Surf Sled

Final Design Review

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Statement of Disclaimer

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Abstract

This Final Design Review document outlines the process by which we designed and built a surfboard sled, nicknamed the “Beachin’ Buggy”, for the AmpSurf program. The document describes the goals and services that AmpSurf provides for those living with disabilities, and the current methods that volunteers use to transport people from to beach to the water and onto a surfboard. It then identifies the need for a new system for beach-to-water transportation, along with all specifications, constraints, and goals for the system. Background research will be introduced to relate similar products to this project, and their relevant features and parameters will be detailed. The final design that has been chosen through a documented process will be presented, as well as the completed manufacturing. Finally, the yet to be completed aspects due to the coronavirus situation will be explained along with instructions to complete them.

Figure 1. Beachin’ Buggy at end of Spring 2020

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1 Introduction

We are a team of four mechanical engineering students at California Polytechnic State University San Luis Obispo who are taking on this project as part of our senior capstone course. Our primary sponsor is Vanessa Salas, the project manager of the Quality of Life Plus organization on our campus. We will create a product for Dana Cummings and his organization, AmpSurf. He has challenged us to create a vehicle that will help the volunteers of AmpSurf transport persons with disabilities to the ocean. This mainly includes amputee veterans. We are in charge of designing, building, and testing our product before giving it to the AmpSurf organization at the end of the year-long course.

This document includes material from the previous Critical Design Review document and expands on it. Any alterations to the Critical Design Review document will be listed in the introduction of each section in this report. The Background section of this document will go into detail about our design considerations and will discuss existing designs, patents, and relevant technical literature. The Objectives section will quantify these needs and rank them by means of a Quality Matrix. The Concept Design section documents all our decision making we used to come up with our design. The Final Design section explains our final design as well as provides evidence to support the functionality of the device. The Manufacturing section describes how the final prototype was built. The Design Verification section describes the specifications of the design and test to ensure all specifications are met and the design is fully functional. The Project Management section includes an updated timeline of the process we followed, as well as changes due to the Covid-19 situation.

2 Background

During the initial stages, we collected as much information as possible about what our customer wanted, similar products currently on the market, and any other relevant technology that could be repurposed and implemented into our project. Creating this device will help amputated and disabled veterans acquire the ability to participate in physical activity as they surf. Adaptive sports help improve the quality of life of amputee Veterans by helping them feel accepted in the community and feel a since of purpose in society through education (Seay). Exercise can also help lower an amputee's depression and anxiety (Stathopoulou). Our team has a drive to make sure we can create the best device possible that will help Ampsurf provide amputee veterans with the service they need to live their best life. This section was expanded to add research about working with people with disabilities, the most important things to consider when designing prosthetics, and relevant ADA regulation considerations.

2.1 Customer Interview

During the first week of the project we attended an AmpSurf event to see first-hand how our customer is currently doing things, and to also identify where they could use help. After the event we had the chance to talk with Mr. Cummings and ask him questions about what he would like to see in our final product, summarized in a list of our customers' wants and needs (Cummings).

- The ability to ride or slide on the sand over a large distance to the water
- The ability for the vehicle to submerge under water so that the rider and their board can float off seamlessly
- The vehicle must fit inside the trailer either on the floor, or possibly hung on the roof of the trailer
- Portable enough for one person to get the vehicle from the trailer to the beach and back
- The ride height must be close to the height of a wheelchair's seat for easy transferability
- Easy to repair in case of failure in the future
- Low cost
- Able to accommodate boards of different widths and lengths, ranging from 20" to 40" wide
- Strong enough to accommodate one adult rider
- Able to be operated by up to 6 volunteers
- The vehicle cannot corrode due to constant submergence in sea water

2.2 Product Research

During the product research phase, we searched the internet to find out if there were currently any products on the market that are already accomplishing our goals. We found out that nobody has made a product that is designed specifically to transport both a person and a surfboard together on the beach. Although we didn't find any products that were designed exactly for our purpose, we did find products that were made to transport similar weight capacities across sandy surfaces.

<u>WheelEEZ® Wheelchair Conversion Kit</u>

WheelEEZ® is a company that specializes in mobility products built for operation on sandy surfaces. They produce large rubber tires, carts, dollies, and wheelchair conversion kits as seen in Figure 2 and Figure 3. The wheelchair conversion kit has a 250 lb weight capacity and is designed to mount a typical wheelchair. Although it has a similar weight capacity to our goal, a surfboard could not be mounted to this product without significant modifications.

Figure 2. WheelEEZ® Wheelchair Conversion Kit (Beach Wheelchair)

Figure 3. WheelEEZ® Wheelchair Conversion Kit with rider and operator (Beach Wheelchair)

<u>Jet Ski Trailer</u>

The typical jet ski trailer is interesting to us because it has a lot of similarities to what we expect to see in our final design. These trailers are able to support very heavy loads, typically about 800 pounds (Valeski), and are designed to roll across sand and fully submerge under water. The trailer seen in Figure 4 appears to have rubber buoy-type rails to protect the bottom of the jet ski. When designing our vehicle, we will also need to ensure that the railing does not damage the bottom of the surfboards as they tend to be fragile, especially those made of foam. The trailer seen in Figure 5 appears to be smaller in size, but also has large wheels made for sandy surfaces. Rather than the rubber mounting rails of the first trailer, this one has plastic rollers to help the jet ski roll off without the trailer needing to be submerged. Both of these trailers would be too heavy and large to meet our portability and size goals, but they could provide a good starting point for us to improve on.

Figure 4. Jet ski trailer with rubber mounting surfaces (JetLift)

Figure 5. Jet ski trailer with plastic rollers (Florida Sailcraft)

Jet Ski Dolly

The jet ski dolly in Figure 6 is manufactured by the same company that makes the trailer in Figure 5. The dolly version accomplishes the same result, but it only has two wheels and is less robust overall. Because of its smaller design it is much lighter, and it could be stood up vertically when placed in storage. This type of trailer is particularly interesting to us because we foresee the available space in the trailer being a big issue, and this product doesn't take up as much space as a typical 4+ wheel design.

Figure 6. Tiger Tote Jet Ski Dolly (Florida Sailcraft)

2.3 Technical Research

We also searched through Google Patents for any technical products that already exist and could be used in our product. Many of the patents have a function that can be repurposed and prove to be helpful in our design. A list of these patents can be found in Appendix A along with a short description and illustration of each. We gained feedback from our adviser that we need to also consider the aesthetics of the build in order to make sure the user feels confident and comfortable using it. The aesthetic of a prosthetic will affect if the intended audience will use the device or not (Wodehouse). While we are not creating a prosthetic, we are creating device that will be used by many people with disabilities and amputations, and we need to make sure that it increases their confidence and does not make them feel marginalized. We considered ADA standards for wheelchairs and constructing ramps. Our design is specifically for the beach where we are not inhibited by space to turn around or the width of a ramp, so those regulations do not apply. The ADA mandates ramps should not be longer than 30 feet without a rest platform, so volunteers and challengers should shortly pause to rest and readjust if travelling farther than 30 feet ("Get to know the ADA Wheelchair Ramp Requirements").

3 Objectives

This section describes the functions the final design performs. By defining specifications and tolerances our design must meet, we are able to quantitatively verify our design performs as required. This section includes how target values were selected for design specifications.

3.1 Problem Statement

AmpSurf helps veterans and others with disabilities learn to surf. To get those with leg injuries into the water, volunteers push people on a wheelchair to the water and maneuver them onto a surfboard. This is difficult, slow, and requires lots of manpower. AmpSurf volunteers need a way to transport those with lower body disabilities from the beach to the ocean while lying on their surfboard, but it must be cheap, light, small, and reliable. The fins cannot interfere upon departure from the vehicle, and it must be able to be operated by able-bodied volunteers.

3.2 Boundary Diagram

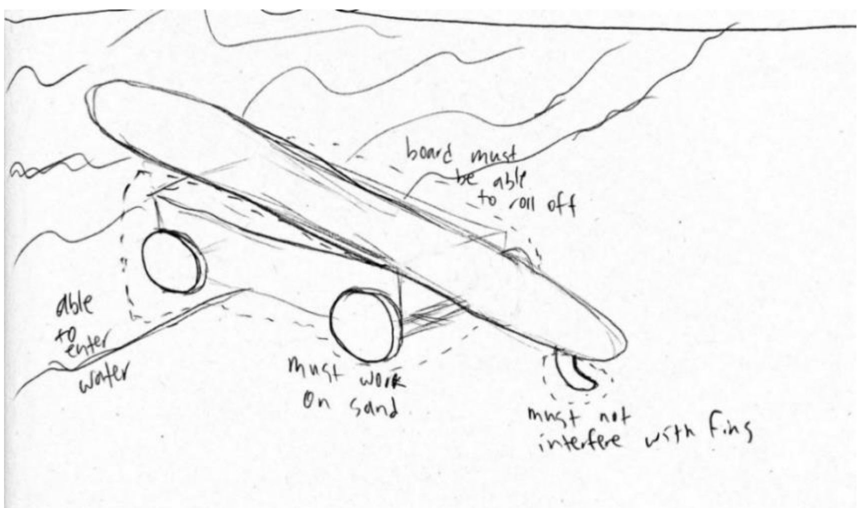

Figure 7. Boundary Diagram for Surfboard Sled

The boundary diagram in Figure 7 serves to define where the project begins and ends and the interactions with the environment we are responsible for. The boundary encompasses the sand and water because the device must easily traverse both environments. The dotted line ends at the board and device interface because we are responsible for how the device grips and releases the board, but everything above the bottom deck of the board is not in the scope of this project. An important note is that the fin is encompassed in the boundary diagram because the sled design must allow the board to slide off into the water without interfering with the fins. The sled must also have ergonomic features for volunteers to guide the challenger across the sand and into the water.

3.3 Design Considerations

The system must be relatively cheap, light, small, reliable, and as compact as possible. From our interviews with the AmpSurf directors, we found that that they want a system similar in function to a boat trailer, where a surfboard is placed on the device, the user transfers from their wheelchair to a prone position on the surfboard, then they are wheeled into the water until it is deep enough that they can float off on the surfboard.

Some considerations must be noted for the design. Because surfboards have up to three large fins on the bottom, there is a risk of the fins catching on the device as the surfboard slides off. Thus, the sled system should support the surfboard along the sides, where there is no chance of interfering with the fins. Another consideration of the sled design is the variation of surfboard sizes that AmpSurf uses. The program has an inventory of surfboards ranging from eight to twelve feet long, and from 20 to 40 inches wide. Because the product should work for all surfboard sizes, it may need to be adjustable to accommodate the different sizes. The method for adjustment should be simple and robust, so a volunteer can quickly and easily configure the sled for the necessary surfboard.

There are several other important factors that we will take into consideration when designing and building the surfboard sled. The material should be waterproof and non-corrosive, as it will be subject to saltwater, sunlight, and wind. It should also stand up to vibration subjected from road transport in a trailer. It should be sturdy enough to support a person weighing up to 300 pounds, while being light enough to push on sand and be lifted in and out of a trailer. We will also be considering a factor of safety of 1.5. By including a Factor of Safety in all our calculations we are ensuring that the vehicle could support loads much larger than what they would actually see under normal use, decreasing the chance of failure. A factor of safety of 1.5 to 2 is a reasonable assumption for average materials under average conditions subjected to loads and stresses (Juvinall). The wheels must be large enough to not sink into deep sand. Finally, as the transport trailer is relatively compact and crowded with other AmpSurf items, the system should be compact and possibly collapsible to fit into a small storage volume.

3.4 Quality Function Deployment (QFD)

Our team used the quality function deployment House of Quality to translate customer requirements into engineering specifications. After interviewing our sponsor and observing the environment and board the sled will be interacting with, we came up with a list of needs and wants to satisfy AmpSurf and their participants. In order to create specific and measurable requirements from these needs and wants, we created target values and ranked the importance of each want. For some needs and wants we are not able to create specific target values or test those values, so those needs and wants are design considerations. We will keep design considerations in mind while going through the design process, but we cannot ultimately test them to a specification. Non-corrosive is an example of a design consideration. We do not have the resources or the time to test if our design will survive in saltwater for a specific amount of time, but we will keep the saltwater environment in mind when selecting materials. The complete QFD chart can be found in Appendix B.

The team created target values by capturing data at an AmpSurf event and talking to event organizers and volunteers. The size dimension was developed given the amount of space left over in the transport trailer after other equipment is loaded in. The organization uses a wide variety of surfboards. The smallest board participants use measured 20 inches wide and the largest measured 40 inches, so our design must be able to accommodate these two extremes as well as many different widths in between. The weight target was developed so that the device can be easily wheeled into the trailer. The ride height is equal to the height of the beach wheelchairs the organization uses, so the challengers can easily transfer over to the sled. Ground clearance was set at six inches to accommodate for the changes in surface profile on the beach. The maximum pull force requirement was selected based on Canadian Centre for Occupational Safety and Health, where they state that a standing person with whole body involved can be required to horizontally exert a force of 50 lbf.

The results of the QFD house of quality have been restructured and entered in Table 1. They are placed in the order of their importance according to the QFD. Each specification has a corresponding risk assessment that the team has decided on. High risk items will likely be the hardest requirements to reach, while the low risk items should be easier to meet.

Table 1. Engineering Specifications

Spec #	Specification Description	Target (units)	Tolerance	Risk	Compliance
1	Size	6’x4’x3’	Max.	H	I, A
2	Board Sizes	20”-40” width	Pass/Fail	H	I, T
3	Weight	75 lb	Max.	H	I, A
4	Standard Hardware	95% purchasable in store and online	Min.	L	I
5	Strength	Accommodates one 300 lb user	Max.	H	A, T
6	Stiffness	Chassis deflection < 1” per 4’ of length	Max.	H	A, T
7	Ride Height	2’	±6”	L	I, A
8	Production Cost	$1000	Max.	M	A
9	Pull force	50 lbf per volunteer	Max.	M	T, I
10	Ground clearance	6”	Min.	M	I
11	Time from beach to water	10 min	Max.	L	T

Specification Table Key
(H= high, M= medium, L= low, I= inspection, T= test, A= analysis)

The specifications listed in Table 1 will be tested through the following processes:

- The weight will be inspected with the SolidWorks mass properties tool, and with a trigger pull scale after it is manufactured
- The board size accommodation will be tested with a measuring tape, and by placing boards of different sizes on the product
- The size, ride height, and ground clearance will be inspected with the measuring tool in SolidWorks, and with a tape measure after it is manufactured
- Purchase receipts will be stored and uploaded to an Excel sheet to keep track of total production costs
- Time from beach to sand will be tested after fabrication with a stopwatch
- Strength and stiffness will be calculated by hand, by use of FEA, and then confirmed with weights and scales after fabrication
- Pull force will be measured by a trigger pull scale after fabrication on a sandy surface
- The number of stock components will be kept track of through the purchasing order Excel sheet

4 Concept Design

Our team used a variety of ideation techniques to gather a large amount of design ideas, then methodically narrowed down the solutions to the best possible ones using decision matrices. Included in this section is a discussion on the processes we used to develop, evaluate, and select our top concepts, with descriptions of the favorable designs and justification for our selected final design we built.

4.1 Ideation

We began by gathering as many ideas as possible for the surfboard sled design. However, attempting to brainstorm a final design for the entire system limits creativity, glosses over subsystem characteristics, and limits the number of possible ideas. Thus, we used functional decomposition, the process of breaking down the overall function of a device into its smaller parts. All functions were kept as simple and concise as possible for ease of ideation. For the surfboard sled, we determined that the overall function it needed to achieve is to "traverse beach." From this overarching requirement, we wrote a number of subfunctions that the sled needed to complete to be able to traverse the beach, like "carry person" and "hold surfboard." We continued this process until the surfboard sled requirements were defined in the simplest possible group of subfunctions. We documented the process on a large whiteboard, set a timer for fifteen minutes, and sought to individually brainstorm as many ideas as possible to accomplish each of the subfunctions. No idea was deemed too silly or impractical, and after fifteen minutes, we had over 50 Post-It notes with possible solutions for all aspects of the surfboard sled design. A list of all the ideas created with this method can be found in Appendix C.

After the function-based whiteboard ideation, we utilized a process known as brainwriting to gather more ideas. We identified four of the most important characteristics the surfboard sled needed: board support mechanism, collapsible/adjustable mechanism, volunteer interface, and beach-traversing method. Each of the four characteristics was assigned to a member of the team, and we sketched and wrote descriptions for designs of the systems over a five-minute time interval. We then switched papers and continued with another characteristic, building off our teammates existing solutions. We repeated this process until we had all ideated on each characteristic, resulting in multiple ideas for each characteristic from each team member. A list of the ideas created with the brainwriting method can also be found in Appendix C.

4.2 Idea Refinement and Selection

With many ideas for every element of the surfboard sled recorded, we sought to narrow down the proposed solutions to the most promising and feasible ones. We accomplished this using a series of decision matrices that systematically ranked and compared designs from a set of requirements. Each team member began with a Pugh matrix to determine the top design for the function they were assigned during brainwriting. For example, one of the surfboard sled characteristics was the board support method. The Pugh matrix incorporated six different ideas for board support, like a tarp, slings, and adjustable rails. Along the side of the matrix, we wrote the requirements from the QFD house of quality that the board support method should meet, like "works for all board sizes." With the designs and requirements, we selected one design as a datum and ranked all the others in comparison to it for each requirement. We then added up the rankings to determine a top design for the function. The four Pugh matrices can be found in Appendix D.

With the top ideas for each of the four important functions selected by the Pugh matrices, we determined the best means of combining each function design into a complete surfboard sled. Through a Morph matrix, we listed and sketched top designs of subsections for volunteer interface, chassis material, accessory material, sand transport method, and board support mechanism. We then drew lines between idea sketches to generate a list of five possible combinations for an overall design. The Morph matrix is listed in Appendix D. The five design ideas are seen in Figures 8 to 14.

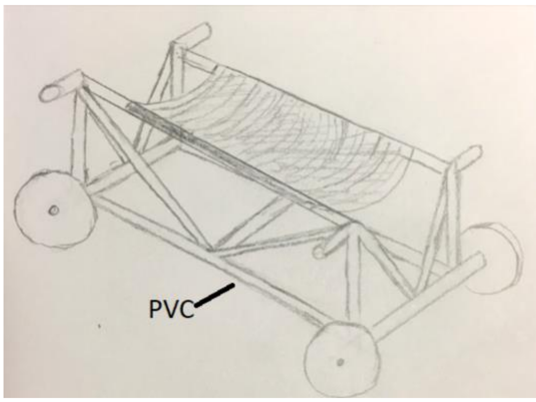

Figure 8. Design 1: rectangular base, sling support, push bars, PVC

Figure 9. Design 1 prototype

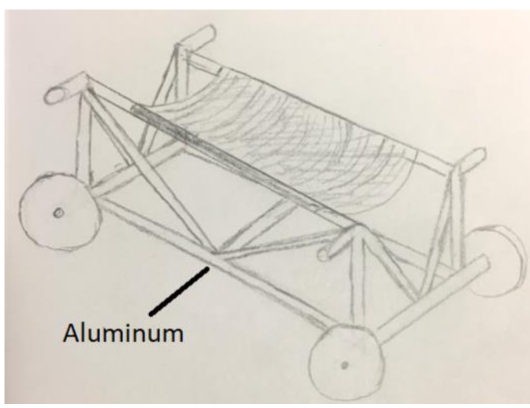

Figure 10. Design 2: rectangular base, sling support, push bars, aluminum round stock frame, PVC accessories

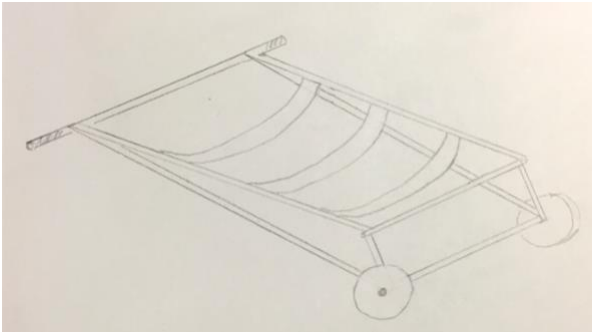

Figure 11. Design 3: wheelbarrow base, sling support, push bars, PVC

Figure 12. Design 4: chariot style base, sling support, rail bars, stainless steel

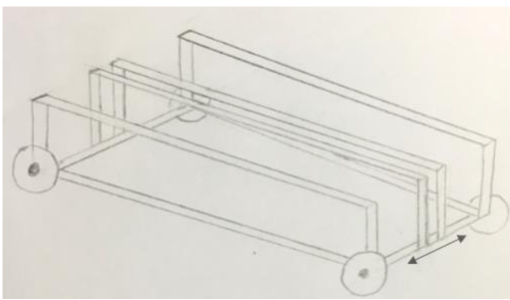

Figure 13. Design 5: rectangular base, slat support, push bars, 80/20 aluminum base, PVC rails

Figure 14. Design 5 Prototype

The last step of idea refinement was to determine the top design using a weighted decision matrix. We listed and sketched the five designs generated from the Morph matrix and copied the criteria from our existing House of Quality chart. Each criterion was given a weighting based on its importance as determined from the chart, then the five designs were ranked out of ten points based on the different criteria. We used Microsoft Excel to automatically multiply the design rank by its criteria weight, then add the individual scores to determine the best possible design. The complete weighted decision matrix is attached in Appendix D. The winning design was found to be a surfboard sled with a rectangular PVC base, four wheels, a tarp for surfboard support, and push bars for volunteers. This design significantly beat out all others with regards to ease of use and adaptability for all surfboard sizes.

4.3 Design Description and Justification

The top design for the surfboard sled was derived from an extensive amount of ideation, along with systematic convergence of ideas by means of feature criteria in decision matrices. The design included a rectangular chassis with four large beach wheels with a 11.8” diameter. A flexible tarp supports the surfboard and user, with the surfboard fins hanging off the back of the sled. Four bars extend outward from the device, allowing volunteers to easily guide and push the sled across the sand and into the water. The tarp is supported by C-shaped channels on one side, allowing volunteers to easily remove it once the surfboard is floating in the water and the load is removed. Removing the tarp allows the surfboard to slide off the device easily, without the fins catching on the frame. The sled is symmetric, so the user can float straight onto the sled to be wheeled back up the beach without any movement of the sled in the water. Figure 15 shows a SolidWorks rendering of this initial conceptual design. The sled is designed to be made from stainless steel.

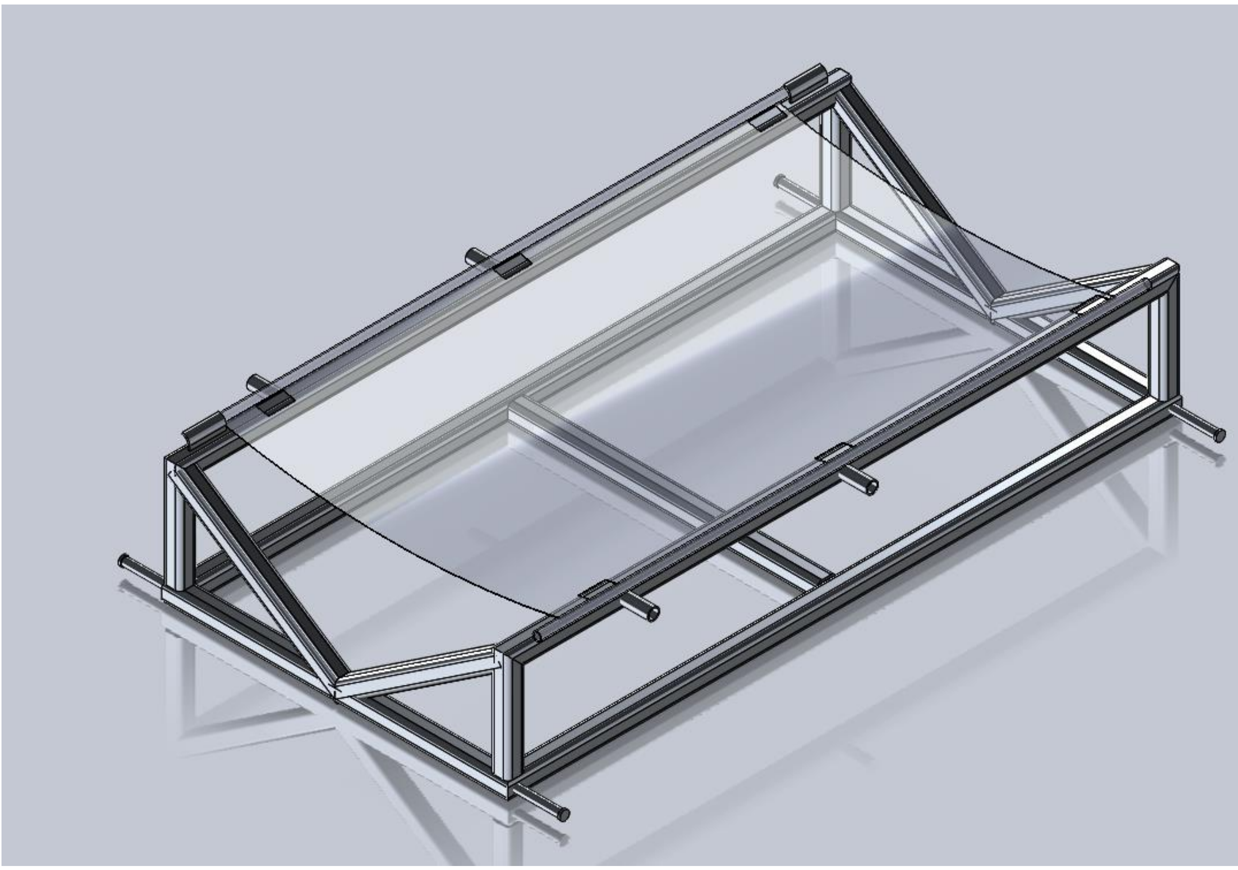

Figure 15. Initial concept design

4.4 Final Concept

Since the convergence on the design discussed previously, we determined that the design should be adapted to be sleeker and aesthetically pleasing. We learned from our journal article research that persons with disabilities love to be proud to use the product, and the design shown in Figure 15 appears cumbersome and rudimentary. Thus, we sought to improve the design while still maintaining the removable tarp mechanism and volunteer interface. We began collectively sketching alternatives and decided on a single beam design with U-shaped supports. The new design can be seen in Figure 16.

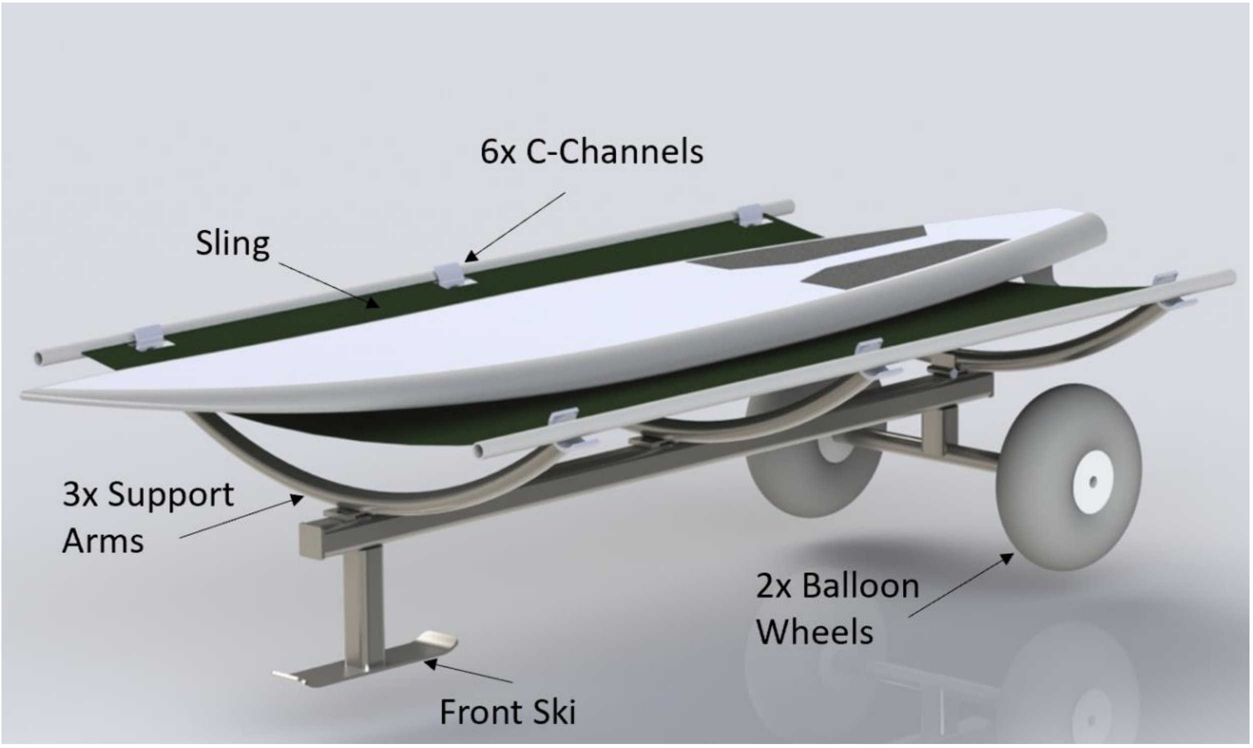

Figure 16. Updated Concept Design

The new design is to be made of stainless steel, as the shape of the structure demands a stronger material than PVC. The sled features a ski on the front, which serves two purposes: the ski replaces a wheel, and since the beach wheels we plan to buy are expensive, any reduction of price gives us more room to ensure that other elements of the sled are improved. Additionally, because the wheels are large and buoyant, there is a concern that the sled will float in the water and prevent the user from sliding off. With a ski in the front, the front end of the sled will reliably sink when in the water. We will test this ski in the near future to determine its feasibility. If we find that the ski does not slide well in the sand, we may convert it to a low-buoyancy plastic wheel that has holes to allow water through. The U-shaped support tubes fit on hinges to fold for storage. The C-channels shown in the CAD model are only a representative of their basic function, but they are still undefined and further research and testing will be done on this component before implementing the best option into the final design. The sled can be collapsed for ease of transportation and storage. Figure 17 shows a rendering of the CAD model in its collapsed state. There is a design hazard checklist in Appendix E that lists any safety concerns related to this design.

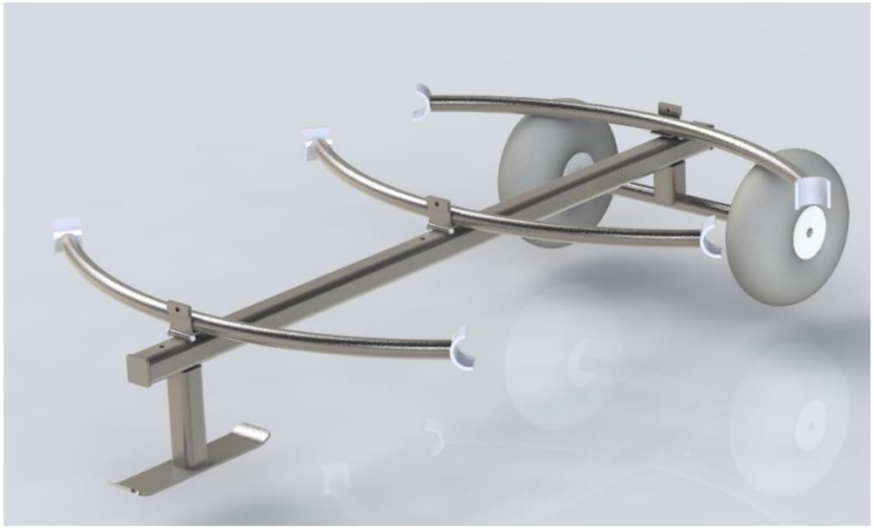

Figure 17. Concept design in collapsed state

4.5 Concept Geometry and Materials

The only material options from our Pugh matrix were PVC, aluminum, or stainless steel due to their anti-corrosive properties. Because of our decision to slim down the design and make it more aesthetically pleasing, 316L stainless steel was our best choice for the chassis material since we could take out a lot of material and not sacrifice much strength. The square tubing that runs along the length has been selected as 2”x2”x.065” thickness. This is because .065” is the smallest thickness available for 2”x2” square tubing and increasing thickness has the greatest effect on cost. Beam calculations supplied in Appendix F shows that this thickness still has a factor of safety of 3.77. We decided not to size down the outer dimensions of the square tubing from 2”x2” because we need enough width to drill a hole and place a pin into for each of the three support arm hinges.

For the wheel axle that holds the two rear wheels, we selected ¾” Schedule 40 pipe because this gives us a factor of safety of 4.66 and increasing the size of round tubing results in negligible costs compared to the square tubing. Since it only costs a few dollars more to increase width from ½” to ¾”, it's worth it to select the larger size and have a very safe design factor.

A preliminary FEA study was conducted on the main frame and support arms, and it proved to match the hand calculations very closely. Because of this, we are confident that these selected geometries will be more than sufficient to support our weight capacity specification of 300 lbs with a 1.5 design factor.

4.6 Manufacturing

To manufacture this product, we will weld the chassis, and also use a horizontal band saw, drill press, and tube bender. We cannot use the MIG welding process because “100% Argon doesn’t provide enough thermal conductivity for a fluid weld pool when MIG welding on ferrous metals. The outer edges of the arc remain cool, resulting in a deep but narrow penetration profile, and minimal fusion” (MIG Welding), and we do not have access to welding shielding gas besides 100% Argon. TIG welding is preferable because of how much cleaner the welds would be, and less time would be spent cleaning up splatter. Because none of the team members are highly skilled welders, we will attempt to use this process first, but if we cannot get good results we will switch to stick welding, which doesn't require as much skill, and would also be an acceptable process.

4.7 Design Changes

Based on feedback from our sponsor, as well as solutions presented at Preliminary Design Review, our design changed from a ski in front to a set of Malone kayak trailer wheels. The ski was originally in our design so that the front would not be buoyant, but our sponsor expressed experience with moving wheelchairs on sand and found the only option that does not dig into sand are wheels with wide surface area. With solid plastic wheels instead of inflatable Malone wheels, we can minimize floating of the front while still allowing for ease of use on sand.

The other major change to the design is the support arms. Originally, the design incorporated round tubing but changed to square cross section tubing to better connect with the square wraparound bracket and center cross beam. Originally, we incorporated collapsible swing arms for storage, but found that the added complexity would lead to much greater probability of failure and concerns with holding design weight. Additionally, the sponsor stated that because the design can be stood up lengthwise, it should fit in the trailer.

5 Final Design

Our final design includes three curved square support arms, a main center beam, support sling, and two sets of wheels. The rear wheels are WheelEEZ® inflated balloon beach wheels and the front wheels are Malone hard rubber compound wheels. The main components will be looked at more closely in the following paragraphs.

5.1 Final Design

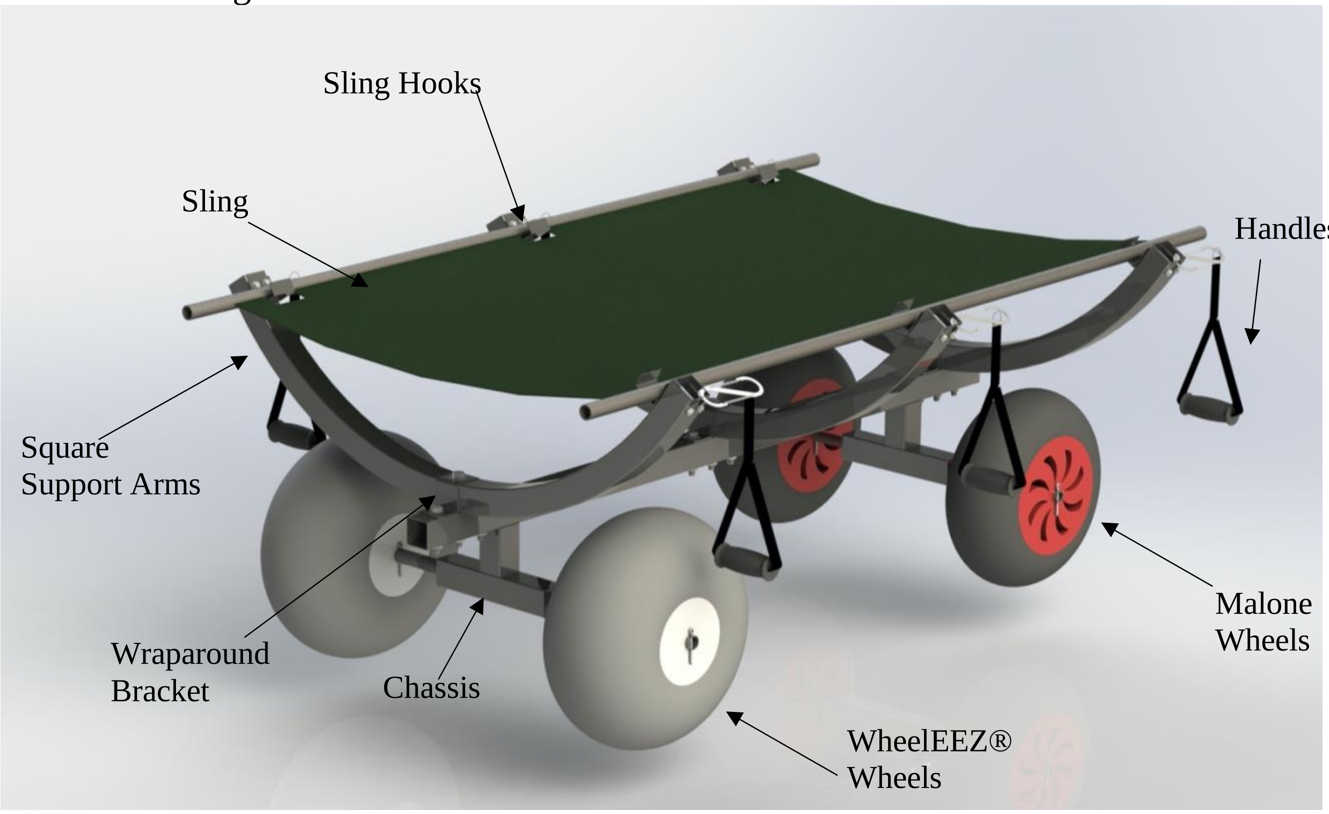

Figure 18. Final design with major components labelled.

The complete design in Figure 18 includes three major subsystems, the chassis, support arms, and sling. Attached to these subsystems are the wheels, handles and wraparound bracket. The chassis and square support arms are 304 stainless steel with 0.083" wall thickness. The design incorporates two sets of wheels, the inflatable WheelEEZ® and hard rubber compound Malone wheels. Both wheels have internally housed bushings and are attached to the front and rear axle via interference fit and cotter pins to hold the wheels in place. The handles are attached to the square support arms with carabiners which are fed through holes in the tubing.

5.2 Chassis

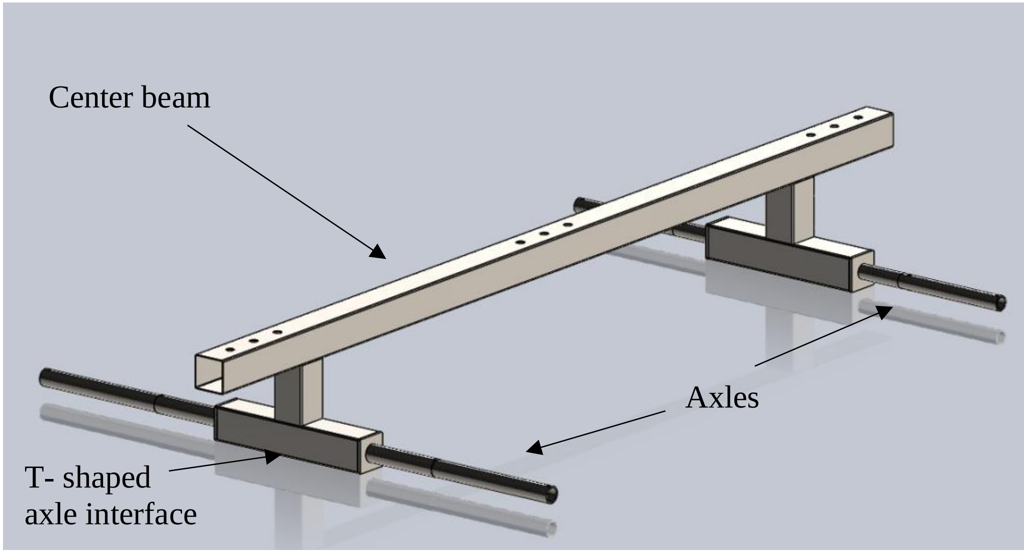

Figure 19. Stainless Steel Chassis and Axles

The center beam of the chassis in Figure 19 is a 2”x2” square cross section beam with 0.083" wall thickness. The beam force calculations in Appendix F show that a beam of 0.065” has adequate strength to withstand our maximum design weight of 300 pounds while maintaining a factor of safety of 3.8, but since we were donated 0.083” thickness squaring tubing, we decided to use that instead as it will only make the structure stronger and would add only negligible weight. The T- shaped axle interface is the same 2”x2” square cross section tube welded to the center beam. Each end of the axle interface has a stainless steel cap welded to the stainless steel axle. Holes on top of the center beam are for the square wraparound bracket to bolt on the support arms. There are also many smaller holes along the underside of all the square tubing so that it can drain ocean water sufficiently. Full dimensioned drawings for this part, and all other manufactured parts can be found in Appendix H.

5.3 Square Support Arms

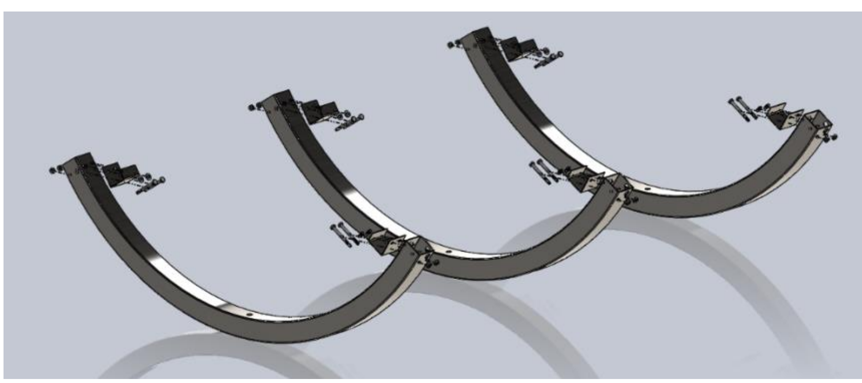

Figure 20. Square Support Arms Assembly

The support arms in Figure 20 are 2x2 inch square cross section 304 stainless steel tube bent by Tube-Tec. The exact geometry of the bent tubes is shown in Appendix H. We selected square tubing in order to have continuity with the main center beam. Bolted to the end of each support arm is a sling hook that holds the weight of the challenger on the vehicle. The hook allows the sling to be lifted off and detached to begin surfing.

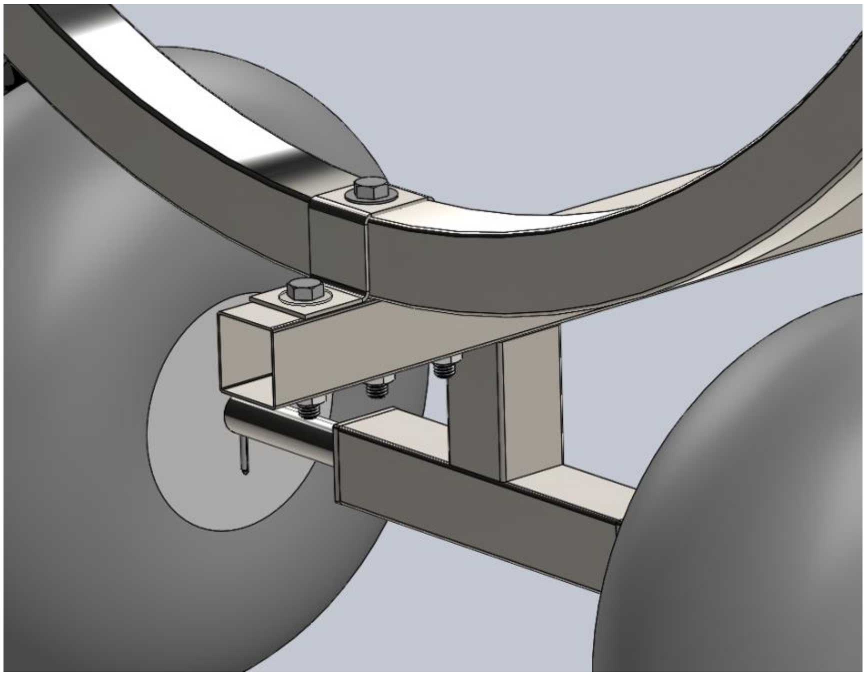

Figure 21. Square Wrap Around Bracket fastened to support arms and chassis

The square tubing is attached to the center main beam with a square wraparound bracket instead of welding, which allows for strength while minimizing rust prone areas and the heat affected zone. The bracket and its attachment to the chassis is seen in Figure 21.

5.4 Sling

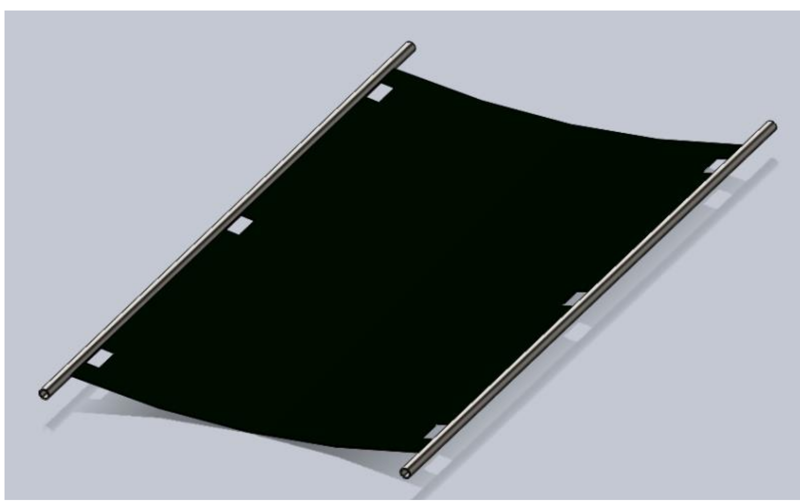

Figure 22. Sling

The sling in Figure 22 is custom made from catamaran trampoline material by SLO Sail & Canvas. The material is marine grade and proven to withstand many seasons of salt water use.

There are six square cutouts to allow for the sling hooks to pass through. Each cutout includes a zig-zag stich around the perimeter to eliminate fraying.

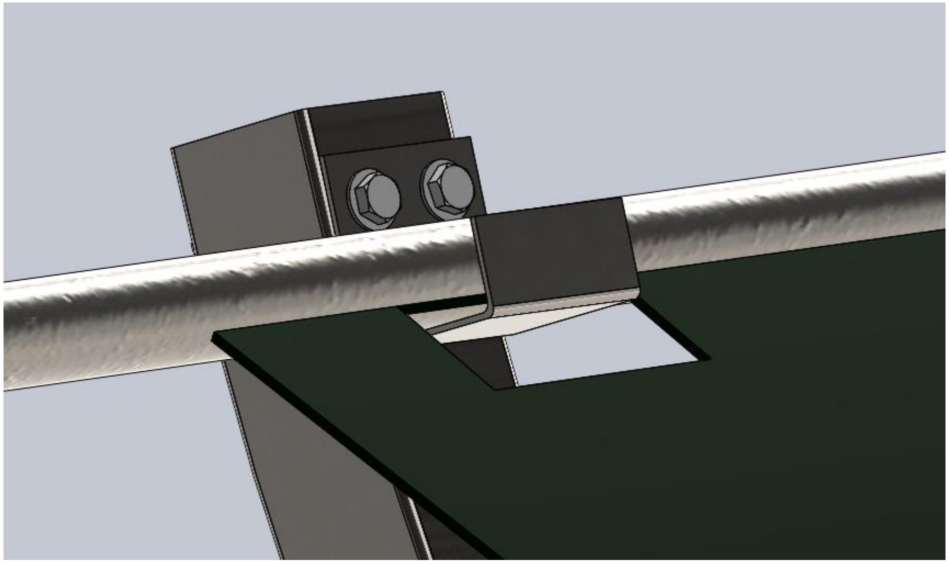

Figure 23. Sling Hooks Bolted to Square Support Arms

The sling hooks in Figure 23 fit inside of the square cutouts on the sling and allows the tarp to be lifted off when in the water or for storage. The edges of the sling hook will be chamfered to avoid any ripping of the sling. See section 8-2 for more details on the Sling design, as this portion of the project was not completed due to the Covid-19 outbreak.

5.5 Wheels

The Beachin' Buggy features two types of wheels, as seen in Figure 18. The WheelEEZ® wheels are inflatable and more buoyant while the Malone wheels are solid rubber and plastic, allowing for sinking. This design choice is so that the front of the device will sink once it reaches a few feet of water. The wheels are slid onto the front and rear axles and held in place with cotter pins.

5.6 Handles

The interface volunteers interact with are standard gym equipment handles. They are attached to the square support arms using a carabiner. The handles have a textured rubber grip for ease of use by volunteers, as well as multiple attachment points so volunteers of various heights can comfortably and safely maneuver the device.

5.7 Safety and Maintenance

The primary concern with our device is damage from saltwater corrosion. We have selected materials like 304 stainless steel and catamaran fabric that are very corrosion resistant and waterproof to prevent damage, but we strongly advise the users to rinse off the vehicle with fresh water after use. This is common practice with wetsuits, surfboards, and other saltwater vehicles. Additionally, checking the vehicle before each use for signs of corrosion or rust is important to ensure structural integrity. According to our Failure Modes and Effects Analysis, this is the highest risk safety concern. The full report can be found in Appendix I.

Volunteers assisting in pulling the vehicle should always pull by the handles to avoid pinch points near the carabiner. Awareness of the wheel location is also important to prevent toes or feet from being rolled over. These safety concerns are detailed in the Design Hazard Checklist located in Appendix E.

The handles and carabiners are off the shelf components and can be quickly replaced if necessary. The supplier and part name are described in the Indented Bill of Materials found in Appendix J. The sling can be repaired with a catamaran trampoline repair patch, however if larger rips occur, we recommend contacting SLO Sail & Catamaran to have the sling rebuilt on the existing Sling Rods. The WheelEEZ® tires should be inflated between 2-4 psi as printed on the tire. Check air pressure monthly or if any tire appears to deform excessively.

5.8 Cost

The total cost for the final product including R&D is $1,941. The detailed breakdown of cost by each part and subassembly can be found in the Indented Bill of Materials located in Appendix J.

Table 2. Cost Breakdown

Structure	$1465
Sling	$300
Labor	$150
Structural Prototype	$26
Total	**$1,941**

5.9 Changes Post-CDR

Since the submission of the Concept Design Review, several aspects of the Surfboard Sled device have been modified. These modifications are largely due to the limitations in construction capability resulting from COVID-19. The most prominent changes were in the manufacturing of the sled. The 1/2" holes on the chassis to mount the wraparound brackets were drilled by hand, rather than with a mill. The same hand drilling process was used for the holes to mount the sling hooks. Because the process is exceptionally slow, the team decided to modify the hole design for the mounting of the sling hooks. Instead of drilling through both sides of the support arms and mounting the hooks with long bolts, we drilled through only one side of the arms, and are mounting the hooks with very short bolts whose nuts lie inside the support arms. Though this mounting process is not yet complete at the date of the release of this document, it will be finished before the end of the 2020 school year. Further testing will be done to ensure that the slink hook mounting method is sufficiently strong, and the bolts will not experience shear failure. This testing is somewhat redundant, due to the fact that the sling hooks were already tested for loading cases and finding that the hooks are more likely to fail first. The hooks were tested with over 100 pounds on each, well over our maximum loading case of a 300-pound person, or 50 pounds per hook. Finally, the holes to mount the carabiners and handles were also drilled by hand.

6 Manufacturing

This section details the process behind purchasing parts, building, and assembling the surfboard sled, with consideration for all used components.

6.1 Procurement

Per the Indented Bill of Materials in Appendix J, our main suppliers for purchased parts were WheelEEZ®, Malone Auto Racks, Valley Iron, OnlineMetals, Tube-Tec, SLO Sail and Canvas, and FitnessFactory.com. All other miscellaneous parts to complete the surfboard sled will be purchased from McMaster-Carr. These include sheet stainless for the main brackets, bolts, nuts, washers, cotter pins, and carabiners.

6.2 Manufacturing

This team completed some manufacturing components in the Mustang '60 or Aero Hangar machine shops at Cal Poly. However due to the Covid-19 pandemic we completed the rest of the manufacturing process at our own home. This proves that this project does not require a shop with sophisticated equipment and can be completed using common house tools. However, there are some tools that will make the work easier and faster. This team used a power saw with an abrasive wheel to cut all tubing to length. Much like the one used in Figure 24 by our teammate Griffin O'Malley. This is the fastest method for cutting stainless steel.

Figure 24. Griffin cutting the chassis with cold saw

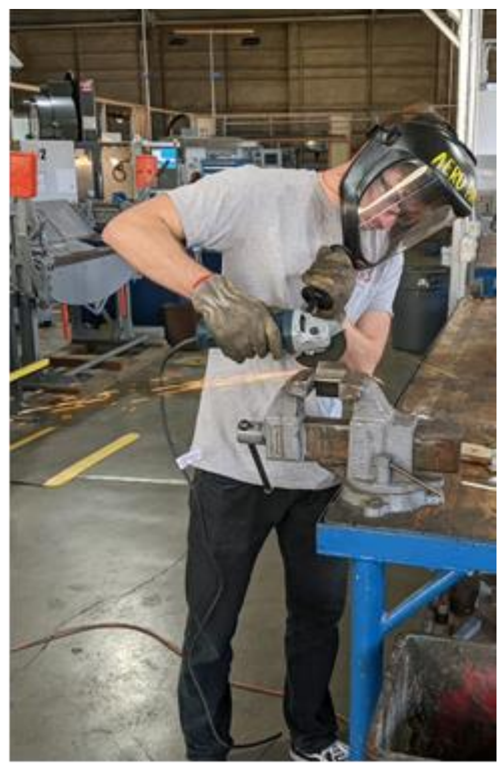

Figure 25. Marius angle grinding sling hooks

We also recommend using a drill press or mill with high speed carbide drilling bits that are rated for stainless steel. An example of this can be seen in Figure 26 as Arthur Zaayer drills holes for the pins in the axel. To create the Sling hooks we recommend using a vise and a angle grinder to cut the square stock. Our team made sure to cut away the seam of the tube to avoid warping. Line up your cut with a clear line of site much like in Figure 27 as Jose Covarrubias is showing. Once you are ready you can start cutting making sure the sparks fly away from your body and you are wearing proper PPE, much like Marius Jatulis is doing in Figure 25.

Figure 26. Arthur drilling pin holes in axles after they were turned down

Figure 27. Jose angle grinding more sling hooks

Due to the global pandemic our team used unconventional methods to manufacture the frame. Each whole was drilled with a 20V hand drill with the Milwaukee Cobalt drill set. By starting with a small 1/8th inch drill bit and slowly increasing the size until we reached the ½ inch hole. The team members had to apply maximum downward pressure on the hand drill which low speed. The team also constantly use lubrication and water to keep metal from work hardening. An example of this setup can be seen in Figures 28 and 29 as Jose Covarrubias and Marius Jatulis are shown working hard to drill into the frame. All cuts can be done with an angle grinder, however they will require several cutting and grinding disks.

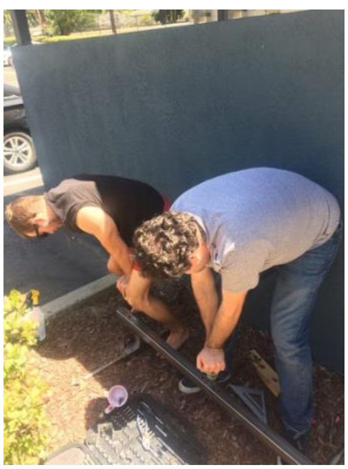

Figure 28. Marius and Jose assembling the prototype

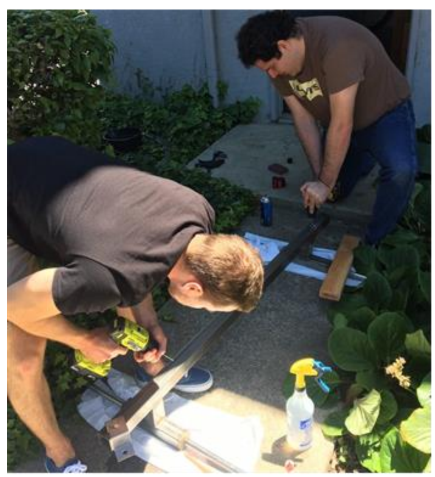

Figure 29. Marius and Jose attaching Wrap-Around-Brackets

Files and other deburring tools were used trough out the project to keep the parts safe from sharp edges. Without a drill press it may take each ½ inch hole up to 20 to 30 mints to drill. If the steel work hardens from insufficient amount of lubrication and improper speed, then the lead time by rise to 40 to 60 minutes each hole. Our team adapted to the pandemic conditions while keeping safety our priority. We were able to complete the manufacturing of the entire skeleton. QL+ will have to outsource the manufacturing of the sling assembly and complete testing on their own. A full list of manufacturing procedures for the Surfboard Sled can be found in Appendix K: Manufacturing Plan. Most operations are relatively simple, and any difficult operations will be outsourced as described in Section 6.4.

6.3 Assembly

A full list of manufacturing and assembly steps can be found in Appendix K: Manufacturing Plan, and Appendix N: Operator's Manual. The Surfboard Sled is assembled initially in three main subsystems: the chassis, support arms, and sling assembly. These are combined from the ground up to finish the overall sled assembly.

6.4 Outsourcing

Welding stainless steel is difficult and important to perform well, or the welds can crack under stress, resulting in a significant failure of the device. Thus, we are outsourcing the welding for the chassis and axle assembly to ensure the longevity of our design. We are paying Gentry Welding & Fabrication in San Luis Obispo, a highly recommended fabrication shop, to complete the necessary welds.

Another outsourced operation is the bending of the support arms. Because of the square tube profile and the strength of stainless steel, Cal Poly does not have the equipment necessary for bending the arms. Instead, we are buying the tubes from Tube-Tec in Houston, TX, who will supply and bend the tubes according to our specified dimensions.

Due to the Covid-19 epidemic we were not able to bend the wraparound brackets ourselves. We outsourced this work to Borden Precision Products Inc., which is a fabrication shop in San Luis Obispo. They generously donated their service to our project.

7 Design Verification

This section will describe the test procedures that that will implement in order to create a proper device. We will discuss how to test our final product as well as describe results from our test on the structural prototype.

7.1 Testing

In order to provide a safe product for the customers, a series of test must be performed to ensure a high level of quality. The Failure Modes and Effects Analysis (FMEA), shows that the three highest areas of concern were the ability for the wheels to traverse the beach and ocean, the ability of the sling system support to hold 300 pounds, and how well the frame supports the rider. More details of the FMEA can be found in Appendix I. Once the initial product is created, additional safety tests will be put in place to optimize the performance of the device.

An important test that must be done is the strength test. It is critical that the sling, frame, and wheels are all be able to support 300 lbs. with a factor of safety of 1.5. Once the frame is built and the wheels are attached, we will place weights on the sling until it reaches the rated maximum weight. The test of the wheels will be done at an earlier stage with the structural prototype, which will be discussed later in this report. The weights will not only test the sling, but the frame as well. Once we gain the results of the test, our team will adjust our design and add support as needed.

The next test that must be completed is the pull test. In a past meeting with our sponsors, they expressed concern that the pull method may cause injury to the volunteers. We will take spring scales and measure how much force is required to move the device with a full load across sand. We want to make sure that it takes less than 50 lbs. of force to move the prototype. This will comply with our safety concerns expressed by our sponsor. Our team will use the device as intended and decide if it is too strenuous to pull. This test will be purely based on our feel of the device.

The last test that will be performed is a full function test. Our team transport a person with a surfboard and attempt to pull them in and out of the water. This will provide us with the data to create a procedural instruction manual that we can give to our customers. Many of the tests can be performed on our structural prototype, not requiring the finished model.

7.2 Prototype Specifications

Figure 30. Structural Prototype

A prototype was created to test components in the design that needed to be finalized before the final build. This structural prototype can be seen in Figure 30. The specifications that were tested were ride height, wheel axle dimensions, wheel capacity and the effectiveness of a handles to pull the device. There are a few caveats to this prototype. First it does not test the ability of the sling to attach and detach. It is also 7.5 feet long and 34” wide. The true dimensions of the final product will be 5 feet long and 40” wide. The main reason we believe these dimensions would satisfy our experiments was because we were not testing the compatibility of the device to various board lengths. We only wanted to test the structural capacity of the axles and wheels, as well as the height of the pull handles.

We fabricated the frame by modifying a table and adding structural integrity with 2”x4” wood support posts. We cut the legs to fit our design height of 24” and to fit the desired axle length. In the front the Malone wheels were set 17” apart and in the back the WheelEEZ® were set 20” apart. The front axle was modified from a piece to galvanized steel pipe from Home Depot. While this is not the material that will be used for the final project, it was a cheap alternative to test the wheels and sand interaction. The rear axle is a 1.05” outer diameter pipe that was turned down to 1.00” on the lathe. This axle is made of stainless steel and will be reused for the final project. The fully dimensioned drawings of these axles are seen in Appendix H. Four holes were made at the corners of the tabletop and handles were attached with rope. The handles in the final model will be attached to the vehicle with carabiners; however, the rope was enough to test the prototype. The test has been broken down in our Design Verification plan (DVP) in Appendix L.

On February 1st our team took our structural prototype that can be seen in Figure 30 to Morro Beach, CA. The intention was to test the ability of the wheels to support the desired weight, and how it will react in the ocean. We initially put on 300 pounds of weight on the prototype and tested how difficult it was to pull across the sand. Another concern we wanted to test if the handles were high enough so an average person can pull the device without producing the danger of back strain. After our experiment we can conclude that the wheels provide enough slip so that it is not too strenuous for two people to pull 300 lbs. These tests were only to get a preliminary idea of the pull force required, but the actual number will still need to be found through tests with a spring scale. The final product will have the capacity for 6 people to pull the device which will provide enough redundancy to be safe. We also concluded that the wheelbase provides enough stability so there will not be any danger of tipping. Our team then moved the prototype in and out of the ocean with the 300 pounds on the board.

We concluded the design satisfied the needs to traverse the ocean floor. We also concluded that it is always optimal for the WheelEEZ® to be in the back of the device no matter what direction it is moving. This is because WheelEEZ® compress and can work better when the load is directly on top of them. Overall, we successfully proved our design concepts for the final product.

The next test is to create the sling hooks in which the sling will sit on from our square pipe. Our goal is to gain analytical data to see when the hooks will break. From there we will be able to perform an uncertainty analysis on the hooks to make sure they are safe to use. A full description of these tests are in Appendix M. The timeline of these future tests are outlined in the Gantt chart seen in Appendix G.

8 Work To Be Continued

Due to the Covid-19 pandemic, certain portions of this project including manufacturing, procurement, and testing were unable to be completed during our time working on this project. This section will detail the work that must be completed in the future by individuals such as the QL+ club before AmpSurf can use the final prototype.

8.1 Sling Procurement and Manufacturing

All parts were purchased, manufactured, and assembled already besides the Sling. When the pandemic hit California, our Sling source, SLO Sail and Canvas, notified us that they could no longer complete our job as they had to strictly focus on essential business. Once they can start working on our job again, individuals will need to purchase the two 60" long 3/4" nominal Sch. 40 aluminum pipes from OnlineMetals and take the assembled Skeleton and these two Sling Rods to the warehouse for them to fit the Sling to. The link to these two Sling Rods can be found at the end of the drawing package in Appendix H. After talking with SLO Sail and Canvas, we determined it would be best for them to fit the sling canvas onto the physical Skeleton in-person, instead of following strict drawing dimensions, as the final product could be out of tolerance and the Sling wouldn't fit the cutouts for the Sling Hooks on the Support Arms. The material of the canvas was not finalized since we could no longer visit their store and discuss options, but we determined that any of their catamaran trampoline materials would work for our project as long as it could support a 300 lbf load and provided sufficient corrosion resistance. It is essential that the 6 cut-outs in the sling canvas align well to the Sling Hooks and are reinforced to prevent tearing.

Attaching the sling canvas to the rods could be accomplished in any manner that the experts at the location think would work best. The attachment technique our team envisioned is illustrated in Figure 31. They would loop the canvas around the sling rods and stitch it back into itself, making sure to create the six reinforced cutouts beforehand. $300 has been allocated in the budget for this job, which includes the cost of the two Sling Rods ($16.79 ea.) and their shipping costs.

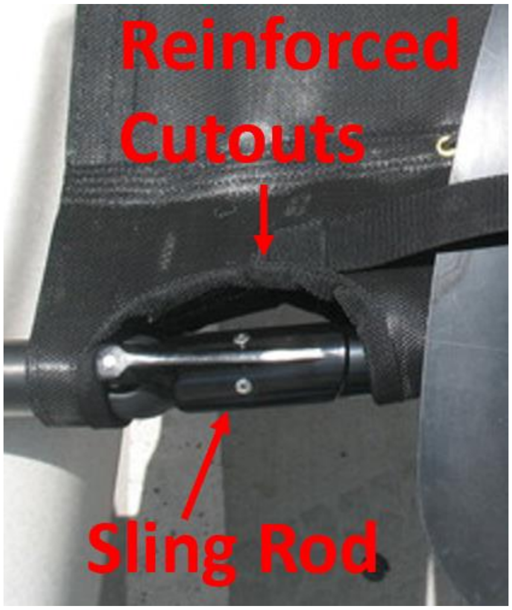

Figure 31. Sling Attachment Method

8.2 Additional Testing

The Testing Procedures in Appendix M detail the testing that still needs to be completed before the product can be used by AmpSurf. The most important of these tests, according to the Failure

Modes and Effects Analysis, is the Sling Tearing Test. It is critical that this test occurs before a person lays on the sling and operates this device.

9 Project Management

This section describes the devices our team used to stay on track and ensure all parties involved with our project were informed and aware of our progress. It also contains a table of the key deliverables that were required throughout the process.

9.1 Design Process

Our design process encompasses four main phases: collecting, designing, building, and testing. The collecting phase includes background research, searching existing designs and patents, and defining project goals. This phase culminated in the Preliminary Design Review document which summarized what we learned and outlines the fundamental goals our design must accomplish. In the design phase, we generated ideas for our design and created preliminary sketches. Once we decided on a promising and feasible design, we built smaller scale concept models to get a sense of how difficult manufacturing the design is. With the models, we completed basic scale testing and observed potential problems. A preliminary CAD model was then created based off the scaled concept models. The building and testing phases were iterative processes that we continued to repeat until we had a design that meets Mr. Cummings' goals. After a design was finalized, we created our structural prototype that tested out a few key qualities: the tire maneuverability on sand, the ride height, the handles, and the buoyancy of the wheels in the ocean. Testing procedures were developed based on tests we deemed appropriated in the Design Verification Plan section. Final prototype manufacturing occurred throughout this testing phase, and afterwards as more shipments of our parts came in.

The COVID-19 outbreak caused significant problems with our original project management plan. At the time school was shut down we had already purchased almost every single part with the plan to alter and manufacture in the Cal Poly SLO machine shops. Once the shops shut down we had to either outsource certain jobs, or change our manufacturing processes to adjust to the available tooling. This led to many days manufacturing in a parking lot with simple drills and wrenches, since we weren't allowed to use most other power tools as it posed a liability issue. This outbreak also had huge effects on our sling procurement. The plan throughout the project was to finish all manufacturing beside the Sling, and then take the finished product and let SLO Sail and Canvas fit the Sling to it on the spot. Once their business partially closed down, we could no longer deliver our product and get the Sling fitted and manufactured. Due to this, we had to make a guide on how to finish this job for a person in the future when their business allows for it.

9.2 Timeline

The key deliverables and dates are found in Table 2. Breaking these milestone tasks up into smaller deliverables is key to staying on target and continually making progress. The Gantt Chart shown in Appendix G is our planning tool for the project. The smaller deliverables are arranged in order and each have an attached group member to ensure completion. The dependent tasks building up to each milestone are linked to show the flow of the project. After the COVID-19 outbreak, we steered away from the Gantt Chart for the most part, and instead opted to have weekly meetings with our advisor to discuss what future tasks on the chart are feasible and which ones must be delayed.

Table 3. Deliverable Due Dates

Key Deliverables	Due Date
Interim Design Review	1/16/2020
Critical Design Review	2/4/2020
Manufacturing & Test Review	3/12/2020
Webpage submitted	5/28/2020
Final Design Report	6/4/2019

The Interim Design Reviews and Critical Design Reviews serve as two major checks on our design where we got feedback on our direction and overall progress. The Manufacturing and Test Review is a short presentation we conducted that shows our progress we have made on manufacturing. The Project Expo/Final Design Review is the final deliverable for this project. This is the day we turn in our final report and display our final prototype model. After this event we will be delivering our prototype to the AmpSurf organization for their use.

9.3 Next Steps

Continued communication with Ms. Salas and Mr. Cummings will be important to make sure all parties are up to date with where we left off our project. If it were not for the unique circumstances, we would have been able to deliver a finished product to our sponsors at this time. Unfortunately, that is not the case, and there is still work to be done. We are confident that we made great progress despite the limitations, and that we are leaving this project in a 99% completed state.

10 Conclusion

This document provides an overview of our progress on the project, including a highly detailed description of our final design. This team created a sled that will help disabled veterans lay on top a surfboard on land and transport them into the water. It can accommodate a variety of surfboard sizes and withstand a heavy load while being lightweight and cost effective. This report details the requirements we met, and those that were not met due to limitations this quarter. This report has also been delivered to QL+ and AmpSurf to serve as both a user manual (Appendix N), and a guide for future work (Section 8).

10.1 Lessons Learned & Recommendations

This team learned how to take a project from scratch going through the entire process of brainstorming, design, and execution. We learned the hard way how to use basic tools to fabricate a complicated device. We learned to work with conflicting ideas and come to a resolution. A few recommendations for others who are going through similar projects are as follows: Create many functional prototypes as possible, build as early as possible, and test often.

It was very helpful for us to see how things would work. We underestimated how long it would take to drill through stainless steel. The last thing we wish we could have done is to test our final design. Unfortunately, due to the pandemic this was not possible. Plans had to change slightly, but this team is proud of what we have accomplished and excited that our device will help countless people get back to surfing.

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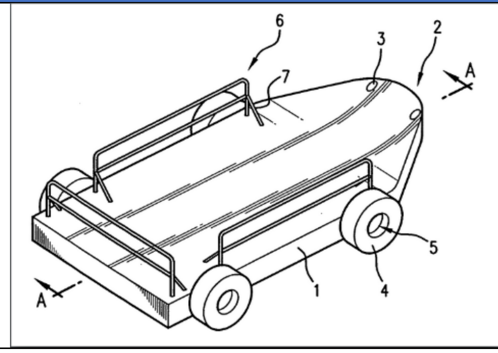
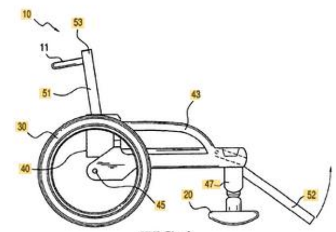
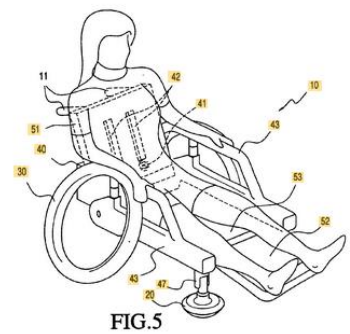
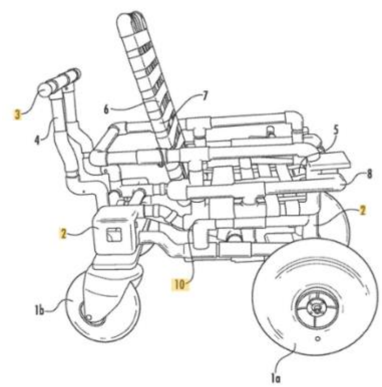
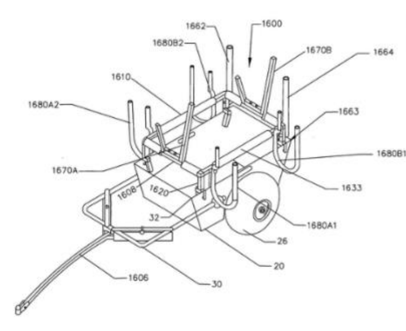
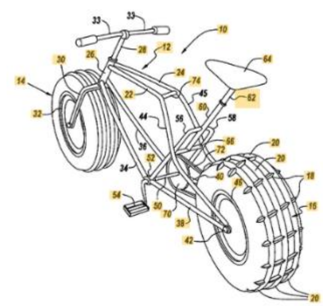
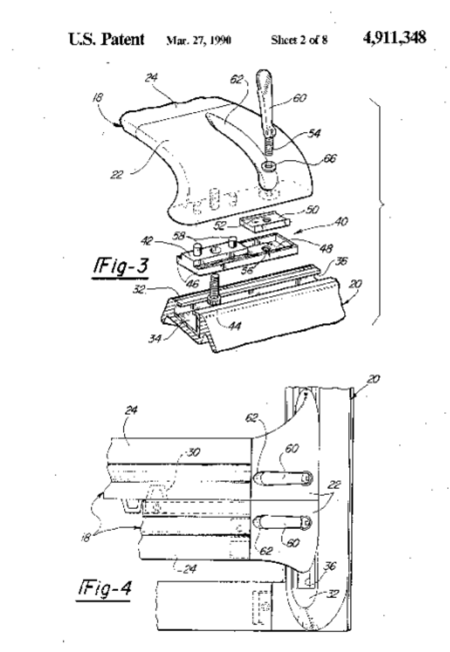
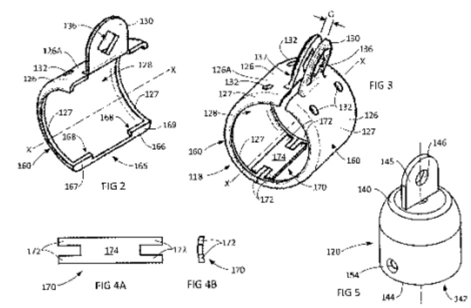
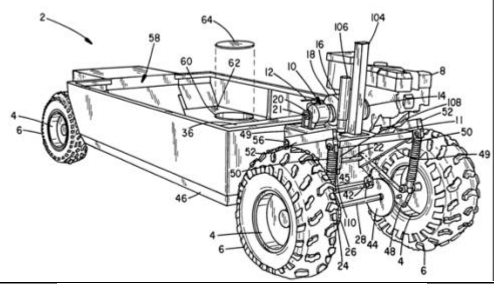
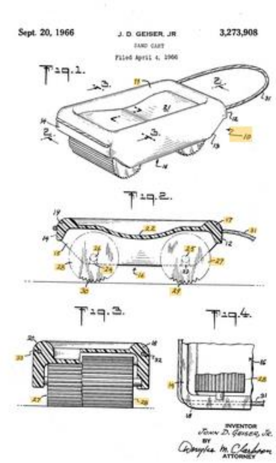
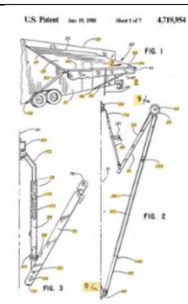
A - Relevant Patents

Patent Number	Patent Title	Description	Drawing
US20070296167A1	Road and sand sled	This is a sled that can move on sand and common roads. It is raised from the ground that allowed for clearance to go over obstacles. This is meant to hold light cargo as it is being pulled along the sand.	
US6869084B2	Dignified broad footprint beach wheelchair	A wheelchair with skids, is equipped with a spring-loaded roller. Two front skids in place of front wheels are compressed to provide a resistance-free, broad footprint in the sand and a low-resistance narrow footprint when used by hard.	 FIG.4  FIG.5
US9554954B2	Convertible wheelchair	This invention is a convertible wheelchair with a removable wheel assembly that can be replaced by a stationary stand. It can be used at the beach and other loose gravel.	

Patent Number	Patent Title	Description	Drawing
US20100059950A1	Modular beach cart system	This is a cart that is meant to hold surfboards and transport them over the sand.	
US8382135B1	Sand-rideable bicycle	A sand-rideable bicycle utilizes oversized balloon tires that have an enlarged footprint to permit the bicycle to ride up over even loose sand to provide ease of pedaling as well as enhanced steering and stability.	
US4911348A	Adjustable cross rail for luggage carrier	An adjustable cross rail for a luggage carrier which utilizes a self-storing lever to release the rail stanchions. The stanchions cooperate with a longitudinal track which receives an adjustable slide bar threadably connected to the release lever.	

Patent Number	Patent Title	Description	Drawing
US20170254347A1	Mounting fixture of a connecting feature	Clamp for round bar that something could be attached to. This could be useful if we need to attach hooks to round pipe on the vehicle chassis	
US7329161B2	Amphibious recreation vehicle	An amphibious passenger vehicle having several open or covered holes and a surrounding cover to accommodate fishing and hunting.	
US3273908A	Sand cart	A cart that moves on sand and holds a load with a rectangular shape.	
US4719954A	Awning assembly with telescoping support arms	An awning assembly which is particularly suited for recreational vehicles includes a pair of telescoping support arm assemblies and a pair of folding rafter arm assemblies. A roller is rotatably supported by the support arm assemblies, and an awning is wound and unwound on the roller.	

B - QFD House of Quality

Correlations
Positive +
Negative −
No Correlation

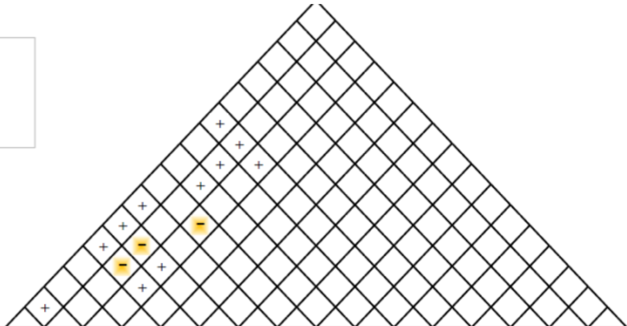
Relationships
Strong ●
Moderate ○
Weak ▽

Direction of Improvement
Maximize ▲
Target ◇
Minimize ▼

QFD House of Quality

Project: Surfboard Sled

Revision Date: 10/15/19



Row #	Weight Chart	Relative Weight	Volunteers	Riders	Maximum Relationship	WHAT: Customer Requirements (Needs/Wants) / HOW: Engineering Specifications (Tests)	Weight	Size of Vehicle	Cost	Time from Beach to Water	Strength	Stiffness	Pull Force	Standard Hardware	Ride Height	Ground Clearance	Board Size Range						Our Current Product	WheelEEZ Beach Wheelchair Conversion Kit	Jet Ski Trailer	Row #
	WHO: Customers					Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NOW: Curr. Products			
						Direction of Improvement	▼	▼	▼	▼	▲	▲	▼	▲	◇	◇	◇									
1		10%	9	2	9	Portable	●	●	▽							▽	○							3	1	1
2		16%	7	7	9	Durable					●	●												4	5	2
3		20%	6	10	9	All Board Compatible	○	●									●							0	0	3
4		7%	10	0	9	Cheap			●					●			○							2	1	4
5		3%	4	0	9	Manufacturable			○					●			○							1	1	5
6		6%	8	0	9	Easy to pull	●	▽		▽			●			▽								4	3	6
7		6%	8	0		Non-corrosive																		0	5	7
8		6%	8	0	9	Sand-Resistant								●										2	4	8
9		11%	1	7	3	Good ride experience				○						○								0	0	9
10		15%	6	7	9	Compatible with wheel chair		○							●									2	1	10
11		0%																								11
12		0%																								12
13		0%																								13
14		0%																								14
15		0%																								15
16		0%																								16
						HOW MUCH: Target Values	75lb	6'X4X3	>1000	10m	accomidates 300lb person + factor of safety	Max deflection < 1in	50 lb each	95%	2ft ± 6 inch	6 in	40'-20'									
						Max Relationship	9	9	9	3	9	9	9	9	9	3	9									
						Technical Importance Rating	200.3	315.6	85.87	40.03	142.5	142.5	53.73	147.8	135.8	49.77	237.2	0	0	0	0	0				
						Relative Weight	13%	20%	6%	3%	9%	9%	3%	10%	9%	3%	15%	0%	0%	0%	0%	0%				

C - Ideation List

- Tow t-bar
- Bike pedals
- Chest harness
- Wheels that turn themselves
- Carry directly
- Solar powered motor
- Gas engine
- Push handles
- Ripstick-like motion
- Pulley system
- Rocket engine
- Magnets
- Track from beach to water
- Wind up motor
- Pull like a wagon
- Rubber band assisted motion
- Pedal you step on a bunch of times
- Trebuchet
- Slide rails
- Team of sled dogs
- Tank treads
- Caster wheels
- Blow up wheels
- Levers the rider pushes with hands
- Propulsion rockets
- Catapult
- Mat from beach to water
- Skis
- Wheels that strap to board "wheel board"
- Tesla batteries
- Throw person
- Elliptical bars
- Motor and pulley
- Walking machine
- Pontoons
- Winch
- Giant fan
- Electric motor
- Wind sail

Brain Writing:

a) Adjustable/Collapsible Mechanisms
    i) Ratchet board (swing up for different sizes)
    ii) Pin & slot system with telescoping arms
    iii) Hinge in center (folds length-wise)
    iv) Hinges at front and back (folds width-wise)
    v) Fin slot down center
    vi) Tri-fold
    vii) Scissor arms to expand and contract the width
    viii) Spring loaded cross beams and pin lock system
b) Volunteer Interface
    i) Contoured grab handles
    ii) Backpack support straps
    iii) Shopping cat push bars
    iv) Push bars extending from corners
    v) Ropes
    vi) Drywall carrier handles
    vii) Winch
    viii) Pulley system
    ix) T bar to pull
    x) Dolley/Hand Truck
    xi) Wheelbarrow
    xii) Hand cart handles
    xiii) Guide rails to push
    xiv) 6 person lift bars

D - **Decision Matrices**

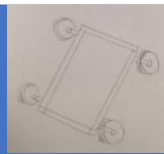
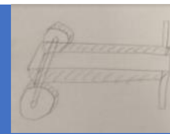
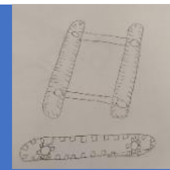
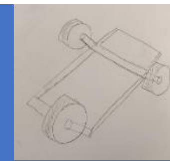
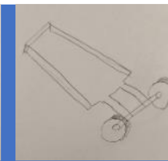
Pugh Matrices:

Criteria	Concept 1	Concept 2	Concept 3 (rope)	Concept 4	Concept 5
Carry capacity	D	+	−	−	+
Time	A	S	S	S	S
Standard Hardware	T	+	S	−	−
Variety of volunteers can use	U	+	−	S	+
Ergonomic	M	S	−	S	+
Force required		+	−	−	S
total	0	+3	−4	−3	+2

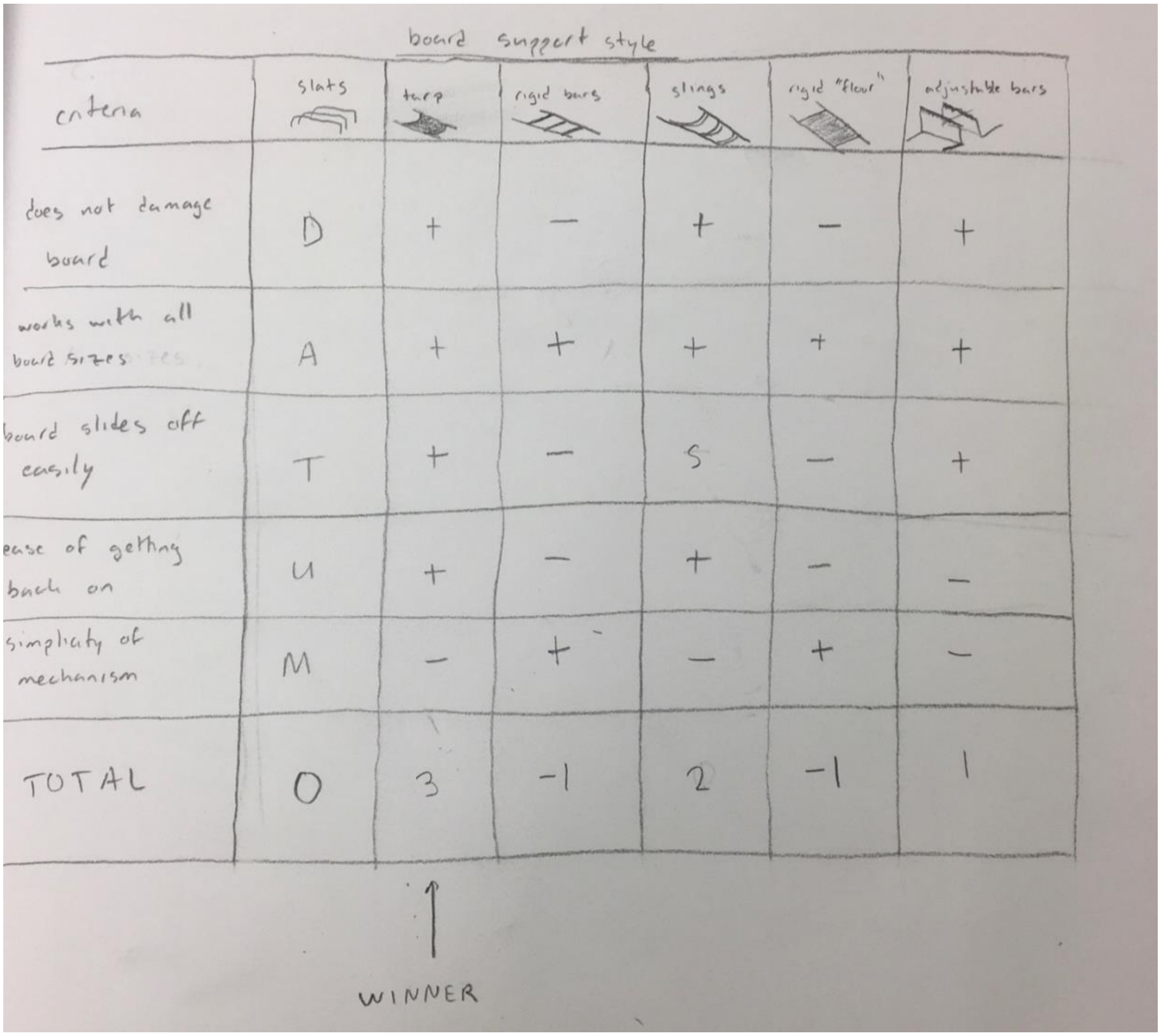
Pugh matrix for Volunteer Interface

	Material				
	PVC	80/20	Alum. Round	316 SS	304 SS
Weight	10	5	5	1.75	1.75
Cost	10	0	5	4	5
Strength	2	9	9	10	8
Stiffness	0	3	3	10	10
Manufacturability	10	7	5	5	5
Corrosion Resistance	10	5	5	9	2
Hardware Compatibility	10	9	9	7	7
Repairability	10	3	3	3	3
Sum	62	41	44	49.75	41.75

Pugh Matrix for Vehicle Material

						
Weight	0	+	+	-	+	+
Portable	0	+	+	-	S	-
Durable	0	-	-	+	-	-
All Board Compatible	0	-	-	+	-	-
Price	0	+	+	-	+	+
Manufacturable	0	+	-	-	+	+
Easy to pull	0	-	-	-	-	-
Non-corrosive	0	S	S	-	S	S
Sand-Resistant	0	-	-	+	-	-
Good ride experience	0	-	-	S	-	-
Compatible with wheel chair	0	-	-	+	-	-
Sum	0	-2	-4	-2	-3	-4

Pugh Matrix for Methods to Traverse the Beach



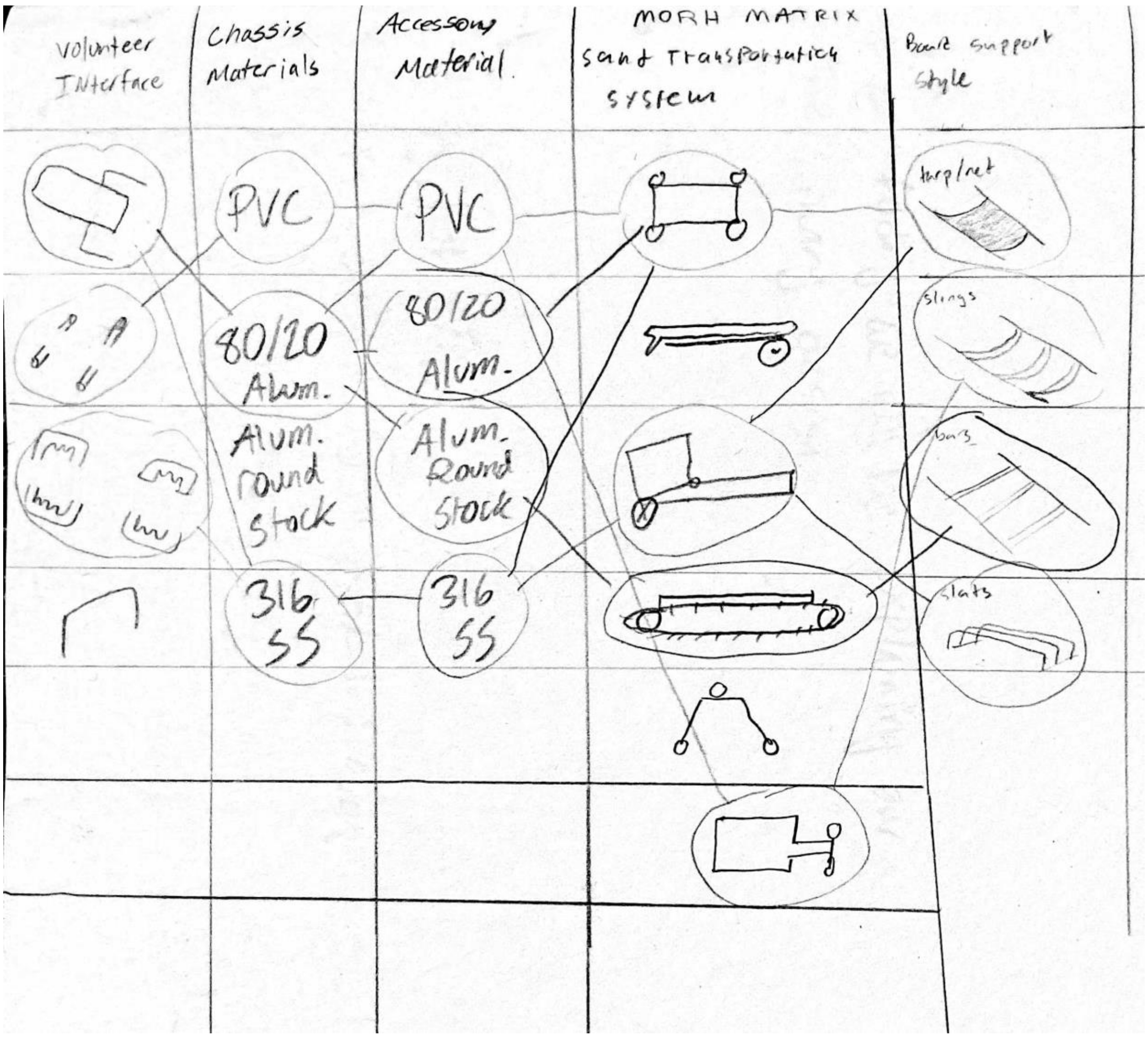
board support style

criteria	slats	tarp	rigid bars	slings	rigid "floor"	adjustable bars
does not damage board	D	+	−	+	−	+
works with all board sizes	A	+	+	+	+	+
board slides off easily	T	+	−	S	−	+
ease of getting back on	U	+	−	+	−	−
simplicity of mechanism	M	−	+	−	+	−
TOTAL	0	3	−1	2	−1	1

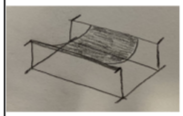
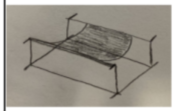
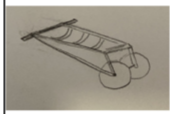
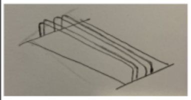
↑ WINNER (tarp)

Pugh Matrix for Board Support Style

Morph Matrix:



Weighted Decision Matrix:

		Options									
		Design 1		Design 2		Design 3		Design 4		Design 5	
											
		Rectangular base, tarp support, push bars, PVC		Rectangular base, tarp support, push bars, Alum round stock frame, PVC misc.		Wheelbarrow Base, sling Support, push Studes , PVC		Chariot base, tarp support, push bars, Stainless Steel		Rectangular base, slat support, push bars, 80/20 Alum base, PVC rails	
Criteria	Weighting	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total
Lightweightedness	0.13	8	1.04	5	0.65	10	1.3	2	0.26	4	0.52
Size of Vehicle	0.2	5	1	5	1	8	1.6	5	1	5	1
Cost	0.06	10	0.6	8	0.48	10	0.6	6	0.36	2	0.12
Time From Beach to Water	0.03	5	0.15	5	0.15	3	0.09	3	0.09	5	0.15
Strength	0.09	2	0.18	5	0.45	2	0.18	8	0.72	5	0.45
Stiffness	0.09	1	0.09	4	0.36	1	0.09	10	0.9	4	0.36
Pull Force	0.03	10	0.3	10	0.3	4	0.12	4	0.12	10	0.3
Standard Hardware	0.1	10	1	6	0.6	10	1	8	0.8	5	0.5
Ride Height	0.09	8	0.72	8	0.72	4	0.36	4	0.36	8	0.72
Ground Clearance	0.03	7	0.21	7	0.21	5	0.15	5	0.15	7	0.21
Board Size Range	0.15	10	1.5	10	1.5	7	1.05	4	0.6	5	0.75
SUM			6.79		6.42		6.54		5.36		5.08

Reasoning for Assigned Values	
Lightweightedness	Based off material density, and number of wheels. Average value used for #2&4
Size of Vehicle	#3 is smaller due to ability to stand upright easily in trailer. #4 would be smaller also, but it needs to be as long as the entire board length, unlike #3
Cost	Based off of material cost/lb, and # of wheels
Time from Beach to Water	#1,2,5 do not need to be picked up, and are constantly at perfect height. #1,2,3,4 need to be unhooked at departure. #5 needs to be set up at beginning, but not departure
Strength	Based on ultimate tensile strength of each material. #2, #5 use average value
Stiffness	Based on module of elasticity of each material. #2, 5 use an average value
Pull Force	#3, 4 need to be picked up as well as pulled/pushed
Standard Hardware	Everything can be used with pvc (#1,3). #2 round stock to pvc fittings may not be standard. #4 steel stock to pvc fitting may not be standard. #5 80-20 stock to pvc fitting may not be standard
Ride Height	#3,4 would be at an angle when loading, and would not constantly be at the best ride height
Ground Clearance	#3, 4 the frame that hangs down and the vehicle rests on may not be very high off the ground when the wheelbarrow is picked up
Board Size Range	#4, it must be at least the same length as the longest board, which may not be good for short boards. #3, a short board might rest in between two slings. #5, slats may not be perfectly configurable for all fin setups

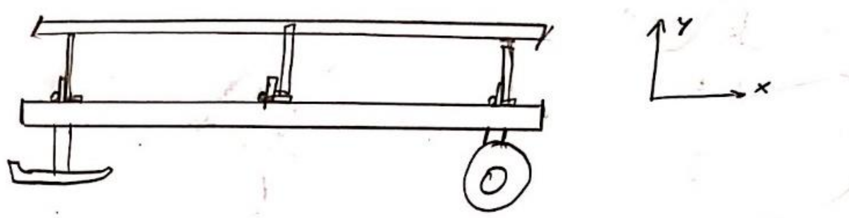
E - Design Hazard Checklist

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

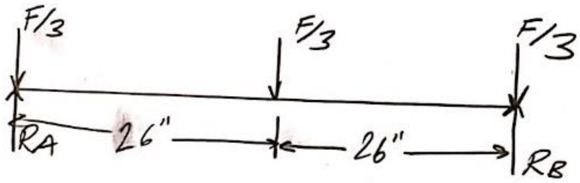
Description of Hazard	Planned Corrective Action	Planned Date	Actual Date
The surfboard sled will be rolling across the beach holding the weight of a full person and a surfboard. We are designing this project with the criteria that it will hold 300 lbs. The volunteers helping push the sled are bare foot and if not careful may have their foot run over by the sled.	We will create handrails and push points away from the wheels. We will also create a comprehensive instruction and warning guide for the volunteers so they can use the equipment in a safe way.	12/1/2019	6/3/2020
This system will be designed to hold 300 lbs.	The project will be made out of materials such as stainless steel, aluminum, and furniture grade PVC. We will not use any material that does not fit the strength criteria. We will also test our system before giving it to our customer.	12/1/2019	INC
The person using the device will be suspended in the air about two feet. If a fail point occurs the person may bump their head or injure themselves.	We will reinforce all contact points to make sure the device is as safe as possible. We will also recommend there be no less than six volunteers be present in helping the user be safe. This will go in our instruction and warning guide.	12/1/2019	6/3/2020
Most users of the surfboard sled will be amputee veterans where they may be missing one or all limbs. In this case they will be required to use whatever means they feel comfortable to get on the device. This may result in abnormal physical movement.	Currently we have planned to use a self-centering sling that will provide the maximum stability for the board. We will also create the sled height the same as the beach wheelchair already in use by our sponsor. This will make sure the transition from the wheelchair to the sled will be as smooth as possible.	12/1/2019	6/2020
Our system will be required to go into the ocean water and be driven in the sand.	To counteract the corrosion created by saltwater we plan to use non-corrosive materials. We are also looking into anti-corrosive paints and sprays that will also help reduce this danger.	12/1/2019	4/12/2020

Description of Hazard	Planned Corrective Action	Planned Date	Actual Date
This system will be made out of heavy and sturdy material that will be on wheels. If someone were to engage in horseplay or tomfoolery around the device and start using it for things other than its intended purpose, this may cause injury.	We are not responsible for the misuse of our product. All we can do is educate the users on the safe and proper way to use the device.	12/1/2019	6/3/2020

F - **Beam Stress Analysis**



FBD



$F = 300 lb$

$$M = \frac{Fx}{2} = \frac{F/3\,(x)}{2} = \frac{\frac{300 lb}{3}(26")}{2} = 1300\ lb\text{-}in$$

For square tubing with OD = d & wall thickness = t

$$I = \frac{d^4 - (d-t)^4}{12}$$

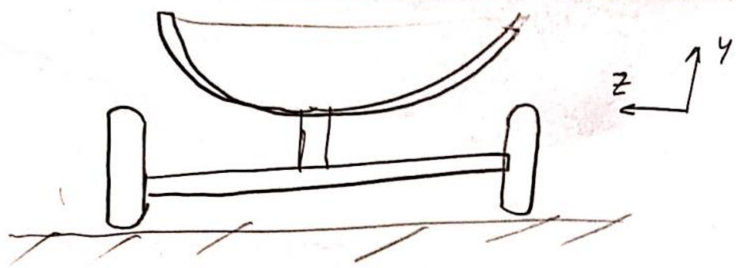
For 2×2×.250 square tubing

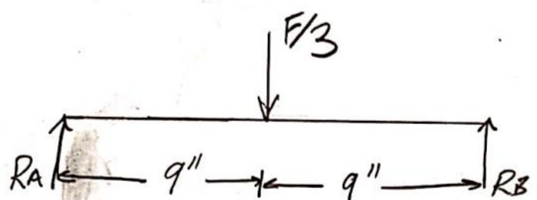
$$I = \frac{2in^4 - (2 - .250\,in)^4}{12} = 0.55176\ in^4$$

$$\sigma_M = \frac{My}{I} = \frac{1300\ lb\text{-}in\,(1 in.)}{0.55176 in^4} = 2356.1 psi$$

For 316L Stainless Steel, $S_y = 29700 psi$

$$FS = \frac{29700 psi}{2356.1 psi} = 12.6$$





$$M = \frac{Fx}{2} = \frac{F/3\,(x)}{2} = \frac{\frac{300lb}{3}\,(9")}{2} = 450\ lb\text{-}in$$

<u>For 1.0" Sch. 40 Round Pipe (316L Stainless Steel):</u>

$OD = 1.315"$, $ID = 1.049"$

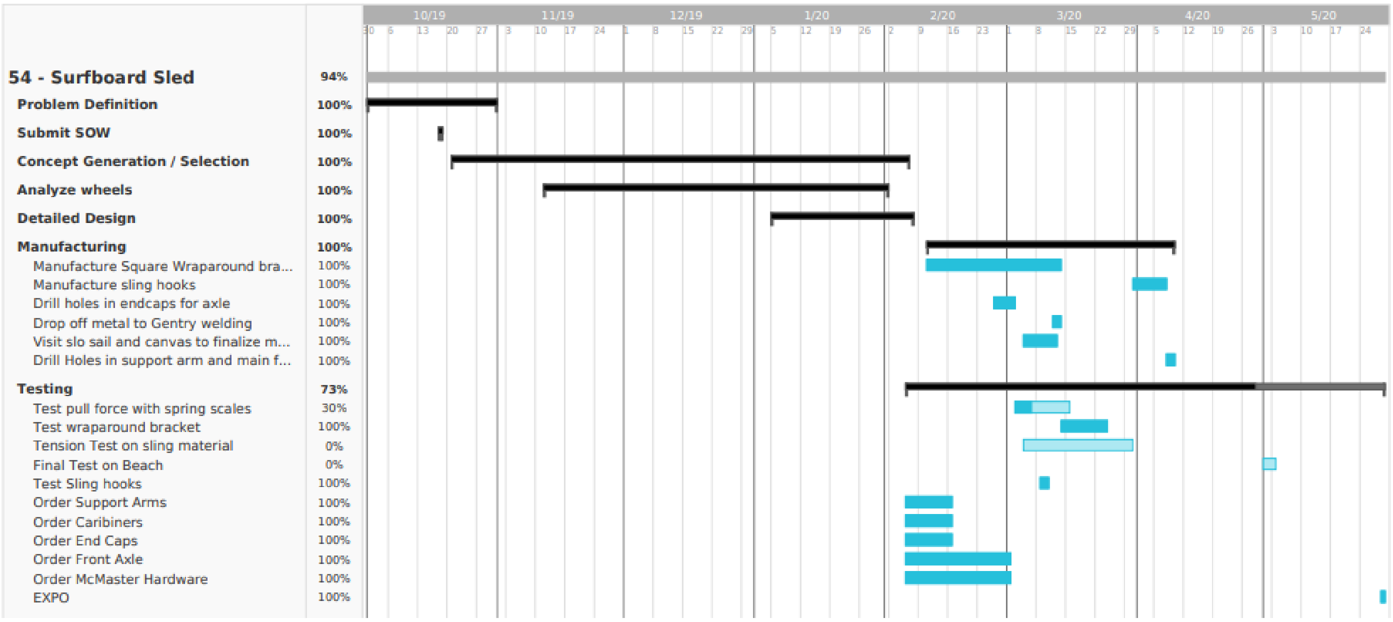
$$I = \frac{\pi(OD^4 - ID^4)}{64} = \frac{\pi(1.315"^4 - 1.049"^4)}{64} = 0.0873\ in^4$$

$$\sigma_B = \frac{My}{I} = \frac{450lb\text{-}in\left(\frac{1.315"}{2}\right)}{0.0873} = 3389.2psi$$

$$FS = \frac{29700psi}{3389psi} = \boxed{8.76}$$

				Sling Rod					
ALUMINUM	.75" SCH 40			M	-195.2	lbf-in			
Weight (omega)	150	lb		V	-37.43	lbf-in			
Total Length (L)	60	in		A	0.332635	in^2			
OD	1.05	in		y	0.525	in			
ID	0.824	in		I	0.037036	in^4			
Yield Strength	4.00E+04	psi							
Density	0.0975437	lb/in^3		Tresca				Von Mises	
				σ_x	-2767.01	psi	σ_x	-2767.01	psi
				τ_{xy}	-225.052	psi	τ_{xy}	-225.052	psi
				τ_{max}	1401.691	psi	sigma'	2794.335	
				FS	14.27		FS	14.31	
				Volume	19.9581	in^3			
				Weight	1.946787	lb			

G - Gantt Chart

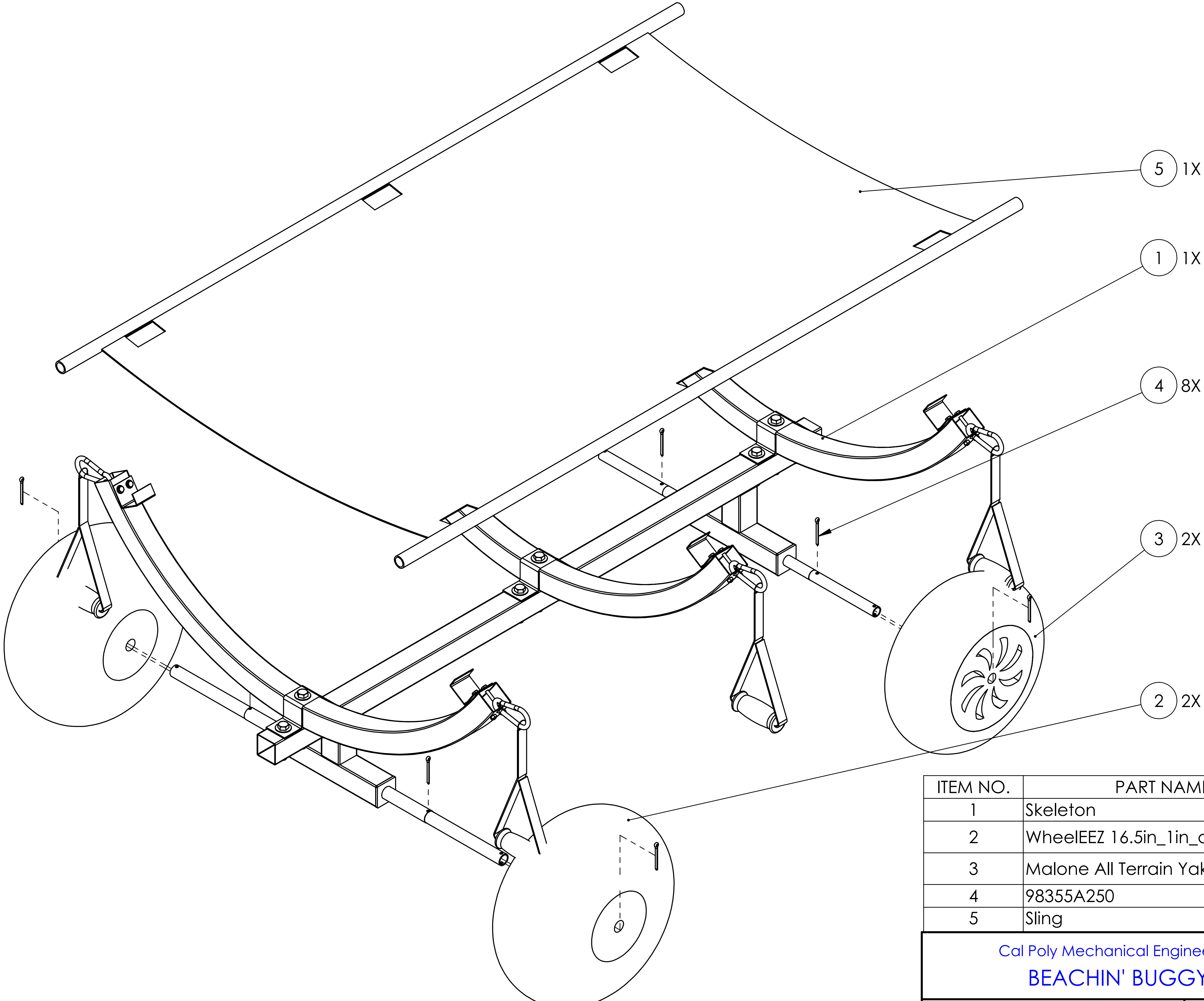


H - Drawing Package

Beachin' Buggy
Indented Bill of Material (iBOM)

Assembly Level	Part Number	Lvl0	Lvl1	Lvl2	Lvl3	Qty	Cost ea.	Ttl Cost	Source
0	100000	Beachin Buggy Assy v7				1			
1	110000		Skeleton			1			
2	111000			Chassis		1			
3	111100				Main Frame	1	0	0	ValleyIron
3	111200				End Cap Rear	2	14	28	TopHardware
3	111300				End Cap Front	2	14	28	TopHardware
3	111400				Axle Rear	1	0	0	ValleyIron
3	111500				Axle Front	1	70.68	70.68	OnlineMetals
2	112000			Support Arm Assy		1			
3	112100				Square Support Arm	3	243.3333	730	Tube-Tec
3	112200				Handle	6	11.99	71.94	FitnessFactory
3	112300				Sling Hook	6	0	0	ValleyIron
3	112400				Carabiner	1	6-PACK	10.95	Amazon
3	112500				316 Stainless Steel Hex Head Screw 1/4"-20 Thread Size, 2-1/2" Long, Partially Threaded	2	10-PACK	9.56	McMaster
3	112600				316 Stainless Steel Washer for 1/4" Screw Size, 0.281" ID, 0.625" OD	1	100-PACK	7.11	McMaster
3	112700				316 Stainless Steel Hex Nut 1/4"-20 Thread Size, ASTM F594	1	50-PACK	4.08	McMaster
2	113000			Square Wrap Around Bracket		1	23.53	23.53	Amazon
2	114000			316 Stainless Steel Hex Head Screw 1/2"-13 Thread Size, 3" Long, Partially Threaded		6	1.46	8.76	McMaster
2	115000			316 Stainless Steel Washer for 1/2" Screw Size, 0.531" ID, 1.25" OD		1	25-PACK	8.16	McMaster
2	116000			316 Stainless Steel Hex Nut 1/2"-13 Thread Size		1	10-pack	4.52	McMaster
2	117000			316 Stainless Steel Hex Head Screw 1/2"-13 Thread Size, 5" Long, Partially Threaded		3	2.47	7.41	McMaster
2	118000			Rubber Sheet		1	Sheet	15.53	McMaster
1	120000		WheelEEZ 16.5in_1in_axle			2	164.34	328.68	WheelEEZ
1	130000		Malone All Terrain YakHauler			2	50	100	Malone
1	140000		316 Stainless Steel Cotter Pin 3/16" Diameter, 2" Long			1	10-PACK	8.83	McMaster
1	150000		Sling			1	300	300	SLO Sail & Canvas / OnlineMetals
							TOTAL COST	1765.74	

= Manufactured/Altered Part



ITEM NO.	PART NAME	PartNo	QTY.
1	Skeleton	110000	1
2	WheelEEZ 16.5in_1in_axle	120000	2
3	Malone All Terrain YakHauler	130000	2
4	98355A250	140000	8
5	Sling	150000	1

Cal Poly Mechanical Engineering

BEACHIN' BUGGY

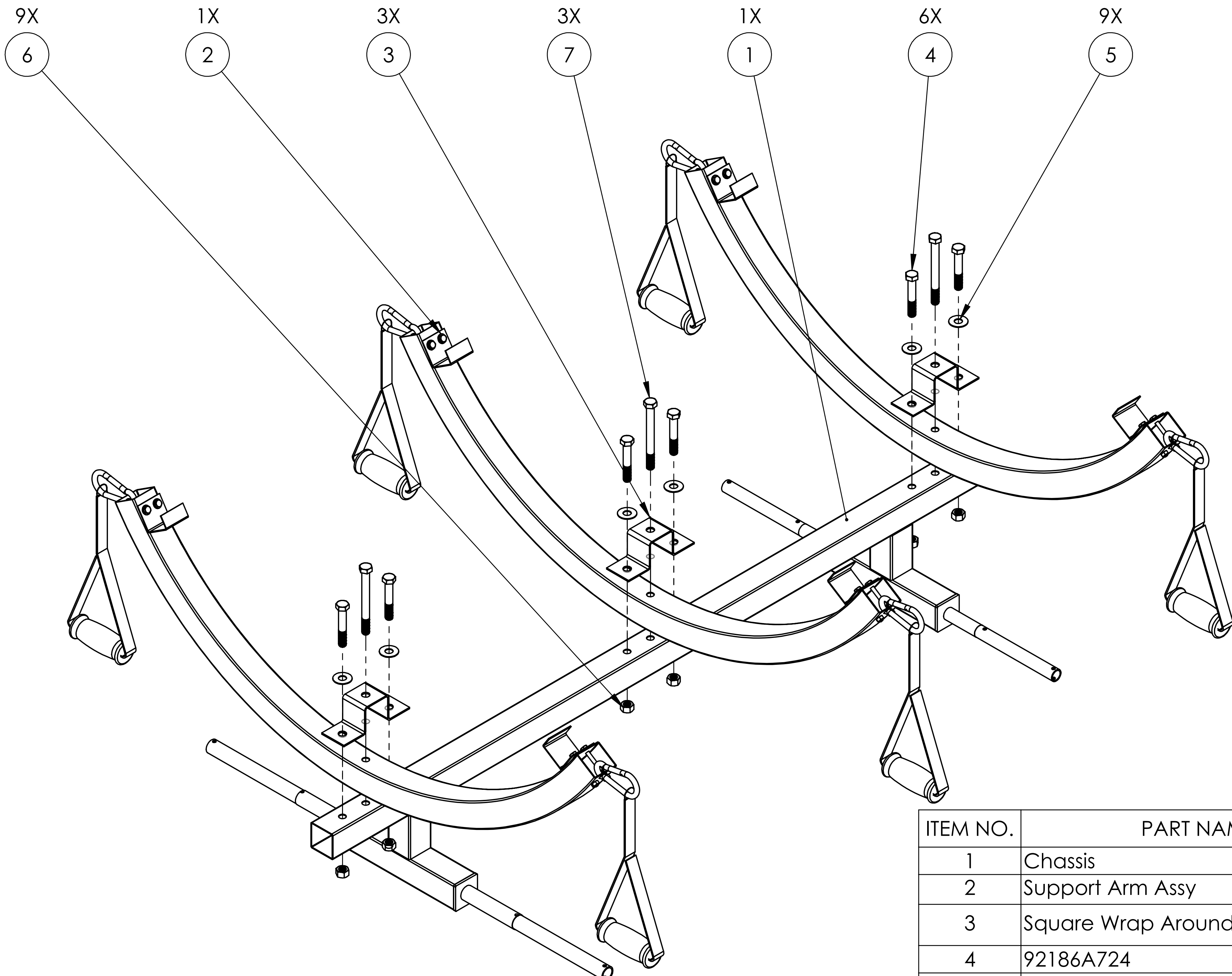
Part: Beachin Buggy Assy

Drwn. By: A ZAAYER

Material: 304 SS

Cost:

Part #: 100000



ITEM NO.	PART NAME	PartNo	QTY.
1	Chassis	111000	1
2	Support Arm Assy	112000	1
3	Square Wrap Around Bracket	113000	3
4	92186A724	114000	6
5	90107A033	115000	9
6	94804A340	116000	9
7	92186A732	117000	3

Cal Poly Mechanical Engineering

BEACHIN' BUGGY

Part: Skeleton

Drwn. By: A ZAAYER

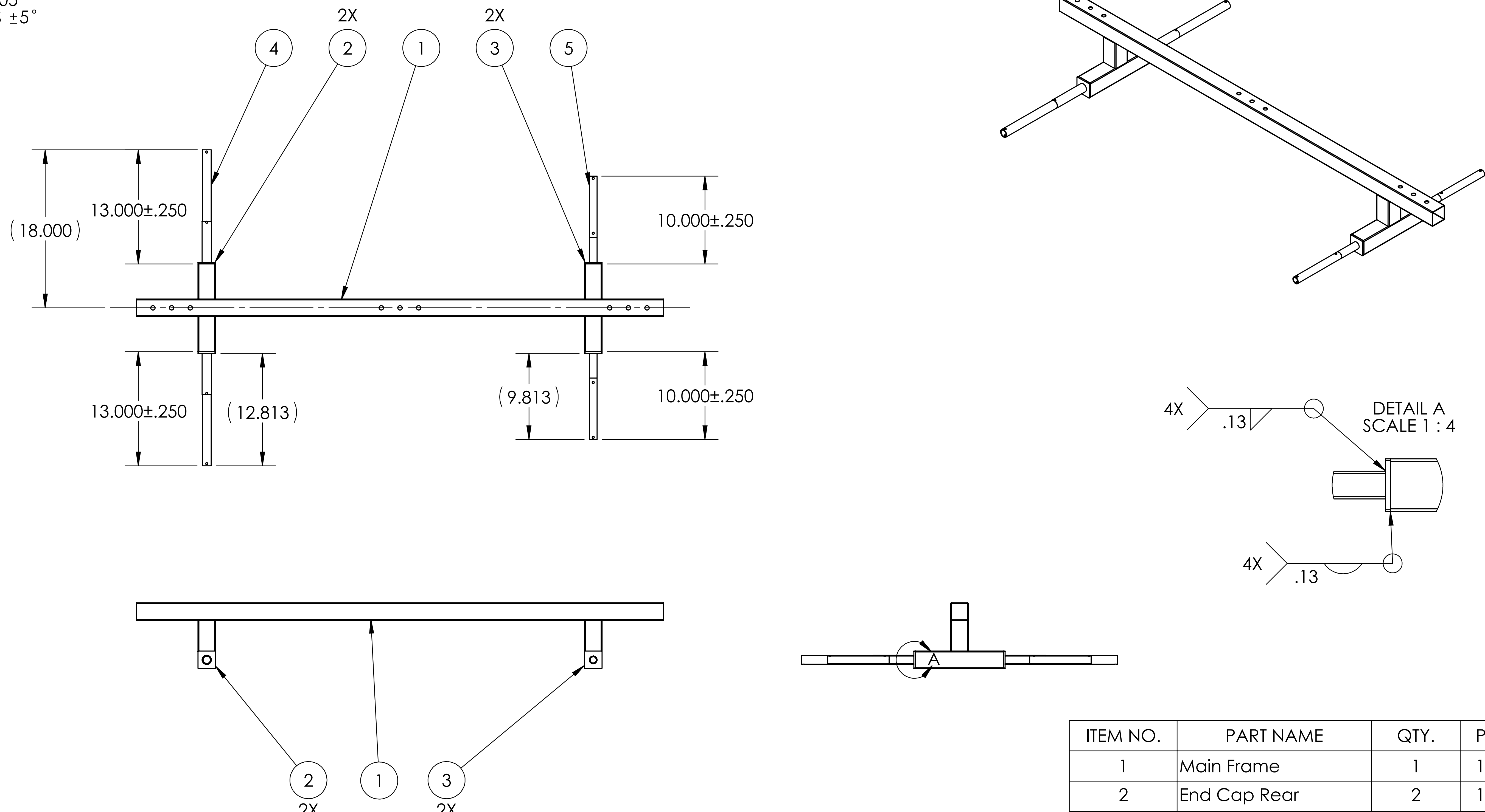
Material: 304 SS

Cost:

Part #: 110000

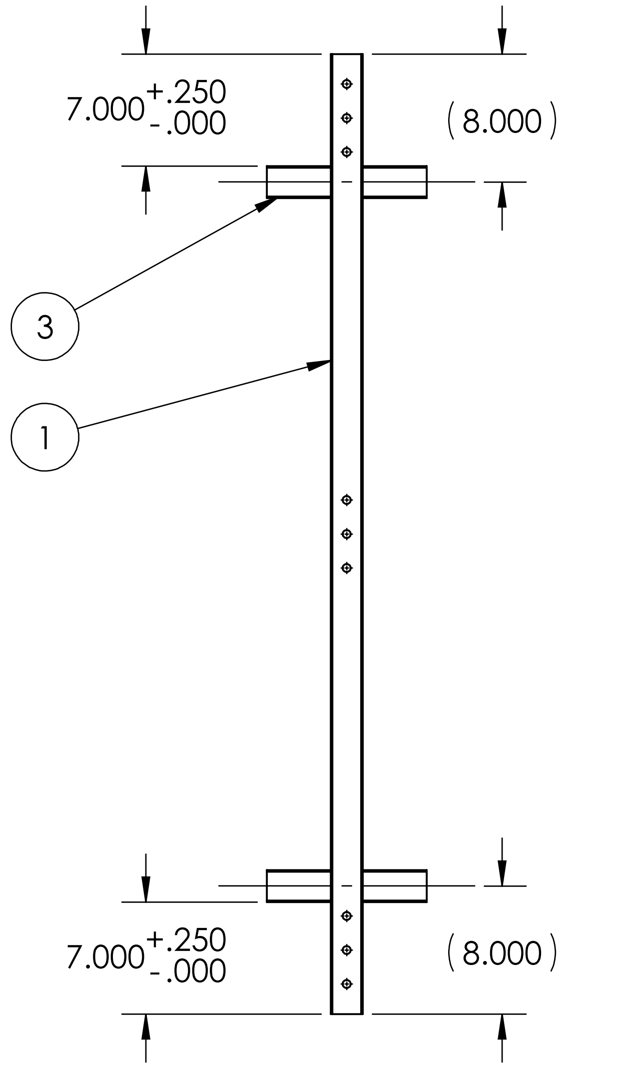
UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES

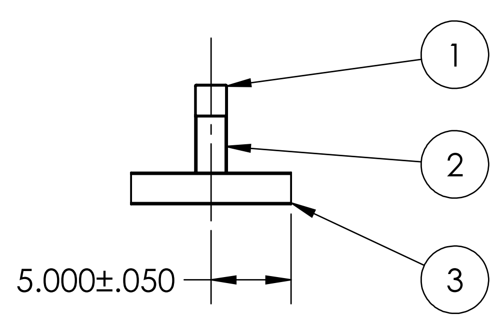
1. .XXX ±.005
2. ANGLES ±5°

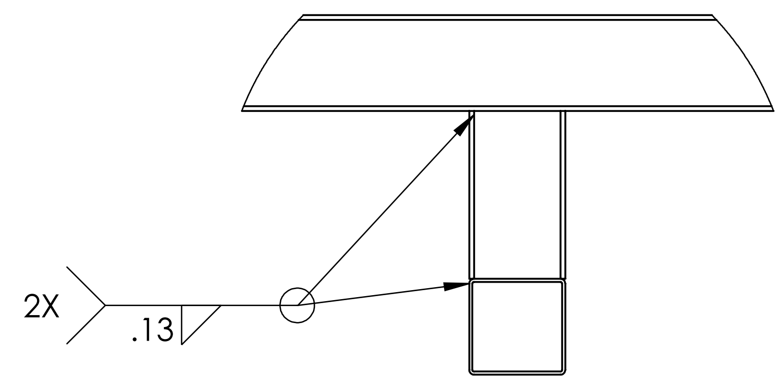


ITEM NO.	PART NAME	QTY.	PartNo
1	Main Frame	1	111100
2	End Cap Rear	2	111200
3	End Cap Front	2	111300
4	Axle Rear	1	111400
5	Axle Front	1	111500

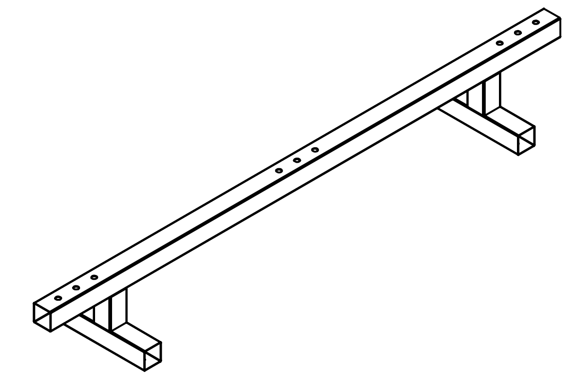
Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: Chassis
Drwn. By:	Cost:	Part #: 111000
Material: 304 SS		

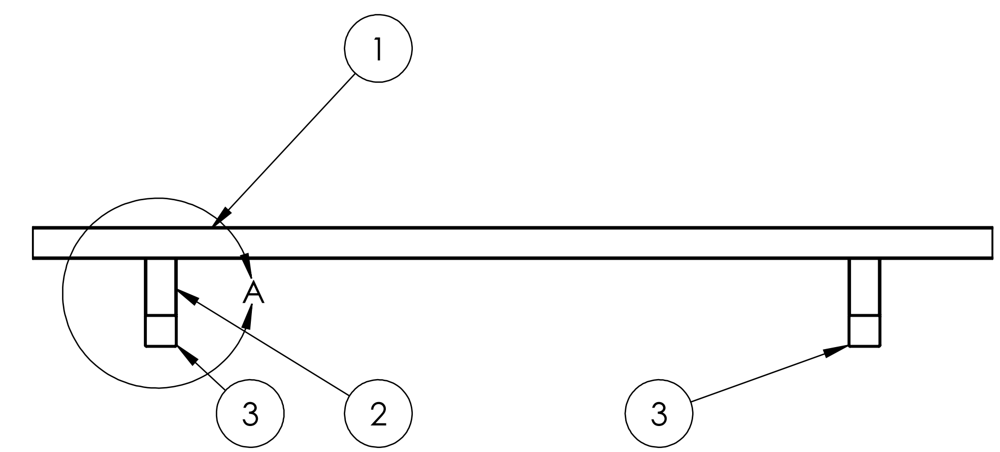






DETAIL A
SCALE 1 : 4





ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	1	TS2x2x0.065	60
2	2	TS2x2x0.065	3.5
3	2	TS2x2x0.065	10

UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES
1. .XXX ± .005
2. ANGLES ± 5°

Cal Poly Mechanical Engineering

BEACHIN' BUGGY

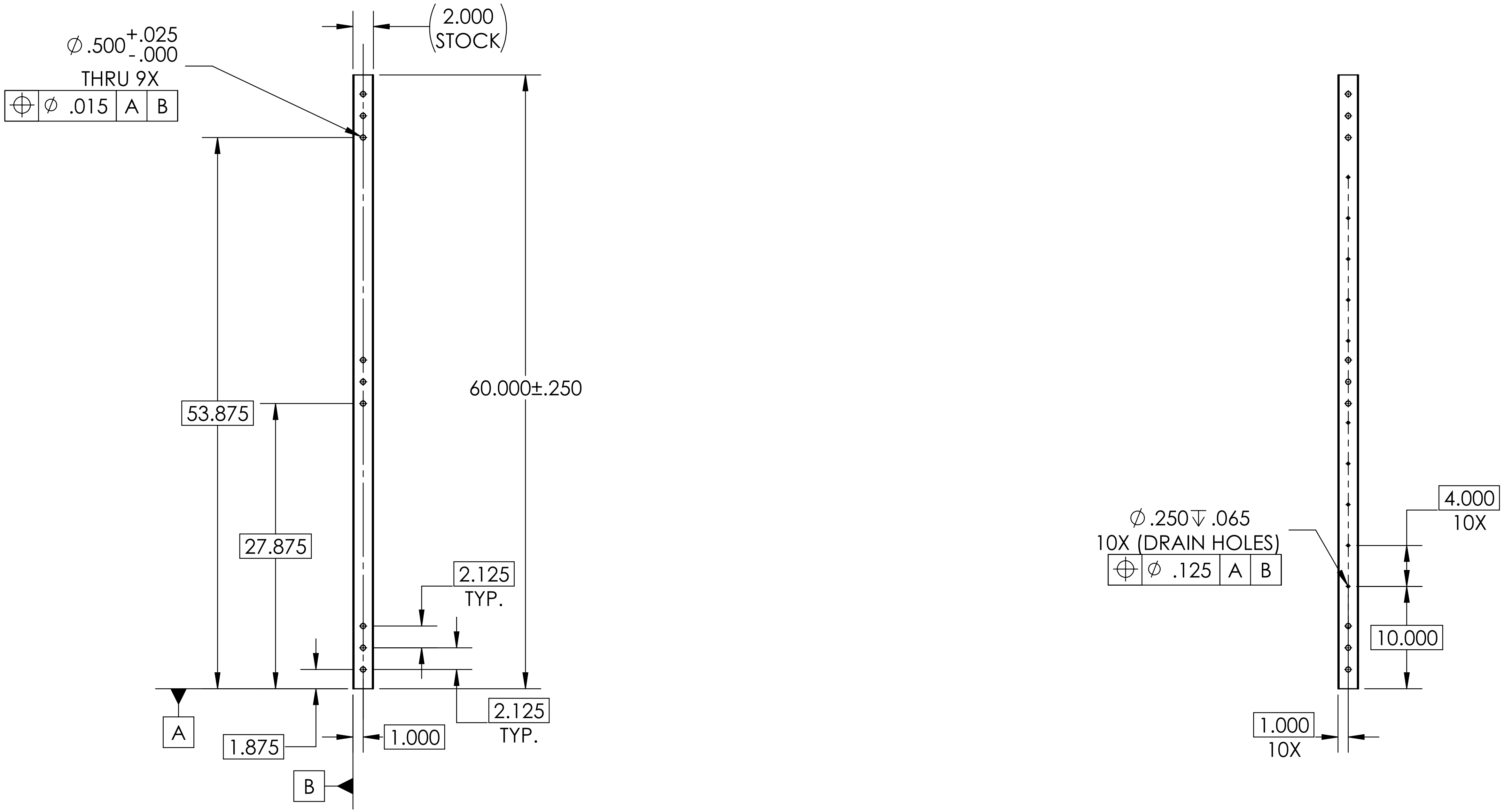
Part: Main Frame

Drwn. By: A ZAAYER

Material: 304 SS

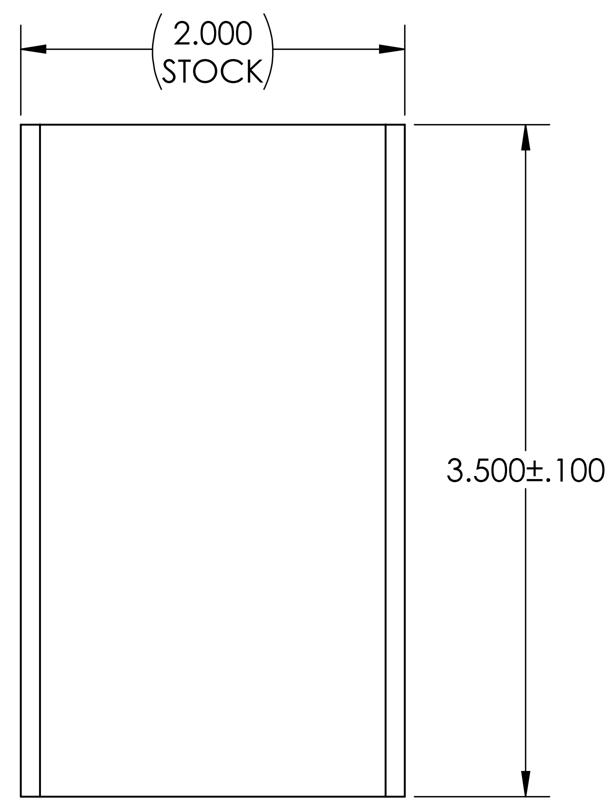
Cost:

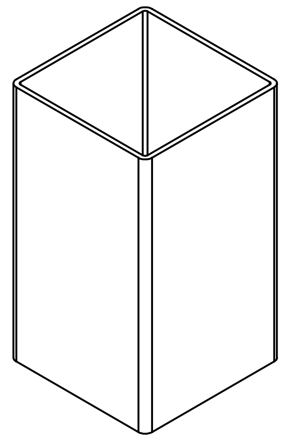
Part #: 111100



ITEM NO. 1

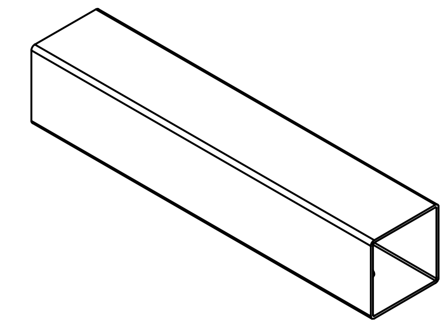
Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: Main Frame
Drwn. By: A ZAAYER	Cost:	Part #: 111100
Material: 304 SS		

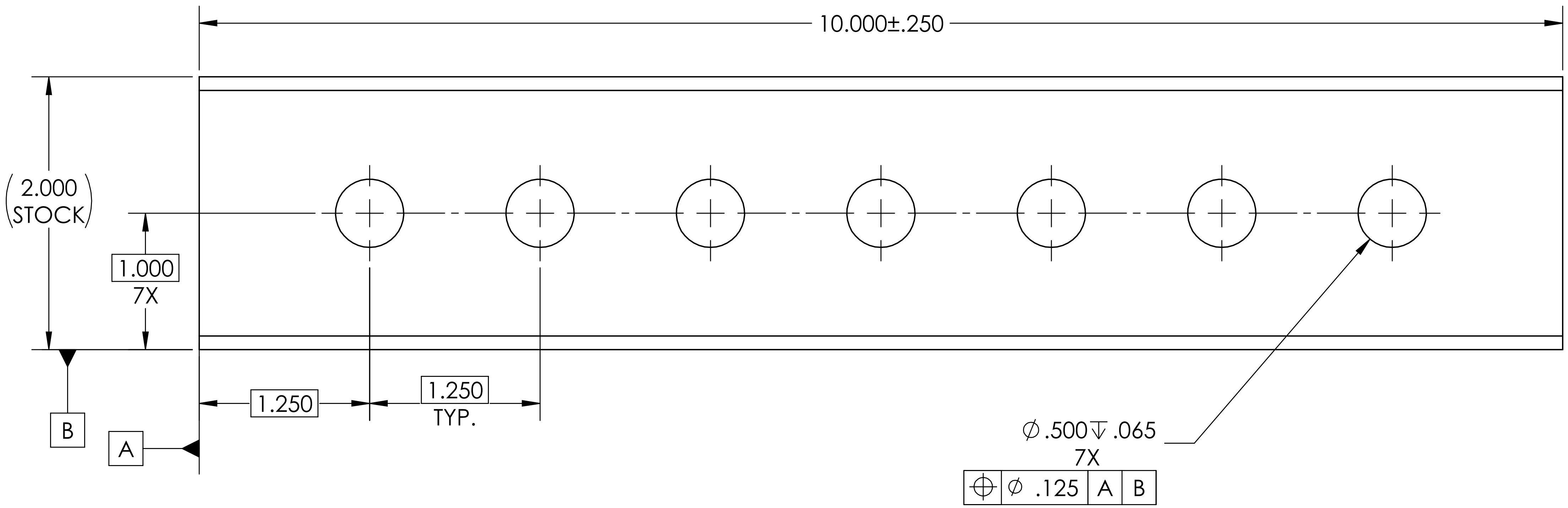




ITEM NO. 2

Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: Main Frame
Drwn. By: A ZAAYER	Cost:	Part #: 111100
Material: 304 SS		

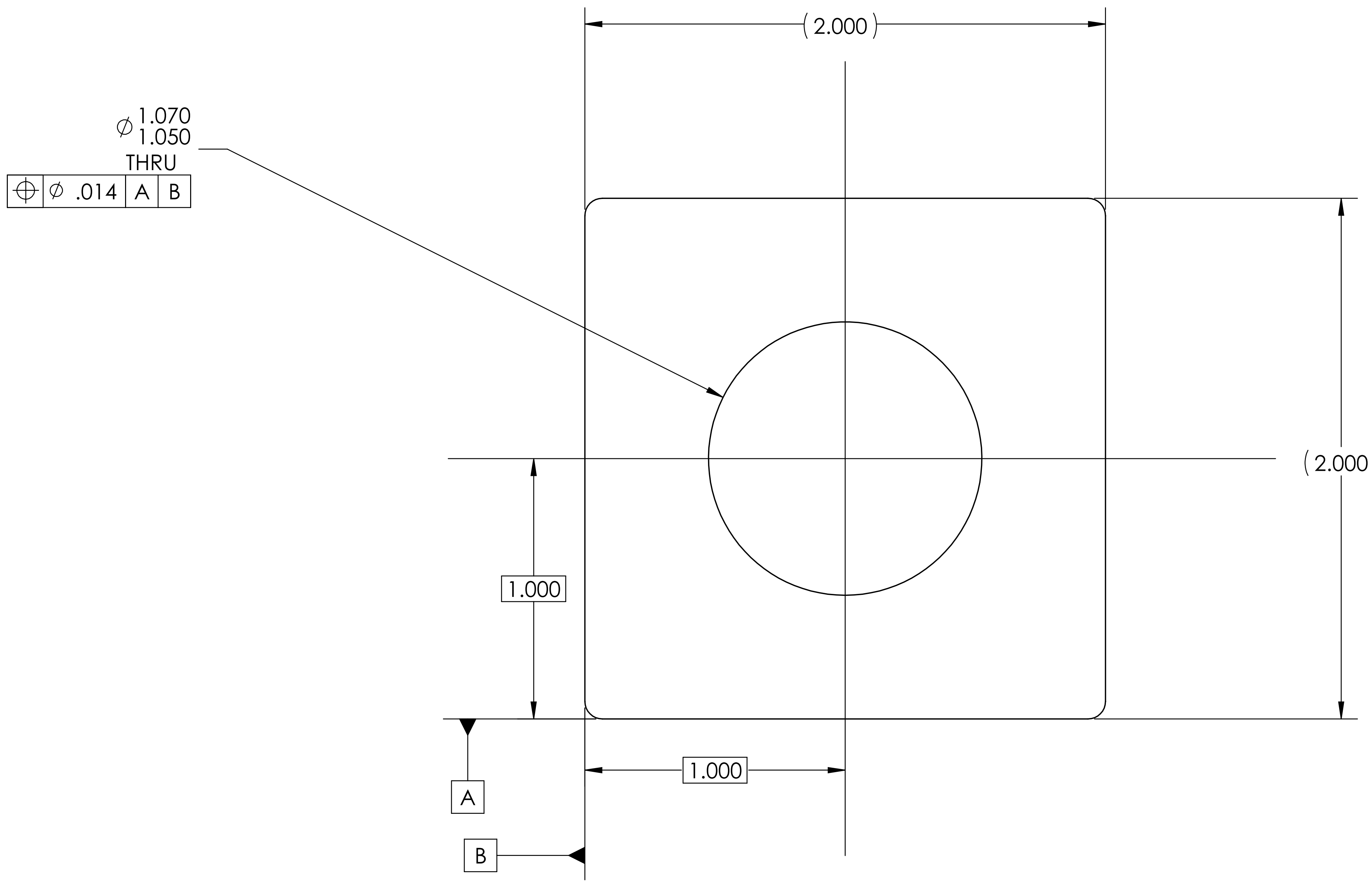


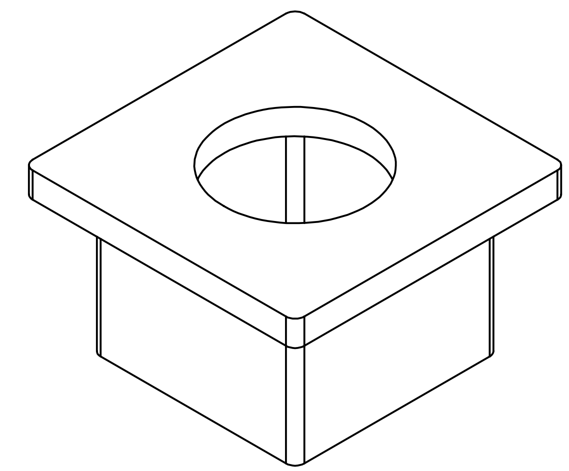


ITEM NO. 3

Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: Main Frame
Drwn. By: A ZAAYER Material: 304 SS	Cost:	Part #: 111100

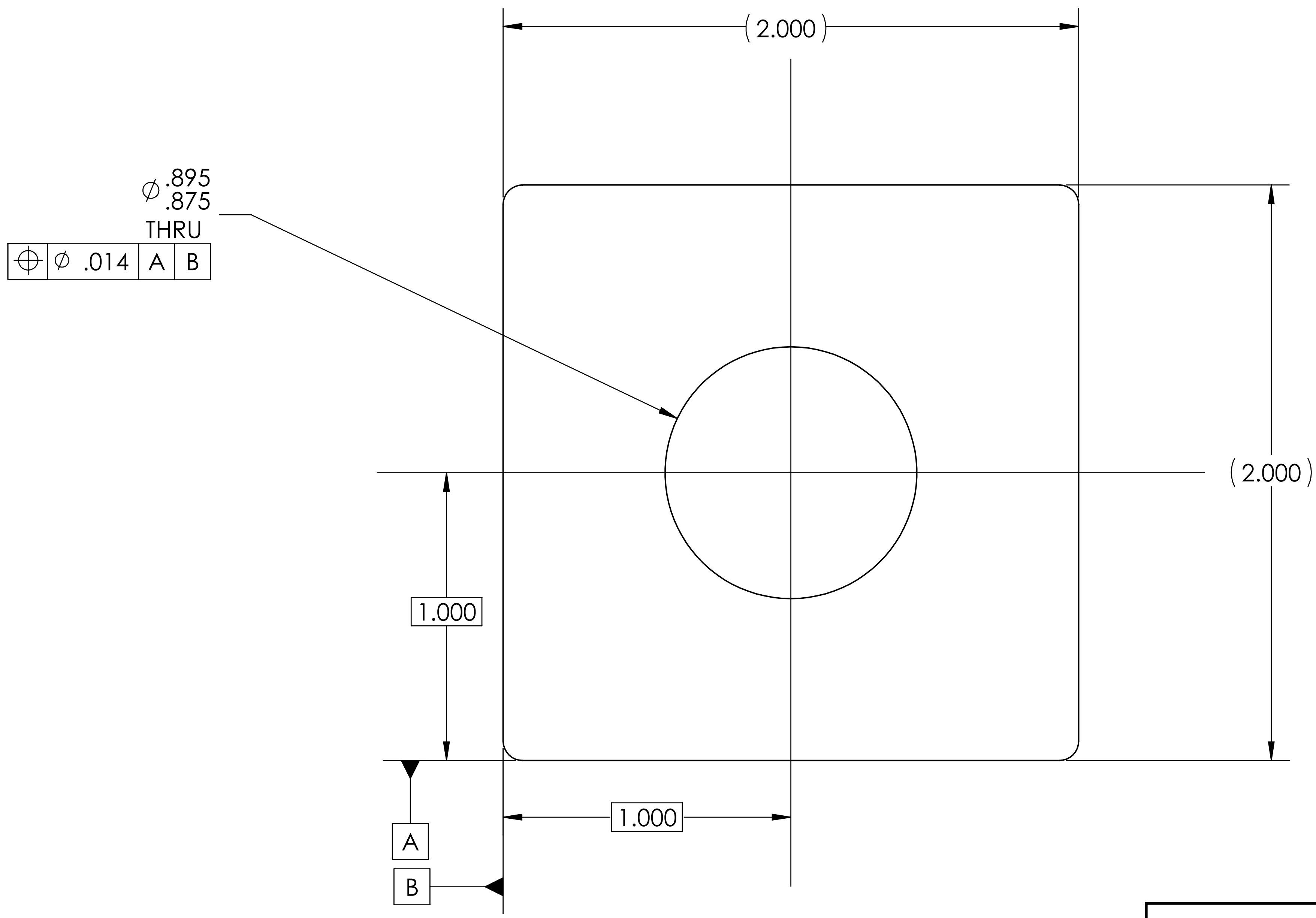
NOTE:
1. UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES
    1. .XXX ±.005
    2. ANGLES ±5°
2. STOCK END CAP PURCHASED, DRILL IS ONLY OPERATION.

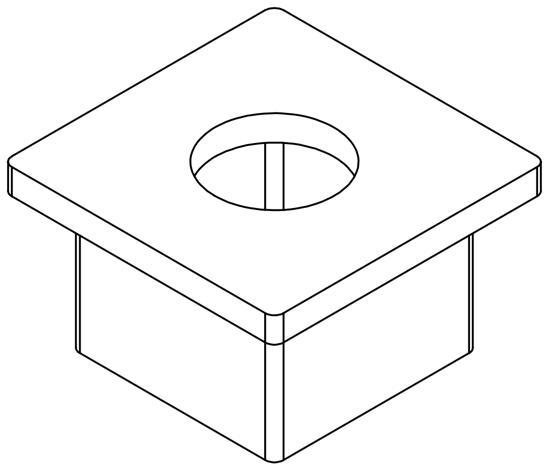




Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: End Cap Rear
Drwn. By: A ZAAYER	Cost: 14.00	Part #: 111200
Material: 304 SS		

NOTE:
1. UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES
   1. .XXX ±.005
   2. ANGLES ±5°
2. STOCK END CAP PURCHASED, DRILL IS ONLY OPERATION.





Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: End Cap Front
Drwn. By: A ZAAYER Material: 304 SS	Cost: 14.00	Part #: 111300

<table>
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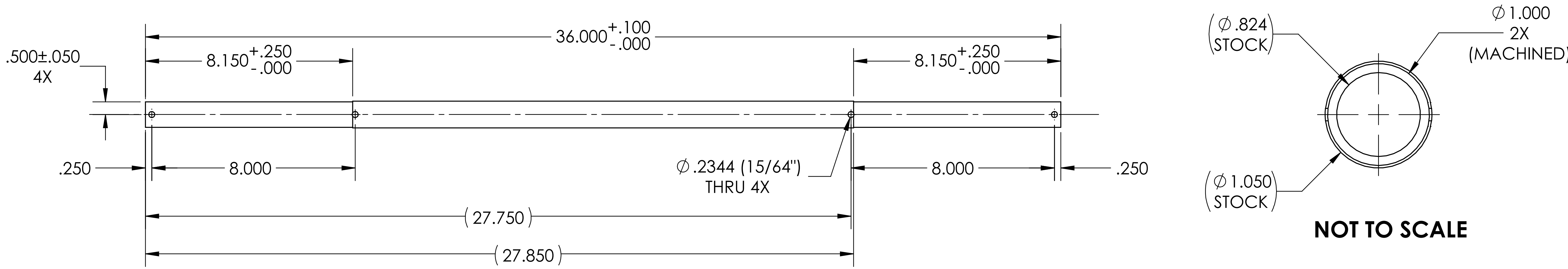
</td></tr>
<tr><td>Part No. 111100 & 111200</td><td>End Cap Rear & End Cap Front</td></tr>
<tr><td colspan="2">Link: https://www.tophardware.com/product/stainless-steel-316-grade-square-tubing-top-end-cap-for-2-x-2-18-gauge-16-gauge-14-gauge-13-gauge-brushed-finish/</td></tr>
</table>

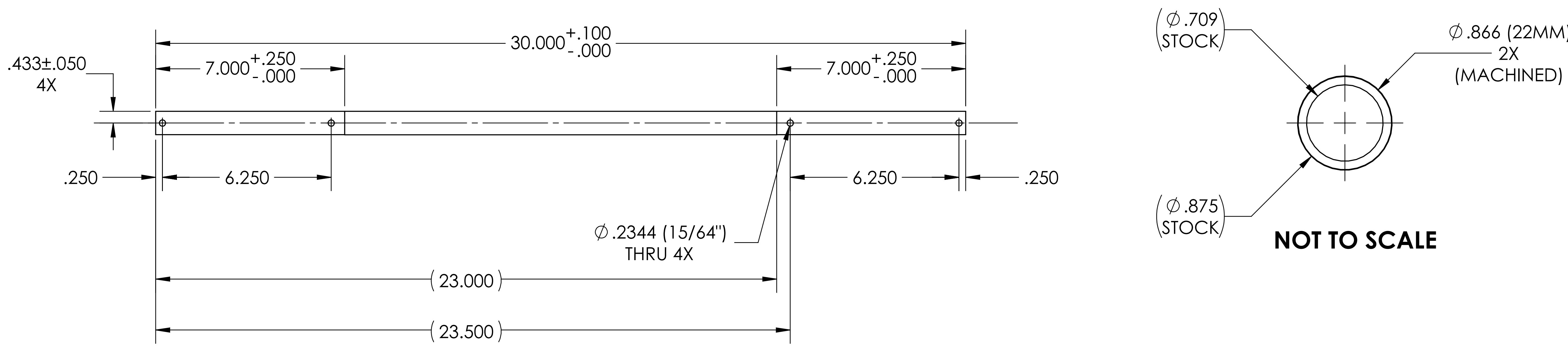
UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES
1. .XXX ± .005
2. ANGLES ± 5°



NOT TO SCALE

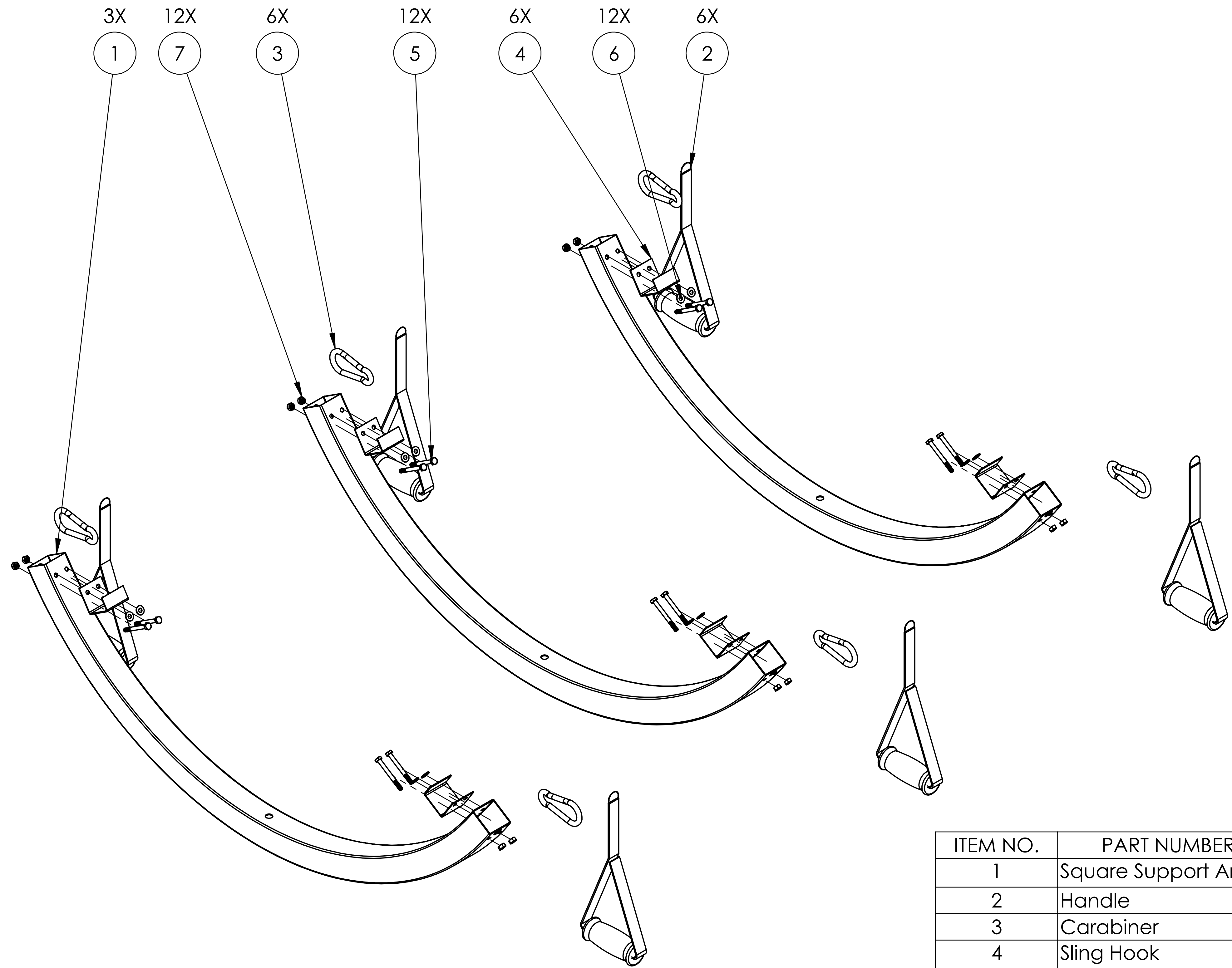
Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: Axle Rear
Drwn. By: A ZAAYER Material: 304 SS	Cost:	Part #: 111400

UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES
1. .XXX ± .005
2. ANGLES ± 5°



NOT TO SCALE

Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: Axle Front
Drwn. By: A ZAAYER Material: 304 SS	Cost: 21.54	Part #: 111500



ITEM NO.	PART NUMBER	PartNo	QTY.
1	Square Support Arm	112100	3
2	Handle	112200	6
3	Carabiner	112400	6
4	Sling Hook	112300	6
5	92186A552	112500	12
6	90107A029	112600	12
7	94819A043	112700	12

Cal Poly Mechanical Engineering

BEACHIN' BUGGY

Part: Support Arm Assy

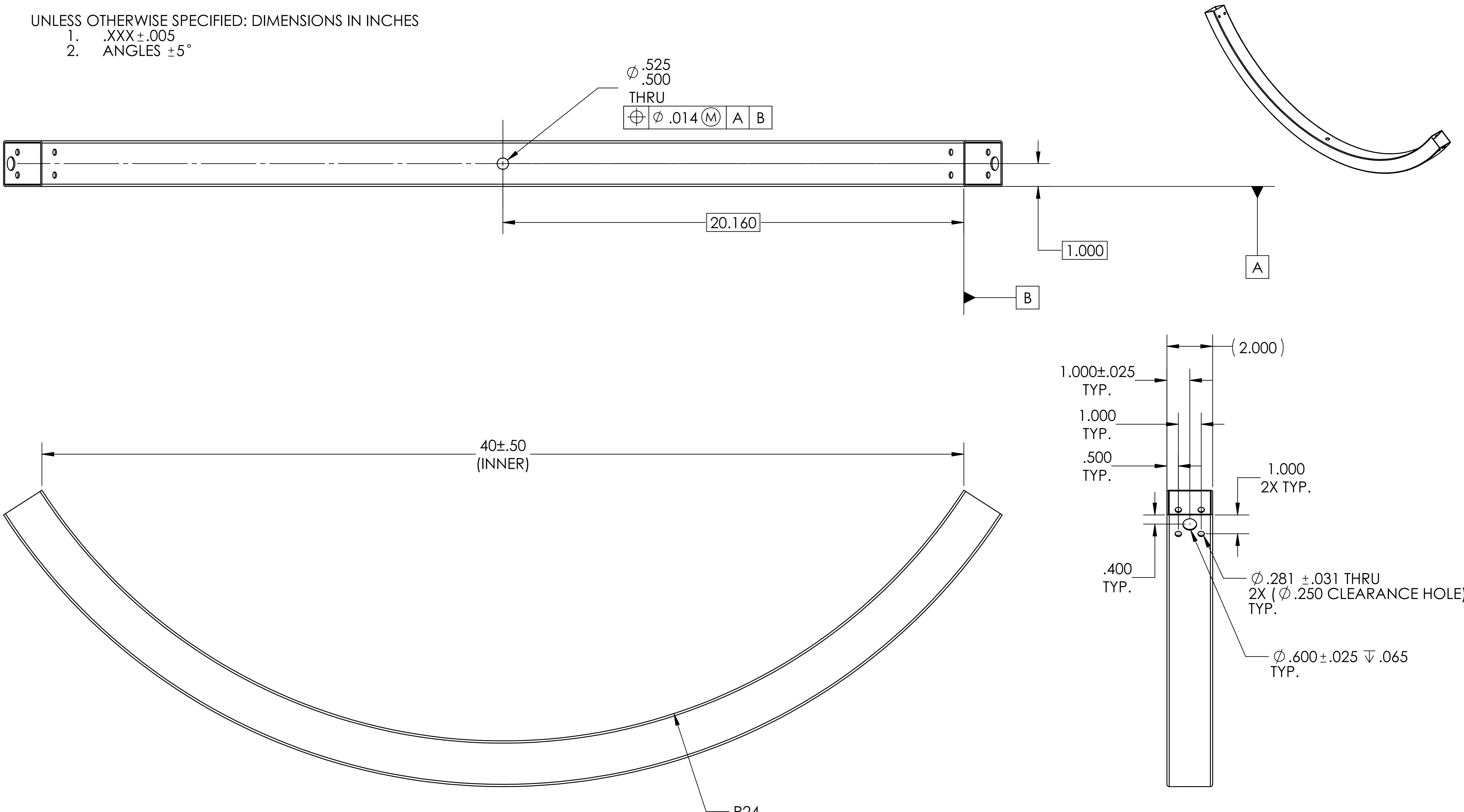
Drwn. By: A ZAAYER

Material: 304 SS

Cost:

Part #: 112000

UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES
1. .XXX ± .005
2. ANGLES ±5°



Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: Square Support Arm
Drwn. By: A ZAAYER	Cost: 169.36	Part #: 112100
Material: 304 SS		

<table>
<tr><td></td><td>

Adjustable Nylon Handle

NB59 - Heavy-duty nylon and rubber handle with easy-adjust steel D-rings, attach to any cable machine

View All *Body-Solid Tools*

Fitness Factory Price $14.99 1 +

~~MSRP $19.99~~

Add to Cart

31 Day Price Protection and Satisfaction Guarantee! (Click to Read)

Click for Veteran & First Responder 10% Discount

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3 customer reviews Write a Review (Must Login)

</td></tr>
<tr><td>Part No. 112200</td><td>Handle</td></tr>
<tr><td colspan="2">Link: https://www.fitnessfactory.com/item/3412/nb59/body-solid_tools_adjustable_nylon_stirrup_handle/</td></tr>
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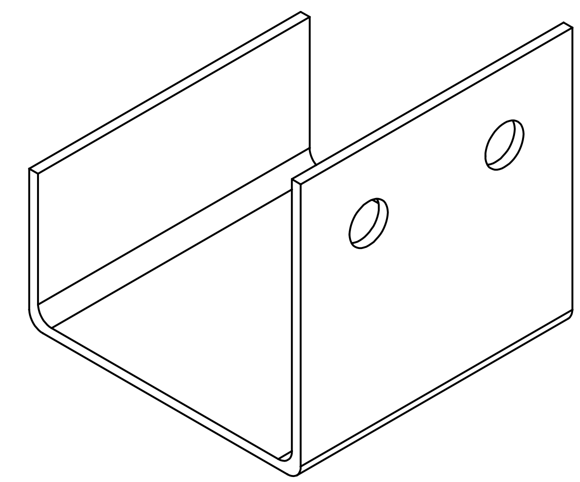
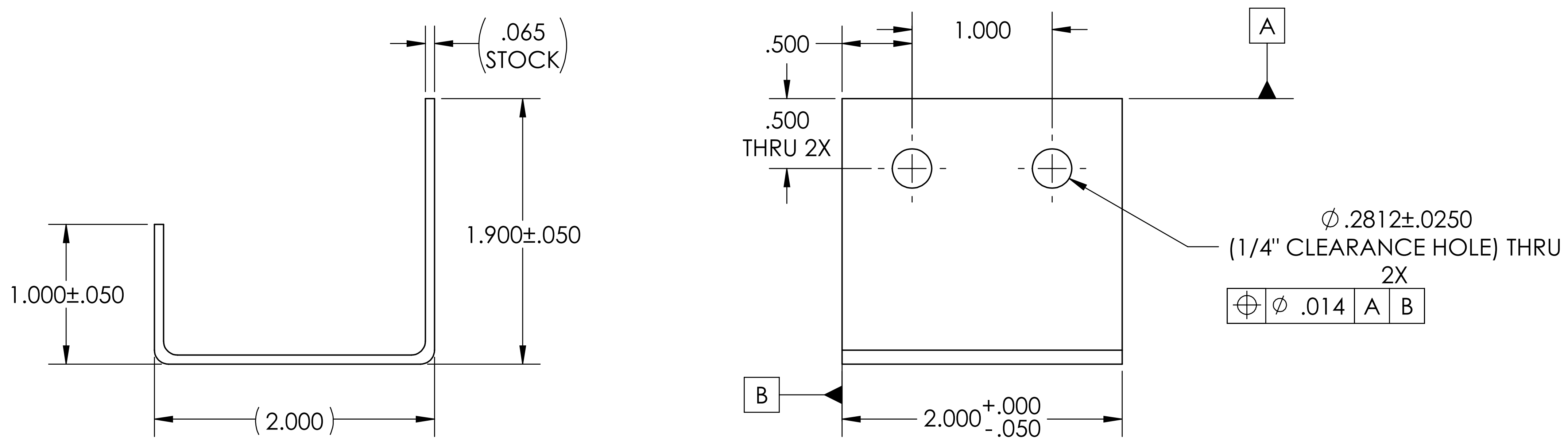
1. UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES
   1. .XXX ± .005
   2. ANGLES ± 5°
2. MATERIAL: 2x2x.065 304 SS SQUARE STOCK





Cal Poly Mechanical Engineering BEACHIN' BUGGY	Part: Sling Hook
Drwn. By: A ZAAYER Material: 304 SS — Cost:	Part #: 112300

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<tr><td colspan="2">
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<tr><td>Part No. 112400</td><td>Carabiner</td></tr>
<tr><td colspan="2">Link: https://www.amazon.com/Sprookber-Stainless-Steel-Spring-Carabiner/dp/B0796NN5YY/ref=sr_1_1_sspa?keywords=stainless+steel+carabiner&qid=1580951675&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFQUzBXMUpSMExGU0wmZW5jcnlwdGVkSWQ9QTA0NjE1NzNLT1Y0UjBGREFRSU8mZW5jcnlwdGVkQWRJZD1BMDM1MjIwNjFCMEQxOUhaOVVaUDYmd2lkZ2V0TmFtZT1zcF9hdGYmYWN0aW9uPWNsaWNrUmVkaXJlY3QmZG9Ob3RMb2dDbGljaz10cnVl</td></tr>
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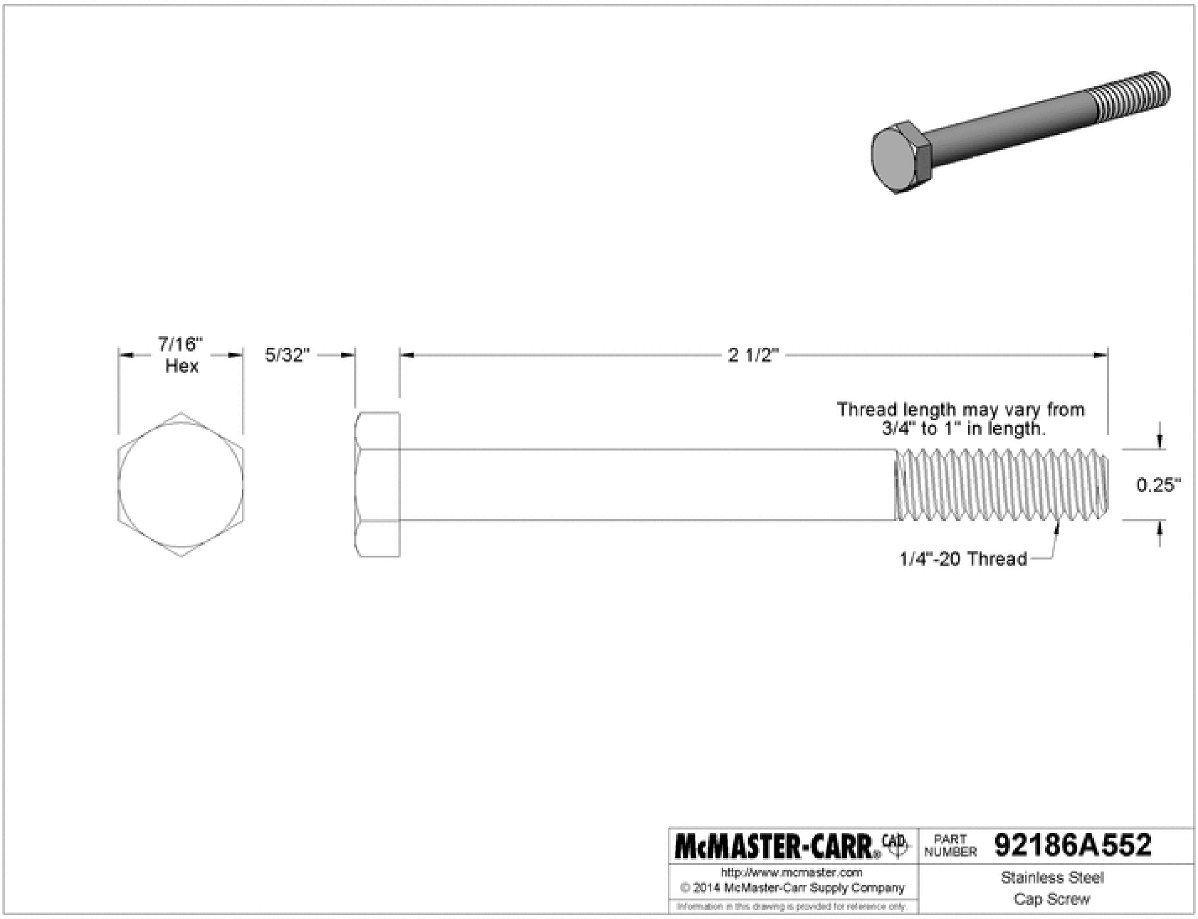
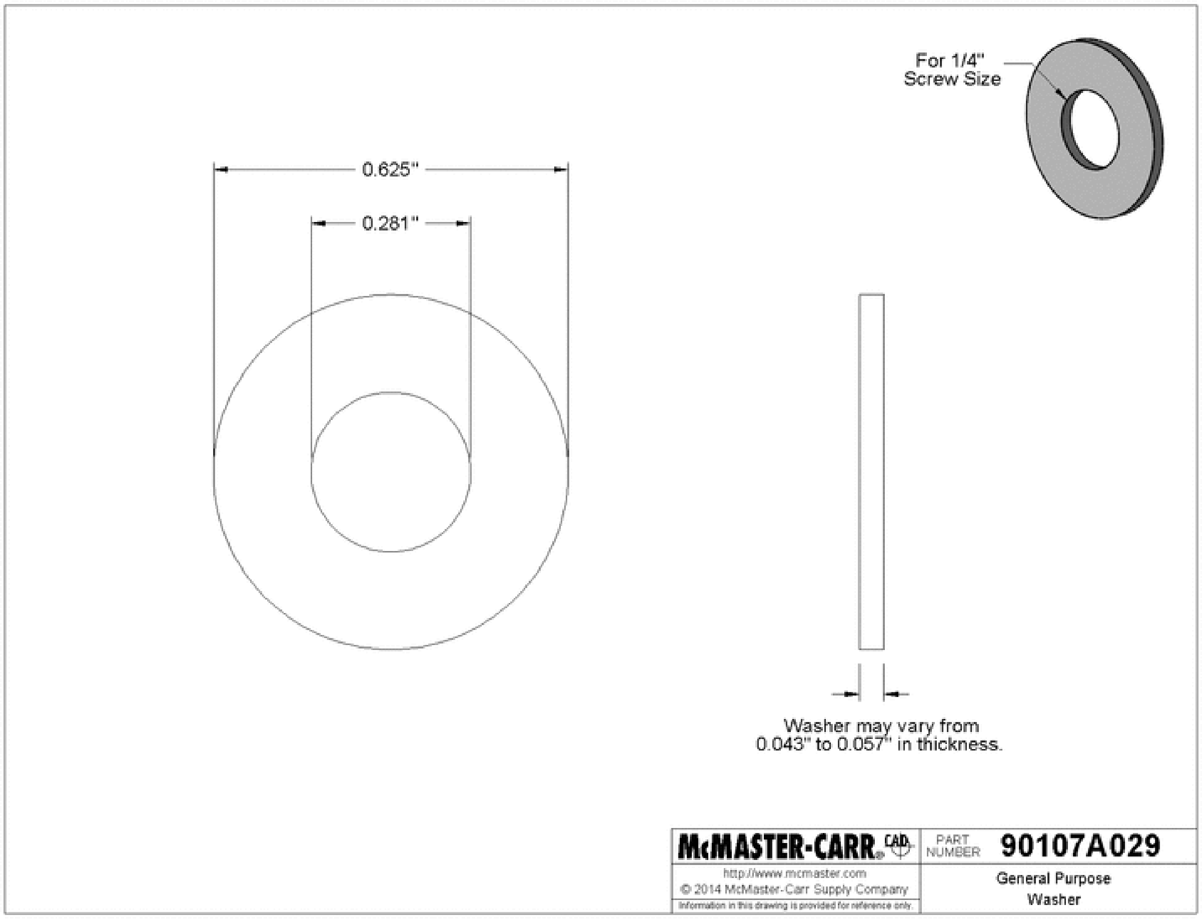


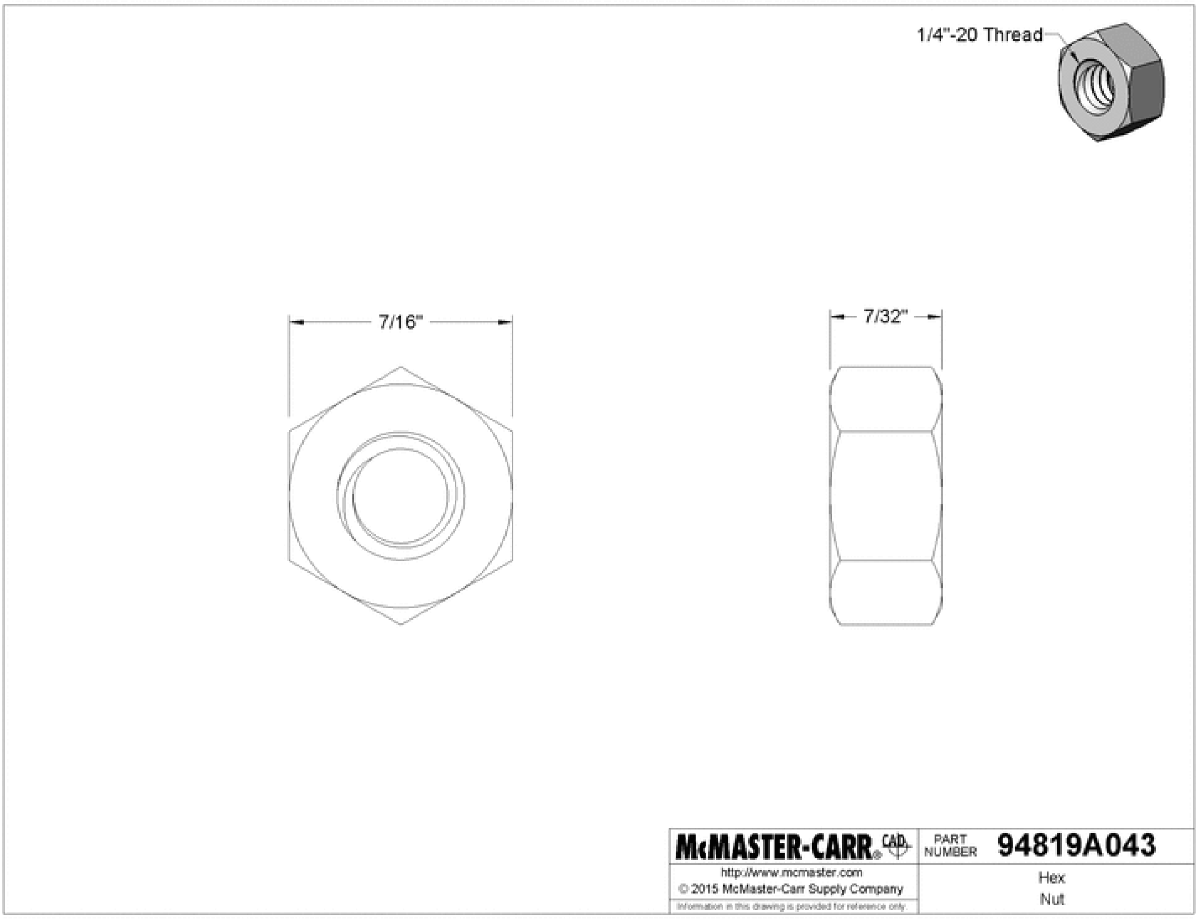
Part No. 112500	"316 Stainless Steel Hex Head Screw 1/4""-20 Thread Size, 2-1/2"" Long, Partially Threaded"

Link: https://www.mcmaster.com/92186A552



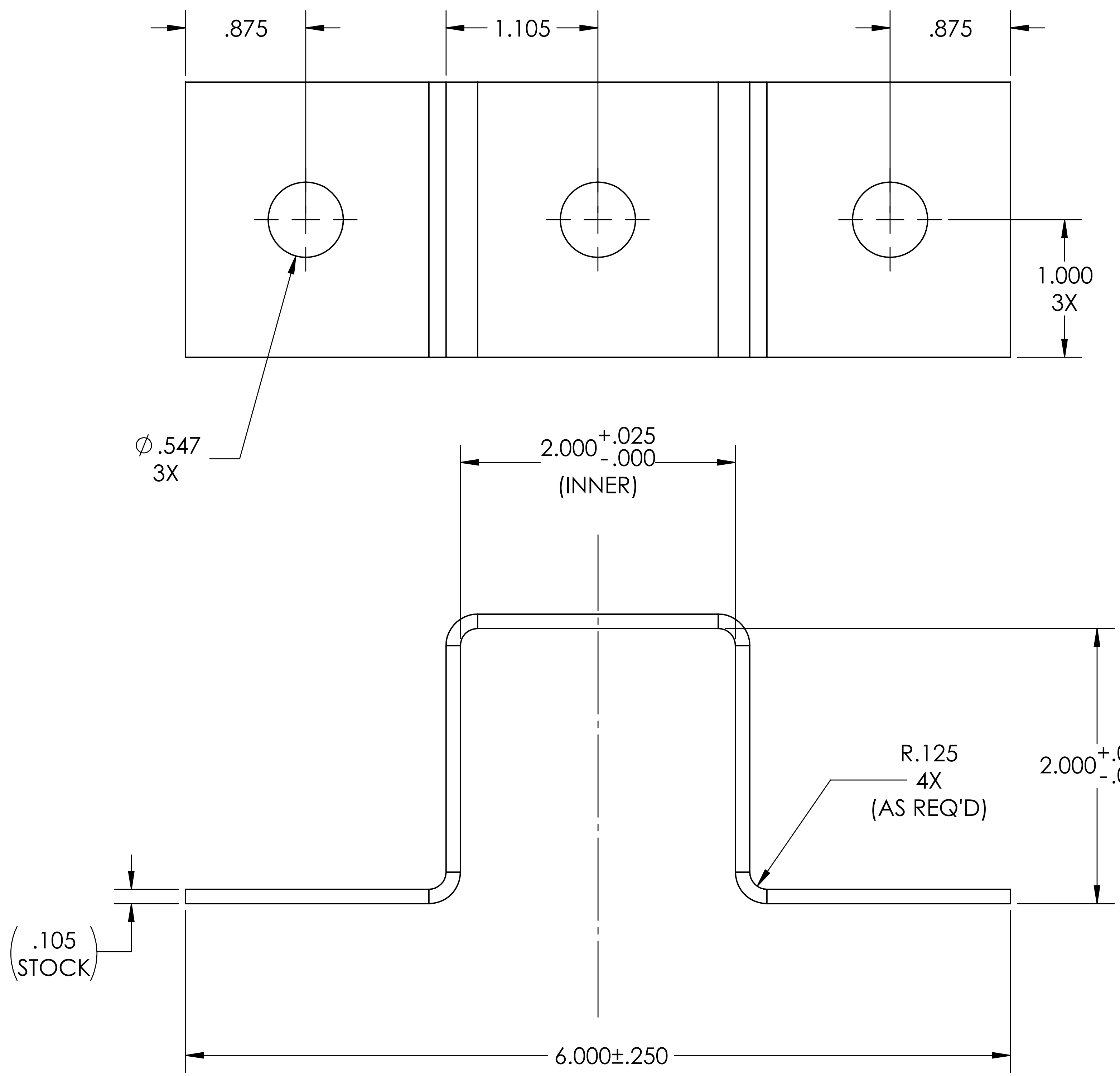
Part No. 112600	316 Stainless Steel Washer for 1/4" Screw Size, 0.281" ID, 0.625" OD

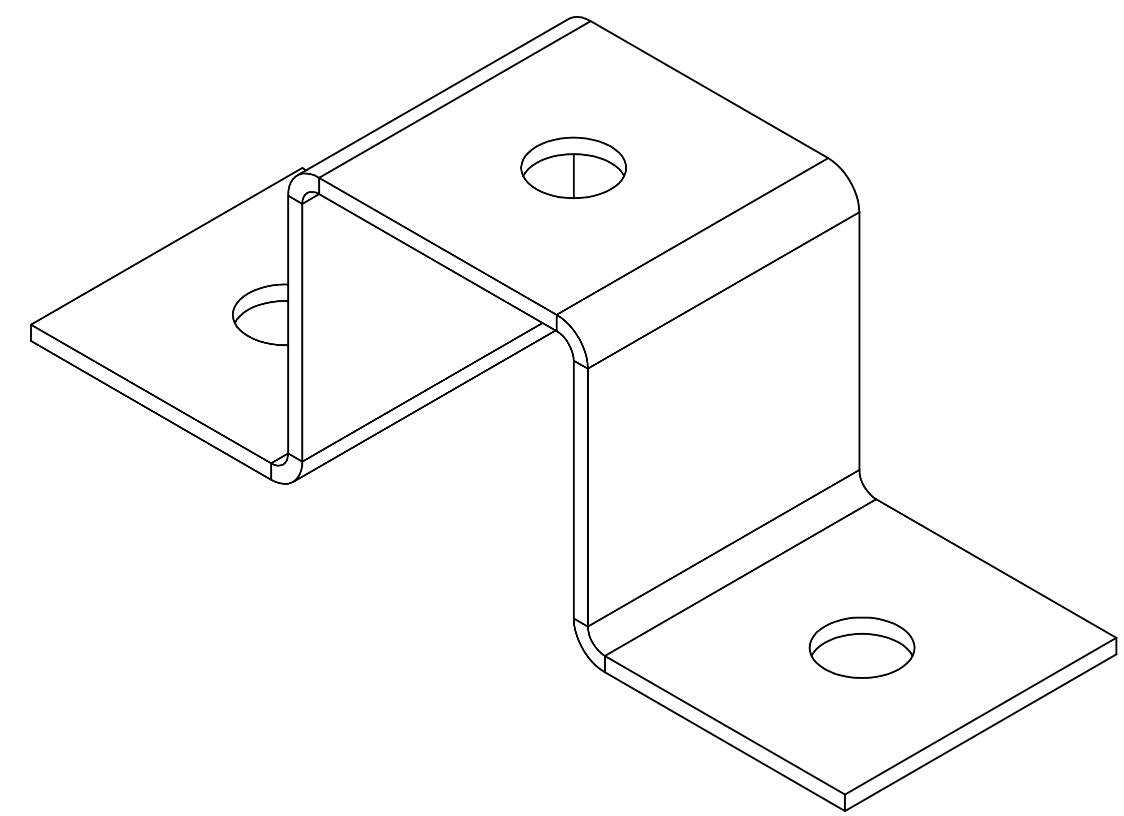
Link: https://www.mcmaster.com/90107A029



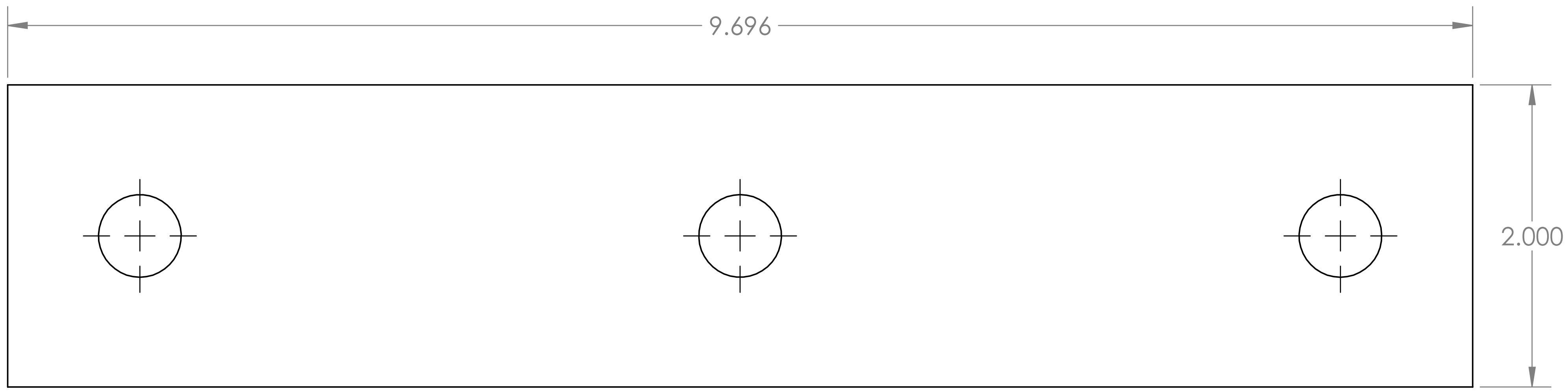
Part No. 112700	316 Stainless Steel Hex Nut 1/4"-20 Thread Size, ASTM F594
Link: https://www.mcmaster.com/94819A043	

1. UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES
    1. .XXX ± .005
    2. ANGLES ±5°
2. MATERIAL: STOCK 12 GAUGE 304 STAINLESS STEEL SHEET





Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: Square Wrap Around Bracket
Drwn. By: A ZAAYER Material: 304 SS	Cost: 16.07	Part #: 113000



FLAT PATTERN
(REFERENCE ONLY)

Cal Poly Mechanical Engineering
BEACHIN' BUGGY

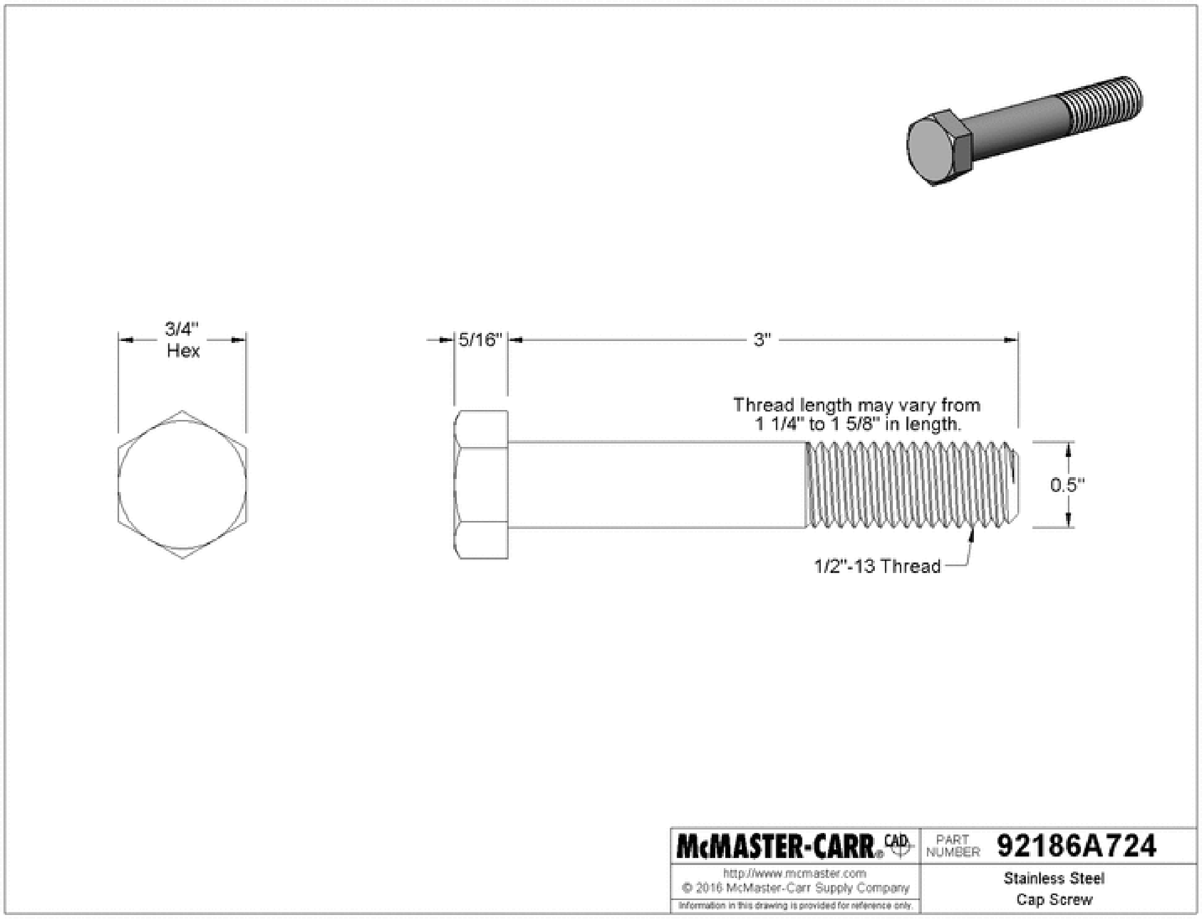
Part: Square Wrap Around Bracket

Drwn. By: A ZAAYER

Material: 304 SS

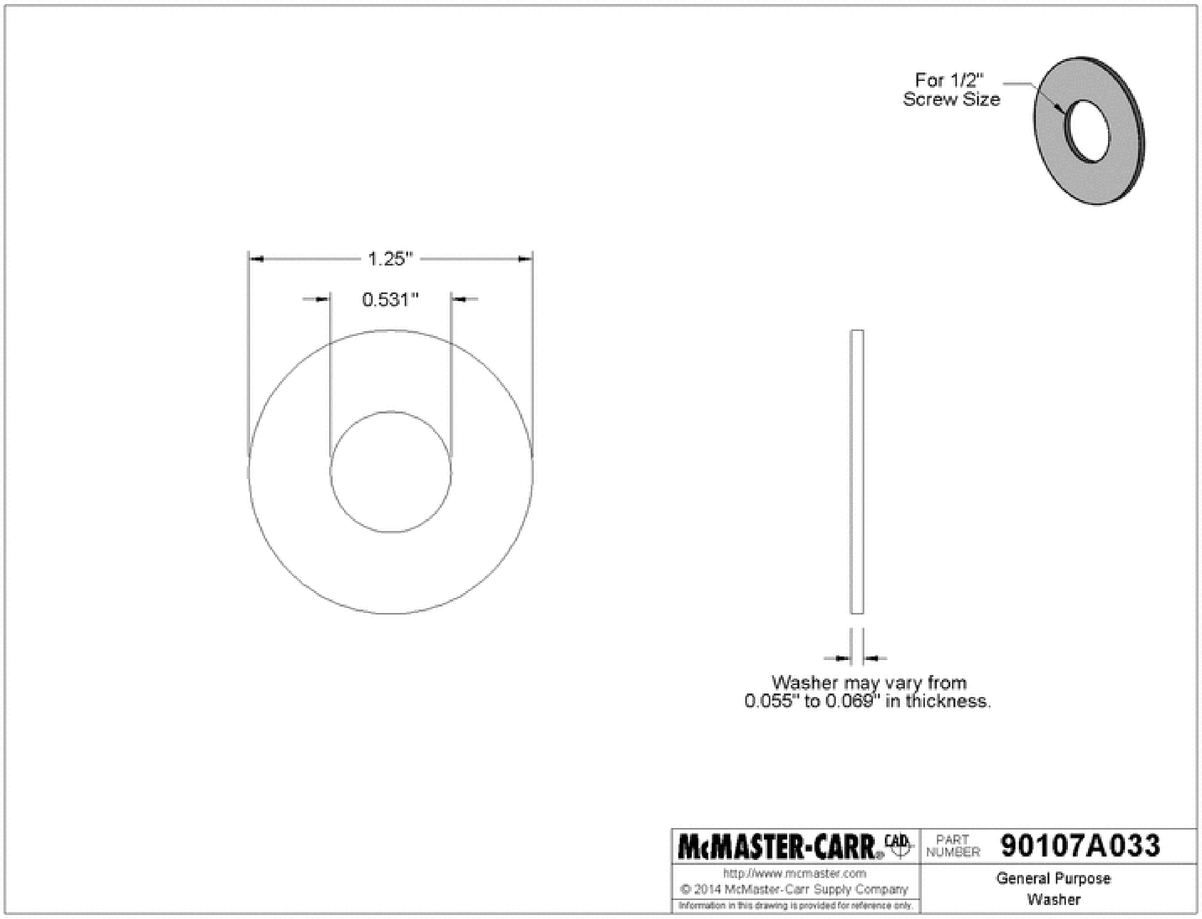
Cost: 16.07

Part #: 113000

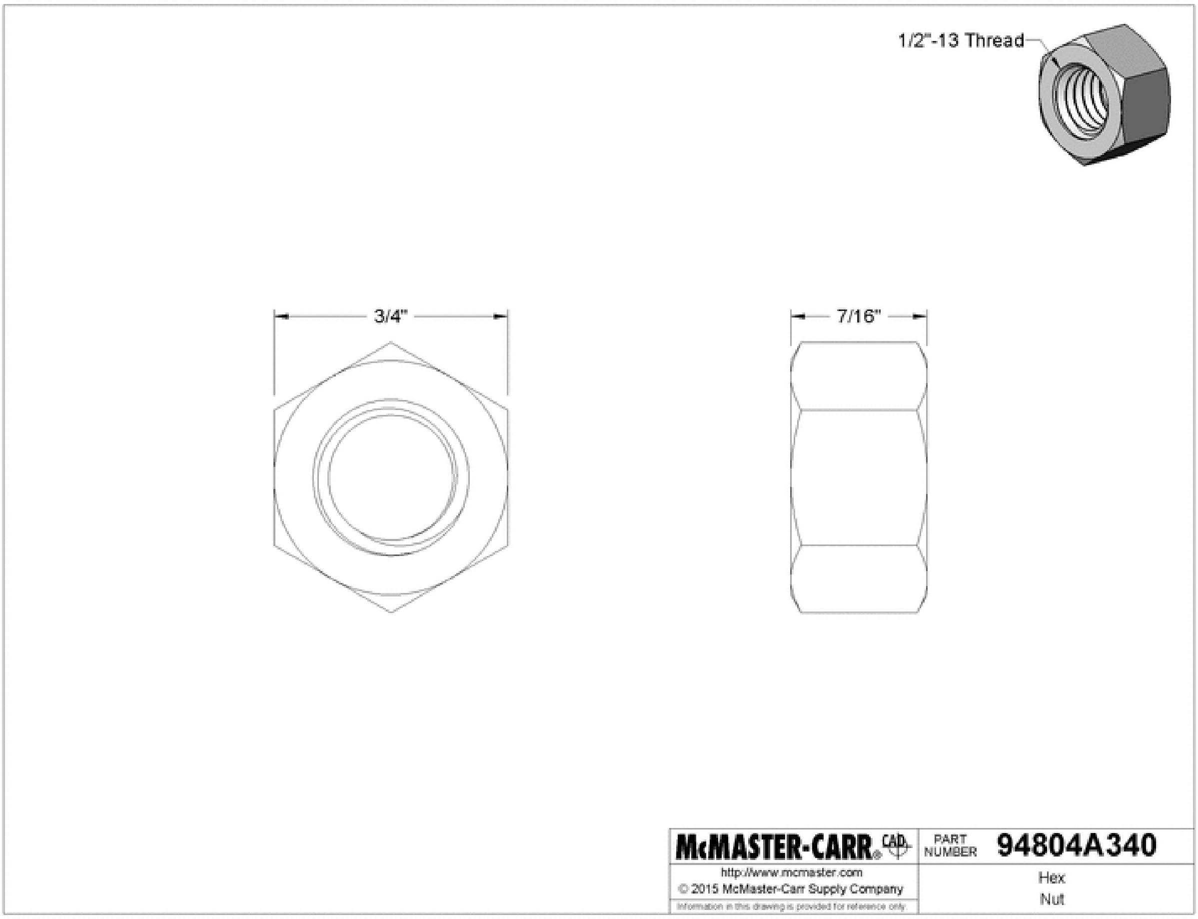


Part No. 114000	316 Stainless Steel Hex Head Screw 1/2"-13 Thread Size, 3" Long, Partially Threaded

Link: https://www.mcmaster.com/92186A724

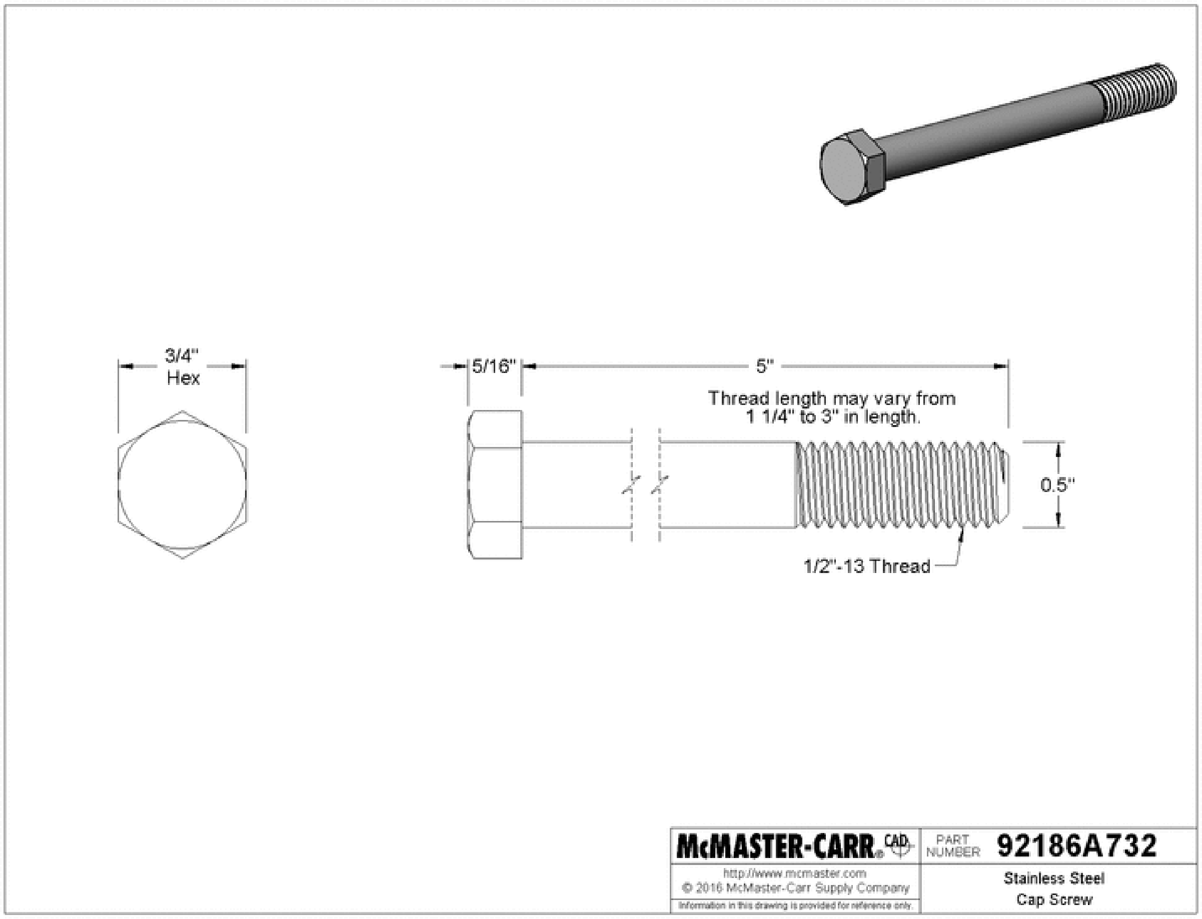


Part No. 115000	316 Stainless Steel Washer for 1/2" Screw Size, 0.531" ID, 1.25" OD
Link: https://www.mcmaster.com/90107A033	



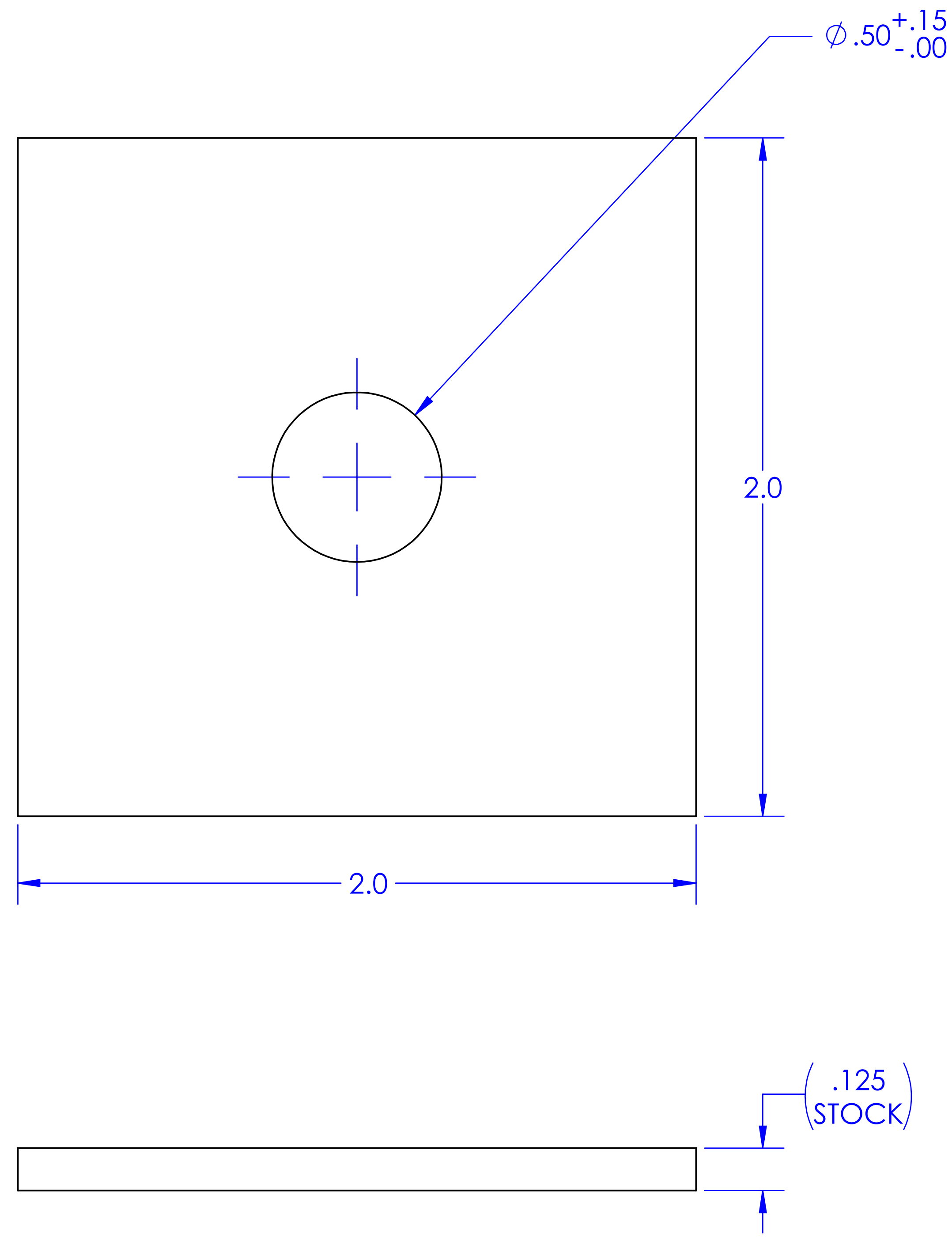
Part No. 116000	316 Stainless Steel Hex Nut 1/2"-13 Thread Size

Link: https://www.mcmaster.com/94804A340

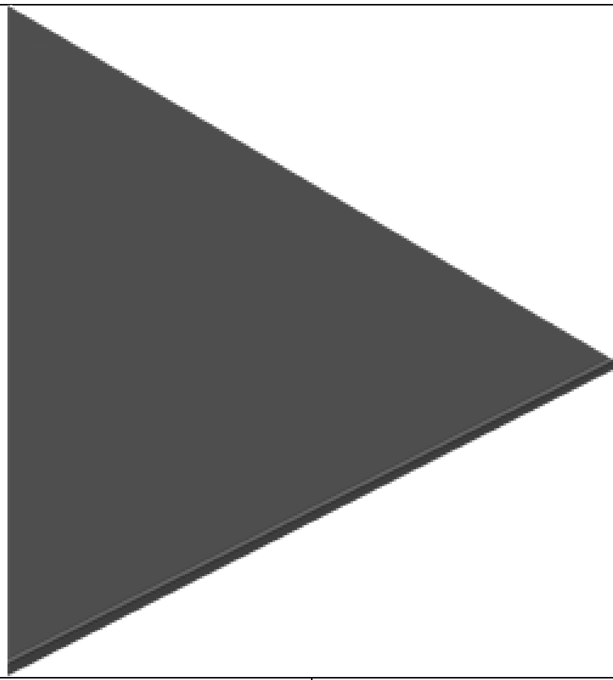


Part No. 117000	316 Stainless Steel Hex Head Screw 1/2"-13 Thread Size, 5" Long, Partially Threaded
Link: https://www.mcmaster.com/92186A732	

1. CUT FROM 12"X12"X1/8" STOCK EPDM RUBBER SHEET



Cal Poly Mechanical Engineering BEACHIN' BUGGY		Part: Rubber Sheet
Drwn. By: A ZAAYER	Cost:	Part #: 118000
Material: EPDM Rubber		



Part No. 118000	Rubber Sheet
Link: https://www.mcmaster.com/8525T67	

WheelEEZ® 42 cm (16.5″) Polyurethane Wheel; 25.4 mm (1″) Bearing

$137.00

This model has 25.4 mm (1″) bearing. WheelEEZ® Polyurethane Beach Balloon Wheels are specifically designed to navigate challenging terrains like soft sand, mud, gravel, grass and rock. They are also great on hard surface terrains like streets and sidewalks. Moving heavy, awkward loads is easy with our wheels, because WheelEEZ® Wheels Go-Anywhere!

- 1 + Add to cart

Description

Dimensions: 42 x 20cm (16.5 x 7.9″)
Width At Bearing: 19.8cm (7.8″)
Maximum Payload: 80 kg (176 lbs)
Weight: 2.5 kg (5.5 lbs)
Tire: Polyurethane
Hub: Polypropylene
Pressure Range: Low Pressure 2-4 psi (0.14-0.28 bar)
Temperature: -15 to 75 C (5-167 F)

Part No. 120000	WheelEEZ 16.5in_1in_axle
Link: https://wheeleez.com/product/wz1-42uc/	

All Terrain YakHauler™ Wheels (set of 2)

Options

SKU: MPG515

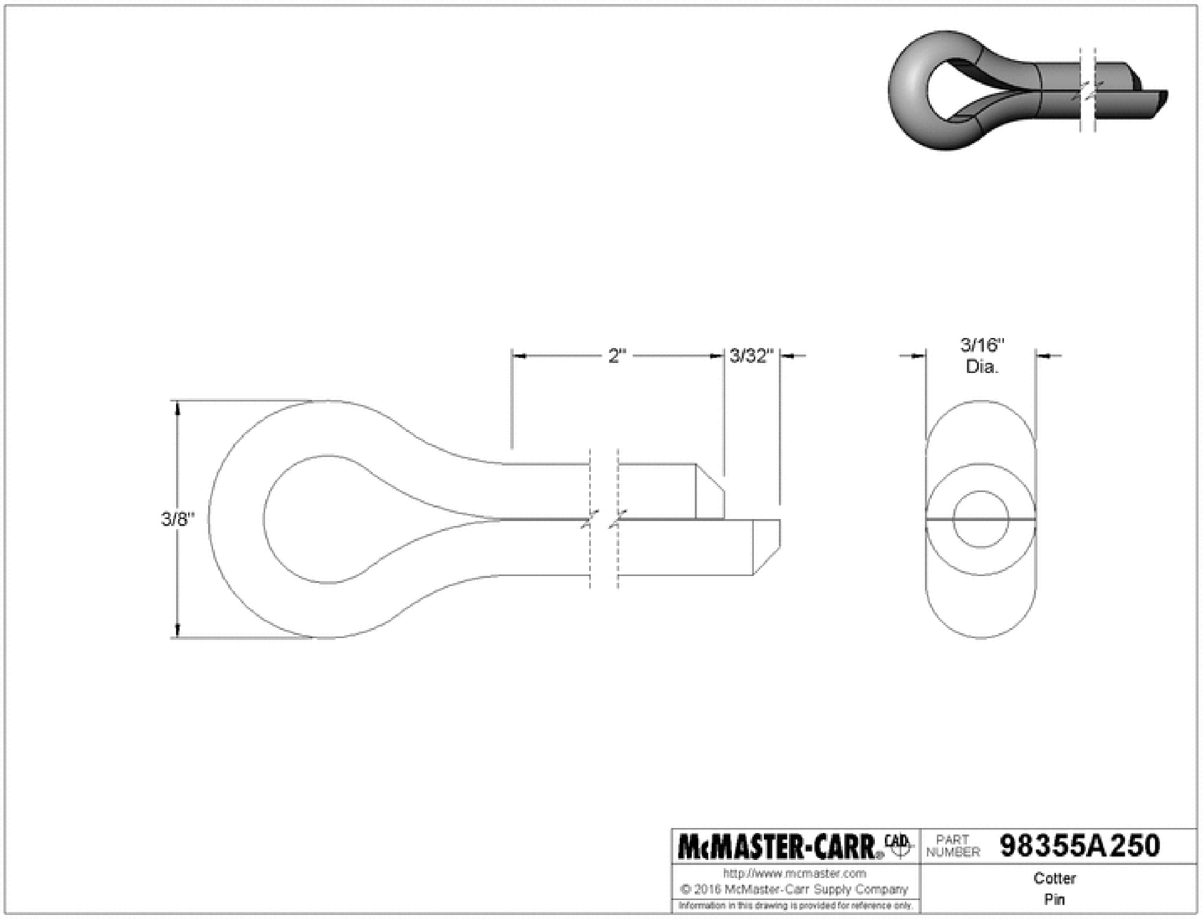
$99.95 USD

Qty 1 Add to

Specifications:

- Load Capacity: 125 lbs per wheel
- Weight: 14 lb
- Dimensions: 15" (diameter) x 6" (wide)
- Axle Diameter: 22.0mm
- Axle Length: 156mm

Part No. 130000	Malone All Terrain YakHauler
Link: https://maloneautoracks.com/All-Terrain-YakHauler-TM-Wheels-set-of-2.html	

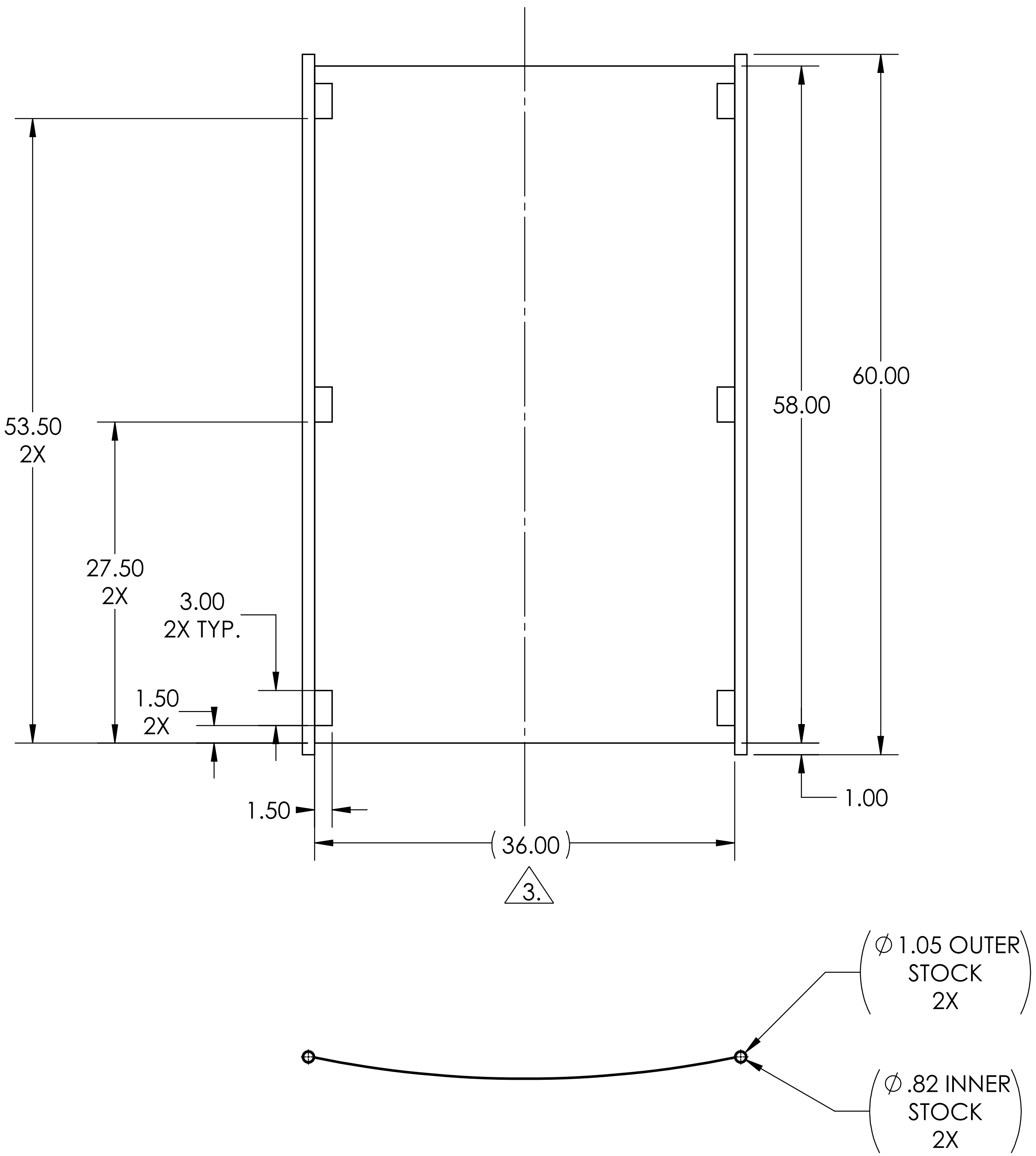


Part No. 140000	316 Stainless Steel Cotter Pin 3/16" Diameter, 2" Long

Link: https://www.mcmaster.com/98355A250

1. 3/4" SCH. 40 6061-T6 ALUMINUM PIPE USED AS SLING SUPPORTS
2. UNLESS OTHERWISE SPECIFIED
   1. X.XX ± .050

3. (△) DIMENSION COULD BE INNACURATE. FIT TO PHYSICAL SKELETON RATHER THAN THIS DIMENSION



Cal Poly Mechanical Engineering BEACHIN' BUGGY	Part: Sling
Drwn. By: A ZAAYER Material: 304 SS	Cost:
	Part #: 150000

Part No. 150000	Sling (Sling Rod)
Link: https://www.onlinemetals.com/en/buy/aluminum/0-75-nom-schedule-40-aluminum-pipe-6061-t6-extruded/pid/1220	

I - Failure Modes and Effects Analysis

System / Function	Potential Failure Mode	Potential Effects of the Failure Mode	Severity	Potential Causes of the Failure Mode	Current Preventative Activities	Occurence	Current Detection Activities	Detection	RPN	Recommended Action(s)	Responsibility & Target Completion Date
Wheels & ski / Traverse beach	Pinch point	May run over foot of volunteers with over 300 lbs	6	Carlessness, or simply not looking were they put there foot as they use the device	1) Provide a safety manual to inform the users of the proper way to use the device and to exercise caution	7	Testing prototype with volunteers	3	126		
Wheels & ski / Traverse beach	Digs into sand	a) expends too much energy from volunteers to push b) rider unsatisfied with ride time c) volunteers cannot retrieve vehicle from deep water	4	Ski too thin to distrubute force, material of ski has too much friction, overall design is too heavy, improper push point design	1) Prototype and test design. 2) Try different configurations in testing	3	testing with a jig that holds weights and a pull scale	2	24		
Wheels & ski / Traverse beach	Tires Pop	a) vehicle will sink when in the water and can cause the vehicle to act as an anchor b) requires too much force from volunteers to push vehicle	4	Overall design is too heavy, wheel material is not durable, sharp edges exposed on design	1) Try to minimize material in use to reduce weight. 2) Use high quality tires to hold the desired load.	2		5	40		
Frame / support sling and load	Support arms/mainframe breaks	a) sharp edges exposed b) 2 ft fall onto steel tubing - injury c) wheel axles collapse	9	This device needs to hold an excess of 300 lbs. This amound of weight can break the device if we do not choose the proper stock of steel. manufacturing methods by inexperience students can also cause failure under load	We will make sure to do extensive testing and practice to be able to provide a safe products. We will also desgin for high factor of safety.	2	Test with fea, test with weights	1	18	We will stress test the arms with extreme force before letting the customer use it. We will use high grade steel in order to make sure it is strong enough to take the load. Won't grind welds too much. Will ensure we don't create a large heat-affected zone when welding. Will air-cool welds	Everyone, 3/12/20
Frame / support sling and load	Frame flexes too much	Vehicle feels unsafe	6	Frame is made of weak material, design cannont withstand total weight	Design frame with factor of safety and test under load.	2		3	36		
Frame / support sling and load	Hardware corrodes	a) wheels cannot roll b) hinges break	3	Materials used are corrosive, design cannot drain saltwater, welding process creates corrosive area, device is not washed off after use.	We plan to research and limit exposure to salt water to all componets that are not stainless steel. We will also inform our sponsor to rinse off all components with fresh water before storing.	6	inspecting after use	6	108	Make sure we use a reliable vendor that provides 100% 316L hardware and tubing, drill drainage points in tubing, remind the sponsor that the vehicle must be washed down after each event, ensure that welding filler metal is also corrosion-resistant	Everyone, 3/12/20
Sling / Support rider and board	Uncomfortable to transfer onto from wheelchair	Cannot enter device	5	Support arms and sling are not at correct height	Test transfer ability from wheelchair to protoype using Ampsurf beach wheelchair	3	Clinic with challengers	6	90		
Sling / Support rider and board	Cannot quickly release sling from c-channels	rider unsatisfied with waiting in water with crashing waves	2	Poor quick release design, quick release mechanism corrodes or fatugues	Test release mechanism under 300 lb laod.	5	Clinic with challengers	4	40		
Sling / Support rider and board	Sling tears	a) 2 ft fall onto steel tubing - injury b) cannot get rider back out of water efficiently	8	Sling fatigues with use, sling material is weakend in saltwater, material is not rated for desing weight.	test sling material to support 300 lbs, in and out of saltwater.	1	Clinic with challengers	1	8	Clinic with structural prototype and after leaving in salt water	Marius 2/29/20
Sling / Support rider and board	Sling flexes too much	Vehicle feels unsafe	5	1) sling material too weak 2) ties that connect sling to steel bar are too weak	Make sure to do extensive testing and buy material that is rated to hold weight with a greater factor of safety than required.	4	loading sling with 300 lb and measuring deflection	5	100		
Sling / Support rider and board	Sling corrodes	a) 2 ft fall onto steel tubing - injury b) cannot get rider back out of water efficiently	8	sling material does not work well with salt water	Use proven material for scuba or surf activites, so there is record of the material used on salt water enviornement and not failing.	2	Insepect after use	2	32		

J - Indented Bill of Materials

Assembly Level	Part Number	Lvl0	Lvl1	Lvl2	Lvl3	Qty	Cost ea.	Ttl Cost	Source
0	100000	Beachin Buggy Assy v7				1			
1	110000		Skeleton			1			
2	111000			Chassis		1			
3	111100				Main Frame	1	0	0	ValleyIron
3	111200				End Cap Rear	2	14	28	TopHardware
3	111300				End Cap Front	2	14	28	TopHardware
3	111400				Axle Rear	1	0	0	ValleyIron
3	111500				Axle Front	1	70.68	70.68	OnlineMetals
2	112000			Support Arm Assy		1			
3	112100				Square Support Arm	3	243.3333	730	Tube-Tec
3	112200				Handle	6	11.99	71.94	FitnessFactory
3	112300				Sling Hook	6	0	0	ValleyIron
3	112400				Carabiner	1	6-PACK	10.95	Amazon
3	112500				316 Stainless Steel Hex Head Screw 1/4"-20 Thread Size, 2-1/2" Long, Partially Threaded	2	10-PACK	9.56	McMaster
3	112600				316 Stainless Steel Washer for 1/4" Screw Size, 0.281" ID, 0.625" OD	1	100-PACK	7.11	McMaster
3	112700				316 Stainless Steel Hex Nut 1/4"-20 Thread Size, ASTM F594	1	50-PACK	4.08	McMaster
2	113000			Square Wrap Around Bracket		1	23.53	23.53	Amazon
2	114000			316 Stainless Steel Hex Head Screw 1/2"-13 Thread Size, 3" Long, Partially Threaded		6	1.46	8.76	McMaster
2	115000			316 Stainless Steel Washer for 1/2" Screw Size, 0.531" ID, 1.25" OD		1	25-PACK	8.16	McMaster
2	116000			316 Stainless Steel Hex Nut 1/2"-13 Thread Size		1	10-pack	4.52	McMaster
2	117000			316 Stainless Steel Hex Head Screw 1/2"-13 Thread Size, 5" Long, Partially Threaded		3	2.47	7.41	McMaster
2	118000			Rubber Sheet		1	Sheet	15.53	McMaster
1	120000		WheelEEZ 16.5in_1in_axle			2	164.34	328.68	WheelEEZ
1	130000		Malone All Terrain YakHauler			2	50	100	Malone
1	140000		316 Stainless Steel Cotter Pin 3/16" Diameter, 2" Long			1	10-PACK	8.83	McMaster
1	150000		Sling			1	300	300	SLO Sail & Canvas / OnlineMetals
						TOTAL COST		1765.74	

= Manufactured/Altered Part

K - Manufacturing Plan

Step 1	Measure main bar for 6 feet and cut to size using band saw
Step 2	Cut remaining pieces of square stock for front and rear axle with band saw
Step 3	Measure and cut tubing for front and rear axle with band saw
Step 4	Drill pin holes on axle with drill press
Step 5	Place main frame bar on table, measure and mark where support arms will be placed
Step 6	Locate and mark center of support arms
Step 7	Cut sheet metal into rectangular shape for bending of wraparound brackets
Step 8	Drill the two outer holes on each piece of sheet metal with the drill press.
Step 9	Make two bends in the sheet metal pieces for bolts
Step 10	Drill holes in chassis at same location as the sheet metal holes
Step 11	Place bolts and nuts through sides of support arms
Step 12	Drill through center of the support arms, sheet metal, and chassis tube
Step 13	Clamp all pieces together in specified positions and mark handle locations
Step 14	Cut support arms to length as specified
Step 15	Weld chassis tubing together as specified. This is to be outsourced
Step 16	Drill drain holes alongside the main chassis tube and support arms
Step 17	Bolt all support arms to chassis as specified
Step 18	Press wheels around each axle, pin in place
Step 19	Take assembly to SLO Sail and Canvas for sizing and assembly of sling
Step 20	Add handles at all six locations with carabiners

L - Design Verification Plan

Senior Project DVP&R													
Date:2/5/2020		Team: Beahin Buggy	Sponsor: QI+			Description of System: Surfboard sled						DVP&R Engineer:	
TEST PLAN										TEST REPORT			
Item No	Specification #	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES TESTED		TIMING		TEST RESULTS			NOTES
						Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	Wheels	Our team created a prototype with a front and rear axle that held two types of wheels. In the front axle two 16" Malones and in the back WheelEEZ with 16 1/2" diameter.	Test to make sure the wheel set up will be stable and be able to roll on sand..	"Jose- Built the frame Griffin-Cut and shape back axle Marius-Use Lathe to Machine front axle Arthur- Cut holes in front axle"	Morro Rock Beach	1 full Prototype	Full size test	2/1/2020	2/1/2020	Both Wheels and axles worked great on sand. we were able to pull 300 lbs on the sand. Our prototype went into the ocean until we reached a height of 23 inches.	Success		This test not only confirmed the ability of the sand wheels but also the stability of the wheel base and the height of our prototype.
2	Handles	Created a prototype that is at the desired height. Our team had concerns on how hard it would be to pull the sled and we wanted to make sure would not cause back strain.	Test to make sure a 6ft person can comfortably pull the prototype and not engage the back muscles	Jose- Be on the prototype. Griffin/Marius=pull prototype	Morro Rock Beach	1 full Prototype	Full size test	2/1/2020	2/1/2020	While the prototype and true design have a handle set up to where 6 people can help pull the sled, our test showed that only 2 people were required to pull the sled through loose and compact sand	Success		While the team held concerns that the handles would require too much strain, our results showed that they provided a very successful and safe method for transporting our sled.
3	Sling Hooks	We will cut 2"X2" square pipe and cut one and a half faces to create a L hook. Our team will then add a sling in between the hooks and add weight to test when the hooks will break.	Hooks must be able to hold 300lb with a factor of safety of 1.5	"Jose-cut metal Griffin-Build structure Marius-find/create sling Arthur- find weights"	Cal Poly Campus	1 hooks	Build a small model that is able to hold substantial weight	TBD	TBD	TBD	TBD	TBD	TBD
4	Full Funtion	We will take the final product and do a full function test were we will take a person on a surfboard and take them into and out of the water.	Takes less time that current method that Amp surf uses	Total team participation	Avila Beach	1 Final Product	Full size test	TBD	TBD	TBD	TBD	TBD	TBD

M - **Test Procedures**

Test #1: Sling hook capacity test (Arthur Zaayer)

Description of Test:

Determine if sling hooks can support maximum weight capacity with a 1.5 factor of safety (150 lbf).

Required Materials:

- 2 sling hooks with mounting fasteners
- Mounting apparatus with 36” width between mounting points
- Scale
- 40” chain/rope
- 150 lbm weight

Testing Protocol:

- Mount sling hooks 36” inches apart
- Attach chain/rope between the two hooks with minimal slack
- Hang 150 lb weight in center of chain/rope
- Observe for any permanent deformation or total failure of either sling hooks
- Repeat test 3 times

Data:

Test #	Data (Circle one)
1	**PASS**/FAIL
2	**PASS**/FAIL
3	**PASS**/FAIL

Test #2 Sling Edge Fray Test (Jose Covarrubias)

Description of Test:

Determine if sling material can withstand a large number of uses without fraying or ripping at the seams.

Required Materials:

- Fully completed chassis to test the sling.
- Two Poles from where the sling attaches to.
- Sling cut out for hooks are complete
- A 100 lbs. weight
- Can be done on any location of flat ground.

Testing Protocol:

- Place sling on the chassis as it would be used in the field.
- Place the 100 lbs. weight in the middle of the sling. This will bring all parts forward and in tension. This is important to simulate the same position the sling will be at, once more weight added.
- Take the sling off and on 100 times. Do it will 4 different people each doing it 25 times. If we consider that for one person QL+ needs to take the sling off twice to get a person into and out of the water than our experiment will simulate over 50 motions.
- Pass/Fail analysis on the visual inspection of fraying or ripping. This will determine how much reinforcement will be needed at the seams.

Data:

Test #	Data (Circle one)
1	PASS/FAIL
2	PASS/FAIL
3	PASS/FAIL
4	PASS/FAIL

Notes: INCOMPLETE

Test #3: Bend Test – Center Support Beam (Marius Jatulis)

<u>Description of Test:</u>

Experimentally determine Young's modulus of 304 Stainless steel used in center support beam

<u>Required Materials:</u>

- Instron Machine or Similar tensile/compression test machine
- 3 Point bend test fixture
- 12" to 20" length test section of center support beam
- Safety glasses

<u>Testing Protocol:</u>

1. Install 3-point bend test fixture in Instron or similar compression test machine
2. Load test section of square cross section support beam into 3-point bend test fixture
3. Start Instron testing software
4. Select bend test program
5. Set upper limit of force to 500 lbf
6. Use manual jog on remote to position top jaw within 1" of test section top
7. Close door to testing enclosure
8. Begin bend test
9. After test is complete, save force and deflection data
10. Use Eq. 1 to calculate second moment of area, where a is the square beam's side length

$I=a412$	(1)

11. Calculate Young's modulus E using Eq. 2 where P is applied load, L is length of test section, w is deflection, and I is second moment of area

$E=L3P48wI$	(2)

<u>Data:</u>

Compare Calculated value to expected Young's Modulus used in deflection calculation.

Calculated	Expected
	28500 ± 500 ksi

Using precision of loading and deflection values from Instron, find propagated uncertainty for calculated Young's Modulus.

Notes: INCOMPLETE

Test #4: Pull Strain Test (Griffin O'Malley)

Description of Test:

Experimentally determine maximum force required for volunteers to pull entire device and rider across sand. Test will be completed with four volunteers, the maximum strain condition for use.

Required Materials:

- Spring scale with 100lb capability (4)
- Volunteers (4)

Testing Protocol:

1. Position vehicle on beach
2. Position volunteer of minimum weight 200lb and Wavestorm surfboard on device
3. Hook each spring scale to carabiner at handle locations
4. Gather four volunteers, pull device into water and back with user on device
5. Record maximum force recorded from spring scales
6. Repeat test three times

Data:

Test Number	**Maximum Force (lb)**	**Under 50lb? Circle One**
1		Pass / Fail
2		Pass / Fail
3		Pass / Fail

Notes: INCOMPLETE

N - Operator’s Manual

Operator’s Manual

Surf Sled

Important:

This product is intended for one rider at a time with a maximum 300 lb capacity and up to 6 volunteers pulling the device. Before using the device, the users must be familiar with all operation protocols as specified in this document.

Assembly Instructions

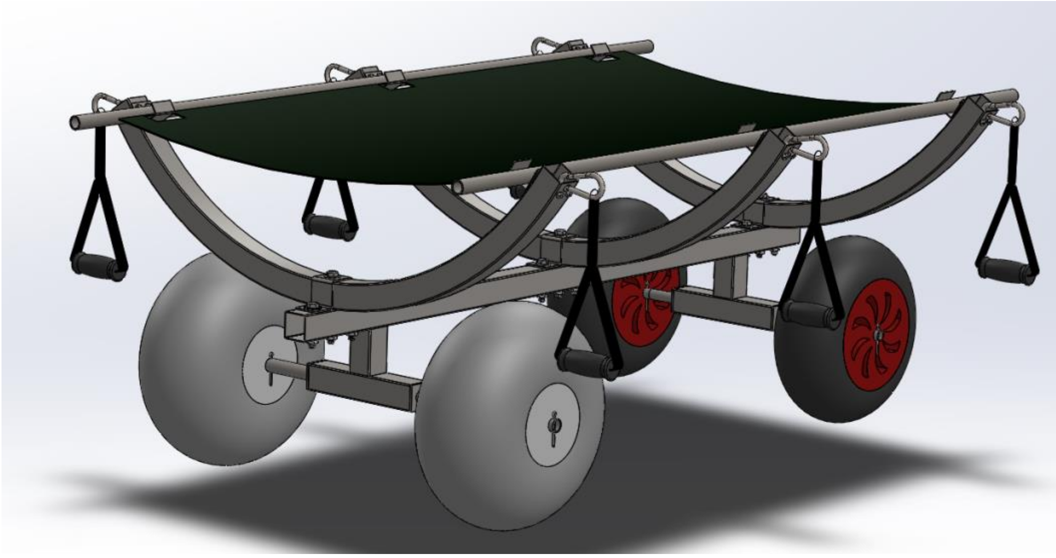


Figure 32. Fully Assembled Surf Sled

The Surf Sled is not a very complex system, although improper assembly procedures could result in injury to all users involved. All assembled parts stem from the Chassis of the sled.

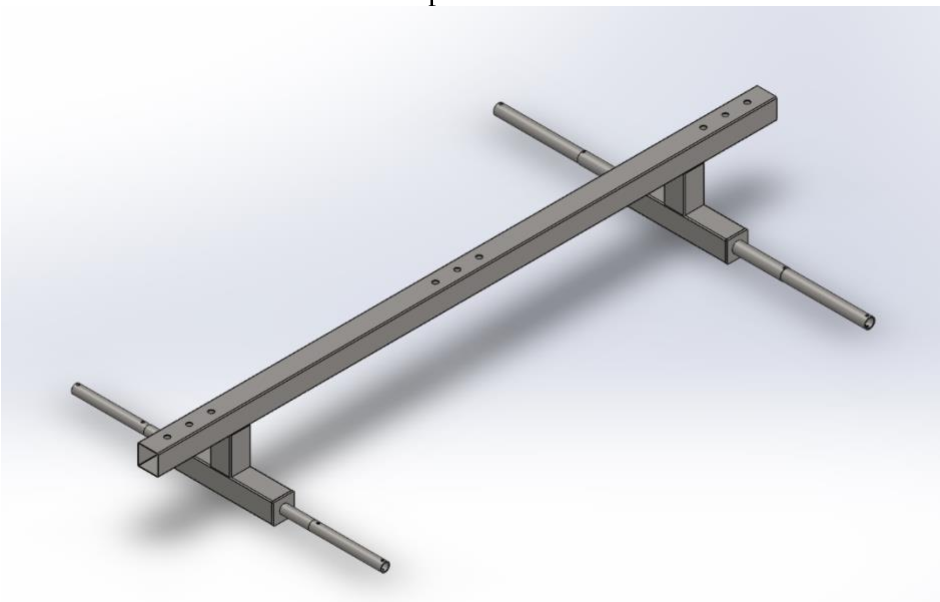


Figure 33. Chassis

The chassis is fully welded and pre-assembled. Nothing should be done to alter this part.

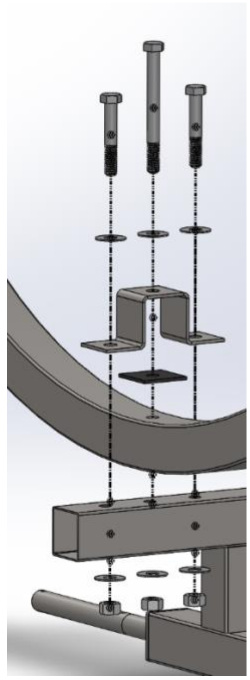


Figure 34. Support arm attachment

The three Support Arms should be attached to the Chassis in the manner pictured in Figure 34. Each support arm requires 2x PN#114000, 1x PN#117000, 6x PN#115000, 3x PN#116000, 1x PN#118000. Use Loctite 242 on all three nuts, and use torque wrench to tighten to 30 ft-lbs.

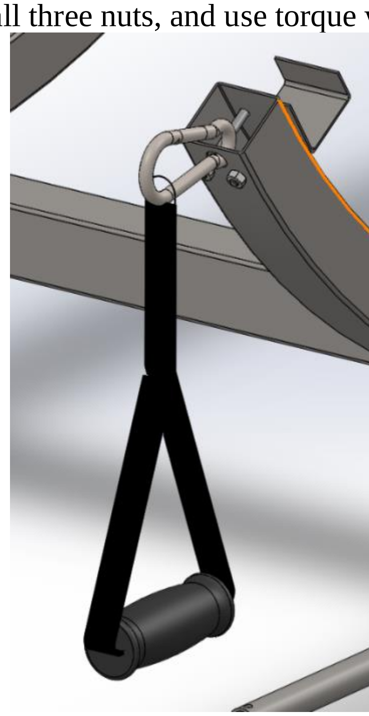


Figure 35. Carabiner and Handle

After the three Support Arms have been bolted to the Chassis, place 1x Carabiner (PN#112400) and 1x Handle (PN#112200) to both ends of each Support Arm.

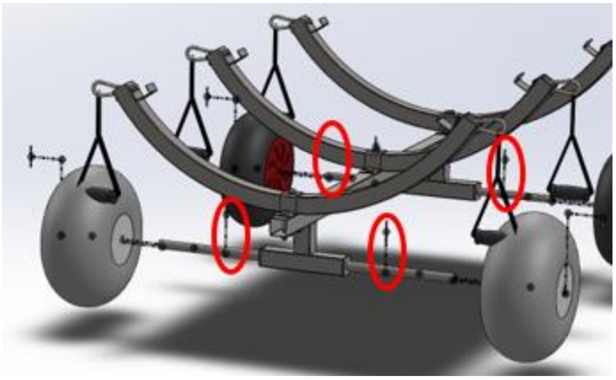


Figure 36. Pins Removed

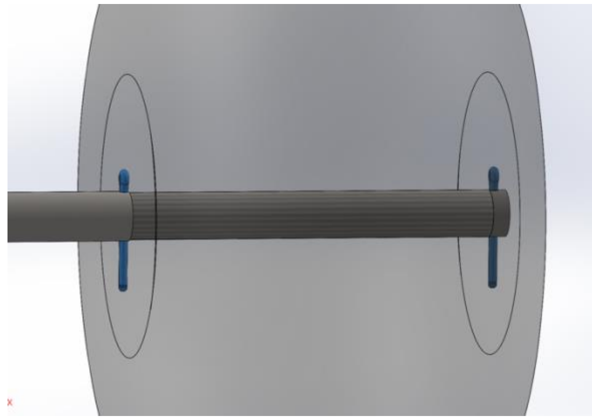


Figure 37. Pins secured

Place one pin in each of the four axle pin holes that are closest to the center of the device (these pins are circled in red in Figure 36.) These pins prevent the wheels from translated toward the center of the device. Next, place the two Wheeleez® tires (PN#120000) on the rear axle. The rear axle can be distinguished from the front axle by its larger wheel span. Place one pin on the outside of each rear tire. There should now be two pins for each rear tire, as seen in Figure 37. Next, repeat this process with the Malone tires (PN#130000) on the front axle.

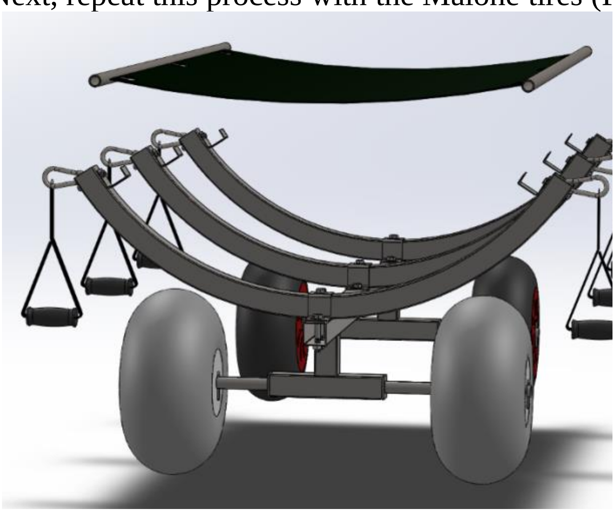


Figure 38. Sling

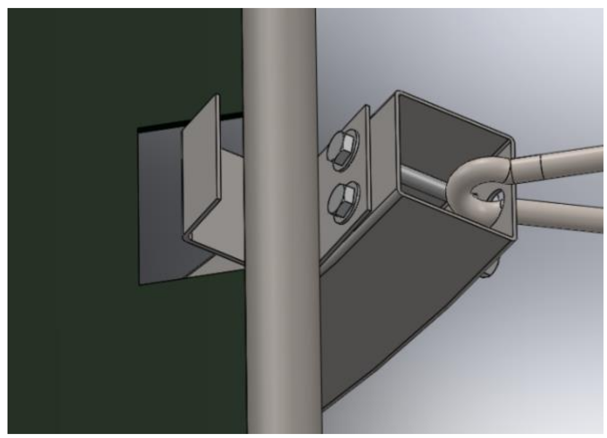


Figure 39. Sling hook in slot

Finally, place the Sling (PN#150000) onto the support hooks. Ensure that the sling is supported by all six sling hooks on the support arm. Ensure that the sling hooks are in the cut-out slots of the sling, as shown in Figure 39, to prevent tearing.

Operating Instructions

Using the sled to transition from beach to water

The surfboard sled is intended to be used by a maximum of six volunteers and one challenger at a time. A surfboard should be placed on the sling, ensuring the fins do not interfere with the sling material and have clearance off the back of the sling. The inflatable Wheeleez® tires should be oriented to the rear of the sled with the hard rubber Malone tires pointed towards the surf. With the help of volunteers, the challenger should transfer from a beach wheelchair onto the surfboard and lay in a paddling position on the board, headfirst in the desired direction. The volunteers should roll the surfboard sled using the attached handles. Once the sled is in waist high water on the volunteers, the sling can be detached from one side of the sled and the surfboard and challenger are free to float out and paddle into the surf.

Using the sled to exit water and traverse beach

Once the challenger is in shallow water, volunteers should bring the surfboard sled into waist high water with the inflatable Wheeleez® tires pointed out towards the ocean. Ensure the sling is affixed to all sling hooks and there are six volunteers around the device to ensure the challenger can be safely guided onto the sling. The challenger should paddle the surfboard over the submerged sling. As the volunteers begin rolling the sled out of the water, ensure the challenger and surfboard are comfortable positioned on the sling. Once the challenger is back on the beach, volunteers should assist in transferring the challenger back into a beach wheelchair.

Maintenance Guide and Resources

Many parts on the Surf Sled are off the shelf components and can be replaced if damaged. The off the shelf components are listed in the Indented Bill of Materials located in Appendix J, which includes links for purchase. The carabiners and handles which the volunteers interact with can be easily replaced by attaching a new part on if they become damaged. Both the WheelEEZ and Malone tires can be replaced by removing the axle cotter pin, sliding the non-functional wheel off, exchanging it for a new wheel, and securing the wheel with a cotter pin.

The stainless-steel frame is designed to minimize the potential for rust and will last for many seasons to come. If the frame becomes damaged in any way, we recommend consulting Gentry Welding and Fabrication in San Luis Obispo for repairs. He originally welded the frame and can perform repairs if necessary. The specification drawings for the chassis are found in the drawing package and have all the dimensions required for manufacturing a replacement or repairs.

The sling is custom made from catamaran trampoline material by SLO Sail and Canvas in San Luis Obispo. If the sling becomes unusable for any reason, we recommend contacting SLO Sail and Canvas for a suitable replacement. The detail drawing for sling is found in the drawing package and has all the information required for manufacturing a replacement.

Contact Information

Gentry Welding & Fabrication
733 Buckley Rd, San Luis Obispo, CA 93401
(805) 544-4130

Slo Sail and Canvas
645 Tank Farm Rd G, San Luis Obispo, CA 93401
(805) 479-6122