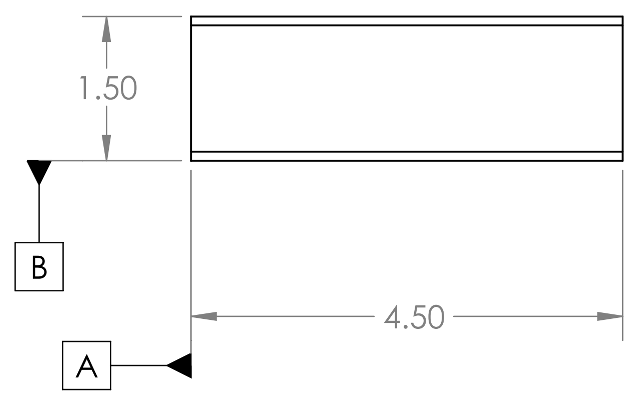


NOTES

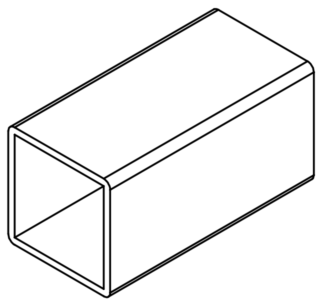
UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX= ±.01
   X.XXX= ±.005
   ANGLES= ±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 T6 ALUMINUM
6. ADD ∅0.25" WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE





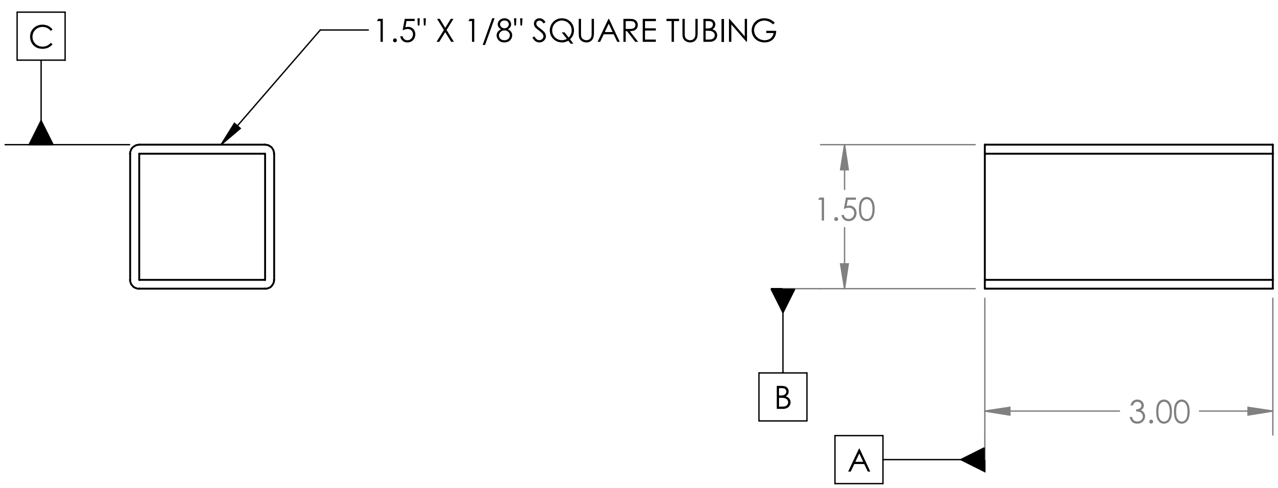
Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: FRONT MID MEMBER	Drwn. By: BRYCE PETERSEN
ME 430 - FALL 2018	Dwg. #: D-0306	Nxt Asb: 003	Date: 10/17/18 · Scale: 1:2	Chkd. By: ME STAFF



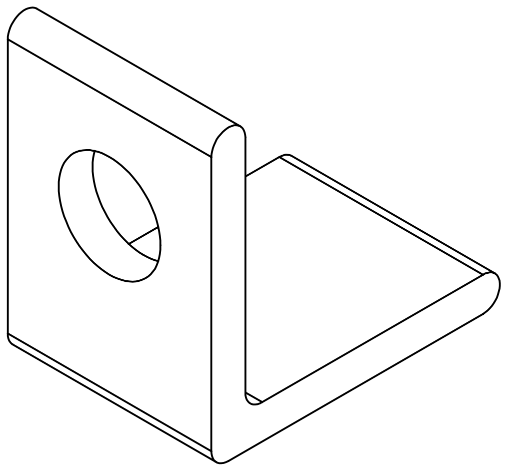
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX=±.01
   X.XXX=±.005
   ANGLES=±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 T6 ALUMINUM
6. ADD ∅0.25" WELD VENT HOLES APPROX 1 IN. FROM WELD SURFACE AS NEEDED
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: FRONT REAR MEMBER		Drwn. By: BRYCE PETERSEN
ME 430 - FALL 2018	Dwg. #: D-0307	Nxt Asb: 003	Date: 10/17/18	Scale: 1:2	Chkd. By: ME STAFF

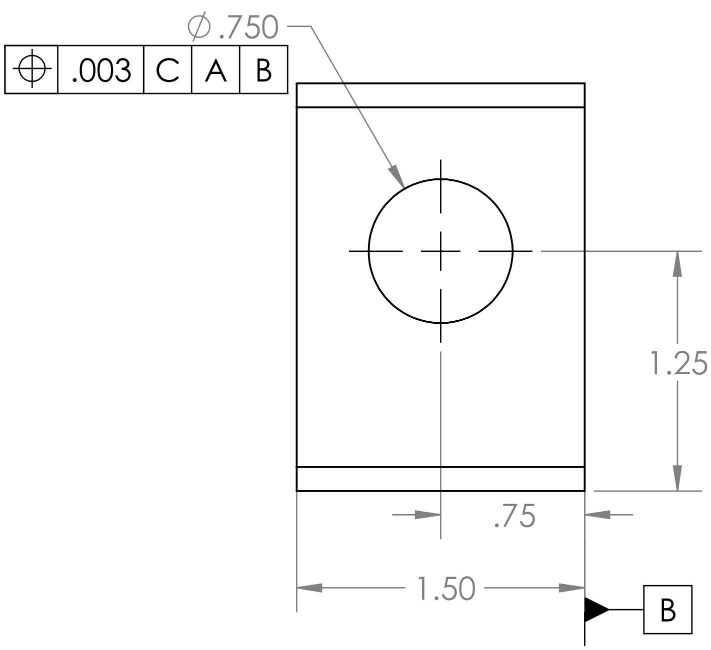


ISOMETRIC VIEW
NO SCALE

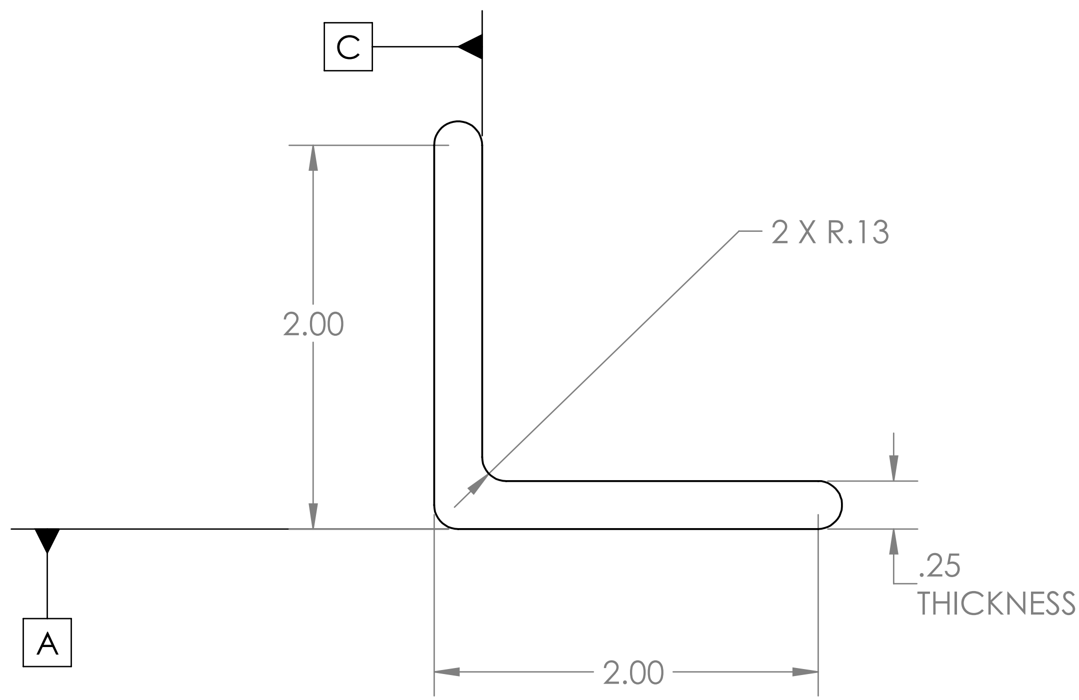
NOTES

UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX=±.01
   X.XXX=±.005
   ANGLES=±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. TO BE FIT TO 1.00" COTTER PIN FOR HYDRAULIC ASSEMBLY
7. SAND FILLETS TO MAINTAIN MATERIAL THICKNESS BETWEEN HOLE AND EDGE
8. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



FRONT VIEW



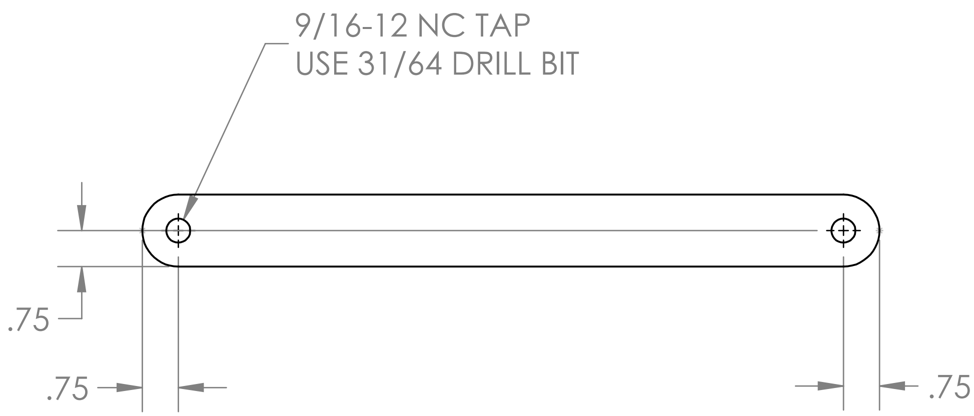
SIDE VIEW

Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: HYDRAULIC CYLINDER (B-001)	Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: D-0401	Nxt Asb: A-007	Date: 10-25-2018 | SCALE: 1:1	Chkd. By: ME STAFF

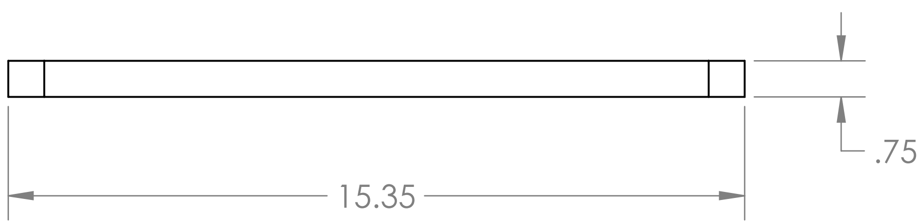
NOTES

UNLESS OTHERWISE SPECIFIED

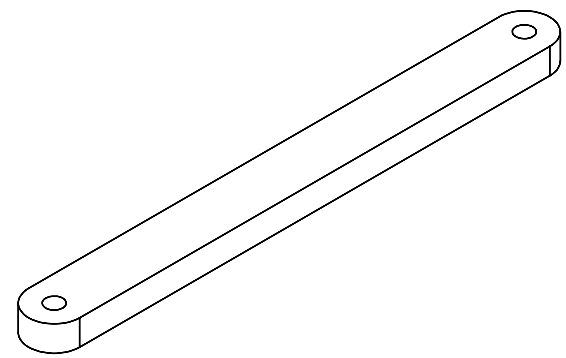
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX=±.01
   X.XXX=±.005
   ANGLES=±2°
3. BREAK SHARP EDGES .02 MAX.
4. INSIDE TOOL RADIUS .02 MAX.
5. MATERIAL: 6061 ALUMINUM
6. SAND FILLETS TO MAINTAIN MATERIAL THICKNESS BETWEEN HOLE AND EDGE
7. TAG PER DRW_NAME_DOC ON VISIBLE SURFACE



TOP VIEW



FRONT VIEW



ISOMETRIC VIEW
NOT TO SCALE

Cal Poly Mechanical Engineering	Lab Section: 01	Assignment #	Title: LINKAGE LEG (M-001)	Drwn. By: AARON KAN
ME 430 - FALL 2018	Dwg. #: D-0501	Nxt Asb: A-008	Date: 10-30-2018 Scale: 1:4	Chkd. By: ME STAFF

Appendix J – Operator's Manual

Operation Manual for Monoski Mobility Cart

This user's manual includes instructions for product use and important safety information. Read this section entirely including all safety warnings and cautions before using the product.

WARNING: This product is intended for persons seated in monoskis. **DO NOT** use this product as a "common seated wheelchair" as injury may occur. Before using this product, the user should be familiar with the operation and safety risks as follows

Standard Operation

Using the monoski mobility cart can be divided into five areas of interest. The standard operating procedures and known safety concerns for the device are outlined below.

1. Loading onto the device

    a. First apply the parking brake by pulling the brake lever backwards towards the wheel. The lever will snap and lock into place when fully engaged with the tire.

        i. *Caution:* Watch out for pinch points when engaging the brake.

Brake unengaged

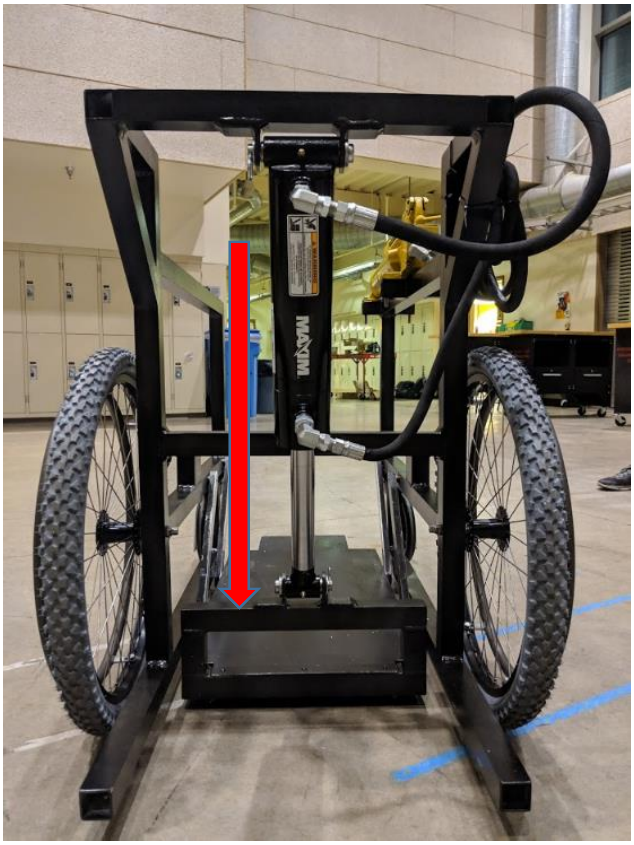
Brake engaged

b. If platform is not already lowered to ground, lower by switching the pump to extension mode and pumping down.

   i. *Caution*: Be aware of pinch point between cylinder and center cross brace.

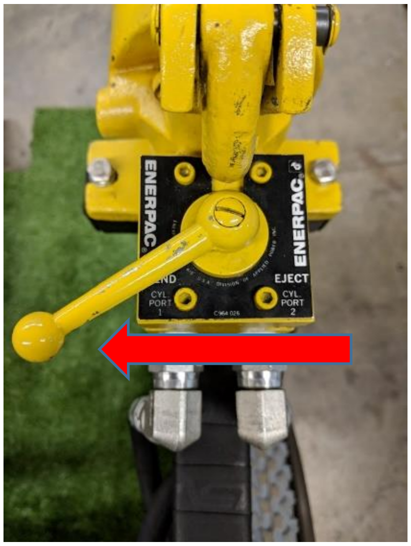
Pump in neutral

Pump switched to extension



c. Slide backwards onto the platform from the front side of the device while lifting the rear tip of the ski above the front edge of the platform.
    i. Ensure that the rear tip of the monoski slides through the gap below the hydraulic cylinder on the rear of the platform.

d. Once loaded, place outriggers in clips on left side of device and switch the pump to retraction mode, then pump up to desired ride height (2-4 inches off ground).



e. Release the parking brakes.

2. Movement on device

a. Forward and backward movement
   i. Grip wheel hand rims and turn wheels at equal rates.
      1. *Caution*: Be aware of pinch points with hands near the rims.

   ii. An assistant can help during transit if necessary by using the support handles in the rear of the device.
      1. *Caution:* The anti-tip bars and user's ski will protrude from the rear of the device, and care should be taken to avoid contact with these items as they create a potential trip hazard for the assistant.
      2. *Warning:* The anti-tip bars are meant to stop the device from a backwards tip only, and should never be stood on by an assistant or someone moving the car. Standing on the anti-tip bars may result in deformation and failure of the tubing, which could potentially immobilize the device.

b. Turning
   i. Left turn: spin right wheel forward while holding the left wheel as steady as necessary based on the desired turn radius.
   ii. Right turn: spin left wheel forward while holding the right wheel as steady as necessary based on the desired turn radius.
   iii. 180-degree turn: spin the wheels in opposite directions while in place for the tightest turn radius.

c. Braking
   i. Apply pressure to wheel hand rim to slow the movement of the device.
   ii. Apply parking brake to lock wheelchair in place.
   iii. Wheel locks (parking brakes) can be used as emergency brakes by user while in motion if an immediate stop is necessary.

d. Pumping
   i. It is possible to continue pumping and raising the platform while in transit. Locking the wheels is recommended while pumping for maximum stability,

but not required. Pumping up a bit farther while in the gondola building elevator would be an efficient use of time and make the overall process faster.

3. Loading onto the gondola

   a. Gondola lift operator begins by stopping the gondola and unrolling artificial turf material onto gondola floor.
   b. Approach the gondola facing forwards.
      i. Ensure that the front of the monoski does not extend past the front of the gondola prior to continuing. Failure to do so could result in the front of the monoski getting caught under the gondola while the platform is raised.
   e. Apply the parking brakes.
   f. Raise the platform to gondola height.
   g. Have gondola lift operator hold device handles for a secure and stable transfer.
   h. Slide forward on the device and grab the gondola doors to slide off of device and into gondola.
      i. User may wish to take their outriggers in the gondola for stabilization.
   i. Gondola operator should then place the device in the following gondola car.
      i. Unlock wheels to roll device into gondola.
      ii. With assistance from a second lift operator or bystander, the device can be lifted and rolled forward into the gondola. One person should stand on either side of the device for this process, and assistants should lift with their legs rather than their back.
         1. *Caution*: Due to the size and weight of the device, a single person should not attempt to lift the device by themselves.
      iii. Lock the wheels during transport in gondola.

4. Unloading off the Gondola
   a. Gondola operator at the top station stops gondola when monoskier and device reach top gondola station and both gondola doors have opened.
   b. Gondola operator first removes the device from the gondola car.
      i. Unlock the wheels to roll device out of gondola.
      ii. With assistance from a second lift operator or bystander, the device can be rolled backward and lifted out of the gondola. One person should stand on either side of the device for this process, and assistants should lift with their legs rather than their back.
         1. *Caution*: Due to the size and weight of the device, a single person should not attempt to lift the device by themselves.
   c. Gondola operator positions device facing the gondola in front of monoskier.
   d. Gondola operator locks parking brakes.

e. Gondola operator adjusts platform to gondola height if necessary.
f. Gondola operator should hold device handles and ensure monoskier safely transfers out of the gondola and onto the platform.
g. Monoskier grabs gondola doors and slides backwards out of the gondola and onto mobility cart platform. This should be done slowly and carefully.
    i. Loss of balance during this procedure could result in monoskier sustaining an injury by falling from the gondola or device.
h. Lower the platform to desired ride height (2-4in).
i. User releases parking brakes and moves away from gondola area, proceeding to exit gondola building and reach the slopes.

5. Unloading off the device
    a. Apply parking brakes in desired unloading location.
    b. Lower platform fully to ground.
    c. Slide forward off of platform.
    d. Take outriggers from clips.
    e. Have fun skiing down the entire mountain.
    f. Gondola station worker at top of mountain returns device to base station by loading it back into a gondola as previously described along with the artificial turf.
    g. Gondola station worker at base of mountain removes device from gondola as previously described along with the artificial turf, and returns the device to the snow outside of DSES office. The artificial turf for the gondola should be stored at base gondola building loading station.

Maintenance

a. **De-icing:** Check for buildup of ice on all moving parts. Try to remove ice whenever possible during use and avoid exposure to harsh weather and environments when possible.
b. **Tire pressure:** Tires should be checked and maintained at specified pressure. For the wheels provided, there is a pressure requirement printed on the tire that reads 40-65 psi.
c. **Fasteners:** Check/tighten brake nuts/bolts, caster nuts/bolts, pump mount nuts/bolts, and wheelchair wheel axle receiver jam nuts regularly during use. Adjust shoulder bolts with allen key to correct platform alignment if misalignment occurs over time.
d. **Hydraulics:**
    a. Inspect all fittings regularly to check for leaks or loosening. Tighten as necessary.
    b. If the pump needs more oil, remove the pump mounting bolts to detach the pump from the frame. Stand the pump up on a table with an assistant, orienting it so that the oil reservoir fill nut is facing upwards. Open the reservoir using a crescent wrench and pour oil until it reaches the level of the dipstick. Proper hydraulic fluid levels are required for efficient use of pump and cylinder.
e. **Paint:** Over time the paint may become scratched or chip off under normal use. Touch-up paint can be applied as desired. Paint should be applied in warm and dry conditions.

Appendix K – Gantt Chart