CALIFORNIA POLYTECHNIC STATE UNIVERSITY – SAN LUIS OBISPO

Final Project Report

Senior Project #7: Longboard Test Apparatus

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Statement of Disclaimer

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

1.0 Abstract

The aim of this project is to create a machine that will test longboards made by Method Sports and Freebord. Through analysis and many iterations, Board Busters has assembled a design to fulfill the requirements set forth by these companies, who also sponsor the project. Through use of a four-bar, frame, and two spinning disks, the machine will accurately simulate riding conditions seen by a board in use by customers, allowing the sponsoring companies to improve designs and verify warranties.

2.0 Introduction

Senior Project #7, officially named as the Longboard Test Apparatus, entails the creation of a device that will fatigue and yield complete longboard skateboards until failure. This project will mainly focus on the fatigue aspect. The loads will simulate road conditions (sidewalk cracks, rocks, etc.) and the distribution of a 300 lb. rider as accurately as possible. The testing period for an individual board will be the equivalent of the average distance, speed, and wear for 2 years, which will be quantified through community polls.

Method Sports Inc. and Freebord are funding the project with a budget of $3000 – Method Sports Inc. will be providing the driving components and machining resources as well. Paul Dickie, CEO of Method Sports, will be the main contact and will forward updates to Freebord through Steve Bianco, the Director of Operations for Freebord. Meetings pertaining to the requirements of both companies will be arranged with both representatives as needed. The Method and Freebord boards are pictured in Figure 2.1 and Figure 2.2, respectively.

Figure 2.1: Method Dylithium Longboard with Negative Camber (NC) set up.

Figure 2.2: Freebord complete board.

3.0 Background Information

Speed Wobbles

In the realm of skateboarding, the term “speed wobbles” describes when a board begins to swerve uncontrollably from side to side – usually resulting in the rider being thrown off. This phenomenon can be found in many situations such as locomotive trains, automatic transmissions, steering systems, etc.

According to Neil Carver, a trucksmith and skateboard designer, the technical name for “speed wobbles” is Self-Exciting Oscillations. Once the system (the whole board and rider) reaches its critical speed it begins to respond by oscillating. The amplitude of the response grows with respect to time because it is a closed-loop feedback system. The source of energy from which the amplitude grows, in this case, is the forward momentum of the rider and skateboard.

The components of the skateboard’s trucks, or steering system, affect its performance as well as its likeliness to wobble. Refer to Figure 1 and the Appendix for the names and respective descriptions of the truck’s components. The bushings, which are located on the kingpin between the hanger and the baseplate, control the amount of damping in the trucks. A board with stiff bushings allows for a more stable ride by increasing the damping of the system. This reduces the amplitude of the oscillations, which makes the board more suitable for tricks. A board with soft bushings allows for more system response by decreasing damping of the system. This allows the rider to make sharper carves, which makes the board more suitable for downhill skating or cruising. Having a lower damped system, however, will lower its critical speed and the board will be more likely to wobble. The pivot angle describes the orientation of the axis that the truck pivots about with respect to the ground. A steeper pivot angle allows for a tighter arc of turn and thus a tendency to oversteer. This is favorable for longboarders who want to have “sharper carves,” which explains why most longboard trucks have a pivot angle ranging between 40°-60°.

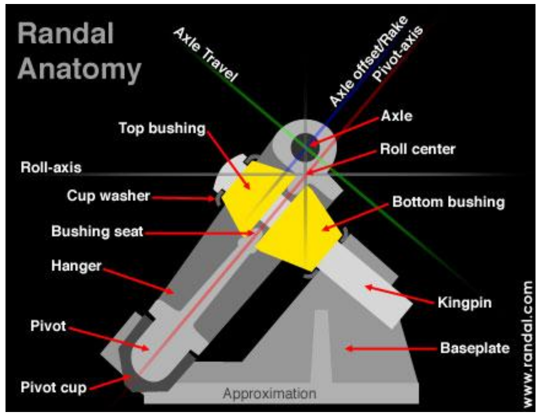


Figure 3.1: Components of a skateboard truck.

Surface Friction Coefficients

According to Engineershandbook.com, the reference range of kinematic friction of rubber on dry asphalt is 0.5-0.8 and 0.6-0.85 on dry concrete.

The table below from Peter J. Blau's *Friction Science and Technology: From Concepts to Applications* lists reference ranges that have been established to reconstruct accidents. The represented kinematic friction coefficient of rubber is 0.6-0.8 on dry, traveled asphalt and 0.55-0.75 on dry, traveled cement.

TABLE 9.4
Friction Coefficients for Tires Sliding on Wet and Dry Road Surfaces at Speeds below 30 mph

Travel Surface Condition	μ (Dry Sliding)	μ (Wet Sliding)
Loose-packed dirt	0.40–0.60	0.30–0.50
Loose gravel	0.40–0.70	0.45–0.75
Truck escape ramps	2.5–3.5	—
New Portland cement	0.80–1.2	0.50–0.80
Traffic polished Portland cement	0.55–0.75	0.45–0.65
New asphalt	0.80–1.2	0.50–0.80
Traveled asphalt	0.60–0.80	0.45–0.70

Source: Parkka, D.J. in *Equation Directory of the Reconstructionist*, Institute for Police Technology and Management (IPTM), Jacksonville, FL, 1996, 212.

Figure 3.2: Reference ranges for kinematic friction coefficients of tires on multiple surfaces.

The data from these sources indicate that the material that is chosen to simulate road conditions, without including the obstacles, must have a kinematic friction coefficient ranging between 0.55-0.85. It is important to note that longboard wheels are not made of the same material as automobile tires – rather they are made of types of polyurethane. These reference values will be used to choose the correct material.

Benchmarks

- Looknround0568's Longboard Rider Simulator
    - http://www.youtube.com/watch?v=TBx37PCPj4U
    - Rider load simulator
    - Springs acts as damping in ankles and knees
    - Load can be varied by placing different weights.
    - Cannot actuate carving motion on its own.
    - Equal amount of load in each "leg."
- Looknround0568's Speed Wobble Simulator
    - http://www.youtube.com/watch?v=AVGk8AfXbSw
    - Forward momentum provided by car.
    - Not at an inclined position.
    - Stability controlled by a connecting rod.
    - Carving actuated by ropes attached to the "legs."
    - Maximum speed of 30 mph.
    - Achieved speed wobble!
    - Assembly must be on center of road for straight path steering.
- Freebord's Current Method of Testing
    - Drop tests with human test subjects of different weights and sizes from multiple heights.
    - Tests structural integrity of the caster assembly.
    - Questionnaires about wheel performance filled out by riders after long period of use.

Planar Four-Bar Linkage

The formal definition of a four-bar linkage, also known as a four-bar, is an assembly of four linkages connected by four joints. While connected into a closed looped, the linkages can be used to manage forces and movement. In particular, the project will be utilizing a planar four-bar linkage, in which the joints have a single degree of freedom and move in parallel planes.

Planar four-bar linkages are critical mechanisms that can be found in many of the machines that are used today. Its dynamic analysis also happens to be a major topic of discussion in Cal Poly's college of mechanical engineering. The four components that make up a planar four-bar linkage are the frame, two grounded links, and coupler. The frame, also called the ground link or fixed link, is the linkage that is fixed. The grounded links are the two linkages that are connected to the frame and act as the input and output of the system. The input linkage, called the driver, provides the motion for the system, while the output linkage, called the rocker, produces the desired movement. The coupler is the link connects the input to the output. For the purpose of this project, the planar four-bar linkage will be implemented in a crank-rocker configuration, in which the driver makes circular rotations (like a crank) while the rocker rocks back and forth. The point of interest for this project is the joint between the coupler and the rocker linkages. This point *accelerates* from one side to another, coming to a complete stop at each

extreme. This movement will be utilized to simulate the leaning of a rider's torso while actuating a carve. An example of this configuration can be found in Figure 3.2.

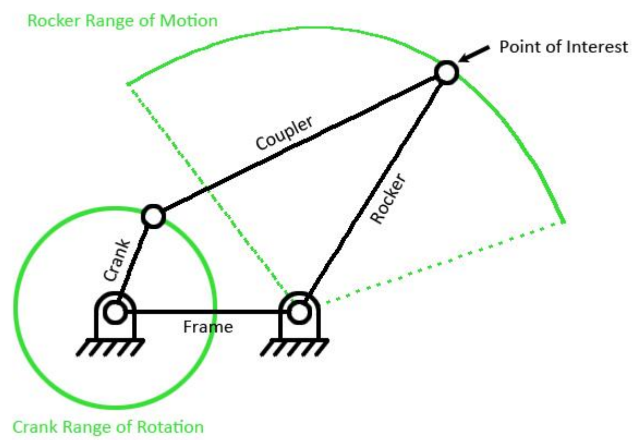


Figure 3.2: Planar Four-Bar Linkage in a crank-rocker configuration.

Belts

Belts will be implemented into all of the drive trains of the board tester in order to keep the machine as quiet as possible. A belt is a cheap and simple way to link two or more rotating shafts. They are usually constructed out of highly elastic material, which is usually reinforced with high-tensile fibers. Belts replace the use of gears and chains in applications that require low weight, little noise, and a simple design. Gears transmit power without the need to worry about misalignment, slipping, or premature failure but at the cost of constraining the geometry of your system and material usage. Chains offer almost the same amount of reliability as gears without the geometric and material constraints but are very noisy. Belts fulfill the cons of gears and chains and also eliminate the need for high tension. The most notable application of a belt is the timing belt, or cam belt, for internal combustion engines. Timing belts are usually constructed out of rubber reinforced with high-tensile fibers, which is shown in Figure 3.4.

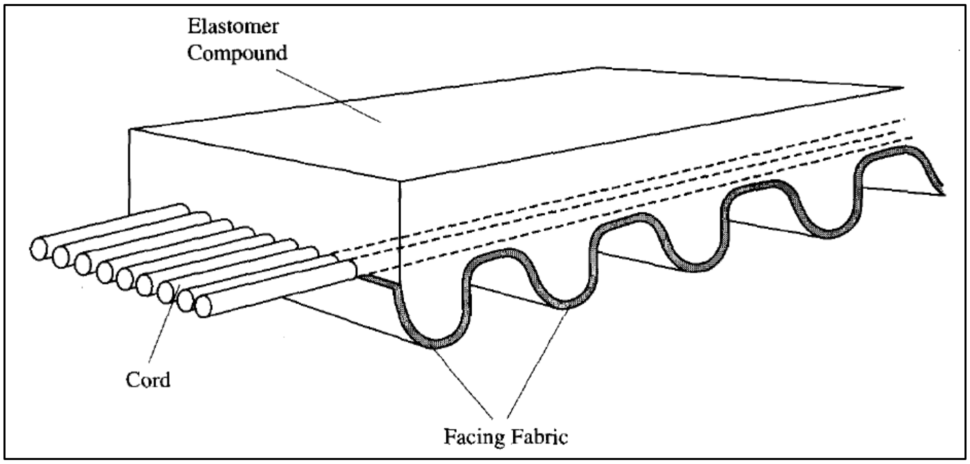


Figure 3.4: Construction of a Timing Belt

In the beginning stages of timing belt development, selection and specification of belts have been a problem due to the lack of a recognized industry standard. The Society of Automotive Engineers (SAE) has compiled data from users and suppliers to create a standard to solve this problem, which is listed in 19.13 of the first volume of the SAE Handbook. Depending on the type of engine, different belt sections are require and have a minimum recommended diameter, which is listed in Table 3.1.

Table 3.1: Minimum Recommended Pulley Diameters

Section	Pitch (mm)	Min Number of Grooves	Min Pitch Diameter (mm)	Min Outside Diameter (mm)
ST	9.525	10	30.32	29.56
SU	12.700	14	56.60	55.23
STA	9.525	19	57.61	56.23

Because timing belts may have the tendency to misalign, flanges are required to hold them in place. Flange dimensions vary with section and are listed in Table 3.2. The minimum width between the flanges can be determined with the following equation: 1.5 (belt plus side tolerance) + nominal width. A maximum surface finish of 2 µm is normally satisfactory, but a 1 µm finish is strongly recommended for crankshaft and other critical drive usage.

Table 3.2: Flange Dimensions

Section	Min Flange Thickness (mm)	Min Flange Height (mm)
ST	1.3	1.6
SU	1.3	2.0
STA	1.3	2.4

Installation tension varies with each system as well as the belt's section. General guidance for belts with widths between 5 to 50 mm is given in Table 3.3.

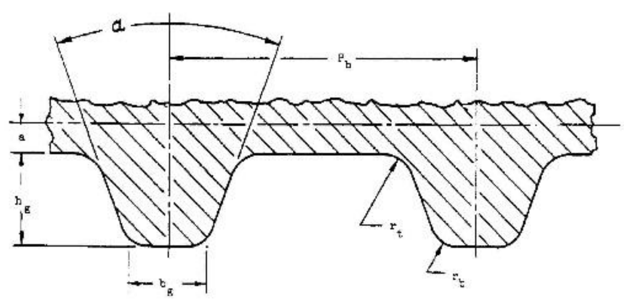
Table 3.3: Installation Tension for Belt Widths 5-50 (mm)

Section	Min Installation Tension (N)		Max Installation Tension (N)
ST	$5.5b_s$-17	≤ 1 ≤	7.6 b_s-24
SU	12 b_s-38	≤ 1 ≤	20 b_s-62
STA	-	-	-
where nominal belt width = b_s (mm)			

The master profile of the belt is generated by Table 3.4 at a specific number of grooves and nominal belt OD.

Table 3.4: Belt Generating Tool Rack Form Dimensions (mm)

Section	# Grooves	P_b Pitch ± 0.003	±.25^0	h_g +0.05 -0.00	b_g +0.05 -0.00	r_b ±0.03	r_t ±0.03	2α
ST	10+	9.525	40	2.13	3.10	0.86	0.53	0.762
SU	14-19	12.700	40	2.59	4.24	1.47	1.04	1.273
SU	19+	12.700	40	2.59	4.24	1.47	1.42	1.372
STA	19+	9.525	40	2.13	3.10	0.86	0.71	1.372



The dimension tolerances of the belt are given in Table 3.5 in six areas, which are described in Figure 3.3.

Table 3.5: Belt Groove Tolerances (mm)

Section	Top Curvature	Max Top Radius	Flank	Bottom Curvature	Depth	Upper Reference Depth
ST	0.04	±0.1/-0.0	0.05	0.05	0.05	0.5
SU	0.04	±0.1/-0.0	0.05	0.05	0.05	0.8
STA	0.04	±0.1/-0.0	0.05	0.05	0.05	0.5

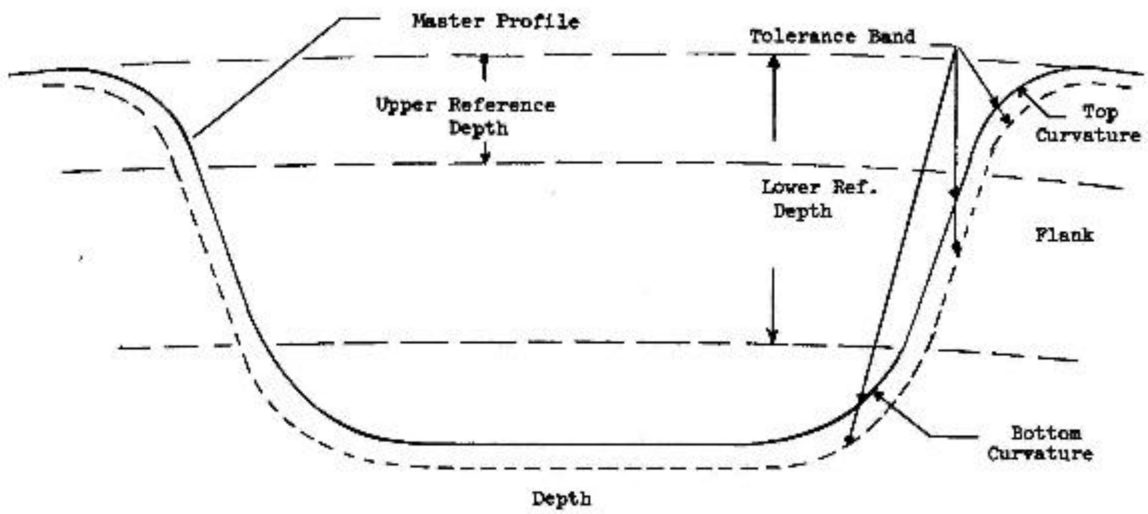


Figure 3.3: Belt Groove Profile.

Bearings

In an endeavor to keep maintenance convenient and at a low cost, Method Skateboard and/or Freebord bearings will be integrated into the machine. Skateboard bearings are rated on an "ABEC" scale. This scale is the industry standard set by the Annular Bearing Engineering Committee (ABEC), which is part of the American Bearing Manufacturers Association (ABMA), for the tolerances of a ball bearing. The rating system categorizes each bearing with an odd number ranging from 1 through 9 – a greater number corresponds to a greater degree of precision. The tolerances levels that are covered include the inner bore diameter, parallelism (deviation in bearing width), and radial raceway runout.

Contrary to popular belief, the ABEC scale was designed to allow the customer to make an informed decision based on tolerances of the bearing they are purchasing – not their ability to spin faster. Higher rated bearings are intended for use in precision applications that require operation at high RPM's. The skateboard bearings will be implemented in the four-bar linkage, disk supports, and the island assembly so low ABEC rated bearings should be fine.

4.0 Objectives

Project Goals

This project will result in a product that will satisfy engineering specifications that have been developed to meet the requirements of Freebord and Method Sports. The focus of this project is safety first as well as a concentration on fatigue of the boards. We will produce one testing apparatus for use by Freebord in San Francisco, CA. This device will also be used by Method Sports, Inc.

Problem Statement

Create a device that will cycle longboards at varying speeds and road conditions, counting cycle numbers for analysis of fatigue failure of the boards.

Development of Specifications

The quality function deployment (QFD) table the Board Buster team created allowed for all of the customer requirements, engineering requirements, objectives, constraints, weight of each requirement, benchmarks, and conceptual ideas to all be interrelated and help choose the most appropriate design. The QFD was a great tool in making sure that engineering requirements were properly meeting all of the sponsor's requirements for this project. It also allowed the team to focus in more on the requirements the project demanded. These demands were chosen by the data and numbers collected from the QFD chart.

In order to come up with our specifications, we talked to our sponsors to find out what specifications they had for the project. Board Busters attempted to put measureable quantities on these specifications in order to measure the successful completion of these specification requirements (engineering requirements). Board Busters focused on specifications that had a high level of importance to the sponsors. The QFD model (see Appendix) was used to weigh the importance of the specifications to the customer and to compare how the team created requirements met these specifications. The team was also able to compare our project scope to other benchmark methods and products fulfilled our sponsors' specifications.

From the QFD, we determined that the top three design considerations would be an adjustable rider weight from 100 to 300 pounds, documentable, and simulates load on caster at set speed conditions. These design considerations have been highlighted in the QFD appendix figure. Adjustable rider weight is important for simulating riding terrain and type of ride. Documentation is important for the sponsor to be able to measure and obtain data that will characterize the forces and loads that the boards are seeing. Simulating loads on caster is the main interest of Freebord and is related to ride simulation and terrain. The way the Freebord slides on a loaded caster will be crucial to satisfy this requirement.

These top design considerations were determined by comparing the weighted customer requirements in the left column to the engineering requirements in the top row. These values established weighted correlations between what the customer wants and our project requirements. The engineering requirements were also compared to the current benchmark for this type of testing based on the right hand column.

When looking at the QFD and comparing the benchmark to our target goals, the benchmark misses over 50% of the targets. These targets were created based on our project requirements which are shown in Table 1. Therefore, it can be concluded that the current method of testing is ineffective and does not meet the desired requirements of this project. Upon completion of this project, we will be setting a new benchmark in the longboarding industry.

The bottom section of the QFD compares our target goals to the current benchmark. These targets were created based on our project requirements which can be found in the Requirements list seen in the Appendix.

On the left side of the QFD chart, the team's conceptual designs are compared to the benchmark and against each other. When filling in the QFD chart, it was realized that there were two different separate areas that needed comparison. These two sections were: road simulation and turning/carving actuation. We had three conceptual ideas for both road simulations and turning actuation. So instead of creating all nine possible combinations, each road condition and turning actuation was analyzed separately. This allowed the team to choose the top two for each category and make then compare the top four combinations in the engineering requirement targets at the bottom of the QFD chart.

In this case the QFD, analyzed showed that the conveyor belt with the swashplate or four-bar linkage actuator would be the best fit for our project. Both the swashplate and the four-bar linage were chosen for actuators because of how close their weighted scores were (294 and 293 respectively). It would later be found that the conveyor road would be inadequate for our project. The main factor behind this was the cost/budget of the project would be greatly exceeded if this road simulator type were pursued. Later on the Board Buster team would choose to go with the horizontal spinning disk, the next highest scoring road actuator on the QFD.

After some iteration and research, a finalized conceptual design was chosen based on data from the QFD and from the research collected. Since the high scoring conveyor belt was not an option, the disk idea was chosen to pursue. (See prototype section). Paul Dickie then pitched the idea of having two disks running horizontal to each other to the ground plane. The two disks could spin in opposite directions and a board could be placed between them. With one wheel on each disk, the wheels would simulate a rider moving at a determined speed and a carving actuator could be used.

This new two disk idea was then compared in the QFD by comparing a two disk with a four-bar linkage and a two disk with a swashplate. It was seen that the four-bar linkage would be the best choice for this application. It was also seen that the two disk four-bar linkage scored greatly higher than the benchmark testing Freebord is currently using.

The development of this list of requirements is crucial to our design process. The ratings placed on the requirements help us to identify areas of the project that require our focus. First, we will need to ensure that we can meet the speed wobble requirement of our project. We may need to increase our maximum speed in order to achieve this milestone. The budget is another topic to be aware of over the course of the project so that we can stay within what our sponsors have committed. System damping will be another subject that will require additional attention as it is not directly in the description of the project. We must ensure that the system does not vibrate uncontrollably, damaging itself, the test subjects, or the testing environment.

Another area of extra thought and consideration is loading the casters on the Freebord. This has spawned several unique ideas that we would not have thought about otherwise in order to

accommodate this requirement. They pose a challenge because of their differences from standard longboard wheels. The motor interface will require thought to develop a drivetrain. This is where we will obtain our power and speed, thus we will likely spend some time developing and improving our interface.

Finally, we will have to meet our milestones in a timely manner, keeping our due dates as drivers in our design steps. Our final delivery after the final report and expo is non-negotiable as our team will disband upon the completion of the spring quarter. In addition, our sponsors are relying on the delivery of their product at this time. Thus, we must finish our project in the time allotted.

This requirements list is split up by categories with a description of the engineering requirement and a quantitative target for each requirement. The categories are: safety, forces and speed, cost, geometry/environment, operations and measuring, reliability, testing, and deliverables/scheduling. Each parameter is assigned a tolerance, risk, and compliance rating. The tolerance gives the allowable variation from the quantitative target. The risk is assigned based on the perceived difficulty of meeting the target, rated from low to high. The compliance notations represent what how each design requirement is to be met. These processes are analysis (A), testing (T), similarity to existing designs (S), and inspection (I).

5.0 Design Development

Over the course of the team's project, Board Buster's anticipate using simple analysis to narrow down our idea list. The plan is to then build prototype models of concepts that we believe may work, performing further, more detailed analysis. From this point, the best idea will be chosen and pursued further in analysis, design, and manufacturability of this concept, forming the team's finished product.

Board Busters has already received our project and formed our team. The team then assigned team roles and defined our project requirements. In the next step of Board Busters' design process, the team continued to collect ideas, performing simple analysis on these ideas to eliminate those that will not work. This was done by several brainstorming sessions/activities. Once the list was narrowed, the group performed more detailed analysis and select ideas that would benefit from a prototype.

After the list of requirements was created, several brainstorming session were performed as a team. Methods included menu matrix, brainstorming, incubation, etc. The results from these sessions led us to several different unique ideas each with their own ways of operating and allowed for different venues to explore. Some of the results can be seen in Figure 5.1, Figure 5.2a, b, c, and Table 5.1a, b.

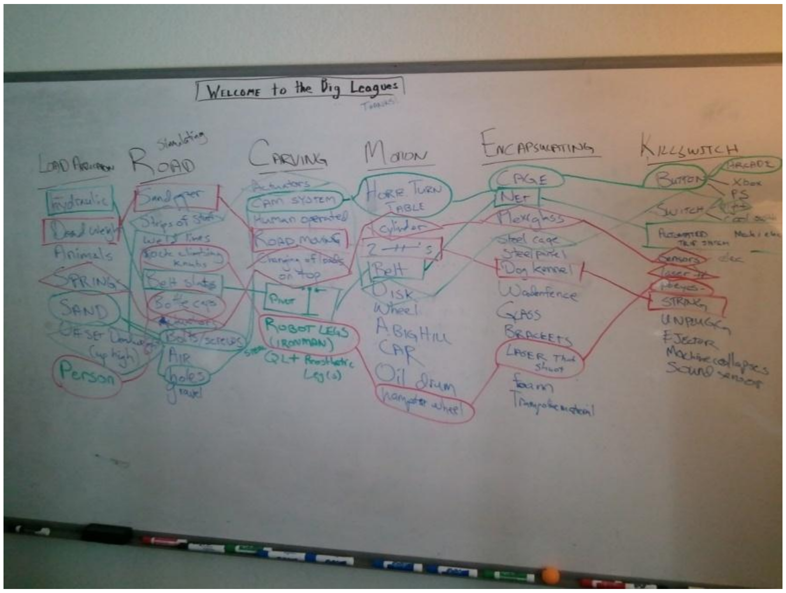


Figure 5.1: Menu Matrix created from brainstorming session. Excel Table of results found in Table 5.1 below.

Table 5.1a: Menu Matrix table organized from Figure 4.1

Categories					
Load Application	Simulating Road	Carving	Motion	Encapsulating	Killswitch
hydraulic	sandpaper	actuators	horizontal turntable	cage	button (arcade)
dead weight	strips of stuff	Cam System	1 cylinder	Net	button (xbox)
animals	weld lines	Human Operated	2 cyliners	Plexiglass	button (playstation)
springs	rock climbing knubs	Moving Road	belt	Steel Cage	switch (light)
sand	belt slats	Changing of loads on top	disk	Steel Panel	switch (cool)
offset deadweight (up high)	bottle caps	Pivot	Wheel	Dog Kennel	Automated trip system (mech & elec)
person	actuators	Robot Legs (Ironman)	A Big Hill	Wooden Fence	Sensors (elec)
	bolts/screws	Steal QL+ Prosthetic Leg(s)	Car	Glass	Sensors (laser)
	air		Oil Drum	Brackets	Paint Ball Eyes
	holes		Hampster Wheel	Laser that shoots	String
	gravel			Foam	Unplugg
				Trampoline Material	Ejector
					Machine Collapses
					Sound Sensor

Table 5.1b: Menu Matrix connections made by each group member

	Load Application	Simulating Road	Carving	Motion	Encapsulating	Killswitch
Derek:	Normal Combination:					
	Sand	**Bolts/Screws & Holes**	**Cam System**	**Horizontal Turn Table**	**Cage**	**Button (Arcade)**
	Weird Combination:					
	Person	**Rock Climbing Knubs & Bottle Caps**	**Robot Legs (ironman)**	**Hampster Wheel**	**Lasers That Shoot**	**Paint Ball Eyes**
Nico:	Normal Combination:					
	Hydraulic	**Belt Slats**	**Pivot**	**Belt**	**Net**	**Automated trip system (mech & elec)**
	Weird Combination:					
	Deadweight	**Sandpaper**	**Moving Road**	**2 cylinders**	**Dog Kennel**	**String**
Colin:	Normal Combination:					
	Offset Deadwieght (up high)	**Strips of Stuff**	**Actuators**	**Disk**	**Steel Cage**	**Switch (light)**
	Weird Combination:					
	Springs	**Actuators**	**Changing of Loads on Top**	**1 Cylinder**	**Plexiglass**	**Sensor (laser)**

These ideas generated from this exercise gave the Board Busters a better sense of what kind of ideas and ways to execute the problem. It was a way for the members to find different combinations not previously thought of. The visual aspect of this exercise greatly helped the effectiveness of this exercise which overall helped us lead to our final design.

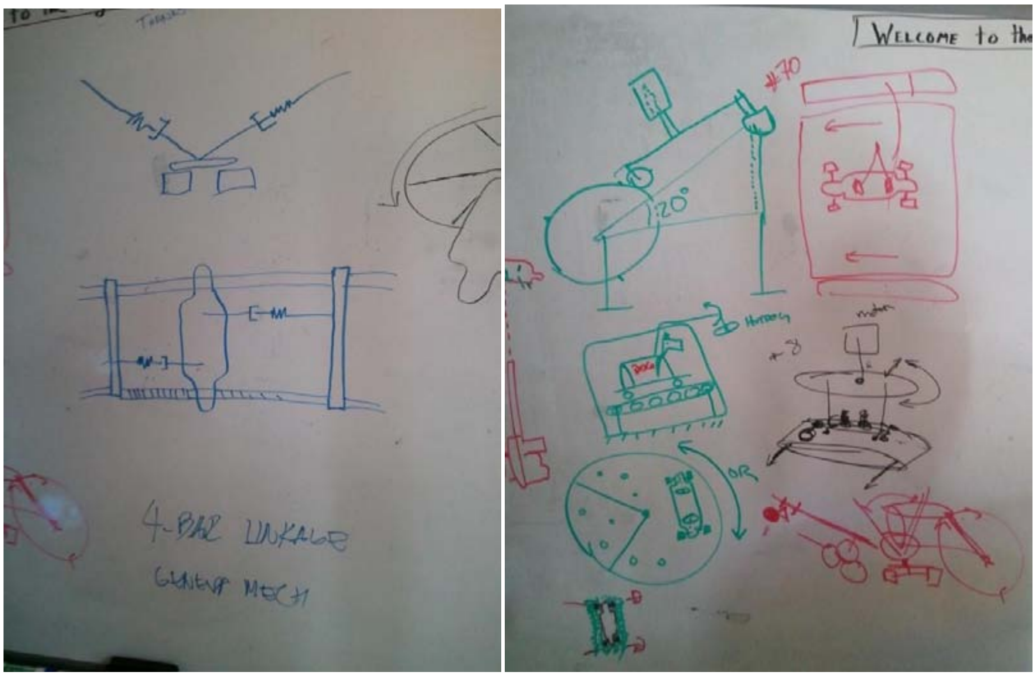


Figure 5.2a & Figure 5.2b: Whiteboard Brainstorming. Several ideas made from a 15minute session (a-Nico Lee, b- Derek Chan)

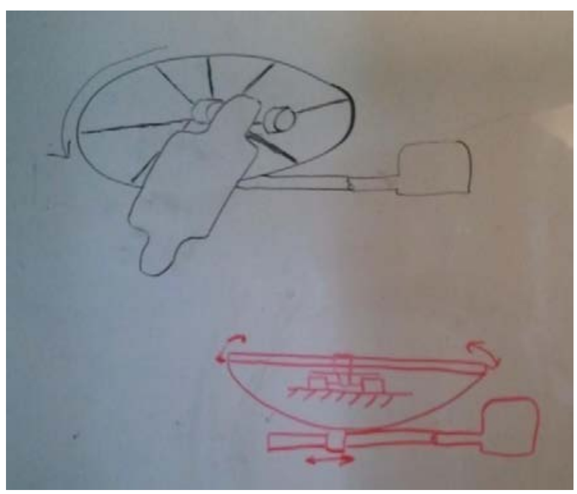


Figure 5.2c: More Brainstorming ideas from whiteboard brainstorming (Colin Harris)

Even though the drawn ideas are very rough, these led to more finalized concepts which were later analyzed in the QFD previously mentioned in section 4.0. The ideas were then able to be analyzed

and determine what direction the project should follow. After finding the results of the QFD the group contacted sponsors, Paul Dickie and Steve Bianco, to discuss the team's finding

After contacting sponsors Paul Dickie and Steve Bianco, Board Busters was able to narrow our conceptual design to two different road simulators/types. These methods were the conveyor belt and the spinning disk. At the time, the conveyor belt road seemed to be the most practical in being able to simulate the road type the team was aspiring to create. After more research was conducted, it was clear the conveyor belt road was not going to be a possibility. The main driving factor for this decision was the price of conveyor belt. The cost of a custom belt that would be durable enough to handle our desired load would cost close to three times the overall project budget. After this option was dismissed, Board Busters decided to pursue the disk idea to simulate the road. When discussing the disk concept with Paul Dickie and Steve Bianco, they expressed they wanted some type of visual in order to see how a longboard and a Freebord will react when put on the disk.

It was determined that a visual aid was needed in order to further the consideration of a disk road simulator. A prototype disk was built in order to fulfill this. The disk would be able to show how a board will react when placed on a spinning 4' diameter horizontal disk. For the team prototype, plywood was chosen. An 8' x 4' sheet was cut in half width wise leaving two 4'x4' squares. One of these squares was used to create the base of the model, as seen in Figure P.1 below. A 1 ½"galvanized plumbing pipe was used as a bushing and placed in the center of the base.

Figure 5.3: Prototype base. Made of a 4'x4' square and a mounted 1 ½" Galvanized pipe.

After the base was created, a 4' plywood disk was cut out of the remaining 4'x4' square. This was done by using a steel cable placed in the center of the square and tracing a 2' radius out all the way around the square. After the tracing outline was complete, the disk was cut out using a jigsaw. Then 8 casters were screwed into the disk. The casters were not rated for high speed, but were still able to

perform well enough to collect good data. The casters were placed such that the weight was distributed evenly across the disk as seen in Figure 5.4. Then a 1 7/8" hole was cut in the center of the disk using a hole bit. This hole allows the 1 ½" pipe to go through the disk and the hole and pipe act as a type of bushing.

Figure 5.4: Bottom View of Top Mounted Disk. Part consists of 8 screwed in industrial casters and a 4' diameter disk with a 1 7/8" hole drilled in the center.

The next step was the assembly of the prototype. The top disk was placed on the base (caster side down). This full assembly can be seen in Figure 5.5. The black/silver line is set at 1.5' out from the center. This creates dimensions for a 3' disk if desired. The disk can now be hand/foot driven. This was the initial driving mechanism we used to collect general data.

After seeing this road simulation had potential Board Busters sought out another way to drive the disk. This was done by having Colin Harris mount his front wheel bicycle wheel in a bicycle lock rack and placing the back wheel on the disk. This was able to achieve a speed of 15mph. This was calculated by looking at the video footage collected and finding the frequency of the disk and also knowing the radius of the disk.

Figure 5.5: Fully Assembled 4' Disk Prototype. Top speed calculated was approximately 15mph

The data collected can be seen in this compilation video: http://youtu.be/BaQcyf9gIaU

The tests run included placing Method boards in various positions on the disk. These included: four wheels on the disk, Front trucks only with two wheels in contact, and front trucks only with only one wheel in contact and the other off the edge of the disk.

For freeboard the front trucks were placed on in a way that a toe side stop or a heel side stop could be simulated. Also a system was created to have the caster on the edge of the disk and rolling onto the already spinning disk and then turning off. This would create a carving motion and caster load if two disks were used.

The results from the test showed that the boards could be positioned to properly simulated Board Busters requirements set for this project. The results of this prototype have defined the road condition the team is pursuing. The disk data produced very reasonable results and gave a solid visualization to something the team and sponsors were unsure about. The visualization helped to let us proceed with our conceptual design with a spinning horizontal disk as the road simulator.

From these results, the group was able to derive our conceptual design. The conceptual design report on the team's chosen idea will presented it in the conceptual design review with our advisor and our sponsors.

Any changes that are demanded from the conceptual design review will be considered. At this point, if the conceptual design is rendered a failure, we will have to discuss with our adviser and sponsors what the course of action is. However, assuming that the changes the team must make to the conceptual model are minor, we will continue with our design process, implementing the necessary changes and generating the product that will eventually be delivered to our sponsor.

This process is visually documented by a Gantt Chart which is located in the Appendix, Figure A.3. This chart schedules our deliverables and progress through the fall quarter of 2011. On the right of the Gantt Chart, the progress of each category is visually represented in a shaded bar graph, transposed over a calendar, which corresponds to the task percent of completion. These deliverables are split up into three categories. The first category, Team Contract, includes a team bonding meal. During the meal, our group discussed the outline of the contract. A draft of this contract was due on 10/6/11 and was also signed on that day. A Project Proposal with an included list of requirements which was completed on 10/13/11. We discussed these requirements with sponsor, Paul Dickie, and sent a finished copy to our Freebord contact, Steve Bianco. The project report turned in on 10/20/11 is also included in this chart category. The project also includes the QFD model, further discussed previously in this report. The final category is Conceptual Design. This includes the conceptual model and report as well as the conceptual design review. The Final Conceptual Design Report and Design Review are due on 12/1/11 and 12/5/11 respectively and will be presented at that time.

6.0 Concepts

Top Concepts

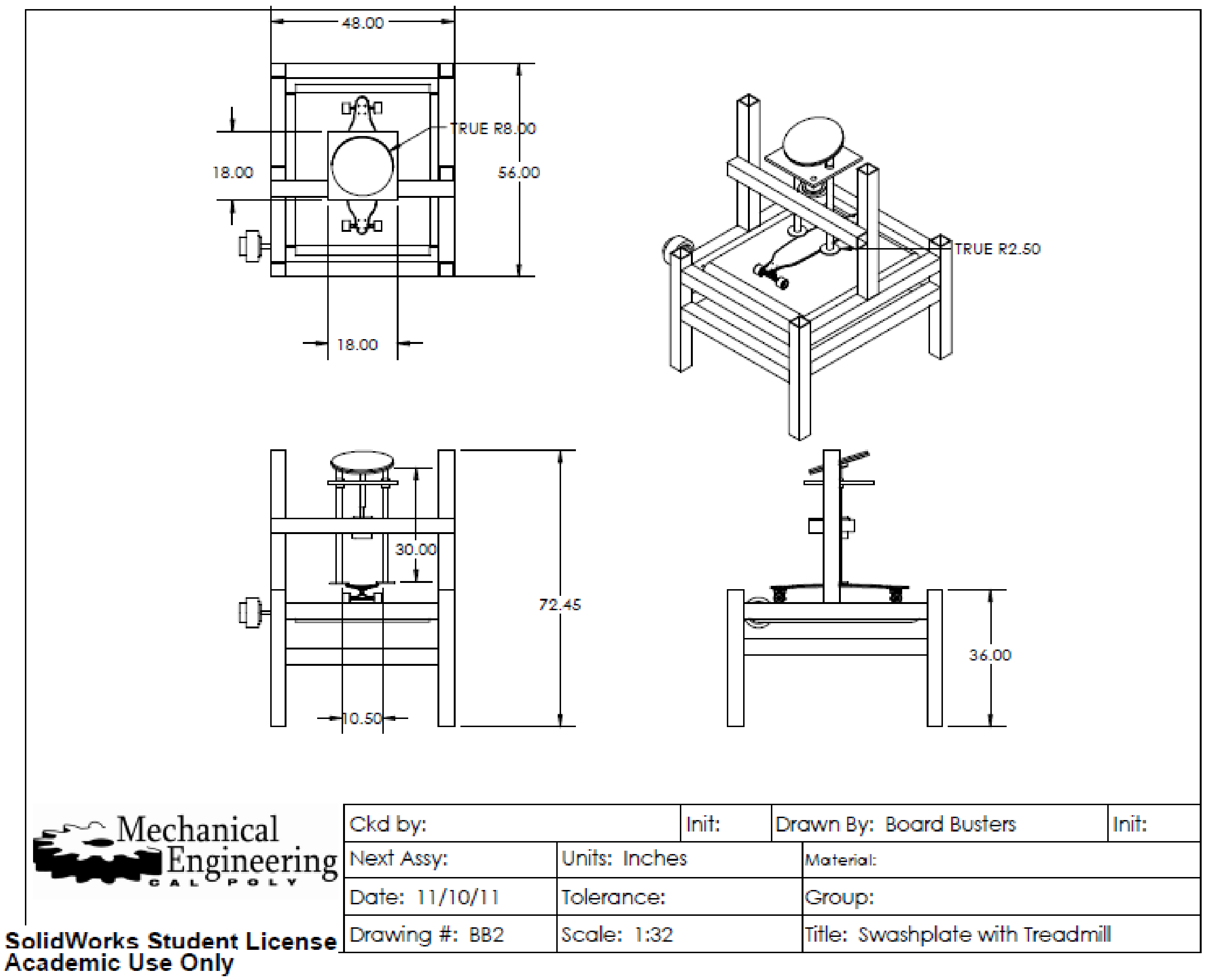


Figure 6.1: The Swashplate with Treadmill idea utilized a running treadmill with a swashplate acting as the carving actuator. This was integrated into a table structure. Direct weight would have been applied to the constrained board. Problems with this idea were the complexity of the swashplate, constraint of the board, and obtaining a treadmill belt within budget.

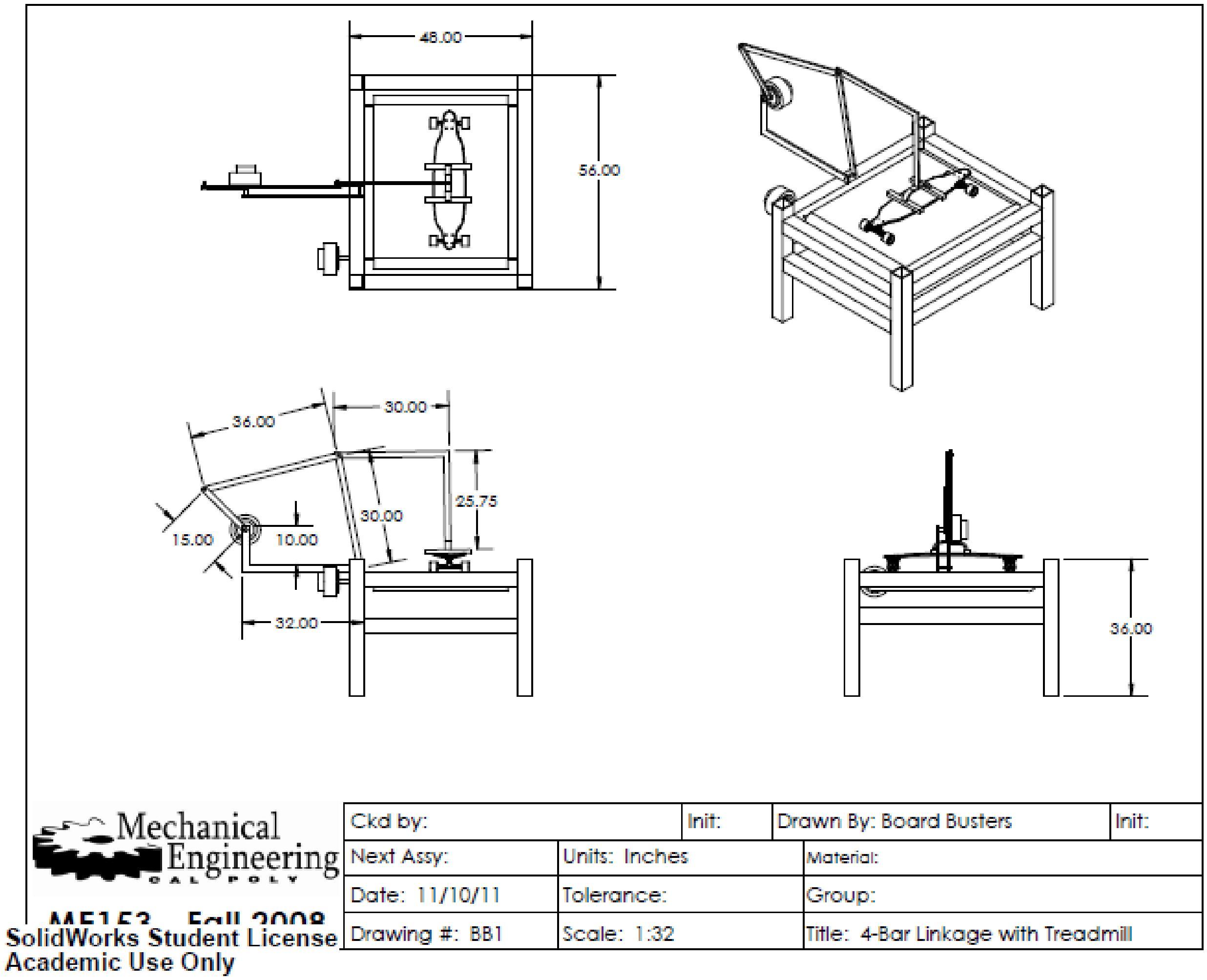


Figure 6.2: This idea contains the same treadmill as in the previous concept, but the actuation is a four-bar linkage. Weight would be applied to the top of the "foot" L-bracket and would oscillate back and forth with the motion of the 4-bar. The obstacles in this design were similar to the last idea with the treadmill belt cost being the main hurdle and constraint of the board being secondary.

Final Conceptual Design

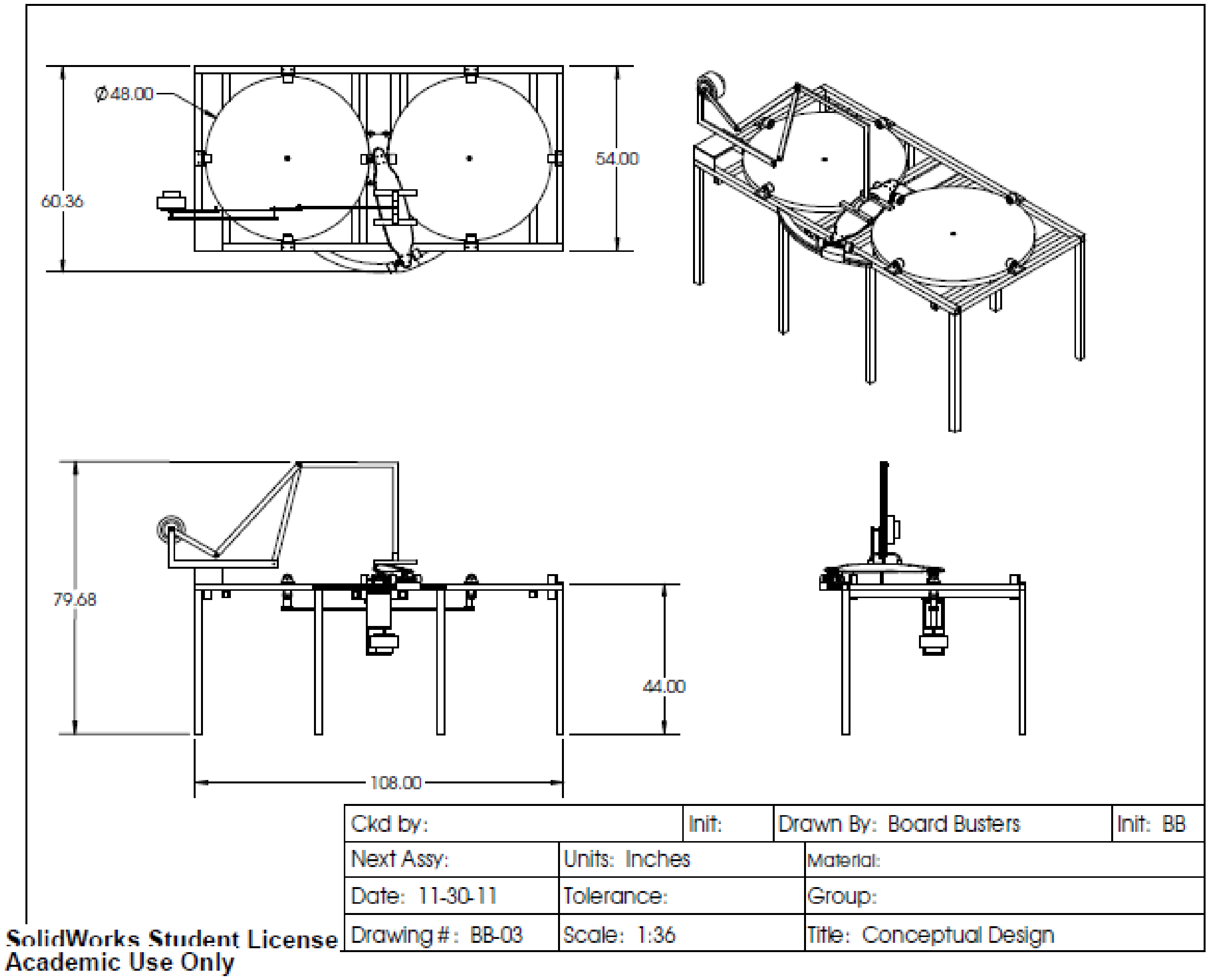


Figure 6.3: Drawing of Conceptual Design with basic dimensions included.

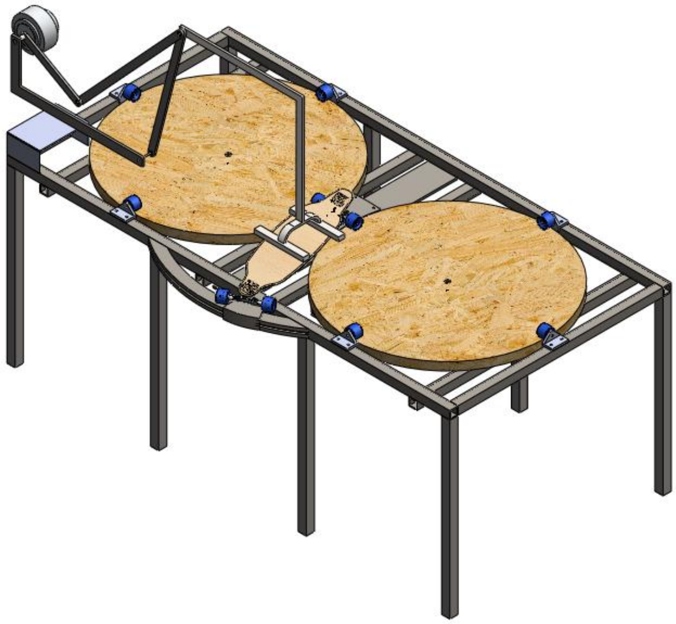


Figure 6.4: Isometric view of conceptual design.

Conceptual Design Description

Road Simulator

The chosen road simulator design Board Busters has chosen to pursue is the two disk idea. This idea entails two disks approximately 4' in diameter spinning horizontally placed next to each other, each an equal height off the ground. The disks will be spinning in opposite directions and allows a board's front trucks to be placed between the disks with one wheel on each disk. This will simulate a forward motion parallel to the board. The disks will be designed to run at up to 35 mph on the outermost part of the disk (the fastest area). The disks are planned to be driven by the provided ETEC motor. The drive train will entail the ETEC motor, a gearbox (most likely some type of spur gear reduction), and a spinning shaft connected to the center of each disk by a belt.

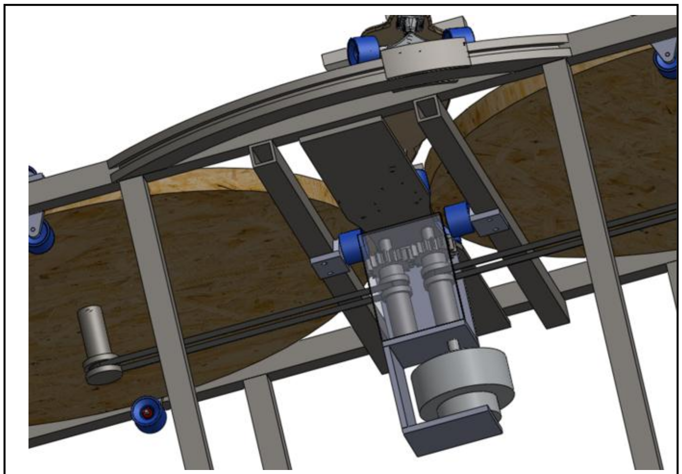


Figure 6.5: Drivetrain for 4 foot disks, showing belts and gears which transfer motor speed and torque

The disks need to be able machined/made accurate enough to not have any major weighting offset that will somehow affect the balance of the wheel. Disk materials that are currently being considered are wood, metal, or some type of composite. Using any of these materials will also allow for

removable road obstacles to be placed on the disks. These may simulate sidewalk cracks, pebbles, or other common obstruction.

The two disk road simulator also allows for the ability to hard-mount a Freebord in a heelstop or toestop. This could help to replicate wheel wear and caster loading.

Frame

The frame needs to be sturdy enough to contain the two disks and the oscillating weight shifting back and forth. The frame will also need a way of attaching support rollers that will help keep the disk from wobbling and stay at a strict horizontal position. It will be comprised of 2"x2" carbon steel rectangular tubes.

For the rollers, the team is planning on using either Method's or Freebord's straight wheels to support the disks. These are ideal because they are designed around running at higher speeds and since it is the company's own product it will come at a cheaper cost than resourcing another outside company. Since the wheels are also made of a polyurethane, the wheels can act as a damper and help to reduce any unwanted vibrations.

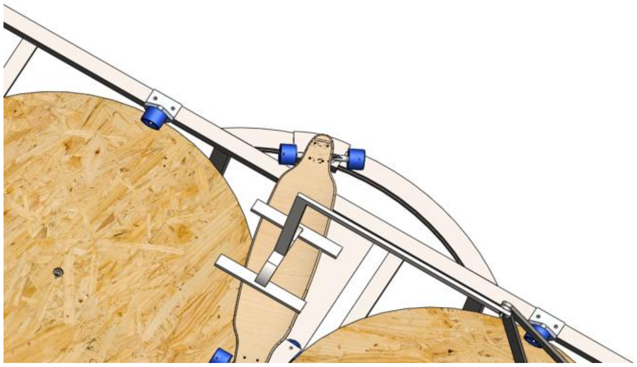


Figure 6.6: Slider bar which will guide back of method board during carving.

The frame also needs a way to mount the back trucks of the board that are not running on the two disks. Ideally the back trucks will be angled 10 to 20 degrees above the ground. This angle would help to better simulate the rider going down a hill. The higher the angle the steeper the hill. The current design will incorporate the back trucks and removing the back wheels to have the trucks clamped to a slider on the slider rail. This would also allow the trucks in the back to still react to a turn and the bushings will still be used in same sense they were designed for.

For the back mount for the back trucks, our design will have Freebord's boards securely pinned down in the back and the back will act as a pivot point. The front trucks will move back and forth across the disk spanning plate, cycling the caster and simulating a sliding motion. For the Method board, the back trucks will slide back and forth with the turn to simulate carving while the front wheels stay stationary.

Four-bar Linkage

The four-bar linkage will be used to actuate all carving/turning for both board types. This four-bar system allows for a motor to rotate freely and, through calculations, a rocker arm can be tuned to oscillate between two desired angles. This actuator is very simple and can be easily repaired in

comparison to the swashplate idea, which scored just as high as the four-bar system. The swashplate idea was also dismissed because it has not been proven and would have required many specific machined parts that would need to be replaced over time. This would have increased cost of the project to an undesired amount.

The four-bar can be manipulated to serve both the requirements set by Freebord and Method. Another positive thing about this design is the ability to implement products already available to the sponsor companies. The links can be designed such that wheel bearings can be inserted into the links and coupler bars. Coupler bars will be a set length and need to be custom made, most likely, but the simplicity of the part should be much cheaper and faster to make in comparison to the swashplate. The links can also be design to help distribute forces/torques so they last much longer than if made on a basic level.

The drive train for the four-bar linkage will run on a provided motor from Method. It will be a lower HP motor than the ETEC motor used to drive the disks, but will be able to drive the four-bar linkage appropriately.

Weight Assembly

The weight assembly will simulate a 300 lb rider and act as the interface between the four-bar linkage and Method longboard and Freeboard. The basic components that make of this weight assembly are the feet, legs, and top weight.

The feet must be compatible with the traditional Method longboards and S2 bindings on the Freebords. It must also have a high enough coefficient of friction between itself and the grip tape on both boards so that it won’t slip off. The legs will connect the feet to the top weight and simulate the damping created by a rider’s ankles and knees.

In order to accurately simulate a human actuating a carve, the majority of the weight in this assembly will be in the top weight. The linkage connecting the joint between the coupler and the rocker to this top weight will simulate a human leaning his torso over the board when carving. Next quarter, the load distribution of a rider on a board will be experimentally determined and applied to the weight assembly.

Island Assembly

The purpose of the island assembly is to allow the fatigue tester to test both the Method longboards and Freebords. When the Method boards are being tested, clamps will be bolted onto the assembly to hold the front trucks in place while the rear trucks slide back and forth. This allows the board to maintain speed in the front trucks while carving. During Freebord testing, the front island will allow the caster to slide from one disk to another. While the caster is rolling on the island, its velocity is slow. When the caster rolls onto the disk, its speed will drastically change and thus simulate the sliding motion.

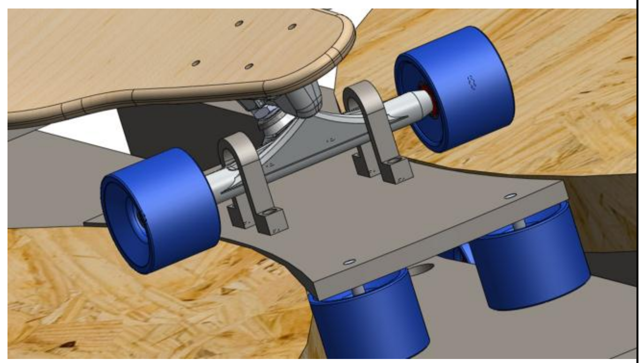


Figure 6.7: Method board carves while front truck is held in place, thus simulating carving while maintaining speed.

The components of the island assembly are two plates and four Method/Freebord skateboard wheels with a high durometer. The two plates will act as the platform for both boards. The four wheels will allow the two plates to be attached between the disks.

***Note**: Carbon steel will be used for all of the afore mentioned metal components unless stated otherwise.

7.0 Final Design Description

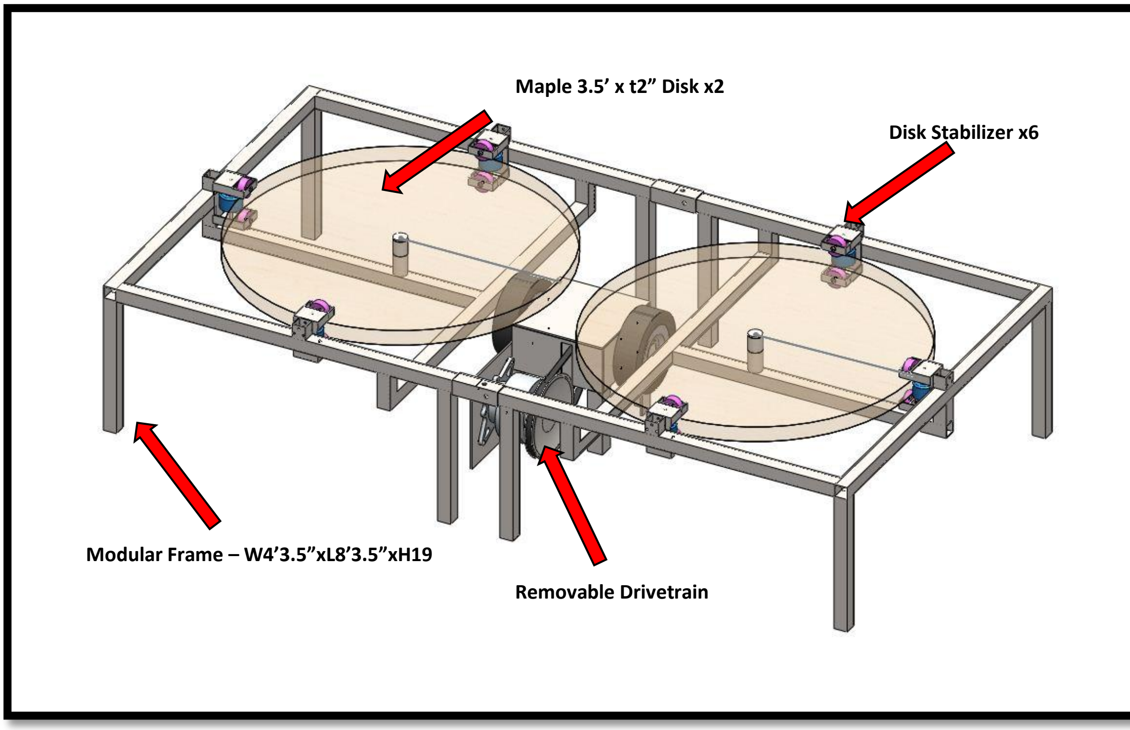


Figure 7.1: Overall labeled lower assembly of fatigue tester

The final design Board Busters has been designing around can be seen in the figure above. The upper frame with four-bar rocker/drivetrain, hard mounts, and weight assembly are not shown. The weight assembly and hard mounts are still underdevelopment, while the four-bar is currently being finalized. The lower assembly, seen above, shows the lower frame, running 3.5’x t2,” maple disks, disk stabilizers, and drivetrain. The design has been made to disassemble in order to transport and store the unit easier when not in use. Some of these modular features include: the frame being able to disassemble into two halves, the maple running disks are removable, the disk drivetrain is separate from the frame and mobile, the upper frame/four-bar/weight assembly will also detach from the lower frame.

Below is a model of how the Freebord will be set on the disk and the motion the four-bar will enforce on the board. Also a toe/heel stop hard mount will be implemented on the upper frame. This will allow the user to place a board on the disks simulating a rider sliding in a toe/heel stop.

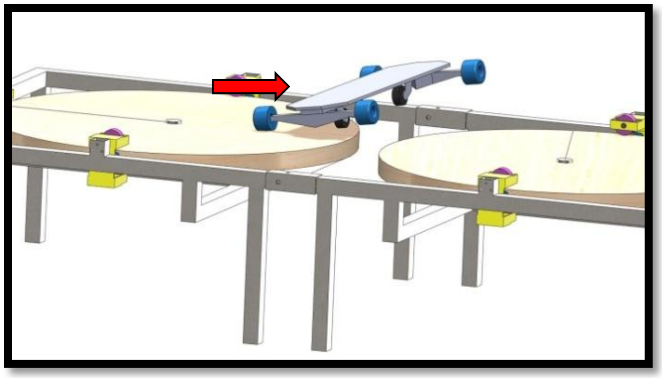


Figure 7.2: Freebord on disks turning/sliding. Note: Island not shown. Freebord will ride between each disk via the island

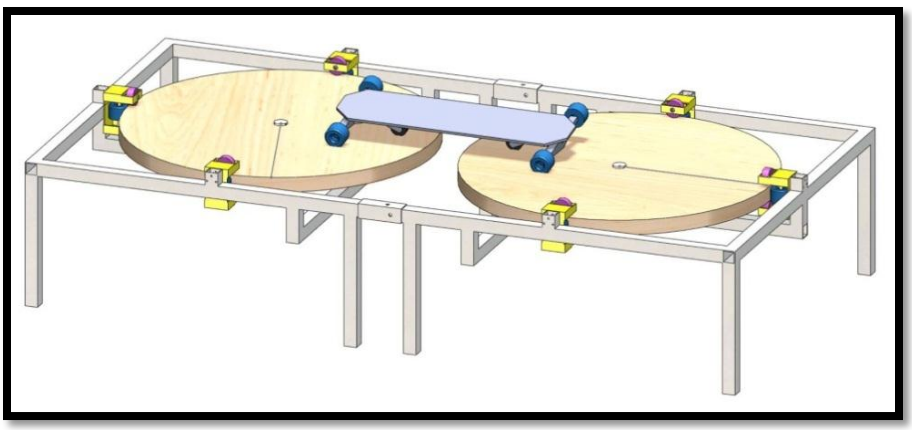


Figure 7.3: Toe/Heel stop for Freebord

Lower Frame

The lower frame, figure 7.3, is design to support the upper frame, weight assembly, two maple disks, four-bar mechanism/drivetrain, and disk stabilizers. It will consist of welded 1 ¾"x 1/8" square steel tube. The frame is also made in two halves. A 2"x1/8" 'collar' is placed around the end of the lengths on one half. The other half can then slide into the collars. The two halves are attached via four – Black Oxide Steel Bolts 0.5" x L2.5" bolts, two bolts per end. This can attachment can be seen in figure 7.4. The frame, assembled, has a footprint of 4'3 ½" x 8'3 ½" with a height of 18"1 ¾".

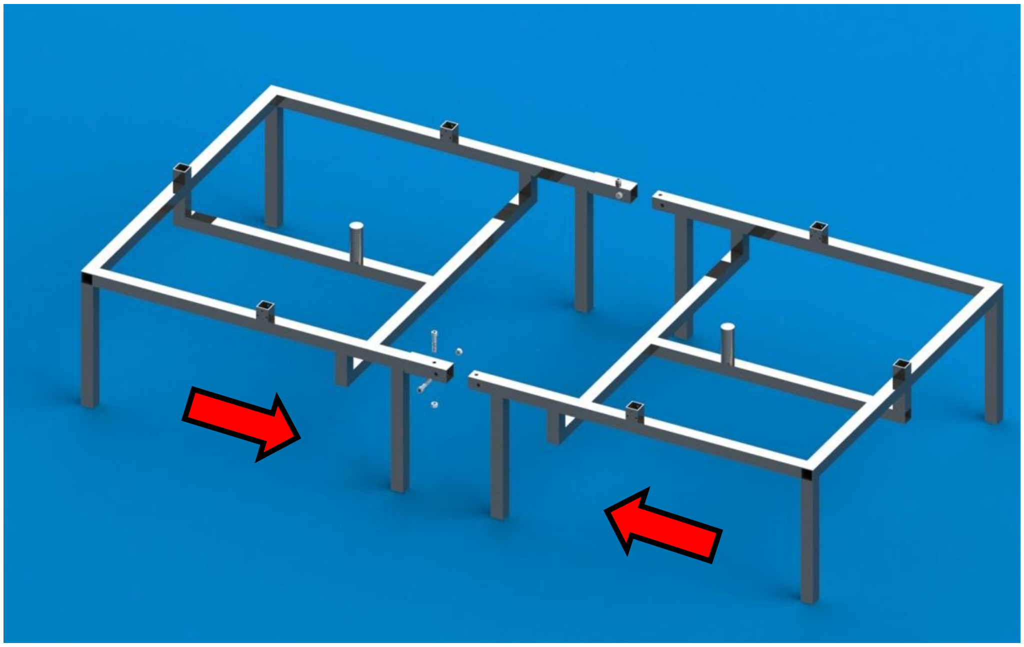


Figure 7.4: Exploded view of lower frame. Each half fits together via the 2” collar in the middle

Each half of the lower frame houses one of the spinning 3.5’ maple disks. The disks are spinning around a step shaft (not shown) and capped on to ensure they do not come off the frame while the machine is in operation. The two bearings attached to each maple disk will be placed around the step shaft seating the disk flush with the top of the lower frame. The frame is designed so that each disk can be removed and stored for when the machine is not in use.

The lower frame will also support the upper frame. The upper frame holds the weight assembly and four-bar rocker, protective Lexan, and drivetrain. The upper frame is still under development and will be detachable from the lower frame. This gives an easier ability to store the machine.

Lower frame calculations were done to ensure the legs would be adequate and would not buckle. An excessive factor of safety was found for the force critical for the buckling of a leg under and overestimated 300lb load on each leg.

The frame is also designed to mount six disk stabilizers and six casters to help support the running disks. Each disk will be supported by three upside-down Freebord casters and three disk stabilizers sandwiching the disks in place. The frame also allows the top of each disk stabilizer to be removed via three ¼” bolts 2 ½” long. This removable feature allows for the disks to be removed and an easier access to change any worn parts on the disk stabilizers. The disk stabilizers design and functionality will be discussed later in this report.

Disk Stabilizer

The disk stabilizer has been designed to be made sole out of welded 1/8" thick steel sheeting. This allows for an easier less expensive way of fabricating rather than machining the part from a stock block. Each stabilizer utilizes two 59mm Freebord provided wheels and one 70mm wheel.

The bracket is also split into two sections a top section and a lower section. The lower section is welded on and is permanently attached to the frame. The top portion is secured via three A574 ¼" – 20 x 2" bolts. These bolts can be found on McMaster Carr item #91251A550. These bolts were chosen through calculations from the stresses the bolts see axially and in shear.

The bolt conditions set for testing their appropriateness were set to very high standards and loading to ensure they were safe. The bolts ended with a factor of safety of 3.25 in shear, the main concern and need to be torqued down to around 120lbf-in. The assumptions made included the top bracket weighing 17lbm (~5-7x greater than expected), analyzing one bolt under the load conditions (instead of three), and a proof strength rated for a lower grade bolt, A325. All these condition were set under an extreme load of 25g's in each direction, axially and plane shear.

The next thing analyzed was the top wheel holder and the forces that are acting on the cantilevered top section. Analyzing a single plate yielded a deflection of only 0.062" with aluminum and a 0.0205" deflection downwards with steel and a 300'lbf load at the end of the bracket. This small deflection for only a third of the supporting material still yield a low enough deflection to show that steel is an appropriate application for the bracket.

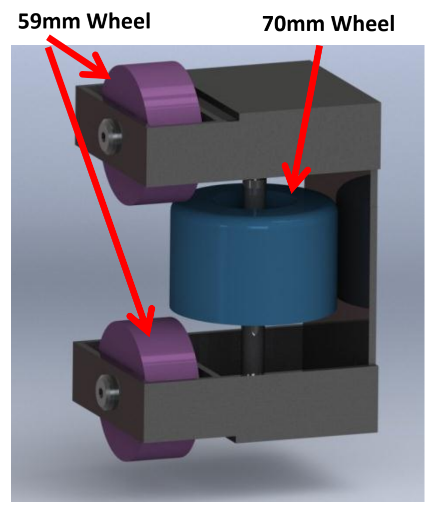


Figure 7.5: Solid Works assembly of single disk stabilizer. 59mm and 70mm wheels labels.

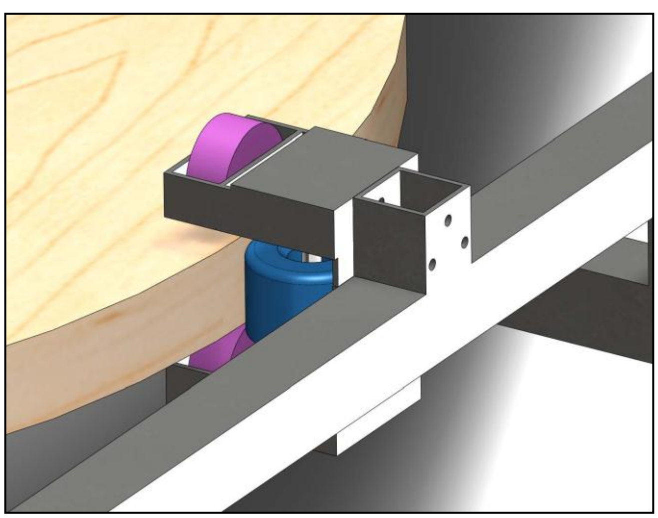


Figure 7.6: Disk Stabilizer assembled sandwiching spinning disks.

After the CAD model was created, it was necessary to check the fitment of the wheel in relation to the team's chosen dimensions. It was decided to make a rapid prototype (RP) of the bracket in order to insure our measuring was correct and it would in fact stabilize the disk. The exploded view of the RP'd bracket and the wheels is seen in the figure below to the left. The gap between the bottom of the top 59mm wheel and the top of the bottom 59mm wheel is 2" with a little bit of clearance on both ends.

The next step was to calculate the deflections the 70mm axle would see and ensure that the wheel will not come in contact with the back of plate of the stabilizer. In order to meet this requirement, the shaft could not deflect more than 0.08". The shaft, even though fixed on both ends, was modeled as a cantilever beam sticking straight up. This allowed for a greater deflection and over design. It was found an aluminum shaft would not meet the requirement with a 300lbf load on the end and a deflection of 0.159". A steel shaft would meet this requirement with a safety factor of 3.25 with only a 0.0552" deflection under the same loading conditions. Also, it should be noted that the shaft was modeled as an 8mm diameter rather than a step shaft of 10mm dropping down to an 8mm. This assumption also helped to overdesign the shaft.

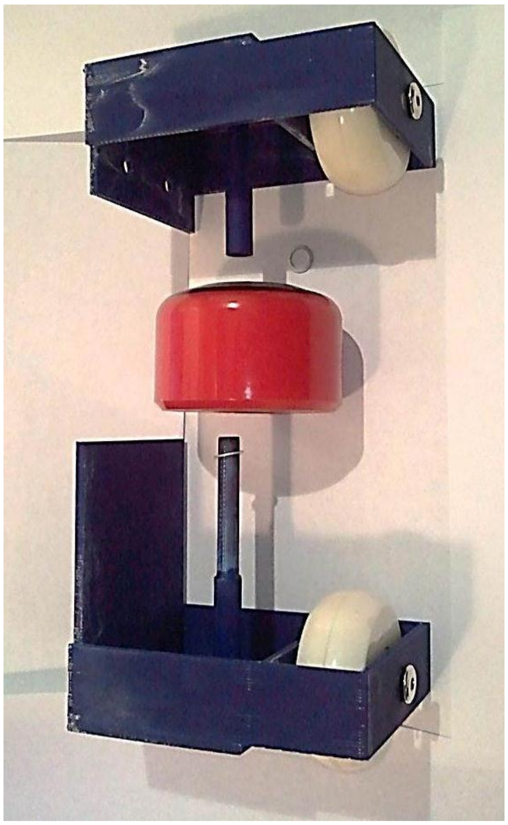


Figure 7.7: Exploded View of rapid prototyped bracket with 59mm and 70mm wheels installed.

The disk stabilizer also offers the use of components Freebord already has readily available. The parts include the axles, 59mm and 70mm wheels, and speed washers. The only component that would need to be turned is the step shaft the 70mm wheel is supported by.

Figure 7.8: Bottom section of bracket. 70mm and 59mm wheel installed.

Figure 7.9: Top section of bracket with single 59mm wheel installed.

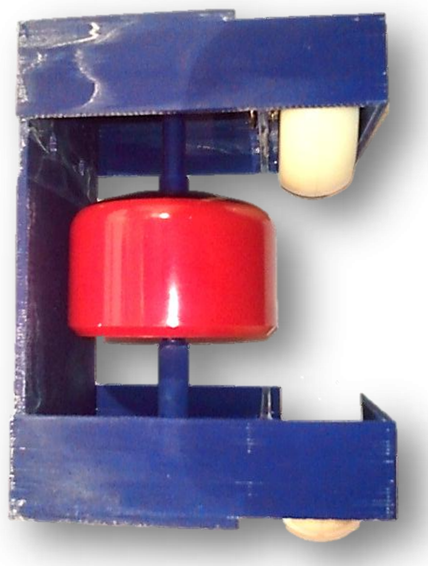


Figure 7.10: Side view of disk stabilizer fully assembled.

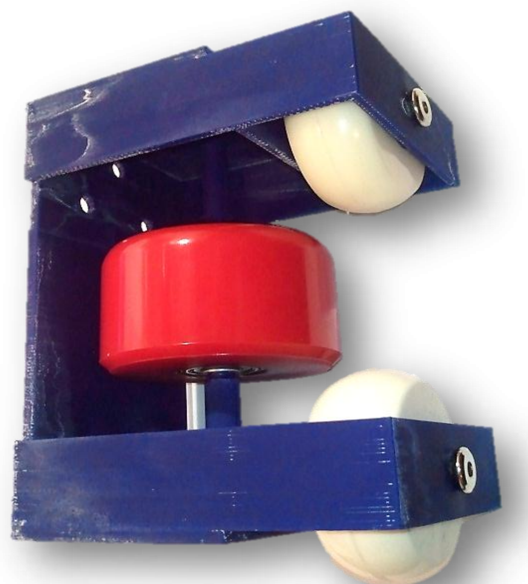


Figure 7.11: Angled view of fully assembled bracket. Bolt holes for top section are visible.

Upper Frame

The upper frame is designed to slide into the lower frame. This allows the fatigue tester to have more module properties and is easier for storage at Freebord's Factory. It is built from 1 ½" x 1 ½" square carbon steel tubing with a 1/8" thick wall. The upper frame supports the four-bar driving mechanism and weight assembly with slider.

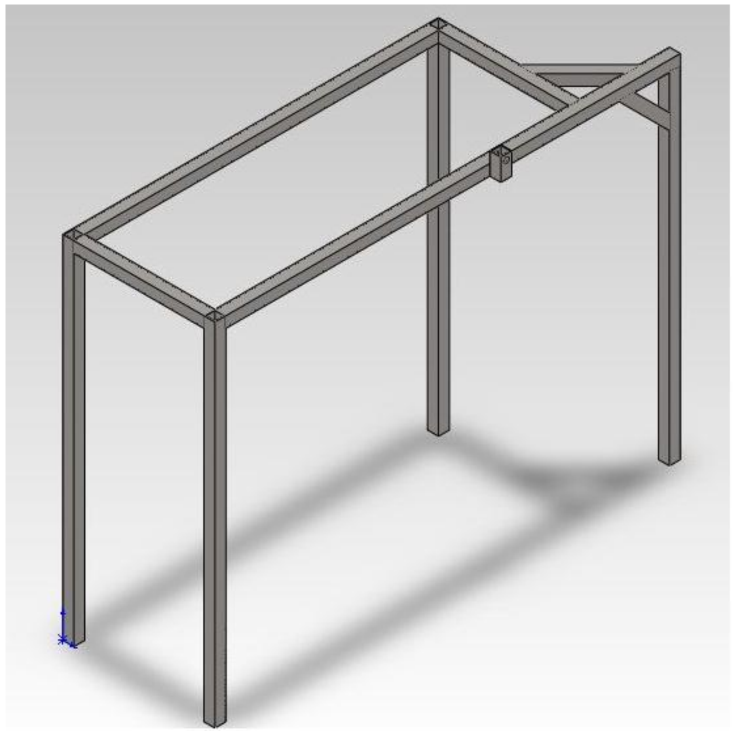


Figure 7.12: Upper frame for fatigue tester. The frame is made of 1 ½" x 1 ½" square carbon steel tubing. The upper frame supports the fourbar and weight assembly with slider.

The frame is designed to have three legs slide into the lower frame and a fourth leg extending out past the original footprint of the unit. The leg extends 12" past the lower frame and it necessary to keep from interfering with other design components; in this case it is the slider plate and plate weights in the weight assembly. The lower frame has three holes/ports that accept the three legs of the upper frame and secure the frame together.

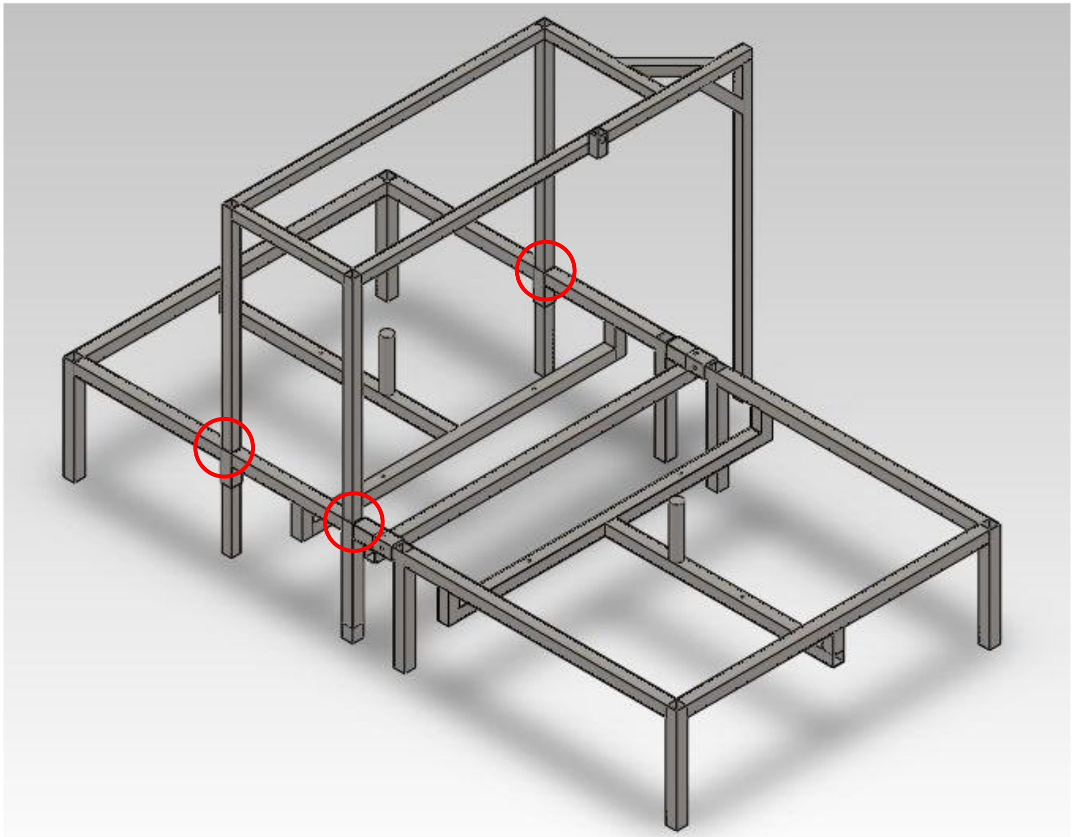


Figure 7.13: Figure showing how the upper frame integrates with the lower frame. The extended leg is supported by several 45 degree gusseting tubes. The extended leg is necessary to not interfere with weights on the weight assembly or the slider.

The upper frame also allows for the four-bar mount to be welded on. The four-bar mount contains the four-bar drivetrain and four-bar mechanism. These components are explained more in the four-bar section. The weight assembly is also attached to the upper frame via a universal ball joint. This ball joint allows for the weight assembly to be free moving while still constrained to a pivot. The weight assembly is explained further in the weight assembly section.

Island

The island is attached to the center of the lower frame and is in between the minimum distance of the two spinning disks. The island serves two purposes: to bridge the gap of a Freebord being tested so the center caster wheel can transfer between disks and to hold removable damping U-bolts that loop around the Method longboard trucks to fix the board in between the two spinning disks. The island is made of carbon steel. The U-bolts are part number 3176T46 on McMasterCarr. Two U-bolts are needed for the island, on for each side of the Method truck.

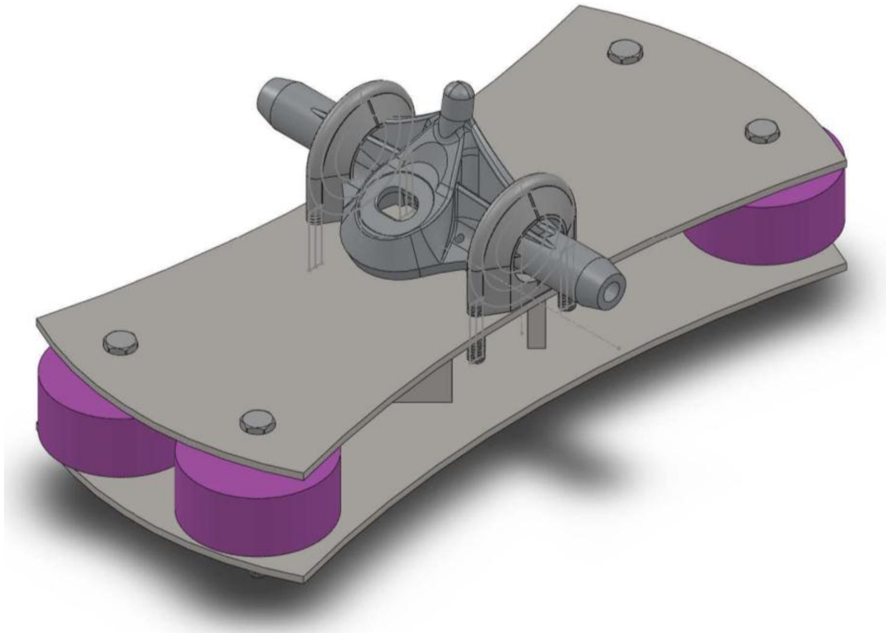


Figure 7.14: Island SolidWorks model is shown above. This model is with a method truck secured with removable damping U-bolts. The U-bolt's damping material needs to be cut/customized to properly fit the Method trucks.

When the fatigue tester is being used with a Freebord, the U-bolts will be removed as to not interfere with the center wheel transferring between the disks. The island is supported to hold the 300lbf load over the surface contact area of the Freebord wheel.

There are also four 59mm wheels that spin in the same axis as the 3.5' wooden disks. These 59mm wheels act as a stabilizer and keep the disks in check. These wheels help to keep the wheels running true and have a more consistent less wobbly rotation when moving at higher speeds.

The island splits into two halves, a lower half and an upper half. The halves are removed from each other in order to remove or add the U-bolts depending on the company brand board being tested. The lower half is welded onto the frame, while the upper half is bolted onto the lower half via 4 bolts that run through the axles of the 59mm wheels. Each half also has the same radial curvature as the outside of the spinning 3.5' disks. This ensures an appropriate fit when integrating the island into the lower frame. When the top half is secured, it sits flush with the top of the spinning 3.5' disks.

Slider

The slider utilizes ball transfers that are attached to the bottom of a Method board in replacement of the trucks. This allows the board to move freely in the back. The design will hopefully induce speed wobbles which would help benefit Method Sports. The slider concept involves a plate with two ball transfers being bolted onto the bottom of a Method board and running the ball transfers across a steel plate attached to the lower frame. The purpose of the slider is to simulate the turning of a board

both for Method and Freebord products. The Method Freebord boards use the ball transfer plate to slide back and forth on the lower frame slide plate.

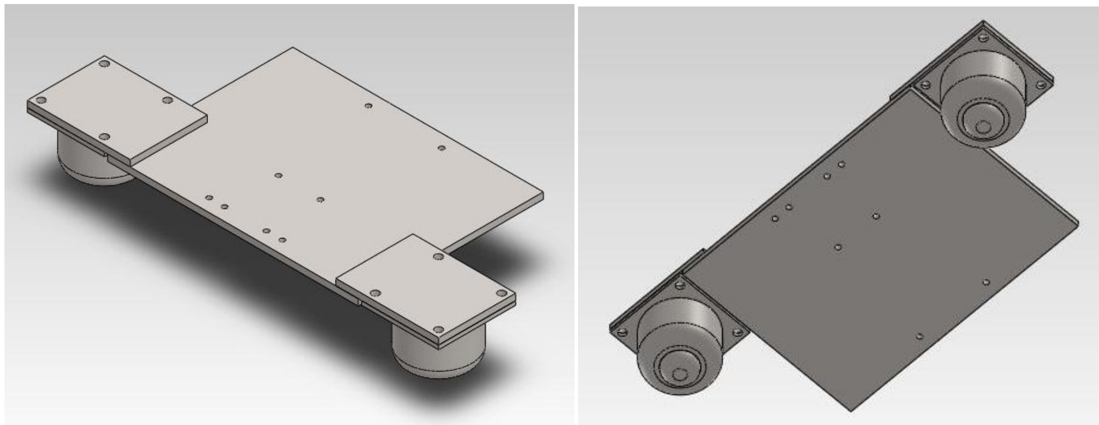


Figure 7.15: Top view and bottom view of the slider board plate. The board plate is bolted onto the boards via the board's truck and binding holes. The ball transfers act as a way for Method board to slide back and forth.

The slider plate and frame will be made of carbon steel. The two ball transfers will be bolted onto the board plate and the lower frame plate will be welded on. The board plate is bolted onto a Method board via the truck holes in the deck. For Freebord, the plate is bolted through four of the truck holes and a two of the binding holes.

Weight Assembly

The weight assembly includes the adjustable loading weights and the securing of the board to the weight and fatigue system. The weights are 200lbs of 25lb plate weights. So there are eight 25lb plate weights. The weights are attached directly to the board secure. The top of the weights are attached to the upper frame via a telescoping rod that attaches to a ball socket joint on top of the upper frame. The telescoping rod allows the rod to contract and extend so that the board is able to stay in contact with the wooden disks. If the rod was fixed, there is a chance the board could be lifted off the tester if not properly tuned. The weight assembly will be made of carbon steel. This material was chosen because it needs to be structurally strong since it is the most weight bearing component on the fatigue assembly not including the board being tested.

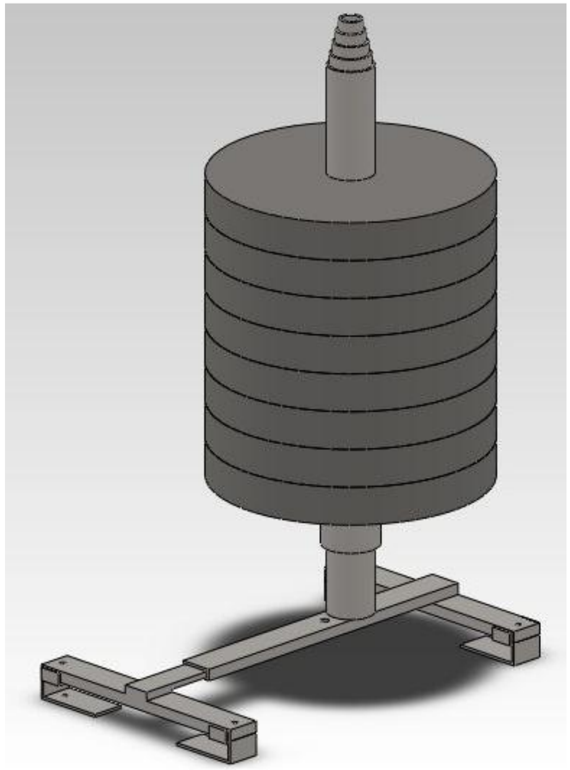


Figure 7.16: Weight assembly for fatigue test. The 8 plate weights each weigh 25lbs equaling a total of 200lbs. The telescoping feature is seen at the top of the figure. The board secure depicts the “wings” that hold the board at the four corners of the board. It also shows how it is able to telescope lengthwise.

The board secure is able to extend length wise similar to a vacuum cleaner attachment. Depending on the desired length will determine which hole to bolt through to get the proper length. The secure sandwiches the board at four corners of the board. The sandwiching parts were designed to not interfere with either Method or Freebord truck performance.

Speedometer

A Bell Cyclometer bicycle computer was purchased to monitor the large 3.5’ disk’s speed. The computer can be programmed by setting the millimeters per revolution. In other words, the computer can be programmed by inputting the wheel’s circumference from a desired point in millimeters. For the 3.5’ disk the outside circumference is 3350mm. This would be set for the outside of the spinning disk. In reality the wheels of the boards would be running a little bit in from the outside edge of the disks. The actually distance will be set after the machine is up and running and an accurate measurement can be made.

Figure 7.17: Bell Cyclometer Bicycle Speedometer used for Board Buster fatigue tester to measure speed, time, distance, and other performance variables. The computer/screen is shown in this figure. Other components included with the speedometer are a wireless magnetic switch and a magnet to activate the switch.

The computer is wireless and is mounted in the front of the fatigue machine. The speed and other data is read via a magnetic sensor. The sensor consists of a magnetic switch and a magnet. Normally the magnet is attached to the spoke of a bicycle and the switch is attached to the fork of the bicycle. In this case, the magnet will be attached to the wooden disk where it will not interfere with testing and the switch will be mounted to the lower frame such that a 1/8" gap is created between the switch and magnet. The number of rotations is transmitted to the computer and the speed and distance travelled is displayed on the screen. The computer also supports a timer function to let the user determine how long the device has been run for.

Four-Bar

After fabricating and testing the four-bar that was proposed in the conceptual design review, it was apparent that the carving motion of the Freebord was wrong. Instead of dragging the back edge wheels during a turn, the front wheels were being pushed towards the direction of the turn. Furthermore, the caster wheel was following the convex path of the rocker linkage.

In order to properly simulate how an actual rider would carve on a Freebord by having the back edge wheels dragged behind the direction of the turn; the caster would have to follow a concave path. The two proposed solutions were to flip the four-bar upside-down or use the point between the rocker and the coupler push a moment arm. The latter solution was chosen so that both the Method Skateboards and Freebord could be tested with little adjustment.

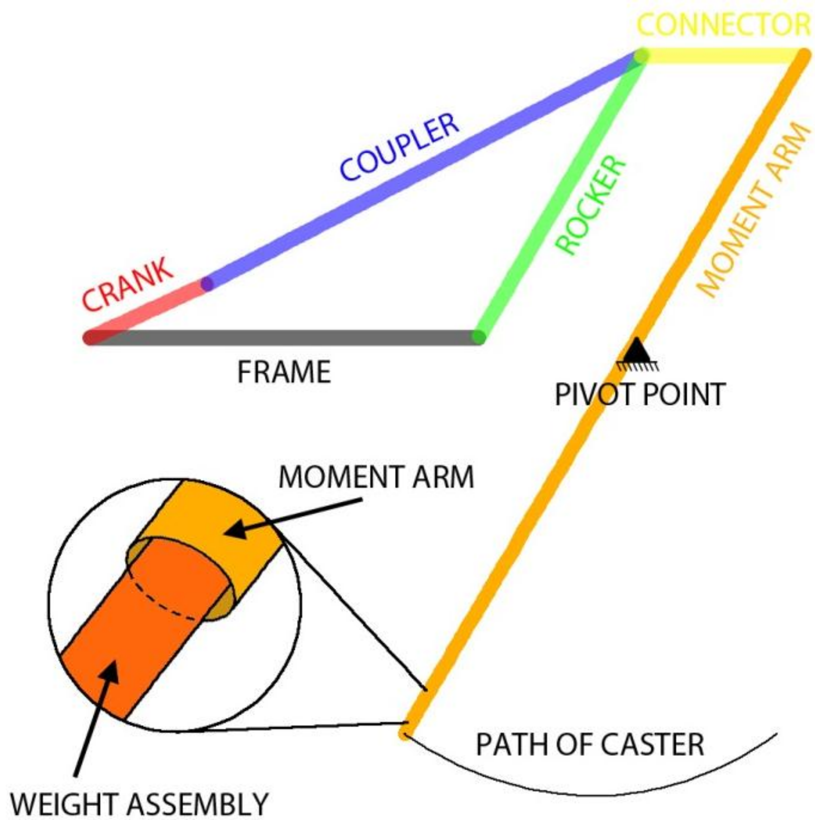


Figure 7.18: Newly proposed method of actuating the carving motion for the Freebord. The expanded view highlights the telescoping feature that allows the caster to maintain contact with the disks while at the extremes of its path.

As shown in figure 7.18, the point between the coupler and rocker would be connected by a link, which has been temporarily named "connector," to the moment arm. The moment arm will still force the board along the desired sweep of 60° but caster will now be able to follow a concave path. At the opposite side of the moment arm, the base of the weight assembly will be interconnected by a telescoping arm. The newly added telescoping feature will allow the caster maintain contact with the discs during the change in height at its extremes. The effective 300 lbs. weight will also be connected onto the base of the weight assembly. However, the moment arm and the weight will move independently. The top of the weight assembly will be fixed to the top of the frame, via a telescoping arm, so that when the board is tilted the weight will remain in the center of the turn. By also having a telescoping connection between the weight and the frame, not too much of the 300 lbs. force will be lost and will act more as a guide. Furthermore, in order to switch to test the Method Skateboard, the pivot of the moment arm will be removed so that the four-bar can still use the titling motion to carve. In order to compensate for the board wanting to translate in both the y-axis and x-axis, the front of the Freebord will no longer be fixed and will be allowed to slide.

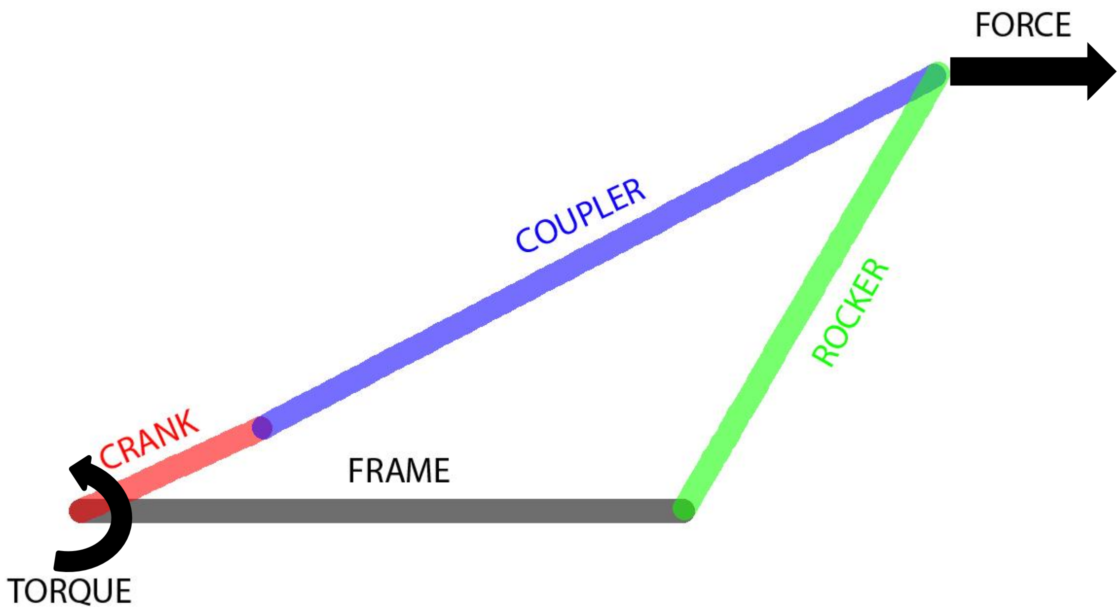


Figure 7.19: Schematic of four-bar static analysis. See table 7.1 for corresponding dimensions.

Table 7.1: Summary of four-bar dimensions used to calculate the force transferred from the torque of the motor to the point between the coupler and rocker.

Linkage	Dimension
Frame	9.00 inches
Crank	3.00 inches (radius)
Coupler	11.31 inches
Rocker	7.50 inches

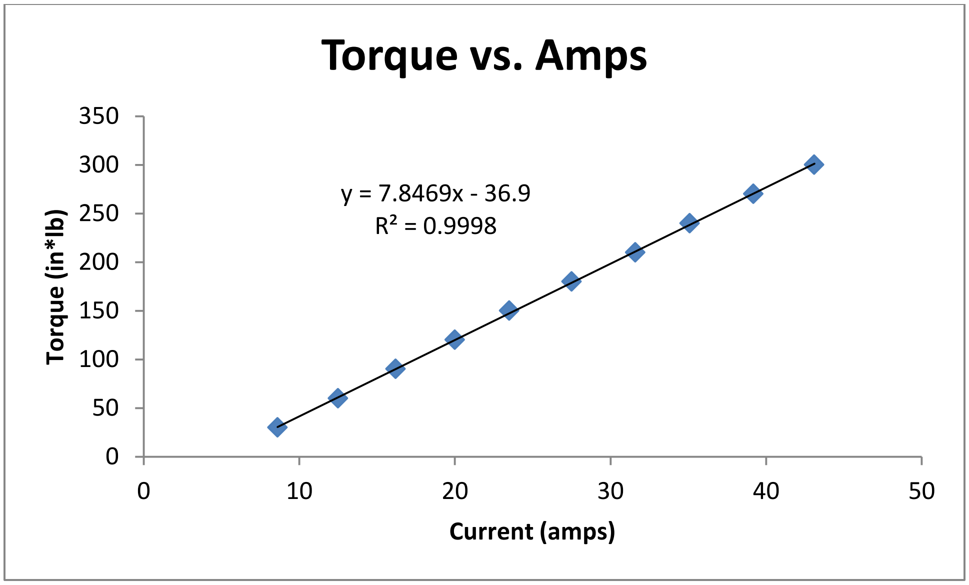


Figure 7.20: A plot showing the relationship between torque and amperage of the NPC-T64. The dynamometer data was taken from Robotic Marketplace's website and plotted in Excel. The data was fitted with a trend line to create a relation.

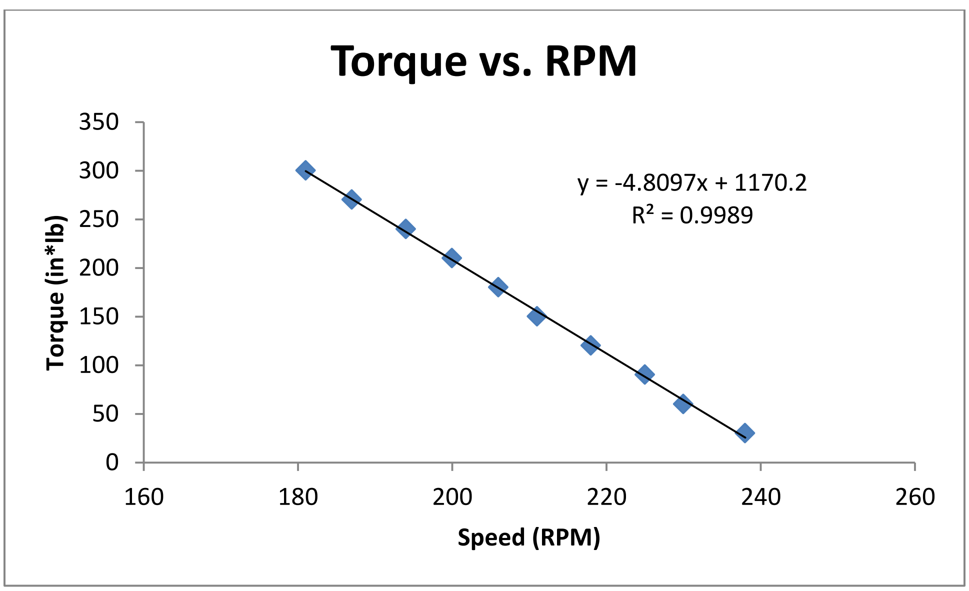


Figure 7.21: A plot showing the relationship between torque and rpm of the NPC-T64. The dynamometer data was taken from Robotic Marketplace's website and plotted in Excel. The data was fitted with a trend line to create a relation.

The internal forces in each linkage were determined using a static and nodal analysis with the dimensions in Table 7.1 and a 300 lbf load applied at the joint between the coupler and rocker. This analysis will yield the internal forces that the four-bar would experience during a worst case scenario, in which the linkages would lock up and take all the force from the weight assembly. A summary of the internal forces in the linkages can be found in Table 8.2 and the hand calculations and EES code can be found in the Appendix.

Table 7.2: Summary of the internal forces determined using static and nodal anaylsis.

Linkage	Force (lbf)
Crank	953.87
Coupler	1907.65
Rocker	499.87

The minimum area moment of inertia was determined using Euler Buckling equation, shown in Figure 8.22. The highest internal force, which occurred in the coupler, of 1907.65 lbf was inputted into equation with a safety factor of 2 and the column effective length factor of 1 was used since both ends of each linkage are pinned. The minimum area moment of inertia was determined to be 0.00475 in^4.

Figure 7.22: Euler Buckling Equation

$$P_{CR}F_S = \frac{\pi^2 E I_x}{K l^2}$$

Where,
P_{CR} = critical force
F_S = safety factor
E =modulus of elasticity
I = area moment of inertia
K = column effective length factor
l = unsupported length of column

Now that the minimum area moment of inertia required to prevent buckling at a worst case scenario is known, the cross-sectional area can be determined. Since the 608ZZ bearing have an outer diameter of 22mm and a thickness of 7mm, the first cross-sectional area that was chosen to be verified was 1.50” by 0.75.” The area moment of inertia of each linkage with these dimensions is 0.0625 in^4, which is greater than the minimum area moment of inertia required to prevent buckling. The first material chosen for verification was 6061 T6 aluminum because it is commonly used in bicycles, which undergo similar magnitudes of loading.

In order to verify the first iteration of dimensions and material, the stress in each linkage was calculated using internal forces that we determined earlier. A yield stress of 6061 T6 aluminum (40,000

psi) was then divided by this stress to produce a safety factor on yielding. The results of this analysis can be found in Table 8.3 below. The lowest safety factor of 15.73 on yielding occurs in the coupler, which verifies that the first iteration of dimensions and material will work and is, in fact, overdesigned. However, this overdesign is justified with respect to material cost because of the unpredictable nature of Method Sports' Longboards and Freebord.

Table 7.3: Summary of the safety factors calculated for yielding in each linkage using the internal forces in Table 8.2, 6061 T6 aluminum, and a 1.5" x 0.75" cross-sectional area.

Linkage	**Yielding Safety Factor**
Crank	31.45
Coupler	15.73
Rocker	60.02

Four-Bar Mount

The four-bar mount was integrated into the upper frame. Its main functions are to provide a sturdy mount for the NPC-T64 motor, act as the frame linkage, and provide the pivoting point for the moment arm. The four-bar mount was modeled in SolidWorks as an assembly with individual part files for each member since it was to be manufactured out of 1.5" square tubing. A picture of the assembly can be found below in Figure 8.23. Table 8.4 summarizes of cut lengths for each individual part that corresponds to the numbers the Figure 8.23. The part drawings listed in Table 8.4 can be found in the Appendix.

The parts FBM05 and FBM10 were designed as a buffer plate to keep the four-bar in plane in case it were to buckle. The dimensions of the four-bar mount were designed so that the four-bar interfaces with the longboards at a position where the front trucks were on the middle of the overall machine. The final design with the four-bar, NPC-T64 motor, and four-bar mount put together is shown in Figure 8.24.

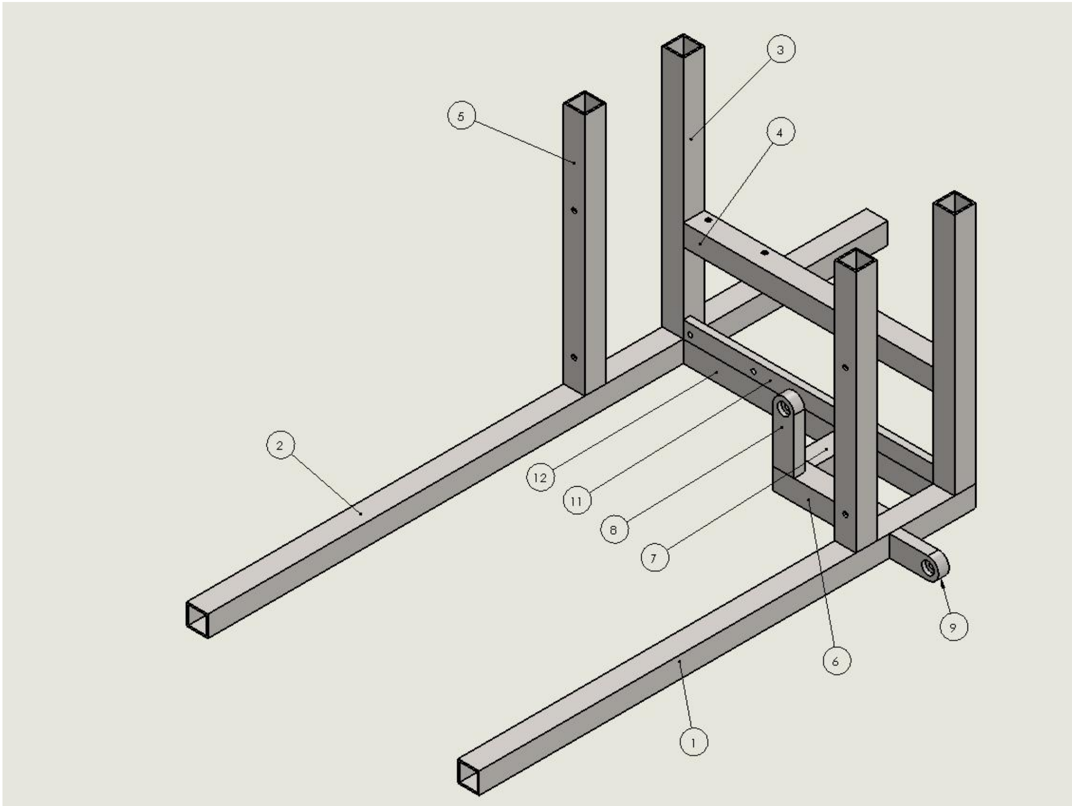


Figure 7.23: The four-bar mount assembly with individual members labeled.

Table 7.4: Summary of the cut lengths and descriptions for each member. The numbers listed in the first column, "Item Number," corresponds to the numbers in Figure 8.23.

Item Number	Part Number	Cut Length/Description	Quantity
1	FBM01	35.25"	1
2	FBM02	48.25"	1
3	FBM03	17.225"	2
12	FBM04	17.755"/See part drawing for hole dimensions.	1
5	FBM05	17.755"/See part drawing for hole dimensions.	2
6	FBM06	6.77"	1
7	FBM07	3.12"	1
8	FBM08	See part drawing for hole dimensions.	1
9	FBM09	See part drawing for hole dimensions.	1
10	FBM10	Not shown in Figure 8.4. See part drawing for hole dimensions.	1
11	FBM11	See part drawing for hole dimensions.	1
4	FBM12	17.755"/See part drawing for hole dimensions.	1

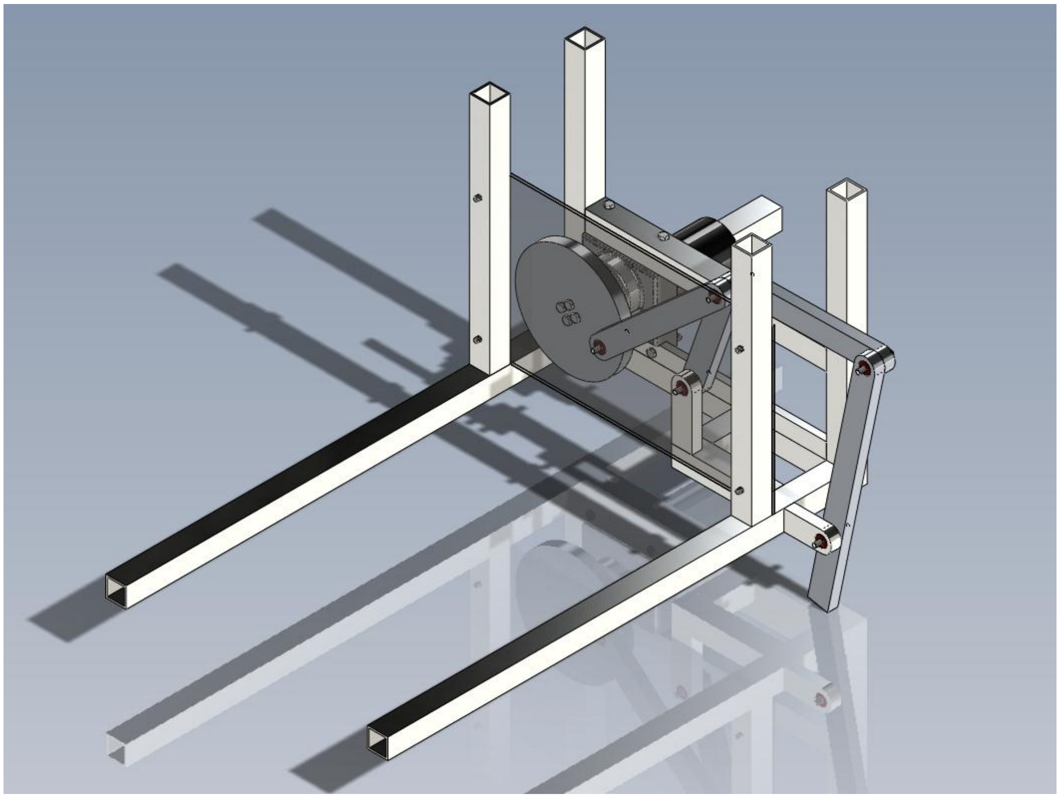


Figure 7.24: The four-bar, NPC-T64 motor, and four-bar mount assembled together.

Drivetrain

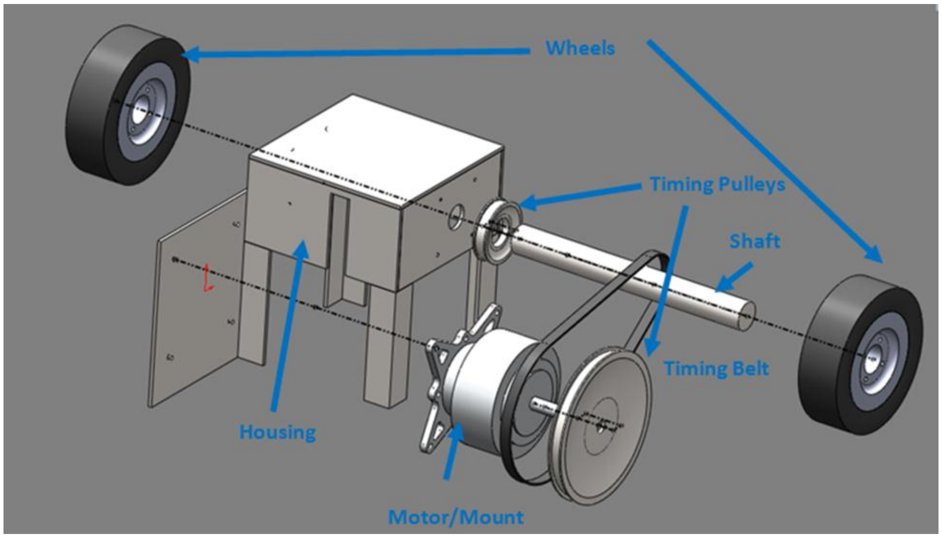


Figure 7.25: Drivetrain exploded view.

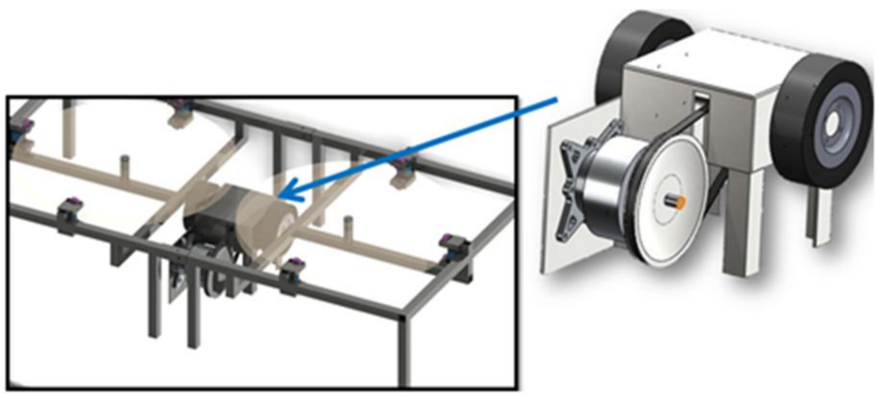


Figure 7.26: Drivetrain and location in machine assembly.

The drivetrain will consist of our motor, a toothed belt, two gears, a driveshaft, and two rubber wheels, including housing for the driveshaft. The motor is the Briggs & Stratton ETEK SN 01.08.0075. We will mount it to the housing using the motor-specific mounting plate, which was found via the internet. This motor mount will be attached to mounting plates on the drivetrain housing that have slots at the angle of the normal vector between the motor output shaft and the driveshaft to allow for tensioning the belt and for stretching and wear in the belt.

The output shaft of the motor will be fitted with a timing pulley which will be linked to the drivetrain by a timing belt and another timing pulley. See Appendix for timing pulleys and belts selected. The housing will be made of 1/4" plain carbon steel plates. The legs will be made of 1 3/4" x 1 3/4" tubes with a thickness of 1/16". The driveshaft will be 3/4 inches in diameter and will be supported in the housing by two 3/4" SKF flange-mounted bearings at either end of the pulley. The calculations we made on the forces seen by the bearings in the drivetrain showed a dynamic load rating safety factor of 13.9. The speed safety factor is 1.7. Reference the disk section again for calculations based on the loads in that application. Also, see Appendix for drawing and design specification sheet. The wheels will be 10 inch wheelchair wheels, NPC-PT444, found on robotmarketplace.com. When driven by the ETEK motor, these wheels will drive the wooden disks of the machine through friction, transferring the rotational

speed of the driveshaft to the disks. This ETEK motor will be driven by a controller selected by the sponsor

Figure 7.27: ETEK motor for drivetrain.

Figure 7.28: SKF 1.5 inch bore bearing for drivetrain, also for disks.

Disks

The disks are made of laminated maple plies with symmetric screwing. The dimensions will be 3.5 feet in diameter and 2 inches thick. The bearings used for the center axles of the disks are further explained in the drivetrain section and in the appendix. However, the calculations we performed based on the anticipated worst-case loads produced a safety factor of 28.1 for dynamic load rating and 7.0 for speed.

Maintenance Considerations

In order to keep maintenance costs low and convenient, Freebord components will be implemented into the machine wherever possible. Also, most of the parts will be fabricated in house so that it will be easy to remanufacture broken parts. The disk stabilizers will be fabricated by Paul and integrated into the frame so that they can be removed. Furthermore, they will use Freebord's caster and edge wheels as the rollers for support. The caster wheels are supported with the 608ZZ bearings and mounted with the caster axels and speed washers. The bearings will also connect the linkages of the four-bar together, along with 8 mm shafts.

Frequency of machine maintenance will be driven down because of the carefully calculated safety factors with which each component was chosen. The components of the machine were designed to operate without breaking any parts for the duration of 20 boards at the worst case scenarios (i.e. overestimating loads and life cycles). Using this conservative approach will allow the customer requires to be overly fulfilled.

The major components of the machine are designed to be modular so that the Freebord employees have the ability to maneuver it around the manufacturing facility. The disk stabilizers were designed to be removal so that the disks could be pulled out. The frame is designed as two pieces and the drive train was not integrated into the frame for maximum portability.

Safety Considerations

Since the purpose of this machine is to fatigue the boards until failure, a safety enclosure will be placed on the front and top of the frame. The machine will be placed in a corner so the sides can be neglected. The enclosure will be made out of polycarbonate Lexan glass, which is priced on McMaster-Carr at $221.63 for a 48" x 96" x ¼" sheet. Polycarbonate Lexan, rather than acrylic Lexan, was chosen for its impact strength, durability, resistance to temperature changes, and low weight.

A kill switch will also be implemented into the machine to shut off power to the motors when the board breaks. The two methods of triggering under consideration are a mechanical switch and an infrared sensor. The basic idea of having a mechanical switch would to be to attach a string to the board and an open circuit. When the board breaks and moves beyond the string's length, the circuit will be broken and the motors will shut off. The latter method entails sensors that work the same way a garage door opener works. When the board breaks the beam will be sensor will be blocked or opened, which would then trigger the motors to shut off.

Budget Estimate

A current budget estimate was made in order to see if the current design was on track for staying under Board Buster's budget. An estimated budget of just under $2500 was calculated. This total was calculate on the higher end of product and hopefully will leave a cushioning for the project as time moves on. It is important to note that the speed controllers and AC to DC converters have not been included in this figure because as of this time the company, type, and price of these units is unknown. The ability to use Freebord materials/product and in-house fabrication from Method has greatly increased the feasibility of the project budget-wise. Without these components, the budget would most likely go over the $3000 limit.

Table 7.5: Budget Estimate without speed controllers/converter included

Item	Quantity	Cost/Unit	Total
Frame			**$540.00**
Fabrication	1	In-house/Free	$0.00
Lexan	2	$120.00	$240.00
Materials	50	$6.00	$300.00
Disk			**$1,147.12**
CNC Routing/Fabrication	2	**$500.00**	$1,000.00
Bearings	4	$36.78	$147.12
Drivetrain			**$605.00**
Axle	1	$45.00	$45.00
Motor Plate	1	$55.00	$55.00
Motor	1	Free	$0.00
Housing	1	$200.00	$200.00
Pulley	2	$30.00	$60.00
Bearings	15	$2.00	$30.00
Belt	1	$15.00	$15.00
Tensioner	1	$40.00	$40.00
Wheel	2	$55.00	$110.00
Speed Controller	2	**TBD**	**TBD**
Hardware	1	$50.00	$50.00
Disk Stabilizers			**$50.00**
Wheels	18	Free	$0.00
Bearings	36	Free	$0.00
Machining/Fabrication	1	In-house/Free	$0.00
Miscellaneous	1	**$50.00**	$50.00
Rocker/Weight Assembly			**$115.00**
Sand	1	$20.00	$20.00
Metal	1	$50.00	$50.00
Bearings	8	Free	$0.00
Shaft	1	$45.00	$45.00
Fabrication	1	In-house/Free	$0.00
Total Cost			**$2,457.12**

8.0 Manufacturing

Lower Frame

The lower frame was built by Method Sports and was built to the specifications listed in the provided drawings of the project. The frame was built from the specified 1 ¾" x 1 ¾" square tubing, except wall thickness was reduced from .120" to 1/16". This was shown chosen because the frame is still under specification requirements with reference to design and safety factors and cost of the material was much cheaper than the original chosen material. This helped the project stay closer to the original budget goal.

Figure 8.1: Lower Frame Assembled with all other components on installed on the fatigue tester

As the frame was being built project sponsor, Paul Dickie, found that some areas would require additional gusseting and support based on his knowledge of working with fatigue testers such as this project for over 20 years. These gussets can be seen in the figure below. It was also determined when truing up the spinning driving disks the 6 Freebord support casters were not necessary and would not offer any support and would not be a wise investment of time based on the short fabrication time available.

Another feature that was slightly altered in comparison to the original design was the fastening system between the two lower halves of the lower frame. The original concept is still intact where two ½” bolts on each side connect the two halves together by bolting the halves together. Except no instead of making a full inclosing collar made of 2” x 2” square tubing, angle iron was used so that there was a more secure fit and the fit was more guaranteed and easier to fabricate. Also the electric weld that in square metal tubing would interfere with the two tubes sliding into each other. The angle iron bypasses this issue. With this new system the drivetrain was also able to be attached to this system. This newer drivetrain connection system is explained more in the drivetrain section.

Figure8.2: Drivetrain is connected via bolts holding the two halves together.

The lower frame is still to original dimensions regarding footprint and height. These were the main driving factors as the teams need to ensure the fatigue tester would properly fit in the Freebord factory based on the previously discussed size requirements.

Disk Stabilizers

The disk stabilizers were made by Derek Chan and David Chan in Shingle Springs, CA. The disk stabilizer brackets were then sent to Method Sports, Inc in Fresno, CA. They were then installed onto the lower frame as planned originally. The lower brackets were welded on, while the top brackets are still removable and are bolted onto the lower frame via 3/8” bolts. The disk stabilizers were made to the set dimensions in the provided engineering drawings found in the following appendices. The stabilizers both top and bottom were constructed out of the originally planned 1/8” carbon steel plate. The brackets were welded using a MIG welder.

Figure 8.3: Since the Upper Frame was originally planned to slide into the Lower Frame, it needed to be insured that the bracket would not interfere with sliding motion of the integration of the upper and lower frames. Each set was labeled with instructions.

Figure 8.4: A top and bottom disk stabilizer bracket. A 59mm wheel w/ bearings and axle are installed on each bracket. The lower half is welding onto the lower frame. The top bracket is bolted onto the lower frame via a 3/8” bolt.

After running a finite element analysis on the bracket, it was shown that the annealing properties the welding gives the steel would cause a possible failure in bending moment mode. This was solved by providing four gussets on each bracket. This would, in theory, solve the bending moment failure mode and would keep the disk stabilizer functional for its intended use.

Another feature changed was using angle iron to create place holders and make installation easier. The lower frame had angle iron welded on so that they could be set easily when being welded on and butted up against the bottom of the top horizontal running tube on the lower frame.

The backings on the brackets were each made differently to accommodate for each brackets specific placement. Some brackets had tubing in the back that needed to be accounted for, while others were just welded onto a single horizontal beam. Each stabilizer was labeled and instructions were provided to Method Sports, Inc. for installation.

Upper Frame

The upper frame of the Board Buster Fatigue assembly was made by Method Sports, Inc in Fresno, CA. The upper frame was made from the specified 1 ½” x 1 ½” steel square tubing with the exception of the wall thickness. Thickness was cut down from .125” to 1/16” thick tubing. This was acceptable because the lower thickness still met all design and safety factor considerations.

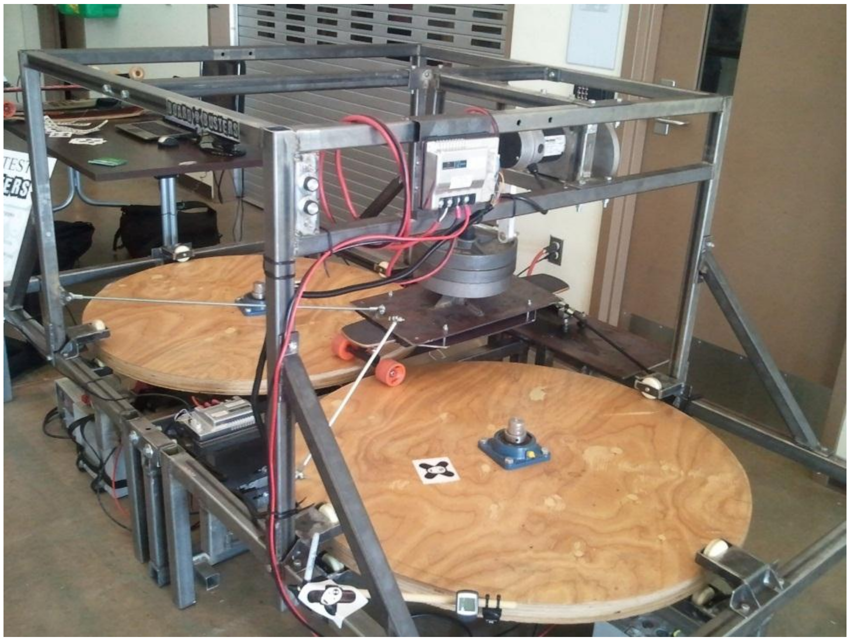


Figure 8.5: Upper frame with all controller and components attached and installed on fatigue tester

The original footprint of the upper frame was rectangular and the 3 of the 4 legs would slide into the lower frame to secure the upper frame to the fatigue machine. When fabrication was done, it was found that the electric weld on the inner of the tubes from when the tube was being made restricted this action and the tubes were not able to slide into each other, without major modification of raw materials. The solution to this was to have the upper frame bolt on using angle iron and fasteners onto the lower frame. This offers better contact points and better structural stability.

The upper frame's footprint was also changed from its original design. The new foot print is now a square and can support the four-bar in different directions. The four-bar mount was also altered slightly to accommodate for the change in shape of the upper frame. This change is discussed further in the four-bar manufacturing section.

The upper frame still has the same concepts and ideas. The fastening and functionality has been improved and will be even more suitable that the original design. The ball socket joint on top of the upper frame is still present as shown in the original design and used for the weight assembly.

Slider

The slider was fabricated by Method Sports, Inc in Fresno, CA. The slider is made of carbon steel as originally specified. In addition to the design, two more ball transfers were added to the board slider plate. The plate has now been modified to make it easier to install by keeping the Method trucks on the board and having the plate attach underneath the trucks. The 4 ball transfers still ride on the slider plate that is welded onto the lower frame.

Figure 8.6: Back Slider. Plate installs on back trucks and uses ball transfers to slide on another plate installed on lower frame

The additional ball transfers were added because there was concern that the board would tip and the ball transfers were not be in contact with the slider plate, thus making the ball transfer not function as originally intended for the fatigue tester simulation. The addition of the extra ball transfers will help the board stay on the tester and the fact that they are integrated with the trucks will provide a more realistic riding and turning simulation.

Weight Assembly

The weight assembly was manufactured by Method Sports, Inc in Fresno, CA. The weights were found in Sacramento by Derek Chan. The assembly is still made of carbon steel and the original concepts are still present. There are several components to the weight assembly that were changed due to possible weakness and time constraints. These changes did not change the original design concept idea they only strengthened and made them more functional.

Figure 8.7: Eight 25lb plate weights used to simulate the load on the boards. The weights are individually removable to adjust rider weight simulation between 25-225lbs in 25lb intervals.

Figure 8.8: The weight assembly was modified to sandwich in a board and hold weights. The fixture without weights is ~ 70lbs.

The weight tubing is not telescoping due to lack of time to gather resources and fabricate, but there are plan for the machine to have a telescoping feature later on in its testing life. The board secure was made beefier and more gussets were given to it to ensure that the part would not fail. This was based on Paul Dickie of Method Sports, Inc ‘s 20 plus years of working with fatigue machinery. The board secure now sandwiches the board all around and uses more material to secure the board to the weights. This is necessary to ensure the life of the fatigue tester requirement is met.

Four-Bar

The four-bar linkages were modeled in SolidWorks and then brought to the Mustang ’60 Shop, which is located on the Cal Poly SLO campus in the Bonderson Engineering Center Building 197. The drawings that were shown to the shop technicians can be found in the Appendix. The linkages were fabricated out of a 5 foot long 1.5” x 0.75” rectangular blank and an 8” diameter circular blank with a CNC Mill. A ½” diameter two-flute carbide end mill was used face the circular blank to a thickness of 0.75” and round of the edges of the linkages. The holes were reamed to the specifications that were listed in the drawings. The total job including coding and machining was quoted to be 7.5 hours. The finished product is shown below in Figure 8.9.

Figure 8.9: A picture of the fabricated four-bar linkages.

During the manufacturing of the upper frame and weight assembly, the connecting linkage was changed from a solid link to an all-thread shaft with ball linkages on the ends. This will allow the sweeping angle of the weight assembly to be adjusted based on the sponsors’ needs. Furthermore, an additional hole was made on the rocker to act as the new joint for the coupler. This change was made because the height of the weights while they were stacked together interfered with the linkage.

However, the overall concept, sweeping angle, and linkage dimensions were still implemented in the machine. The four-bar implemented in the actual machine is shown in Figure 8.10.

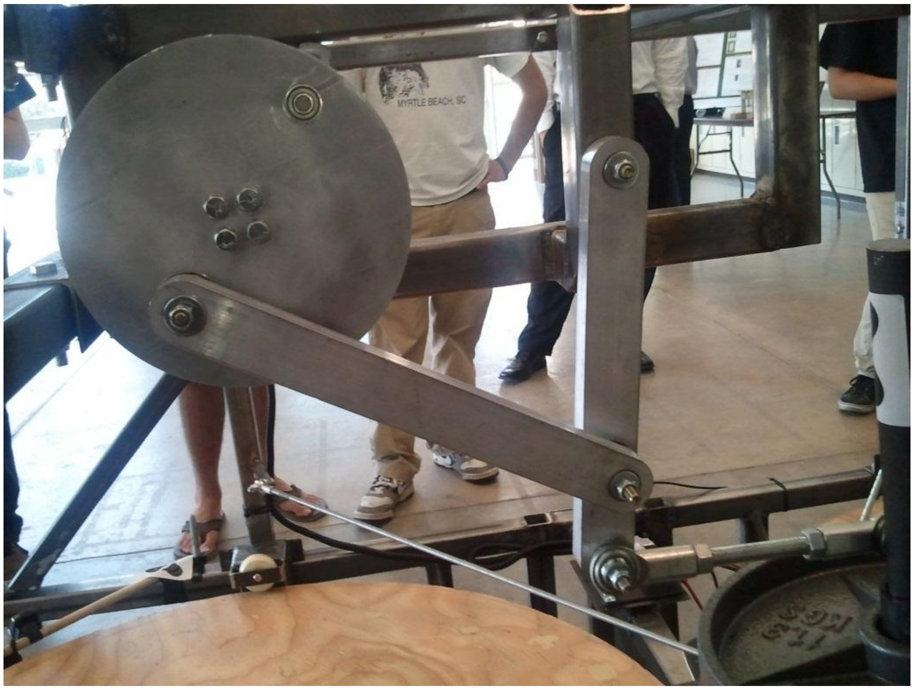


Figure 8.10 The four-bar implemented in the machine while testing a Method Sports Longboard.

Four-Bar Mount

The four-bar mount was altered during fabrication so that the NPC-T64 motor and four-bar can be mounted in different positions. This will allow for the longboards and Freebords to be configured in different riding positions. The 1.5" tubes were cut to and then SMAW welded together. The final four-bar mount construction is shown in Figure 8.7.

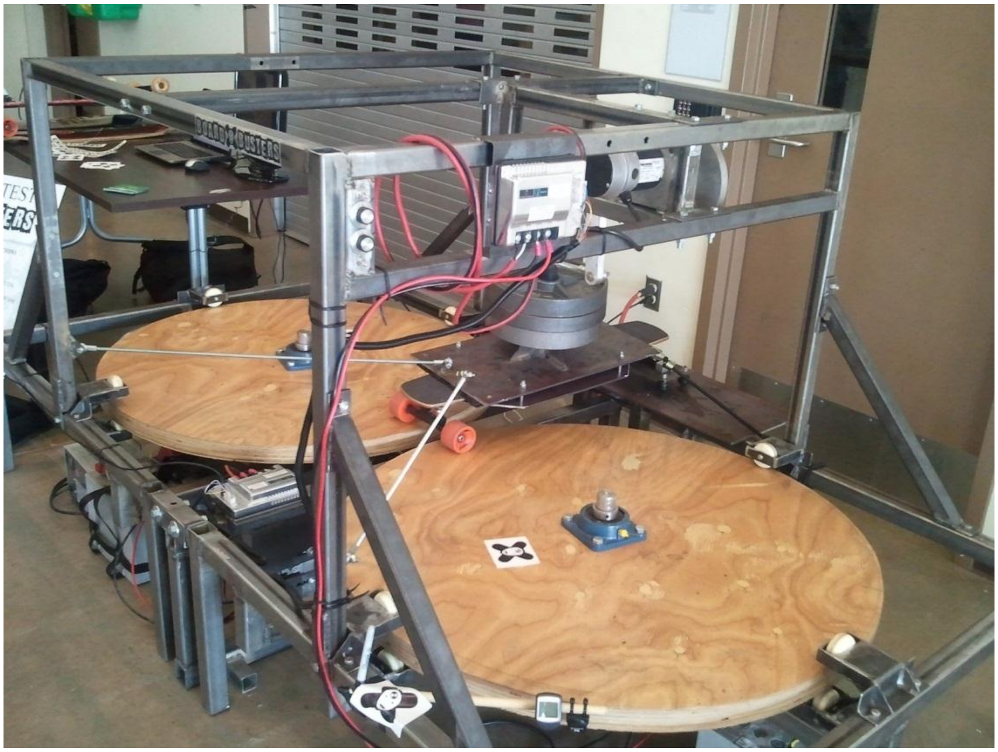


Figure 8.11: Final four-bar mount construction. The holes in the picture show the different positions in which the four-bar can be mounted.

Drivetrain

The drivetrain of the Board Buster's apparatus was manufactured by Method Sports, Inc. It underwent a few design iterations, but ended up being made of the same 1 3/4" x 1 3/4" square tubing as the lower frame with 1/16" thick walls. This was chosen as a convenience to allow the same tubing to be used for the drivetrain as that which was already being purchased and used for the lower frame.

Figure 8.11: Drivetrain module.

The original design of the drivetrain was changed in order to integrate it into the lower frame more effectively. Previously, the drivetrain was to be held in place by friction as well as tabs which would interface with the lower frame. The drivetrain now connects the two pieces of the lower frame together, which also acts to hold the drivetrain in place with the lower frame. This also eliminated the majority of the actual housing, which would have proved to be cumbersome. The final alteration that happened was due to manufacturing constraints, and it proved to work more effectively. This was the addition of a power screw to allow for adjustability of the wheels as wear occurs. The power screw acts as a jack to raise and lower the wheelchair wheels (which drive the wooden disks). This will be easier than adjusting five separate screw feet and will ensure solid contact between the driving wheelchair wheels and the driven wooden disks.

Many of the original ideas were carried over to the final design. The adjustability of the motor mount has stayed, allowing for adjustability due to timing belt wear and for tensioning of the belt. The changes that were made have simplified the original design while keeping the basic ideas and improving some of the functionality and ease of use.

Disks

The disks in the fatigue tester were manufactured by a wood shop that does work for Method Sports, Inc. They were made from laminated plywood sheets, cut to a diameter of 3.5 feet. The thickness is 2" with a through-hole in the middle to accommodate the center axles. Four additional holes were drilled around the center hole for attaching the bearings.

The bearings – donated by SKF – are attached by the through-holes in the disks. There is one disk per side to provide maximum stability. The disks were manufactured per design with the only change being that they ended up having a little less thickness than originally prescribed due to standard thicknesses of plywood sheets. This was acceptable as the disks were not deemed to be close to failure due to their thickness.

9.0 Design Verification Plan

In order to verify the apparatus is in its intended working condition, Board Busters have devised a Design Validation Plan and Report (DVPR) which will test all aspects of the customer requirements. Each specification has a complimentary test which it must pass to the satisfaction of a defined acceptance criteria. When testing takes place, each specification will be assessed to see if it passes the acceptance criteria and the date and any additional notes will be recorded. While developing this plan, Board Busters ensured that all aspects of the beginning customer requirements would be tested to their acceptable level. See the Appendix for the Design Verification Plan.

10.0 Management Plan

Derek Chan

Sponsor Contact	Main contact with Paul Dickie and Steve Bianco.
Documentation of Project Progress	Documenting the progress of the project so information will be organized/available when needed.
Testing Plans	Organizing any testing and scheduling how and when the tests will be performed.
FEA	Creating Finite Element Analysis models for a determined Component.
Stress and Fatigue Analyst	Examine any stresses present in our system.
Solid Modeling	Responsible for developing any CAD models needed.
Head of Presentations	Heading the creation of any presentations. Includes compiling, transferring, etc.
Frame	Head of designing and developing the frame of our system.

Colin Harris

Solid Modeling	Responsible for developing any CAD models needed.
Stress and Fatigue Analysis	Examine any stresses present in our system.
Program Specialist	Head of implementing/developing any type of program present in the system.
Drafter	Responsible for hand drawings and any other hand drafting.
Testing Plans	Organizing any testing and scheduling how and when the tests will be performed.
FEA	Creating Finite Element Analysis models for a determined Component.
Hydraulics and Loading	Responsible for developing any hydraulic or load systems in our Project.
Head of Reports	Heading the creation of any reports. Includes compiling, organizing, etc.

Nico Lee

Prototype Fabrication	Head of building/organizing the prototype creation.
Documentation of Project Process	Documenting the progress of the project so information will be organized/available when needed.
Information Gathering	Heading the background information collection.
Outside Resources/Vendor Relations	Main contact for outside resource companies and responsible for contact them.
Drafter	Responsible for hand drawings and any other hand drafting.
Static/Truss Analysis	Responsible for analyzing any statics/truss present in our Project.
Controls Specialist	Any type of controls system will be headed by Nico.
Drive Train	Head of designing the drive train.
Manufacturing Considerations	Responsible for determining how parts made by Board Busters should be created/machined.

Tasks Involving Sponsor

~~Project Proposal (10/20/11)~~

~~Conceptual Model (11/1-8/11)~~

~~Conceptual Design Review (12/5/11)~~

~~Critical Design Review (1/26/12)~~

~~-Design review finalizing all major design components~~

Design Report (2/2/12)

-Continued development of conceptual design report

Manufacturing and Test Review (3/6/12)

-Review of testing, manufacturing, and assembly procedures and progress

Project Update Memo (3/26/12)

-Final major sponsor update on project progress

Hardware Demo (5/7/12)

-Demonstration of fully-obtained and working hardware

Design Expo (5/31/12)

-Public demonstration and presentation of completed project

Appendix

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Anatomy of a Truck

Axle	This holds the bearings, which hold the wheels.
Axle offset/rake	This describes the axle's position compared to the pivot axis. This is also referred to as the Caster Angle.
Axle travel	This is the path the axle takes when it rotates on the pivot axis.
Baseplate	This bolts to the board, in turn holds the kingpin and pivot-cup.
Bottom bushing	Made from polyurethane, it helps hold the hanger in place and control turning. The bottom bushing also takes rider weight.
Bushing seat	This part of the hanger is shaped to help the bushings keep the hanger in the right place.
Caster	Positive Caster is the tendency for the truck to stay centered. Negative Caster is the tendency of the truck to stay in a turn. This is determined by the axle offset being either above or below the axle.
Cup washer	These help push the bushings into the hanger's bushing-seat. The cup shape also helps control the shape of the bushing's distortion when the hanger turns.
Hanger	The hanger holds the axle, the bushings and has a pivot. Its width controls the distance between the truck's wheels.
Kingpin	This bolt holds the truck together as one unit. How tight it is affects how the board turns.
Pivot	Part of the hanger, it helps hold the hanger in place, as well as constrain its motion to the pivot axis.
Pivot-axis	This is what the hanger rotates around when it turns.
Pivot-cup	Made from hard polyurethane, it holds the pivot in the correct position.
Roll-axis	This line is what the board rotates around when it leans.
Roll center	Defined where a line, square with the board, crosses both the axle's center, and the pivot axis. A line between these points on both trucks defines the roll axis.
Top bushing	Made from polyurethane, it helps hold the hanger in place and control turning.

Table A.1: Disk bearing calculations.

Property	Formula	Property	Values	units	Answer	Units
V	73.3	speed	50	mph	73.3	ft/sec
omega	400.2	r	1.75	feet	400.2	rpm
Ld	5.76E+05	Length per day	24	hr/day	5.76E+05	revs
		Length of test	5	day		
		# of tests	20	boards		
af	1.5				1.5	
Fe	120	Fr	240	-	120	
Kr	0.219	X0	0.02	-	0.219	
		theta	4.459	-		
		b	1.483	-		
		Rd (desired reliability)	0.99	-		
x_d	0.58				0.58	
Lr	1.00E+06				1.00E+06	revs
a	3				3	
C10req'd	248.5				248.5	lbf
C10req'd	1.09				1.09	kN
Rated C10	3.3				30.7	kN
C10 Safety Factor	28.1				**28.1**	
Limiting Speed	2800				2800	rpm
Speed Safety Factor	7.0				**7.0**	

Table A.2: Drivetrain bearing calculations.

Property	Formula	Property	Values	Units	Answer	Units
V	73.3	speed	50	mph	73.3	ft/sec
omega	1680.7	r	0.417	feet	1680.7	rpm
Ld	2.42E+06	Length per day	24	hr/day	2.42E+06	revs
		Length of test	5	day		
		# of tests	20	boards		
af	1.5				1.5	
Fe	150	Fr	300	-	150	
Kr	0.219	X0	0.02	-	0.219	
		theta	4.459	-		
		b	1.483	-		
		Rd (desired reliability)	0.99	-		
x_d	2.42				2.42	
Lr	1.00E+06				1.00E+06	revs
a	3				3	
C10req'd	501.2				501.2	lbf
C10req'd	2.21				2.21	kN
Rated C10	3.3				30.7	kN
C10 Safety Factor	13.9				**13.9**	
Limiting Speed	2800				2800	rpm
Speed Safety Factor	1.7				**1.7**	

Table A.4: Caster bearing calculations.

Property	Formula	Property	Values	units	Answer	Units
V	73.3	speed	50	mph	73.3	ft/sec
omega	7219	r	0.097	feet	7219	rpm
Ld	1.04E+07	Length per day	24	hr/day	1.04E+07	revs
		Length of test	5	day		
		# of tests	20	boards		
af	1.5				1.5	
Fe	12.5	Fr	150	-	12.5	
Kr	0.219	X0	0.02	-	0.219	
		theta	4.459	-		
		b	1.483	-		
		Rd (desired reliability)	0.99	-		
x_d	10.4				10.4	
Lr	1.00E+06				1.00E+06	revs
a	3				3	
C10req'd	67.9				67.9	lbf
C10req'd	0.30				0.30	kN
Rated C10	3.3				3.3	kN
C10 Safety Factor	11.0				**11.0**	
Limiting Speed	34000				34000	rpm
Speed Safety Factor	4.7				**4.7**	

Figure A.5. Driveshaft calculations.

Allowable Yield Strength, 1018 Steel (psi)

32000

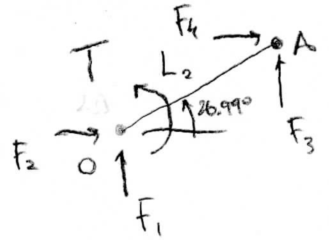
Attribute	Value	Unit	Description
W	300	lb	Load
x	1.22	in	Distance
l	2.44	in	Total Distance between bearings
Z	0.041417481		Section Modulus of the cross-section of the beam
E	3.00E+07	psi	Modulus of Elasticity
I	0.015531555	in^4	Moment of Inertia
y	-	in	deflection
s		psi	Stress at the cross-section being evaluated
d	0.75	in	Shaft Diameter
b	0.53	in	Beam Base
h	0.53	in	Beam Height

	Value	Units	Safety Factor
Stress at Specific Point	8836.848	psi	3.621
Stress at the Support (Must be Constant Cross Section)	17673.697	psi	**1.811**
Deflection at Specified Point	0.00097	in	
Deflection at Unsupported End	**0.00312**	in	

Table A.3: Four-bar bearing calculations.

Property	Formula	Property	Values	units	Answer	Units
V						ft/sec
omega	20	r	1.75	feet	20.00	rpm
Ld	2.88E+04	Length per day	24	hr/day	2.88E+04	revs
		Length of test	5	day		
		# of tests	20	boards		
af	1.5				1.5	
Fe	132.5	Fr	265	-	132.5	
Kr	0.219	X0	0.02	-	0.219	
		theta	4.459	-		
		b	1.483	-		
		Rd (desired reliability)	0.99	-		
x_d	0.029				0.029	
Lr	1.00E+06				1.00E+06	revs
a	3				3	
C10req'd	101.1				101.1	lbf
C10req'd	0.44				0.44	kN
Rated C10	3.3				3.3	kN
C10 Safety Factor	7.4				**7.4**	
Limiting Speed	34000				34000	rpm
Speed Safety Factor	1700				**1700**	

FBD: MEMBER OA

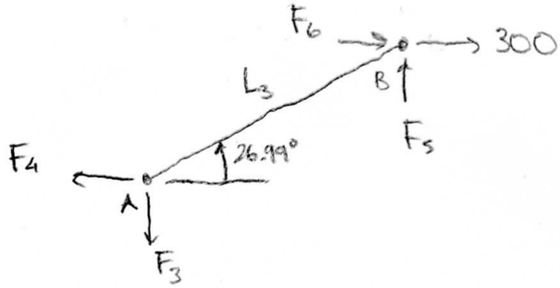


$$+\uparrow \Sigma F_y: F_1 + F_3 = 0 \quad (1)$$

$$\xrightarrow{+} \Sigma F_x: F_2 + F_4 = 0 \quad (2)$$

$$+\circlearrowleft \Sigma M_O: T + \underbrace{F_3 L_2 \cos 26.99°}_{a} - \underbrace{F_4 L_2 \sin 26.99°}_{-b} = 0 \quad (3)$$

FBD: MEMBER AB

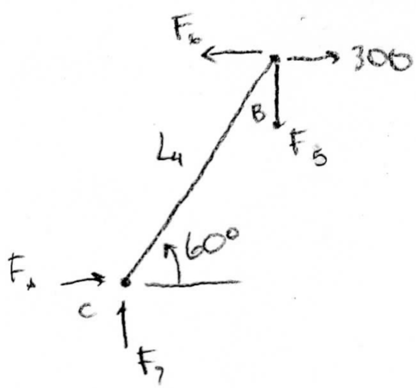


$$+\uparrow \Sigma F_y: -F_3 + F_5 = 0 \quad (4)$$

$$\xrightarrow{+} \Sigma F_x: -F_4 + F_6 = -300 \quad (5)$$

$$+\circlearrowleft \Sigma M_A: \underbrace{F_5 L_3 \cos 26.99°}_{c} - \underbrace{F_6 L_3 \sin 26.99°}_{-d} = \underbrace{300 L_3 \sin 26.99}_{d} \quad (6)$$

FBD: MEMBER BC



$$+\uparrow \Sigma F_y: -F_5 + F_7 = 0 \quad (7)$$

$$\xrightarrow{+} \Sigma F_x: -F_6 + F_8 = -300 \quad (8)$$

$$+\circlearrowleft \Sigma M_B: \underbrace{-F_7 L_4 \cos 60°}_{e} + \underbrace{F_8 L_4 \sin 60°}_{f} = 0 \quad (9)$$

[SEE EES CODE FOR SOLUTIONS]

$F_1 = -432.9$ lbf

$F_2 = -849.9$ lbf

$F_3 = 432.9$ lbf

$F_4 = 849.9$ lbf

$F_5 = 432.9$ lbf

$F_6 = 549.9$ lbf

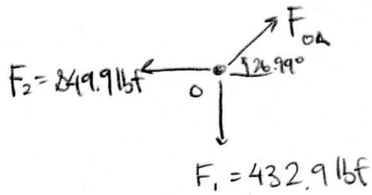
$F_7 = 432.9$ lbf

$F_8 = 249.9$ lbf

$T = 0$ in.lbf

SOLVE FOR MEMBER FORCES

FBD @ NODE O



$+\uparrow \Sigma F_y$: $-432.9\,lbf + F_{OA}\sin 26.99° = 0$

$$F_{OA} = \frac{432.9\,lbf}{\sin 26.99°}$$

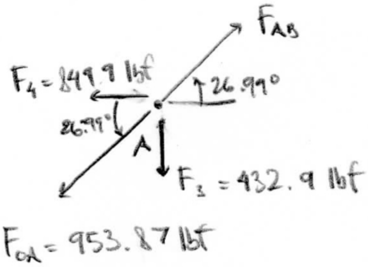
$$F_{OA} = 953.87\,lbf$$

$\overset{+}{\rightarrow} \Sigma F_x$: $-849.9\,lbf + F_{OA}\cos 26.99° = 0$

$$F_{OA} = \frac{849.9\,lbf}{\cos 26.99°}$$

$$F_{OA} = 953.87\,lbf \checkmark$$

FBD @ NODE A



$+\uparrow \Sigma F_y$: $F_{AB}\sin 26.99 - 432.9\,lbf - 953.87\sin 26.99 = 0$

$$F_{AB} = \frac{953.87\sin 26.99° + 432.9}{\sin 26.99°}$$

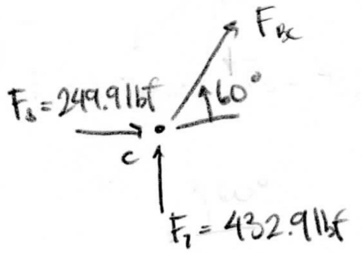
$$F_{AB} = 1907.74\,lbf$$

$\overset{+}{\rightarrow} \Sigma F_x$: $F_{AB}\cos 26.99° - 849.9\,lbf - 953.87\cos 26.99° = 0$

$$F_{AB} = \frac{849.9\,lbf + 953.87\cos 26.99°}{\cos 26.99°}$$

$$F_{AB} = 1907.65\,lbf \checkmark$$

FBD @ NODE C



$+\uparrow \Sigma F_y$: $432.9\,lbf + F_{BC}\sin 60 = 0$

$$F_{BC} = \frac{432.9\,lbf}{\sin 60°}$$

$$F_{BC} = 499.87\,lbf$$

$\overset{+}{\rightarrow} \Sigma F_x$: $249.9\,lbf + F_{BC}\cos 60 = 0$

$$F_{BC} = \frac{249.9\,lbf}{\cos 60}$$

$$F_{BC} = 499.87\,lbf \checkmark$$

CHOOSE CROSS-SECTIONAL AREA BASED ON EULER BUCKLING AND HIGHEST MEMBER FORCE (MEMBER AB - COUPLER LINKAGE)

$$P_{CR} F_S = \frac{\pi^2 E I_x}{l^2}$$

E → $E_{AL} = 10.4\text{E}6$ psi

l → LENGTH OF COUPLER

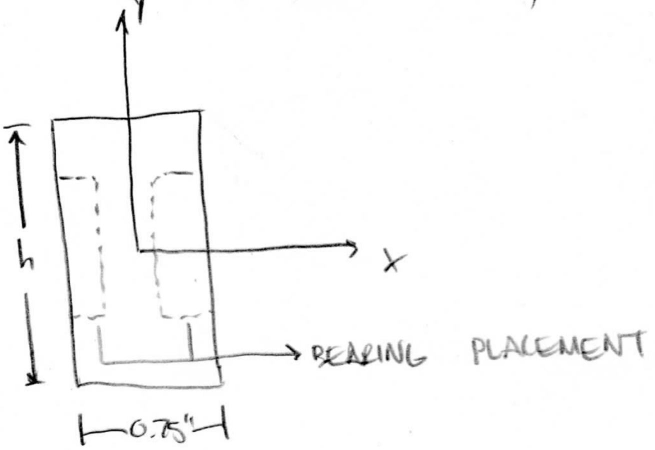
F_S → FACTOR OF SAFETY OF 2

P_{CR} → PLUG IN 1907.65 lbf

$$I_x = \frac{P_{CR} F_S l^2}{\pi^2 E_{AL}} = \frac{(1907.65)(2)(11.31\text{ in})^2}{\pi^2 (10.4\text{E}6\text{ psi})}$$

$$I_x = 0.00475 \text{ in}^4$$

CHOOSE RECTANGULAR CROSS-SECTIONAL AREA AND A BASE OF 0.75" INCHES SINCE A BEARINGS WILL BE INSTALLED ON EACH FACE. BEARINGS ARE 7 mm WIDE $(0.276 \text{ in} \times 2 = .552 \text{ in})$. SOLVE FOR MINIMUM HEIGHT (h_{MIN})



$$I_x = \frac{bh^3}{12}$$

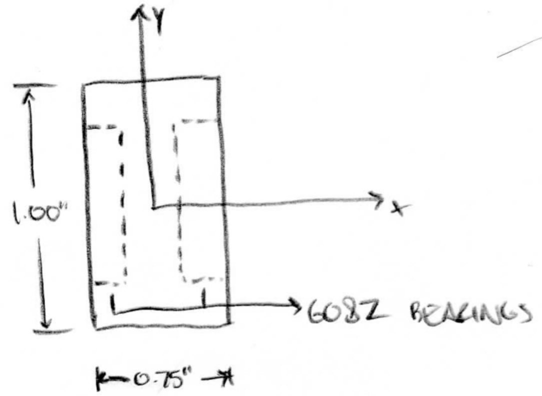
$$h_{MIN} = \sqrt[3]{\frac{I_x 12}{b}} = \sqrt[3]{\frac{(0.00475 \text{ in}^4)(12)}{0.75\text{in}}}$$

$h_{MIN} = 0.42$ → MINIMUM HEIGHT OF LINKAGES

SINCE BEARING HAS AN OD OF 22 mm (.866 in), CHOOSE A HEIGHT OF 1 in

1ST ITERATION DIMENSIONS

CROSS-SECTIONAL CUT



MATERIAL PROPERTIES (MATWEB)

ALUMINUM 6061 T6

$\sigma_{ULT} = 45000$ psi

$\sigma_{YIELD} = 40000$ psi

$E = 10.4 \times 10^6$ psi

$\nu = 0.33$

$\rho = 0.0975$ lbf/in^3

$I = 0.0625$ in^4

CHECK FOR YIELDING / CALCULATE AXIAL DEFORMATION

COUPLER : MEMBER AB

$$\sigma_{ACTUAL} = \frac{P}{A} = \frac{1907.65 \text{ lbf}}{(1.00" \times 0.75")} = \underline{2543.53 \text{ psi}}$$

$$F_{S_{COUPLER}} = \frac{\sigma_{YIELD}}{\sigma_{ACT}} = 15.73$$ → YIELD SAFETY FACTOR FOR COUPLER

$$\delta_{COUPLER} = \frac{\sigma L}{E} = \frac{(2543.53 \text{ psi})(11.31 \text{ in})}{(10.4 \times 10^6 \text{ psi})}$$

$$\delta_{COUPLER} = \underline{0.0028 \text{ in}}$$ ✓

CRANK : MEMBER OA

$$\sigma_{ACTUAL} = \frac{953.87 \text{ lbf}}{(1.00" \times 0.75")} = \underline{1271.83 \text{ psi}}$$

$$F_{S_{CRANK}} = 31.45$$

$$\delta_{CRANK} = \frac{(1271.83 \text{ psi})(3 \text{ in})}{(10.4 \times 10^6 \text{ psi})}$$

$$\delta_{CRANK} = \underline{0.0004 \text{ in}}$$ ✓

ROCKER: MEMBER BC

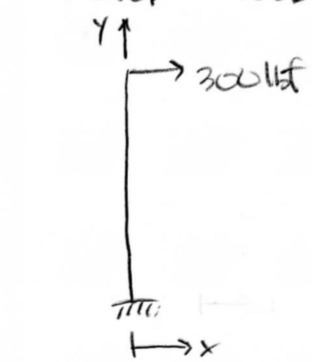
$$\sigma_{ACTUAL} = \frac{499.87\ lbf}{(1.00" * 0.75")} = \underline{666.49\ psi}$$

$$F_{S_{ROCKER}} = 60.0R$$

$$\delta_{ROCKER} = \frac{(666.49\ psi)(7.5\ in)}{10.4 * 10^6\ psi}$$

$$\delta_{ROCKER} = \underline{0.0005\ in} \checkmark$$

→ MODEL ROCKER AS CANTILEVER BEAM AS WORST CASE SCENARIO



FROM SHIGLEY'S SUPERPOSITION TABLES

$$x_{MAX} = \frac{Fl^3}{3EI} = \frac{(300\ lbf)(7.5\ in)}{3(10.4 * 10^6\ psi)(0.0625\ in^4)}$$

$$x_{MAX} = \underline{0.0012\ in} \checkmark$$

Each Bracket Labeled: **Position # / Orientation** (on a yellow dot)

Position #

Since all lower frame backings are **NOT** the same. The labeled number represents the bracket placement seen in Figure 2.

Orientation

T = Top
B = Bottom

i.e. 3B – Represents the bottom bracket at the #3 bubble in Figure 2

Tops (T)

-NO tops should be welded on to the main frame.

-# 1, 4, 5, 6 are identical

-#2, 3 are identical

-Back angle-iron holes are 3/8" diameter holes. 3/8" thru holes need to be drilled into the top of the horizontal running 1 ¾" x 1 ¾" square tube on the lower frame. Bolts are then used to secure the tops to the frame. Sure lock washers will be used to keep bolts from loosening.

-Washers can be stacked to adjust for bracket height (different road thickness, tolerance accommodation)

-#2,3 have a space in the middle of the angle iron on the back of the bracket. This is to accommodate for the vertical 1 ½" square tube from the upper frame that slides into the 1 ¾" square hole in the lower frame.

Bottoms (B)

-ALL bottom brackets will be welded on to the main lower frame.

-Welds on the main lower frame should be ground flush every where the backing of brackets touch.

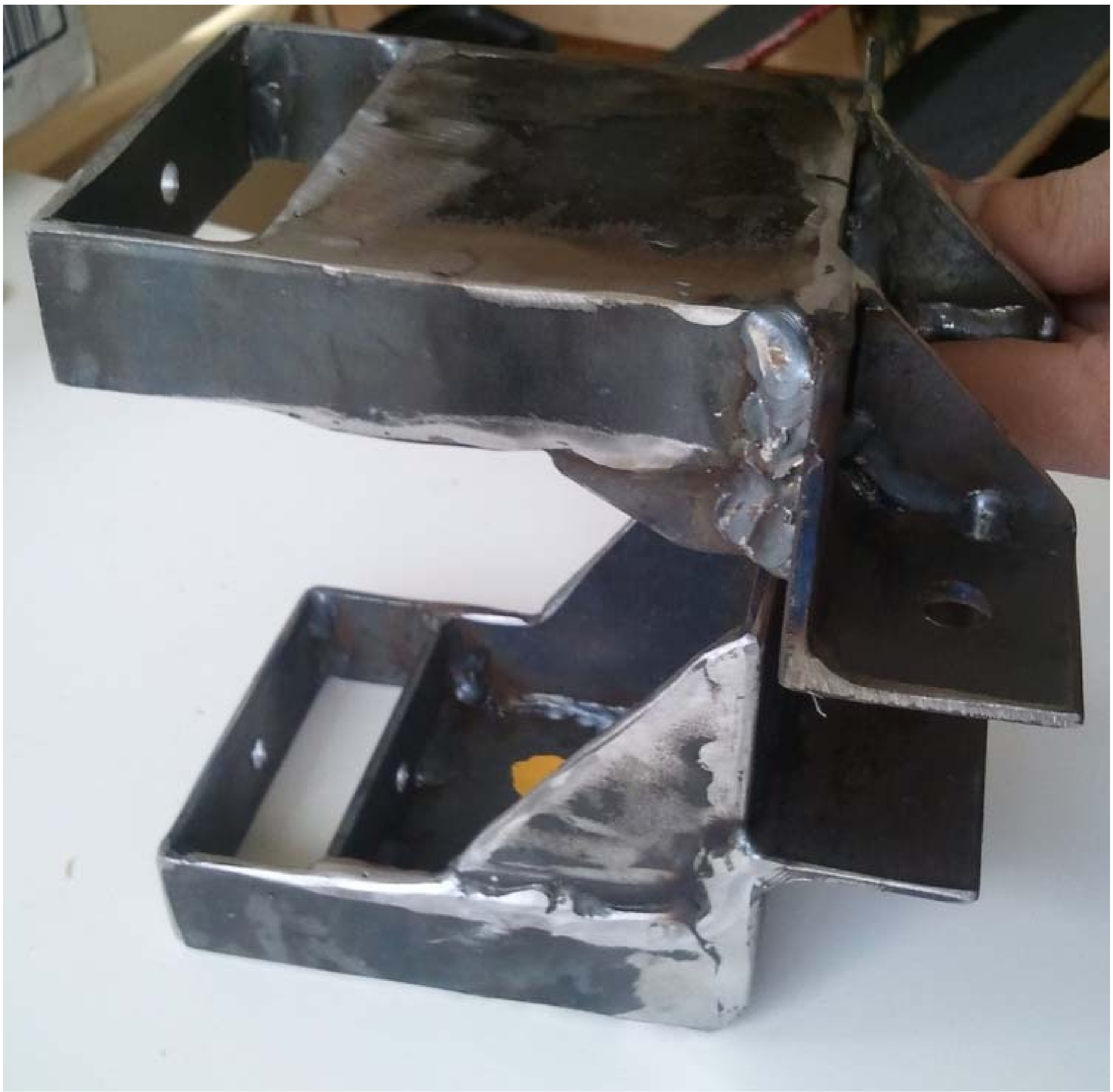
-The top edge of the bottom bracket should be welded **FLUSH W/ THE TOP FACE** of the horizontal 1 ¾" square tube running behind it. This edge is marked w/ 2 UP arrows in sharpie on each bottom bracket.

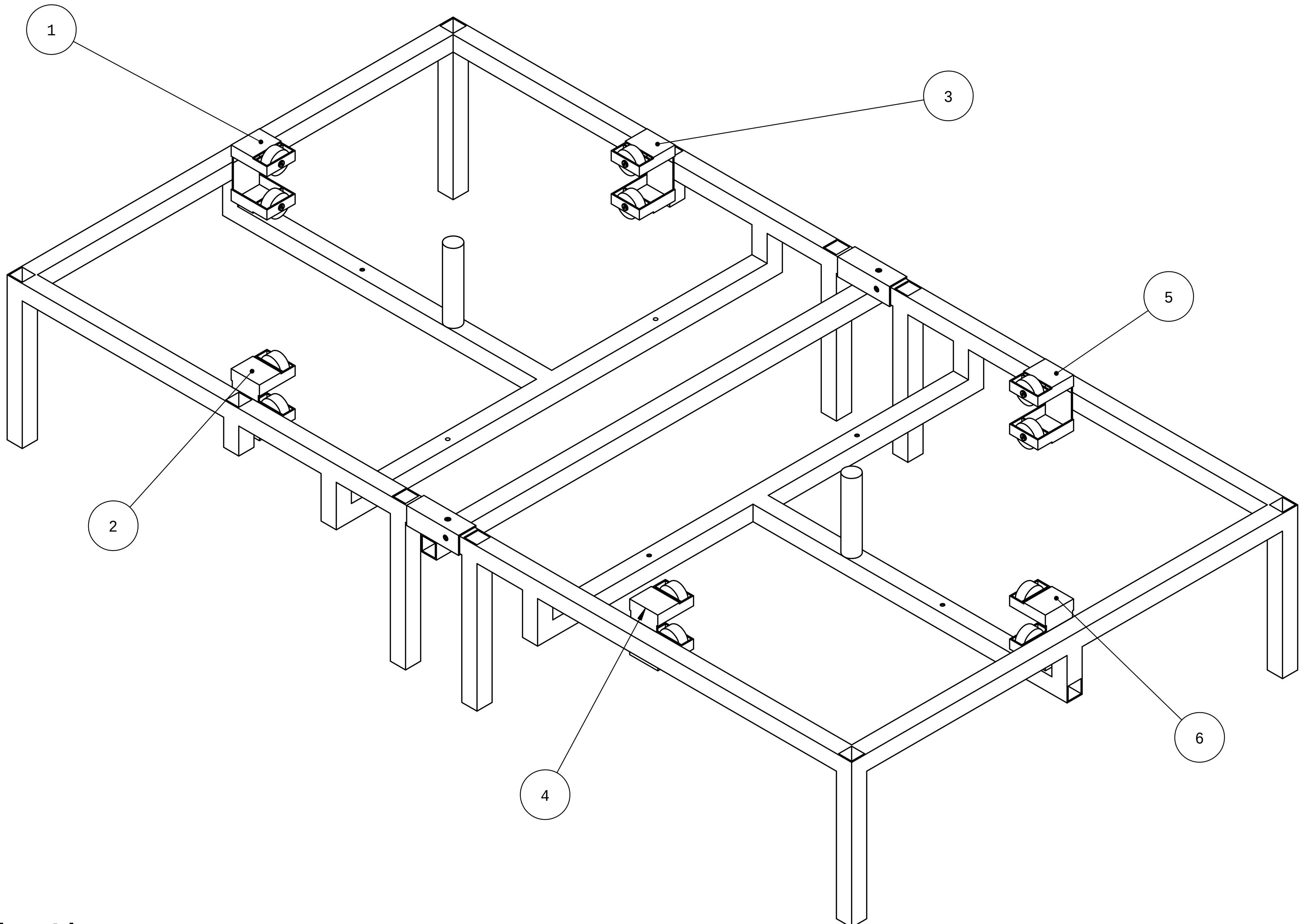
-# 1, 2, 3, 6 are identical

-#4 , 5 are identical

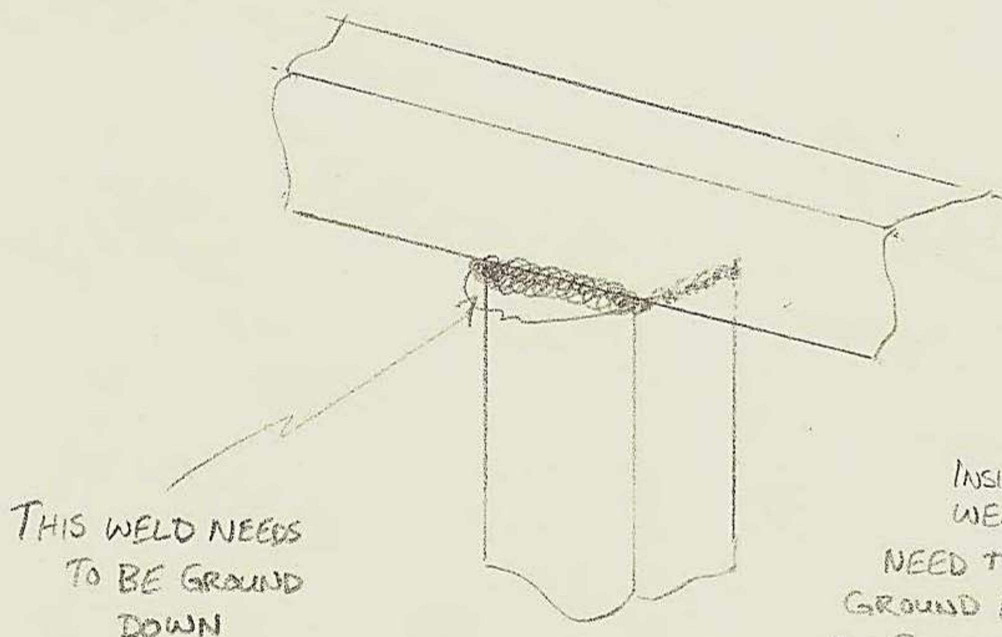
-# 1, 2, 3, 6 have NO angle iron on the backs. This is because there is a vertical member running behind them.

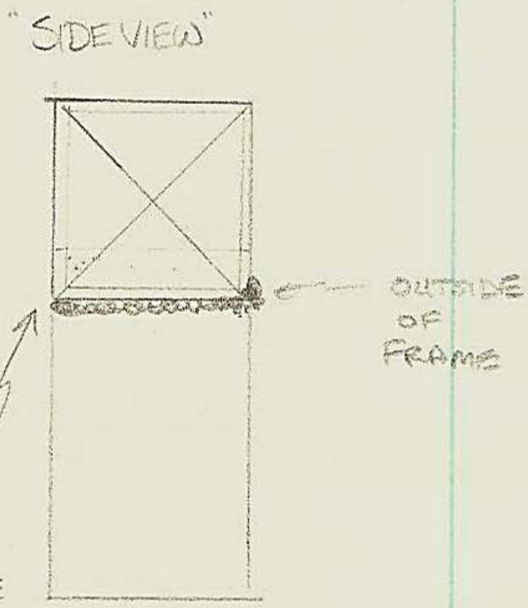
-#4 , 5 HAVE angle-iron on their backs. The top of the angle-iron butts up with the bottom of the horizontal running 1 ¾" square tube on the lower frame. This ensures the top edge is flush with the top of the square 1 ¾" tube.




1
2
3
4
5
6

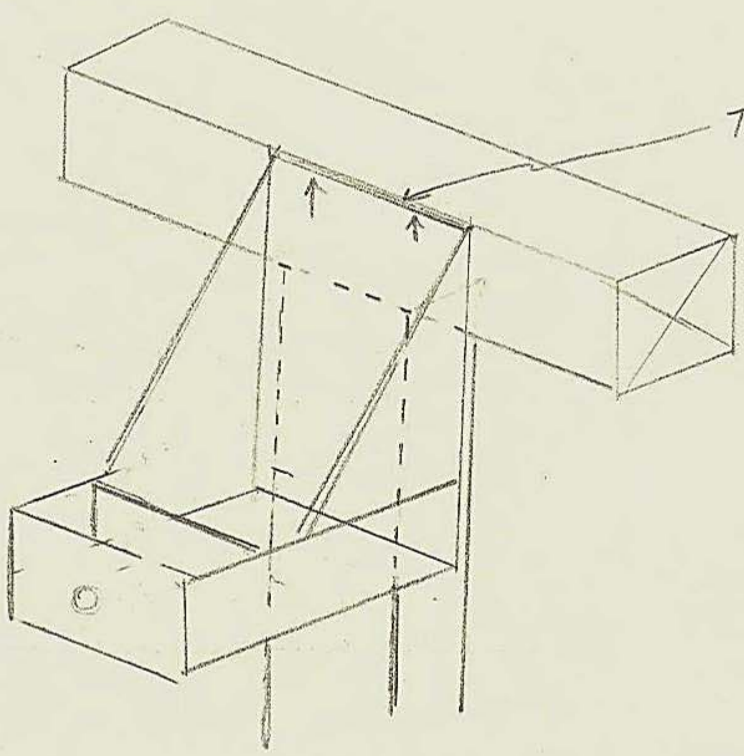
(1)



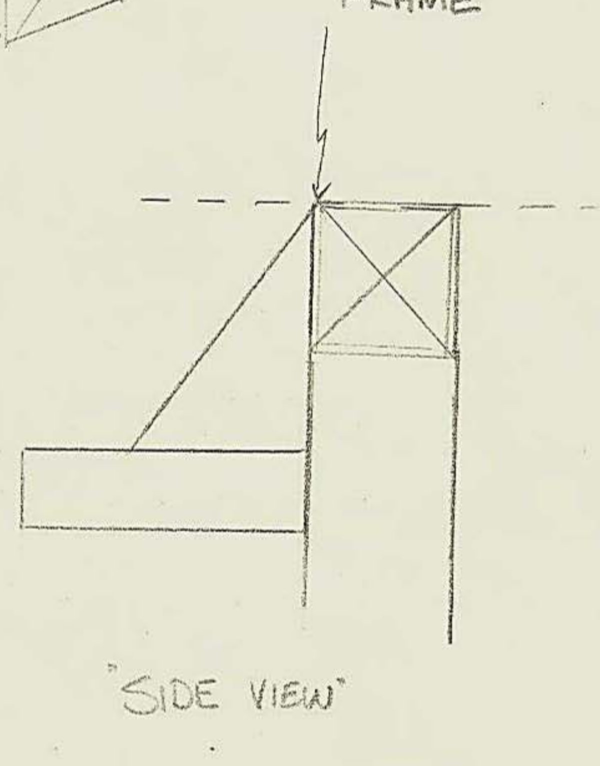


INSIDE WELDS NEED TO BE GROUND FLUSH TO THE 1¾" × 1¾" SQUARE TUBE FACES SO BOTTOM PIECES CAN BE WELDED ON FLAT.

(2)

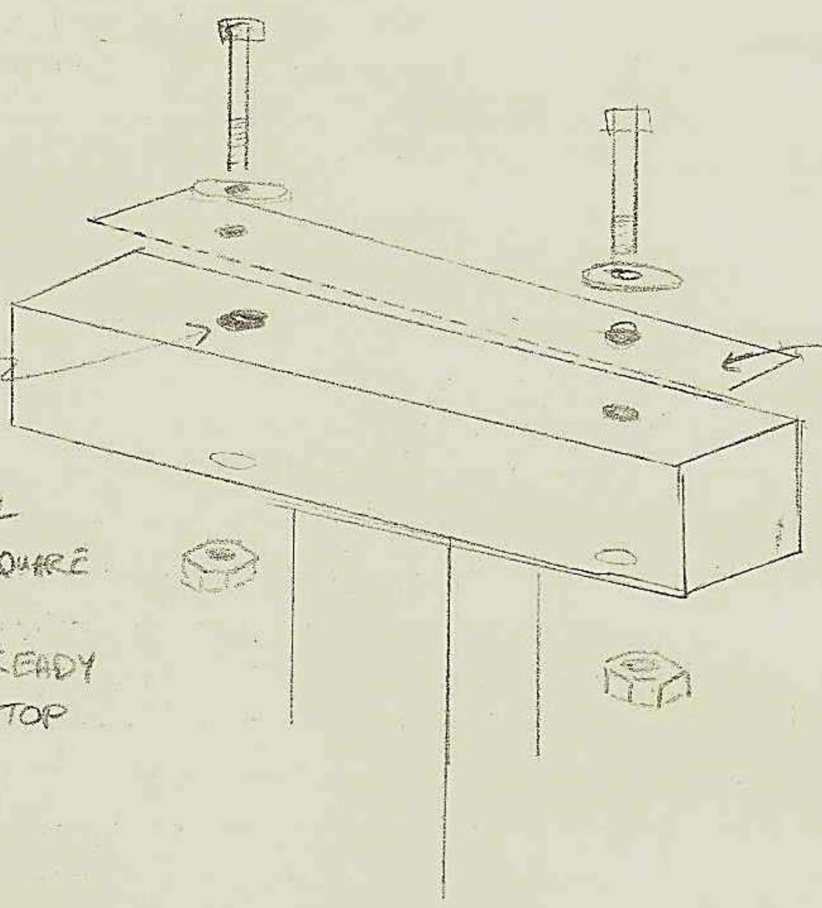


THIS EDGE IS FLUSH WITH THE TOP OF THE HORIZONTAL RUNNING 1¾" × 1¾" SQUARE TUBE ON THE LOWER FRAME



"SIDE VIEW"

TOP BRACKET (T)
ARE <u>NOT</u> WELDED
ON



HOLES NEED
TO BE DRILLED
INTO THE HORIZONTAL
RUNNING 1¾" x 1¾" SQUARE
TUBE TO ACCOMADATE
FOR THE HOLES ALREADY
DRILLED INTO THE TOP
BRACKET

BACK OF TOP
BRACKET

PLEASE CALL OR EMAIL
DEREK W/ ANY QUESTIONS
530.417.2985
or
cpboardbusters@gmail.com

Project Requirements					
Category	Parameter Description	Requirement or Target	Tolerance	Risk	Compliance
Safety					
	Kill Switch	Stops machine upon board failure	MIN	L	S, T
	Encapsulating Structure	Keeps board from leaving apparatus	MIN	L	S, T, A
Forces and Speed					
	Rider's Loads	100-300 lbs	MIN	L	T, A
	Minimum Maximum Speed	40 mph	MIN	M	I, A
	Speed Adjustability	0→40 mph	MIN	M	I, A, T
	Turning Angle	18°	MIN	M	I, T
	Speed Wobble Test	40 mph straight run	MIN	H	T, A, I
Cost					
	Budget	3000 Plus machining provisions	MAX	H	A
Geometry/Environment					
	Unit Size	5' x 5' x 5'	±3' height	M	I, A
	Number of Units	1 (for Freebord, S.F.)	MIN	L	I
	Portability	Portable from Cal Poly to Freebord, S.F.	MIN	M	I, A
	System Damping	Damping of system vibration	MIN	H	A, T
	Aesthetics	Determined by Board Buster group	MIN	L	I
	Power Plug-in	110 V	MAX	L	A
Operations and Measuring					
	Measure Test Time	Cycle counter	MIN	L	T, S, A
	Measure Loads on Boards	Documentation	MIN	M	A, T
	Load Freebord Caster	Conditions seen at set point load and speed conditions	MIN	H	T, A
	Cycle Initiation	Start button	MIN	L	T, I, S
	Test Subject Sizes	Up to 26" wheel base	MAX	L	I, T, A
Reliability					
	Number of Boards Tested Before Unit Part Failure	At least 20 boards	MIN	H	T, A, I
Testing					
	Removable Road Conditions: Asphalt	Smooth	MIN	L	A, T
	Removable Road Conditions: Concrete	Rough	MIN	L	A, T
	Removable Road Conditions: Sidewalk Crack	Simulate roadway cracks	MIN	L	A, T
	Ease of Testing	Operable by any Freebord Technician	MIN	L	I
	Test Length	5 day maximum	MAX	M	A
	Motor Interface	With Method's provided motor	MIN	H	I, A, T
Deliverables/Scheduling					
	Explanation of Safe Operation	User Manual	MIN	L	I
	Product Deliverable	1-Jun-12	MIN	H	I
	Hardware Demo	7-May-12 to 11-May-12	MIN	H	I
	Final Report	4-Jun-12	MIN	H	I

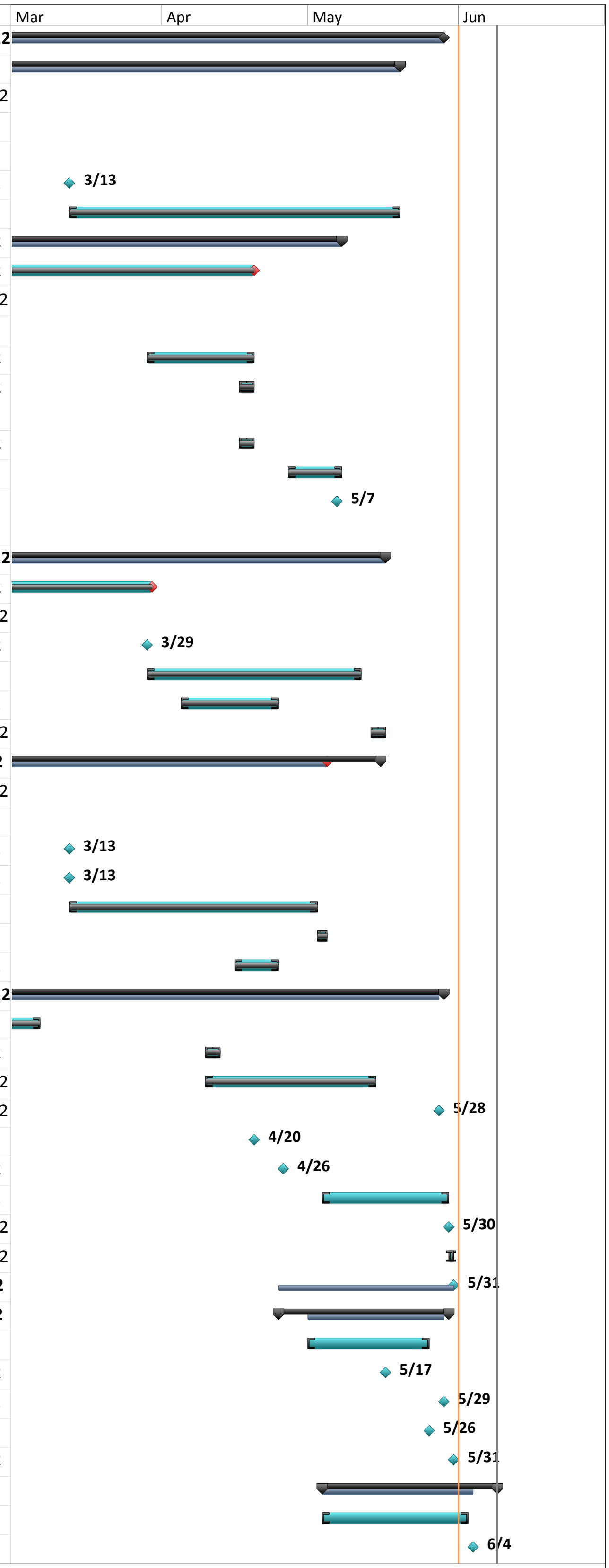
Note: These project requirements are subject to change upon agreement by both parties.

	Weighting	Kill Switch	Encapsulating Structure	Adjustable 100-300lb rider weight	Speed Adjustability 0-35mph	Simulates a 18* turn	Size 5'x5'x8'	Tester is under 1000lbs	Damping System	Looks good to board busters	Board Busters Logo	110V Power Source	Cycle Counter/Timer	Documentable	Simulates load on caster at set speed conditions	Tests 20 boards before any component failure	Adjustable up to 20"-26" wheelbase	Simulates Smooth & Rough Surface	Operable by any Freebord Tech	5Day Max Test time	Uses Method's Provided Motor	Uses readily available basic components	Project under $3000	Simulates Speed Wobbles	Has a Start Button	Benchmark: Freebord Pro Ride/Test Team	Roads: Disk	Roads: Oil Drum*	Roads: Conveyor Belt	Roads: Dyno	Actuator: 4-Bar-Linkage	Actuator: Hydraulics	Actuator: Moments*	Actuator: Swashplate	2-Disk/4 bar	2-Disk/Vibrator
		Engineering Requirements																								Benchmark	Roads				Actuator					
Safety	9	9	9						1			1				3			1						1	2	2	3	5	5	4	5	5	5	4	4
Simulates Rider	6			9		3								1	9		1			1				3		5					5	4	3	5	5	4
Simulates Terrain	6			3	3	1								1	9			9		1				1		5	5	3	3	4					4	4
Simulates Ride	6			9	9	9							1	1	9		3	3		1				1		5	4	3	4	2	5	3	4	5	5	4
Cheap Budget	5								1							1							9			2	5	5	2	4	5	2	4	2	3	3
Size Kept Compact	3						9																			2	3	5	5	5	5	4	3	4	4	5
Transportability	3						3	9														1	1			1	3	5	5	5	5	4	4	4	4	4
Damp out Vibration	4		1				1	1	9					1							1					1	2	2	5	2	3	3	3	3	4	4
Aesthetics	1		1							9	9															2	5	5	5	5	4	5	4	5	5	3
Power Plug-in	2	1										9														1									5	5
Measurable Test	6			1	1	1	1						9	3												1	5	5	5	5	2	5	4	4	4	4
Measure Loads	6			1	1	1							3	9												1					3	5	5	3	4	4
Loads Freebord Caster	7			1	1	1								9	9					1						5	4	1	4	2	3	3	1	5	5	5
Reliability/Life	6													3		9				1		3	3			2	5	5	3	5	3	4	5	3	5	3
Tests different board sizes	5		1	1	1	1								1			9									5	5	5	5	3					5	5
Cycle Initiation	4	1																					1		9	3									5	5
Simulates Road Obstacles	5																	9								5	5	5	2	5					5	5
Ease of Testing	4																		9	3						1	3	5	5	3	5	4	5	4	4	4
Reasonable Test Length	3												1			3				9						1									4	4
Motor Interface	4											9							1		9	1				1	5	5	5	5	5	2	5	3	4	4
Maintenance ease	4		1											3		3			9			9				2	5	5	2	5	3	3	3	3	3	3
Speed Wobbles	1			1																				9		3	2	2	5	2	5	1	4	3	3	3
Units	100	87	95	151	96	102	46	31	50	9	9	63	81	192	225	107	69	117	85	70	40	61	70	39	45	278	320	310	316	312	293	280	291	294	432	409
Targets		Y	Y	100-300lb	35 mph	18 degrees	5'X5'X8'	<1000lb	Y	Y	Y	110V	Y	Y	Y	20 boards	26"	Y	Y	5 Days	Y	Y	$3,000	Y	Y											
Benchmark - Freebord Pro Team/Tester		N	N	150-250lb	50 mph	18 degrees	1'x1.5'x6'	<250lb	n/a	Y	N	food	N	Y	Y	2 boards	26"	Y	N	2 years	n/a	Y	$15-30/hr	Y	N											
Disk/4Bar		Y	Y	Y	35mph	18 degrees	6'x5'x4'	~400lbs	Y	Y	Y	Y	Y	Y	Y	20boards	26"	Y	Y	5 Days	Y	Y	Y	N	Y											
Disk/Swashplate		Y	Y	Y	35mph	18 degrees	6'x4'x4'	<1000lbs	Y	Y	Y	Y	Y	Y	Y	20boards	26"	Y	Y	5 Days	Y	Y	Y	N	Y											
Conveyor/4Bar		Y	Y	Y	35mph	18 degrees	5'x5'x5'	<1000lbs	Y	Y	Y	Y	Y	Y	Y	20boards	26"	Y	Y	5 Days	Y	Y	N	Y	Y											
Conveyor/Swashplate		Y	Y	Y	35mph	18 degrees	5'x5'x5'	<1000lbs	Y	Y	Y	Y	Y	Y	Y	20boards	26"	Y	Y	5 Days	Y	Y	N	Y	Y											
2 Disk/4 Bar		Y	Y	Y	35mph	18 degrees	5'x5'x5'	<1000lbs	Y	Y	Y	Y	Y	Y	Y	20boards	26"	Y	Y	5 Days	Y	Y	Y	Y	Y											

Top 3 Design Considerations Higlighted

*Some are good for freebord and not good for method and vice versa

ID		Task	Task Name	Duration	Start	Finish
1			**Design Details**	**103 days**	**Thu 1/5/12**	**Mon 5/28/12**
2	✓		**Frame**	**98 days**	**Thu 1/5/12**	**Sat 5/19/12**
3	✓		Calculations	16 days	Wed 1/4/12	Wed 1/25/12
4	✓		Design	38 days	Wed 1/4/12	Fri 2/24/12
5	✓		Disk Stabalizer Prototype	3 days	Wed 1/25/12	Fri 1/27/12
6	✓		Frame Drawings to Shop	0 days	Tue 3/13/12	Tue 3/13/12
7	✓		Machining Time	50 days	Tue 3/13/12	Sat 5/19/12
8	✓		**4-bar/Weight Assy**	**88 days**	**Thu 1/5/12**	**Mon 5/7/12**
9	✓		Dimensions/Design	77 days	Wed 1/4/12	Thu 4/19/12
10	✓		Calculations	29 days	Wed 1/4/12	Mon 2/13/12
11	✓		Prototyping	23 days	Thu 1/5/12	Sat 2/4/12
12	✓		Slider Work	16 days	Thu 3/29/12	Thu 4/19/12
13	✓		4-bar/Weight Assy Drawings Complete	3 days	Tue 4/17/12	Thu 4/19/12
14	✓		Materials Shipping	3 days	Tue 4/17/12	Thu 4/19/12
15	✓		Machining Time	7 days	Fri 4/27/12	Mon 5/7/12
16	✓		4-Bar/Weight Assy Procurement	0 days	Mon 5/7/12	Mon 5/7/12
17	✓		**Drivetrain/Pivoter**	**90 days**	**Thu 1/12/12**	**Wed 5/16/12**
18	✓		Dimensions/Design	56 days	Thu 1/12/12	Thu 3/29/12
19	✓		Calculations	28 days	Thu 1/12/12	Mon 2/20/12
20	✓		Drivetrain Drawings to Shop	0 days	Thu 3/29/12	Thu 3/29/12
21	✓		Machining Time	32 days	Thu 3/29/12	Fri 5/11/12
22	✓		Part Orders/Shipping	14 days	Thu 4/5/12	Tue 4/24/12
23	✓		Drivetrain Complete	3 days	Mon 5/14/12	Wed 5/16/12
24	✓		**Disk/Road Conditions/Island**	**92 days**	**Fri 1/6/12**	**Tue 5/15/12**
25	✓		Dimensions/Design	20 days	Tue 1/17/12	Mon 2/13/12
26	✓		Calculations	19 days	Tue 1/17/12	Fri 2/10/12
27	✓		Disk Drawings to Shop	0 days	Tue 3/13/12	Tue 3/13/12
28	✓		Island Drawings to Shop	0 days	Tue 3/13/12	Tue 3/13/12
29	✓		Machining Time	37 days	Tue 3/13/12	Wed 5/2/12
30	✓		Disk/Island Complete	2 days	Thu 5/3/12	Fri 5/4/12
31	✓		Bearing Shipping Time	7 days	Mon 4/16/12	Tue 4/24/12
32			**Controllers**	**93 days**	**Thu 1/19/12**	**Mon 5/28/12**
33	✓		Controller Research	34 days	Thu 1/19/12	Tue 3/6/12
34	✓		Motors Shipped to Method	3 days	Tue 4/10/12	Thu 4/12/12
35	✓		Controller Orders	25 days	Tue 4/10/12	Mon 5/14/12
36			Power Source Procurement	0 days	Mon 5/28/12	Mon 5/28/12
37	✓		Pack-N-Go	0 days	Fri 4/20/12	Fri 4/20/12
38	✓		Ship Bearings	0 days	Thu 4/26/12	Thu 4/26/12
39			Building	18 days	Fri 5/4/12	Tue 5/29/12
40			Apparatus Procurement	0 days	Wed 5/30/12	Wed 5/30/12
41			Testing	1 day	Wed 5/30/12	Wed 5/30/12
42			**Design Expo**	**0 days**	**Thu 5/31/12**	**Thu 5/31/12**
43			**Poster**	**25 days**	**Wed 4/25/12**	**Tue 5/29/12**
44			Poster Work	19 days	Tue 5/1/12	Fri 5/25/12
45	✓		Preliminary Poster Layout	0 days	Thu 5/17/12	Thu 5/17/12
46			Print Poster	0 days	Tue 5/29/12	Tue 5/29/12
47			Obtain Poster Board	0 days	Sat 5/26/12	Sat 5/26/12
48			Expo	0 days	Thu 5/31/12	Thu 5/31/12
49			**Final Report**	**26 days**	**Fri 5/4/12**	**Fri 6/8/12**
50			Report Work	22 days	Fri 5/4/12	Sat 6/2/12
51			Report Due	0 days	Mon 6/4/12	Mon 6/4/12



Board Busters
Date: Fri 6/1/12

Task		External Milestone		Manual Summary Rollup	
Split		Inactive Task		Manual Summary	
Milestone		Inactive Milestone		Start-only	
Summary		Inactive Summary		Finish-only	
Project Summary		Manual Task		Deadline	
External Tasks		Duration-only		Progress	

ME428/ME481 DVP&R Format

Report Date		Sponsor	Freebord	Method Sports, Inc.			Component/Assembly	Longboard Tes	REPORTING ENGINEER:

TEST PLAN / TEST REPORT

Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsi	Test Stage	SAMPLES Quantity	SAMPLES Type	TIMING Start date	TIMING Finish date	TEST RESULTS Test Result	TEST RESULTS Quantity Pass	TEST RESULTS Quantity Fail	NOTES
1	Kill Switch	Attempt Use of Kill Switch	Kill switch shuts machine off		PV	N/A	N/A						
2	Encapsulating Structure	Ensure Loose Parts Will Not Eject from Tester	Parts contained		DV	N/A	N/A						
3	Rider's Loads (300lbs)	Verify 300lbs can be applied to operating tester	Tester operates as specified with full load		PV	N/A	N/A						
4	Maximum Speed (50mph)	Verify tester speed can reach 50mph	Tester operates as specified at full speed		PV	N/A	N/A						
5	Adjustable Speed (0-50mph)	Verify tester speed can be varried from 0 to 50mph	Tester speed can be varied over specified range		PV	N/A	N/A						
6	Turning Angle (18°)	Verify minimum turning angle of 18°	Turning angle reaches at least 18°		PV	N/A	N/A						
7	Speed Wobble Test	Achieve speed wobble by reaching maximum speed on a straigh run	Speed wobble achieved		PV	N/A	N/A						
8	Budget	Ensure costs lower than $3000	Project completed within budget of $3000		PV	N/A	N/A						
9	Unit Size (8'x5'x5')	Verify that unit is within 8'x5'x5'	Unit is no larger than specified size		DV	N/A	N/A						
10	Number of Units	Ensure one unit delivery	Complete and deliver one unit		DV	N/A	N/A						
11	Portability	Verify that unit can be transported	Transport unit		DV	N/A	N/A						
12	System Damping	Run system at full speed	Verify acceptable amount of shaking/vibrating		PV	N/A	N/A						
15	Aesthetics	Visually inspect machine	Pass visual appeal		DV	N/A	N/A						
16	Power Plug-in	Verify 240V plug-in	240 V power required		DV	N/A	N/A						
17	Measure Test Time (Cycle Counter)	Verify that cycle counter works	Cycle counter accurately counts and tracks cycles seen by board		PV	N/A	N/A						
18	Measure Loads on Boards (Documentation)	Verify accurate documentation of board loads can be obtained	Accurate documentation of loads, speed, and cycles seen by boards		PV	N/A	N/A						
19	Load Freebord Caster	Ensure Freebord caster is loaded through cycle	Freebord caster is loaded through cycles		DV	N/A	N/A						
20	Cycle Initiation (Start Button)	Verify that start button works	Start button begins operation of tester		PV	N/A	N/A						
21	Test Subject Sizes (Up to 26" Wheel Base)	Verify that up to 26" wheelbase boards can be tested	26" board fits on tester		DV	N/A	N/A						
22	Number of Boards Tested Before Unit Failure (At Least 20)	Verify with fatigue analysis that at least 20 boards can be tested before unit failure	20 boards tested before unit failure		DV	N/A	N/A						
23	Removable Road Conditions: Asphalt	Verify that road conditions can be removed and replaced	Road conditions can be removed and interchanged		DV	N/A	N/A						
24	Removable Road Conditions: Concrete	Verify that road conditions can be removed and replaced	Road conditions can be removed and interchanged		DV	N/A	N/A						
25	Removable Road Conditions: Sidewalk Crack	Verify that road conditions can be removed and replaced	Road conditions can be removed and interchanged		DV	N/A	N/A						
26	Ease of Testing (by Freebord Technician)	Ensure that someone not familiar with design can operate tester with use of user manual and/or minimal training.	Someone not familiar with design is able to operate tester		PV	N/A	N/A						
27	Test Length	Run system on a long run to observe continuous-running effects	Ensure no breaking or overheating of components		DV	N/A	N/A						
28	Motor Interface	Verify that motor is effectively incorporated into design	Motor drives tester		DV	N/A	N/A						
29	Explanation of Safe Operation (User Manual)	Verify that user manual is effective in explaining safe operation o tester by proof-reading	User Manual completed		DV	N/A	N/A						
30	Product Deliverable (1-Jun-12)	Ensure delivery availability by date	Available for delivery by date		PV	N/A	N/A						

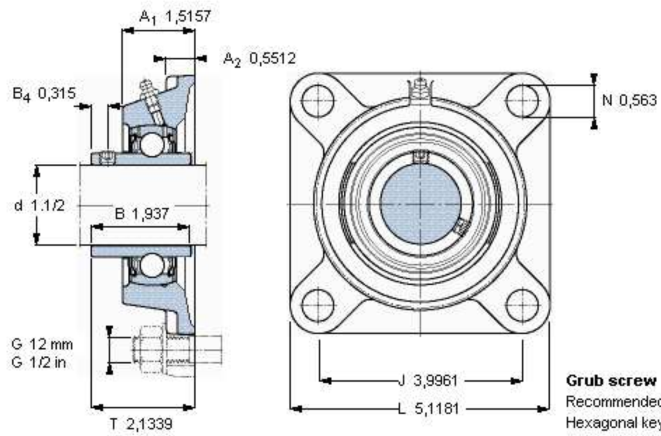
Status	Part Number	Quantity	Location	Description	Type	Obtain	Vendor	Cost
Buy	90499A033	8	Disk	1/2"-13 nuts	Fastener	Order	McMaster (same part #)	
Buy	91251A726	8	Disk	1/2"-13 x 3.5" bolts for bearings	Fastener	Order	McMaster (same part #)	$12.72
Buy	90499A031	4	Drivetrain	3/8"-16 nuts for motor mounting	Fastener	Order	McMaster (same part #)	
Buy	91251A621	8	Drivetrain	3/8"-16 x 5/8 bolts (for bearing)	Fastener	Order	McMaster (same part #)	
Buy	BB007	1	Drivetrain	Drivetrain Shaft	Part	Order	Robot Marketplace	$25.02
Buy	BB008	1	Drivetrain	Shaft Side Pulley	Part	Order	Bbman.com	$52.98
Buy	BB009	1	Drivetrain	Drivetrain Belt	Part	Order	Bbman.com	$25.32
Buy	BB010	1	Drivetrain	ETEK Side Pulley	Part	Order	Bbman.com	$28.68
Buy	BB013	1	Drivetrain	ETEK Motor Mount	Part	Order	Robot Marketplace	$55.00
Buy	BB021	5	Drivetrain	Drivetrain Screw Feet	Part	Order	McMaster	$29.50
Buy		8	Drivetrain	3/8"-16 x ?? bolts for motor mounting (from plate to frame & motor to plate)	Fastener	Order		
Buy		4	Drivetrain	5/16"-18 x ?? bolts for motor mounting (from motor to plate	Fastener	Order		
Buy	91247A634	18	Frame: Lower	3/8" - 16 L2.5"Grade 5 Zinc-Plated Steel Hex Head	Fastener	Order	McMaster (same part #)	$8.96
Buy	91251A722	4	Frame: Lower	1/2" - 13 L2 1/2"	Fastener	Order	McMaster (same part #)	$10.52
Buy	93852A104	12	Frame: Lower	General Purpose Washer for 3/8" Center Wheel Scr	Part	Order	McMaster (same part #)	$6.62
Buy	93852A104	24	Frame: Lower	General Purpose Washer for 3/8" Center Wheel Scr	Part	Order	McMaster (same part #)	$6.62
Buy	93852A113	8	Frame: Lower	1/2" Washer	Fastener	Order	McMaster (same part #)	$6.74
Buy	95462A031	18	Frame: Lower	3/8"-16 Grade 5 Steel Nut	Fastener	Order	McMaster (same part #)	$6.32
Buy	95462A033	4	Frame: Lower	1/2" -13 nuts	Fastener	Order	McMaster (same part #)	$13.77
Buy	3176T46	2	Island	Vibration-Damping U-Bolt	Part	Order	McMaster (same part #)	
Buy	91247A552	4	Island	1/4"-20 x L 2 1/2" Bolt	Fastener	Order	McMaster (same part #)	
Buy	94945A205	8	Island/WA	1/4-20 Self-Locking Nut	Fastener	Order	McMaster (same part #)	
Buy	1-1/2 NEFMC	2	Slider	Ball Transfer model NEFMC	Part	Order	balltransfer.com	$18.20
Buy	6960T51	1	Weight Assembly	3/4"-16 Ball Socket Joint for Freebord	Part	Order	McMaster (same part #)	
Buy	91247A546	4	Weight Assembly	1/4"-20 L1 1/2" Partially Threaded Bolts	Fastener	Order	McMaster (same part #)	$11.21
Buy	97135A285	1	Weight Assembly	3/4" -16 Steel Nylon-Insert Hex Locknut	Fastener	Order	McMaster (same part #)	$5.82
Designing	LX1001	1	Frame	Corner Lexan Holding Post for 2 sheets	Part	Fabricate		
Designing	LX1002	4	Frame	Lexan Holding Post for 1 sheet	Part	Fabricate		
Fabricated	23S	6	Disk Stabilizer	Top Disk Stabilizer	Part	Fabricate		
Fabricated	SFJ3	6	Disk Stabilizer	Lower Disk Stabilizer	Part	Fabricate		
Fabrication @ Cal Poly		1	4-bar	Coupler	Part	Fabricate		
Fabrication @ Cal Poly		1	4-bar	Driver	Part	Fabricate		
Fabrication @ Cal Poly		1	4-bar	Rocker	Part	Fabricate		
N/A	BB026	1	Drivetrain	ETEK Motor Assy	Assembly			
Sent for Fabrication	UF001	1	Frame: Upper	Upper Frame	Part	Fabricate		
Sent for Fabrication	BBS001	1	Slider	Board Mount	Part	Fabricate		
Sent for Fabrication	BBS003	1	Slider	Slider Frame Plate	Part	Fabricate		
Sent for Fabrication	BBS002	2	Slider	Slider Side Plates	Part	Fabricate		
Sent for Fabrication	BBSA001	1	Slider	Slider Assembly	Assembly			
Sent for Fabrication	WA1011	1	Weight Assembly	Bottom Weight Holder	Part	Fabricate		
Sent for Fabrication	WA1012	1	Weight Assembly	Top tube of Weight Assembly	Part	Fabricate		
Ordered	BB025	2	Drivetrain	Wheelchair Wheel	Assembly	Order		
Ordered (donation)	D010	4	Disk	SKF flanged Y-bearing Disk Bearing FY 1.1/2 TF	Part	Order	SKF	$0.00
Ordered (donation)	BB006	2	Drivetrain	SKF flanged Y-bearing Disk Bearing FY 3/4 FM	Part	Order	Applied.com	$0.00
Sent for Fabrication	D009	2	Disk	3.5' Laminated Maple Disk	Part	Fabricate		
Sent for Fabrication	D011	2	Disk	3.5' Disk Assembly	Assembly			
Sent for Fabrication	BB001	1	Drivetrain	Drivetrain Top Plate	Part	Fabricate		
Sent for Fabrication	BB002	1	Drivetrain	Drivetrain Plain Side Plate	Part	Fabricate		
Sent for Fabrication	BB003	2	Drivetrain	Drivetrain Side Plate with Bearing Cutouts	Part	Fabricate		
Sent for Fabrication	BB004	1	Drivetrain	Drivetrain Slotted Side Plate	Part	Fabricate		
Sent for Fabrication	BB005	4	Drivetrain	Drivetrain Housing Legs	Part	Fabricate		
Sent for Fabrication	BB011	1	Drivetrain	Motor Mount Plates	Part	Fabricate		
Sent for Fabrication	BB012	1	Drivetrain	Motor Mount Leg	Part	Fabricate		
Sent for Fabrication	BB017	4	Drivetrain	Drivetrain to Frame Adapters	Part	Fabricate		
Sent for Fabrication	BB018	5	Drivetrain	Drivetrain Leg Screw Feet Plates	Part	Fabricate		
Sent for Fabrication	BB019	1	Drivetrain	Drivetrain Housing Legs Assy	Assembly			
Sent for Fabrication	BB020	1	Drivetrain	Motor Mount Foot Assy	Assembly			
Sent for Fabrication	BB022	1	Drivetrain	Motor Mount Upper Plate	Part	Fabricate		
Sent for Fabrication	BB023	1	Drivetrain	Mounting Plate Spacer	Part	Fabricate		
Sent for Fabrication	BB024	1	Drivetrain	Drivetrain Assy	Assembly			
Sent for Fabrication	BB027	1	Drivetrain	Drivetrain Housing Assy	Assembly			
Sent for Fabrication	F011	1	Frame: Lower	Non-collared Frame half (small)	Part	Fabricate		
Sent for Fabrication	F021	1	Frame: Lower	Collared Frame half(big)	Part	Fabricate		
Sent for Fabrication	IS1001	1	Island	Bottom Plate of Island	Part	Fabricate		
Sent for Fabrication	IS1002	1	Island	Top of Island	Part	Fabricate		
Sent for Fabrication	BS2001*	1	Weight Assembly	Board securing base	Part	Fabricate		
Sent for Fabrication	BS2002*	1	Weight Assembly	Board Securing length	Part	Fabricate		
Sent for Fabrication	BS2003*	4	Weight Assembly	WA securing bracket	Part	Fabricate		
Sent to Method		1	4-bar	Motor	Part	Supplied		$0.00
	DS011	6	Disk Stabilizer	Disk Stabilizer Assembly	Assembly			
	BR001	1	Fatigue Tester	Overall Fatigue Tester Assembly	Assembly			
	F001	1	Frame: Lower	Lower Frame Assembly	Assembly			
	UF010	1	Frame: Upper	Upper Frame Assembly	Assembly			
	IS1011	1	Island	Island Assembly	Assembly			
	WH021	16	Misc	59mm Wheel w/ bearings & washers	Part	Supplied		
	WA1001	1	Weight Assembly	Weight Assembly Assembly	Assembly			
				Controllers, Motors, Steel, (Labor)				$4,000.00
							Total Cost	**$4,300.00**

3D view | PDF | CAD | Metric | Print | Close

Y-bearing flanged units, cast housing, square flange, grub screw locking, inch bearings

Product information

Dimensions					Basic load ratings dynamic	static	Limiting speed with shaft tolerance h6	Mass	Designations Bearing unit	Housing	Bearing
d	A_1	J	L	T	C	C_0					
in					lbf		r/min	lb	-		
1.1/2	1,5157	3,9961	5,1181	2,1339	6900	4270	4800	4,28	**FY 1.1/2 TF**	FY 508 U	YAR 208-108-2F



Grub screw	5/16-24×5/16
Recommended tightening torque [Nm]	6,5
Hexagonal key size [mm]	3,96875

APPLIED Industrial Technologies

Product Detail

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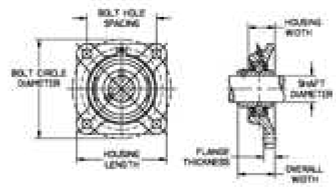
SKF



Item Details		Shopping	
Part#:	Part#: FY1.1/2TF Item#: 161781	Price:	$86.14
Manufacturer:		Order Quantity:	1
Weight:	**4.242 lbs.**		
Product Name:	FY-TF Series Cast Iron 4-Bolt Ball Bearing Flange Unit		
Description:	1 1/2" Shaft, 4" Bolt Hole Spacing, Contact Seals (With Flingers), Setscrew Locking, Regreasable, Non -Expansion		

Specifications

Inch/Metric	Inch	Flange Type	4-Bolt Flange
Shaft Dia. [Min]		**Shaft Dia. [Max]**	
Shaft Dia.	1 1/2 in	Mounted Unit Duty	Normal-Duty
Bearing Type	Ball Bearing	**Locking Device**	Setscrew Locking Collar
Housing Length	5 1/8 in	**Bolt Hole Spacing**	4 in
Bolt Circle Dia.	5 21/32 in	**Bearing Design**	Non-Expansion
End Type	Open End	Housing Construction	1 Piece
Housing Material	Cast Iron	Lubrication	Relubricatable
Seal Type	Contact Seals w/Flingers	Center of Bearing to Back of Flange Unit	
Radial Internal Clearance Specification		Series	
Axial Load [Max]		**Axial Load**	
Bearing Cavity Dia.		Bearing Clearance	
Bearing Insert	YAR 208-108-2F	Bolt Hole Size	

Bolt Size	1/2 in	Center Line to Base Dimension [Min]	
Center Line to Base Dimension [Max]		Center Line to Base Dimension	
Center of Bearing to Back of Inner Ring		Center of Bearing to Front of Inner Ring	
Collar Extension		Collar O.D.	
Color		Counterbore Dia.	
Dynamic Load Rating	5310.00 lbf	Flange Style	
Flange Thickness	21/32 in	Housing Height	5 1/8 in
Housing No.		Housing Width	1 17/32 in
Insert Type		Length Through Bore	
Location Spigot N		Location Spigot V	
Lub Fitting Type		**Misalignment Range**	
Outer Ring Size		Overall Width	2 3/32 in
Pilot Depth		Pilot Diameter [Min]	
Pilot Diameter [Max]		Pilot Diameter	
RPM [Min]		RPM [Max]	
RPM		Size Code	
Special Features		**Static Load Rating [Max]**	
Temperature Range [Min]		**Temperature Range [Max]**	
Total Float			

Product Information

Features

- Cast iron flange
- Four-bolt mounting
- Setscrew locking
- Wide inner ring
- M-seal and flingers

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Product Detail

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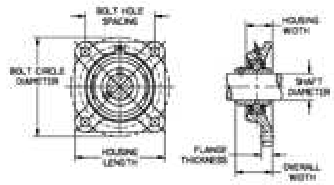

Item Details		Shopping	
Part#:	Part#: FY1.1/2TF Item#: 161781	Price:	$86.14
Manufacturer:		Order Quantity:	1
Weight:	**4.242 lbs.**		
Product Name:	FY-TF Series Cast Iron 4-Bolt Ball Bearing Flange Unit		
Description:	1 1/2" Shaft, 4" Bolt Hole Spacing, Contact Seals (With Flingers), Setscrew Locking, Regreasable, Non -Expansion		

Specifications

Inch/Metric	Inch	Flange Type	4-Bolt Flange
Shaft Dia. [Min]		**Shaft Dia. [Max]**	
Shaft Dia.	1 1/2 in	Mounted Unit Duty	Normal-Duty
Bearing Type	Ball Bearing	**Locking Device**	Setscrew Locking Collar
Housing Length	5 1/8 in	**Bolt Hole Spacing**	4 in
Bolt Circle Dia.	5 21/32 in	**Bearing Design**	Non-Expansion
End Type	Open End	Housing Construction	1 Piece
Housing Material	Cast Iron	Lubrication	Relubricatable
Seal Type	Contact Seals w/Flingers	Center of Bearing to Back of Flange Unit	
Radial Internal Clearance Specification		Series	
Axial Load [Max]		**Axial Load**	
Bearing Cavity Dia.		Bearing Clearance	
Bearing Insert	YAR 208-108-2F	Bolt Hole Size	

Bolt Size	1/2 in	Center Line to Base Dimension [Min]	
Center Line to Base Dimension [Max]		Center Line to Base Dimension	
Center of Bearing to Back of Inner Ring		Center of Bearing to Front of Inner Ring	
Collar Extension		Collar O.D.	
Color		Counterbore Dia.	
Dynamic Load Rating	5310.00 lbf	Flange Style	
Flange Thickness	21/32 in	Housing Height	5 1/8 in
Housing No.		Housing Width	1 17/32 in
Insert Type		Length Through Bore	
Location Spigot N		Location Spigot V	
Lub Fitting Type		**Misalignment Range**	
Outer Ring Size		Overall Width	2 3/32 in
Pilot Depth		Pilot Diameter [Min]	
Pilot Diameter [Max]		Pilot Diameter	
RPM [Min]		RPM [Max]	
RPM		Size Code	
Special Features		**Static Load Rating [Max]**	
Temperature Range [Min]		**Temperature Range [Max]**	
Total Float			

Product Information

Features

- Cast iron flange
- Four-bolt mounting
- Setscrew locking
- Wide inner ring
- M-seal and flingers

APPLIED Industrial Technologies

Product Detail

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SKF

Item Details		Shopping	
Part#:	Part#: FY3/4FM Item#: 6489637	Price:	$39.84
Manufacturer:		Order Quantity:	1
Weight:	**1.329 lbs.**		
Product Name:	FY-FM Series Cast Iron 4-Bolt Ball Bearing Flange Unit		
Description:	0.75" Shaft, Contact Seals, Eccentric Collar, Regreasable		

Specifications

Inch/Metric	Inch	Flange Type	4-Bolt Flange
Shaft Dia. [Min]		**Shaft Dia. [Max]**	
Shaft Dia.	3/4 in	Mounted Unit Duty	Normal-Duty
Bearing Type	Ball Bearing	**Locking Device**	Eccentric Locking Collar
Housing Length	3 3/8 in	**Bolt Hole Spacing**	2 1/2 in
Bolt Circle Dia.	3.536 in	**Bearing Design**	Non-Expansion
End Type	Open End	Housing Construction	1 Piece
Housing Material	Cast Iron	Lubrication	Relubricatable
Seal Type	Contact Seals	Center of Bearing to Back of Flange Unit	
Radial Internal Clearance Specification		Series	
Axial Load [Max]		**Axial Load**	
Bearing Cavity Dia.		Bearing Clearance	
Bearing Insert	YEL 204-012-2F	Bolt Hole Size	
Bolt Size	3/8 in	Center Line to Base Dimension [Min]	

Center Line to Base Dimension [Max]		Center Line to Base Dimension	
Center of Bearing to Back of Inner Ring		Center of Bearing to Front of Inner Ring	
Collar Extension		Collar O.D.	1.297 in
Color		Counterbore Dia.	
Dynamic Load Rating		Flange Style	
Flange Thickness	5/8 in	Housing Height	3 3/8 in
Housing No.		Housing Width	1 1/8 in
Insert Type		Length Through Bore	
Location Spigot N		Location Spigot V	
Lub Fitting Type		**Misalignment Range**	
Outer Ring Size		Overall Width	1 43/64 in
Pilot Depth		Pilot Diameter [Min]	
Pilot Diameter [Max]		Pilot Diameter	
RPM [Min]		RPM [Max]	
RPM		Size Code	
Special Features		**Static Load Rating [Max]**	
Temperature Range [Min]		**Temperature Range [Max]**	
Total Float			

Product Information

Features

- Cast iron flange
- Four-bolt mounting
- Eccentric locking collar
- Narrow inner ring
- M-seal

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Shafts

Fully-Keyed 1018 Steel Shafts

Our cold rolled steel shafts are fully keyed along the entire length, and may be purchased in lengths of 18", 36" or 72".

Finish is flat, non-polished for regular use. Diameter tolerance +.000" and -.002". For maximum durability, we recommend your shafts be hardened by a heat-treating service once you have cut them to length and done any further machining.

Shaft Dia.	Keyway	Weight/in.	Price/in.
1/2"	1/8"	0.056lb.	$1.04
5/8"	3/16"	0.087lb.	$1.20
11/16"	3/16"	0.105lb.	$1.34
3/4"	3/16"	0.125lb.	$1.39
13/16"	3/16"	0.146lb.	$1.55
7/8"	3/16"	0.17lb.	$1.58
1"	1/4"	0.223lb.	$1.79
1 1/8"	1/4"	0.282lb.	$1.95
1 3/16"	1/4"	0.314lb.	$2.09
1 1/4"	1/4"	0.346lb.	$2.14
1 5/16"	5/16"	0.383lb.	$2.16
1 3/8"	5/16"	0.421lb.	$2.19
1 7/16"	3/8"	0.46lb.	$2.30
1 1/2	3/8"	0.491lb.	$2.46
1 5/8"	3/8"	0.588lb.	$2.67
1 3/4"	3/8"	0.682lb.	$3.29
1 15/16"	1/2"	0.833lb.	$4.92

3/4"

Total Inches: 18 inches

$25.02 2.25 lb.

Add To Cart

*Sorry, we are no longer able to cut lengths of non-keyed shaft other than 18", 36", and 72"

We recommend ordering a longer piece and using a band saw to cut your shaft to the length desired.

Need to order multiple shafts? No problem, just put one shaft into your shopping cart, then come back here, and add another, and so on. Each time you Add one to Cart, it will be entered as a new shaft.

Product Detail

Print This Page

Item Details

Part#:	Part#: FY3/4FM Item#: 6489637
Manufacturer:	
Weight:	**1.329 lbs.**
Product Name:	FY-FM Series Cast Iron 4-Bolt Ball Bearing Flange Unit
Description:	0.75" Shaft, Contact Seals, Eccentric Collar, Regreasable

Shopping

Price:	$39.84
Order Quantity:	1

Specifications

Inch/Metric	Inch	Flange Type	4-Bolt Flange
Shaft Dia. [Min]		**Shaft Dia. [Max]**	
Shaft Dia.	3/4 in	Mounted Unit Duty	Normal-Duty
Bearing Type	Ball Bearing	**Locking Device**	Eccentric Locking Collar
Housing Length	3 3/8 in	**Bolt Hole Spacing**	2 1/2 in
Bolt Circle Dia.	3.536 in	**Bearing Design**	Non-Expansion
End Type	Open End	Housing Construction	1 Piece
Housing Material	Cast Iron	Lubrication	Relubricatable
Seal Type	Contact Seals	Center of Bearing to Back of Flange Unit	
Radial Internal Clearance Specification		Series	
Axial Load [Max]		**Axial Load**	
Bearing Cavity Dia.		Bearing Clearance	
Bearing Insert	YEL 204-012-2F	Bolt Hole Size	
Bolt Size	3/8 in	Center Line to Base Dimension [Min]	

Center Line to Base Dimension [Max]		Center Line to Base Dimension	
Center of Bearing to Back of Inner Ring		Center of Bearing to Front of Inner Ring	
Collar Extension		Collar O.D.	1.297 in
Color		Counterbore Dia.	
Dynamic Load Rating		Flange Style	
Flange Thickness	5/8 in	Housing Height	3 3/8 in
Housing No.		Housing Width	1 1/8 in
Insert Type		Length Through Bore	
Location Spigot N		Location Spigot V	
Lub Fitting Type		**Misalignment Range**	
Outer Ring Size		Overall Width	1 43/64 in
Pilot Depth		Pilot Diameter [Min]	
Pilot Diameter [Max]		Pilot Diameter	
RPM [Min]		RPM [Max]	
RPM		Size Code	
Special Features		**Static Load Rating [Max]**	
Temperature Range [Min]		**Temperature Range [Max]**	
Total Float			

Product Information

Features

- Cast iron flange
- Four-bolt mounting
- Eccentric locking collar
- Narrow inner ring
- M-seal

Product Details for 350H150G

Category: Timing Belts

Print this page

Attributes	Values
Product Number	350H150G
Teeth	70
Tooth Style	(H) 1/2 pitch
Pitch Length (in)	35.000
Belt Width (in)	1.500
Pitch Length (mm)	889.00
Belt Width (mm)	38.10
Weight (lbs)	0.32
Construction	Neoprene
Reinforcement	Fiberglass
List Price	$25.32
Discount Price (10-24 Qty.)	$22.79
Discount Price (25-49 Qty.)	$20.26
Discount Price (50-99 Qty.)	$17.72
Discount Price (100-249 Qty.)	$15.19
Unit System	Inch
Competitor Part Number	350H150

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Sprockets
Pulleys
Timing Belts/Pulleys
Chain
Belts
Shafts
Bearings
Shaft Collars

Motors

Motor Mounts

Etek motor mount

Part# DCW-ETEK50

(average customer rating)

$55.00

QTY 1

Add To Cart

Stock Status: Available

General Product Information | Alternate Photos | Other Documentation | Reviews & Comments

When it comes to holding down this powerful motor, you don't want to kid around. This slick-looking and extremely durable mount was designed specifically for the huge Etek motor and the rigors of Robotic Combat.

This custom-designed mount is made of 1/2" thick 6061-T6 aluminum and comes with eight countersunk bolts to fasten directly to an Etek motor without any modifications. Simply bolt up the 8 holes to the face of your Etek, and then bolt the four remaining holes on the flanges to your bulkhead, standoff posts, or frame of your bot, and you have a very solid mount for this powerful motor.

The mount has 8 countersunk holes in 3/8" and 5/16" sizes, bolts are included. Total weight (not including bolts) is 27.16oz.

Other products you may be interested in:


Briggs & Stratton Etek Motor


Mars Brushless PMAC Motor

Home > **Timing Belt Pulleys** > **14H150-6FS8**

Product Details for 14H150-6FS8

Category: Timing Belt Pulleys

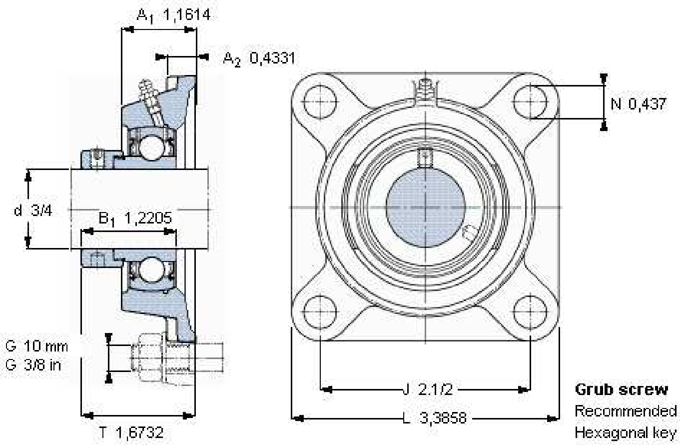
Print this page

Attributes	Values
Product Number	14H150-6FS8
Teeth	14
Tooth Style	(H) 1/2 pitch
Type	6F
Bore Type	Min. Plain Bore
Pitch Diameter (in)	2.228
Outside Diameter (in)	2.174
Flange Dia (in)	2.461
Bore / Bushing (in)	0.750
Min. Bore (in)	0.750
Max. Bore (in)	1.000
Face Width (in)	1.812
O.A.L. (in)	2.375
Pulley Belt Width (in)	1.562
Hub Dia (in)	1.625
Weight (lbs)	1.84
Material	Steel
Finish	Clear Zinc Plated
Width of Belt (in)	1.500
Width of Belt (mm)	38.100
List Price	$28.68
Discount Price (10-24 Qty.)	$24.38
Discount Price (25-49 Qty.)	$21.51
Discount Price (50-99 Qty.)	$17.93
Discount Price (100-249 Qty.)	$15.54
Unit System	Inch
Competitor Part Number	14H150

3D view | PDF | CAD | Metric | Print | Close

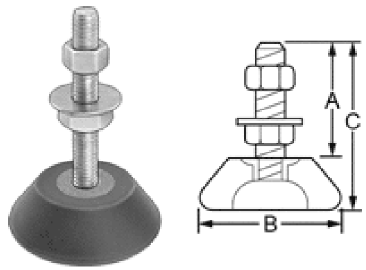
Y-bearing flanged units, cast housing, square flange, eccentric locking collar, inch bearings
Product information

Dimensions					**Basic load ratings** dynamic	static	**Limiting speed** with shaft tolerance h6	**Mass**	**Designations** Bearing unit	Housing	Bearing
d	A_1	J	L	T	C	C_0					
in					lbf		r/min	lb	-		
3/4	1,1614	2,5	3,3858	1,6732	2860	1470	8500	1,39	**FY 3/4 FM**	FY 504 U	YET 204-012

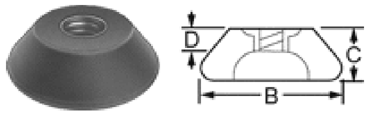


Grub screw	10-32×1/4
Recommended tightening torque [Nm]	4
Hexagonal key size [mm]	3,175

Heavy Duty Vibration-Damping Leveling Mounts



With Stud



With Threaded Hole

Higher deflection ratings translate to greater vibration and shock isolation. Mounts have a black rubber base bonded to a threaded steel insert. Temperature range is -20° to 180° F.

Mounts **with stud** include a flange nut and a hex nut for height adjustment. Stud is zinc-plated steel.

Mounts **with threaded hole** can be used with your own threaded rod or bolt. Grade 2 is recommended.

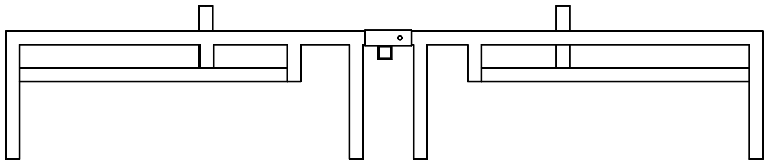
					With Stud			With Threaded Hole			
Thread Size	Cap. per Mount, lbs.	Deflection @ Max. Cap.	Base Dia. (B)	Thread Lg. (A)	O'all Ht. (C)		Each	O'all Ht. (C)	Thread Dp. (D)		Each
3/8"-16	35	0.25"	2 3/16"	2 1/2"	3 5/16"	60855K72	$5.90	13/16"	1/2"	60855K71	$3.12
3/8"-16	65	0.25"	2 3/16"	2 1/2"	3 5/16"	60855K74	5.90	13/16"	1/2"	60855K73	3.12
3/8"-16	130	0.25"	2 3/16"	2 1/2"	3 5/16"	60855K76	5.90	13/16"	1/2"	60855K75	3.12
1/2"-13	40	0.20"	2 3/16"	2 1/2"	3 5/16"	60855K51	7.42	13/16"	1/2"	60855K31	4.00
1/2"-13	80	0.20"	2 3/16"	2 1/2"	3 5/16"	60855K52	7.42	13/16"	1/2"	60855K32	4.00
1/2"-13	180	0.20"	2 3/16"	2 1/2"	3 5/16"	60855K53	7.42	13/16"	1/2"	60855K33	4.00
1/2"-13	300	0.20"	2 3/16"	2 1/2"	3 5/16"	60855K54	7.42	13/16"	1/2"	60855K34	4.00
1/2"-13	600	0.20"	2 3/16"	2 1/2"	3 5/16"	60855K55	7.42	13/16"	1/2"	60855K35	4.00

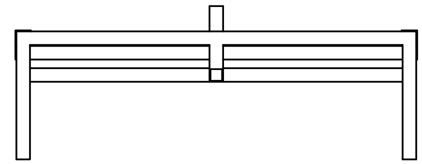
Product Details for 28H150-6FS8

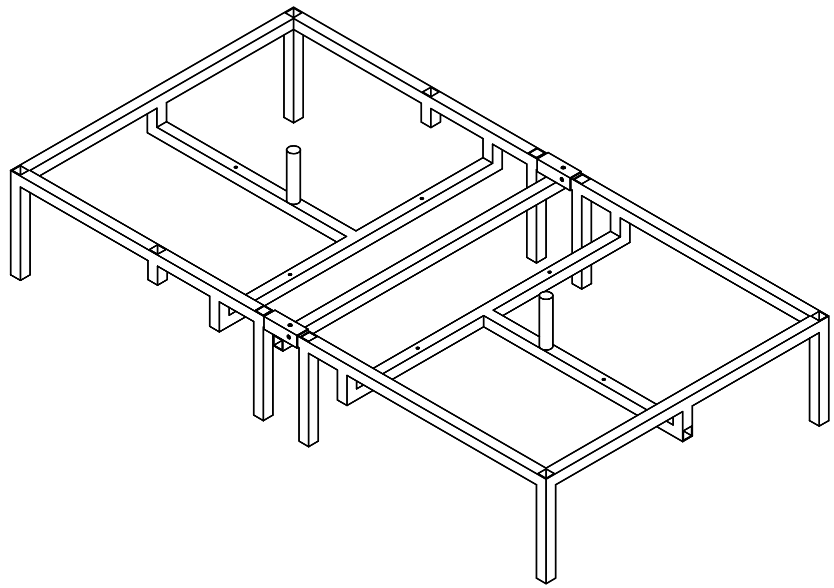
Category: Timing Belt Pulleys

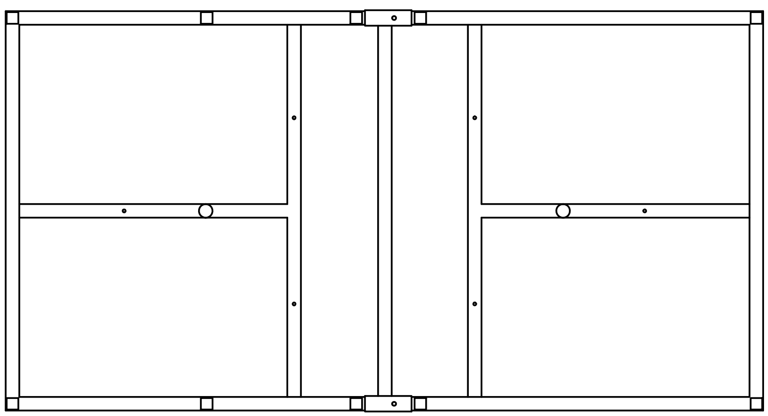
Print this page

Attributes	Values
Product Number	28H150-6FS8
Teeth	28
Tooth Style	(H) 1/2 pitch
Type	6F
Bore Type	Min. Plain Bore
Pitch Diameter (in)	4.456
Outside Diameter (in)	4.402
Flange Dia (in)	4.687
Bore / Bushing (in)	0.750
Min. Bore (in)	0.750
Max. Bore (in)	2.500
Face Width (in)	1.812
O.A.L. (in)	2.875
Pulley Belt Width (in)	1.562
Hub Dia (in)	3.500
Weight (lbs)	9.99
Material	Steel
Finish	Clear Zinc Plated
Width of Belt (in)	1.500
Width of Belt (mm)	38.100
List Price	$52.98
Discount Price (10-24 Qty.)	$45.03
Discount Price (25-49 Qty.)	$39.74
Discount Price (50-99 Qty.)	$33.11
Discount Price (100-249 Qty.)	$28.72
Unit System	Inch









ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
2	F011	Frame Small	1
1	F012	Frame Big	1

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

NEXT ASSY | USED ON

APPLICATION

DO NOT SCALE DRAWING

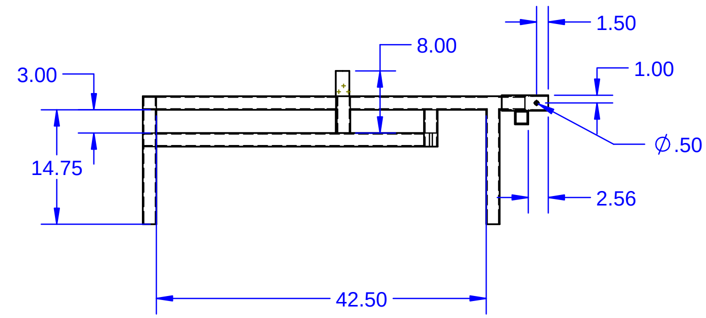
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

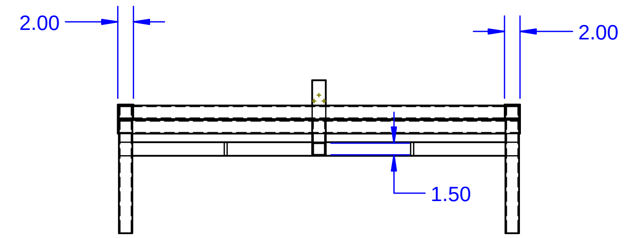
COMMENTS: FRAME SIDES CONNECT TOGETHER VIA 4 - 1/4-20" 2 1/2" BOLTS

TITLE: FRAME ASSEMBLY. FRAME BIG AND FRAME SMALL CONNECT

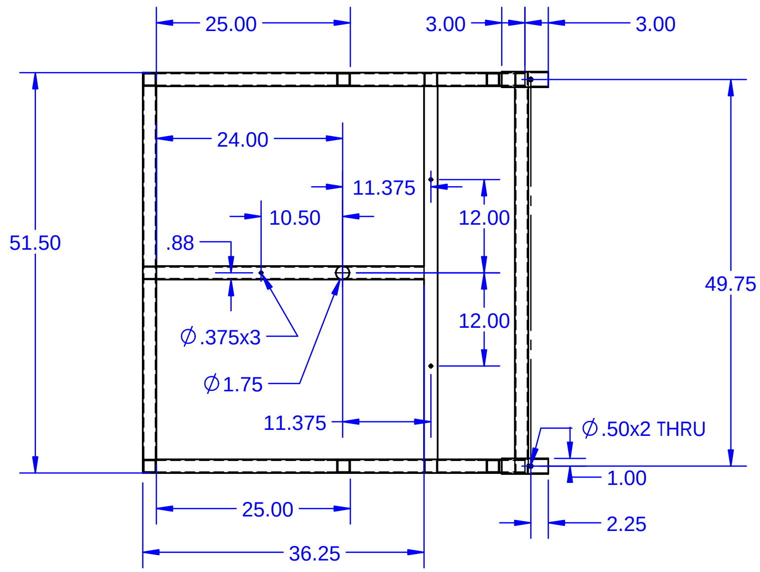
SIZE **B** DWG. NO. F001 REV

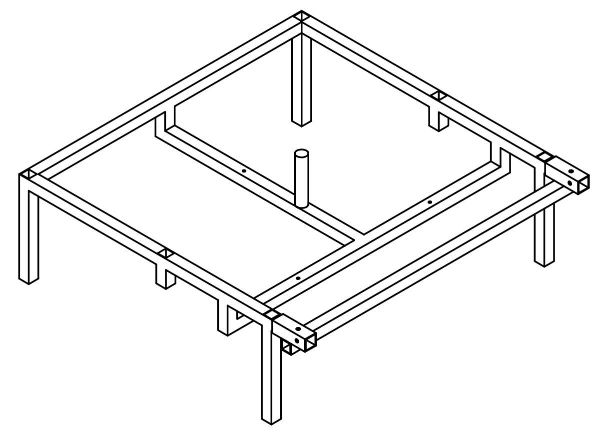
SCALE: 1:16 WEIGHT: SHEET 1 OF 1





*ALL TUBING IS 1 3/4" X 1 3/4" X t 0.125" STEEL TUBING. EXCEPT FOR 2"X2"Xt.125" CONNECTOR COLLAR





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL: STEEL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	DCHAN	
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

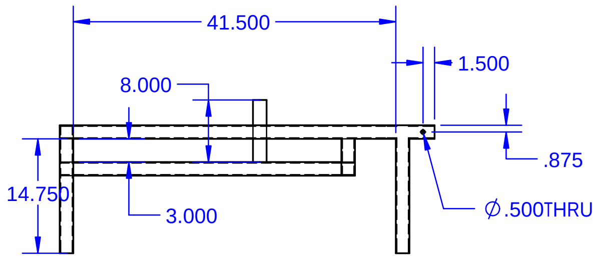
COMMENTS:
ALL TUBING 1 3/4" X 1 3/4" X t1/8" SQUARE. EXCEPT FOR 2X@'Xt1/8 CONNECTING COLLARS

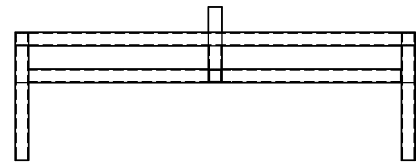
F1021	L001
NEXT ASSY	USED ON
APPLICATION	

TITLE: FRAME WITH CONNECTOR COLLAR AND ISLAND BAR

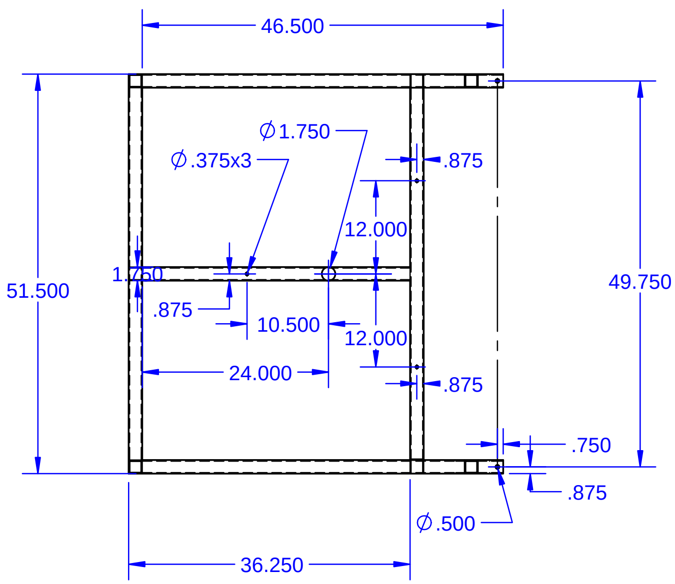
SIZE B DWG. NO. F021 REV

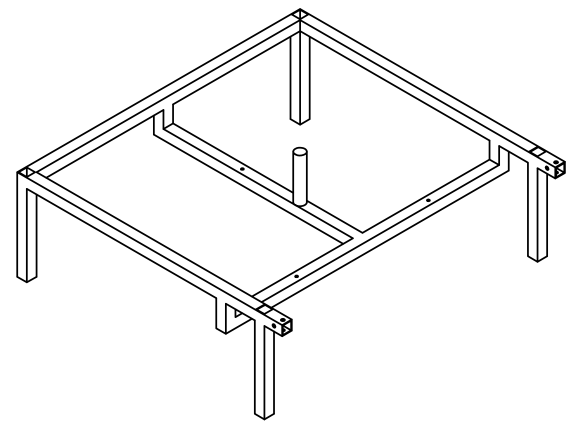
SCALE: 1:16 WEIGHT: SHEET 1 OF 1





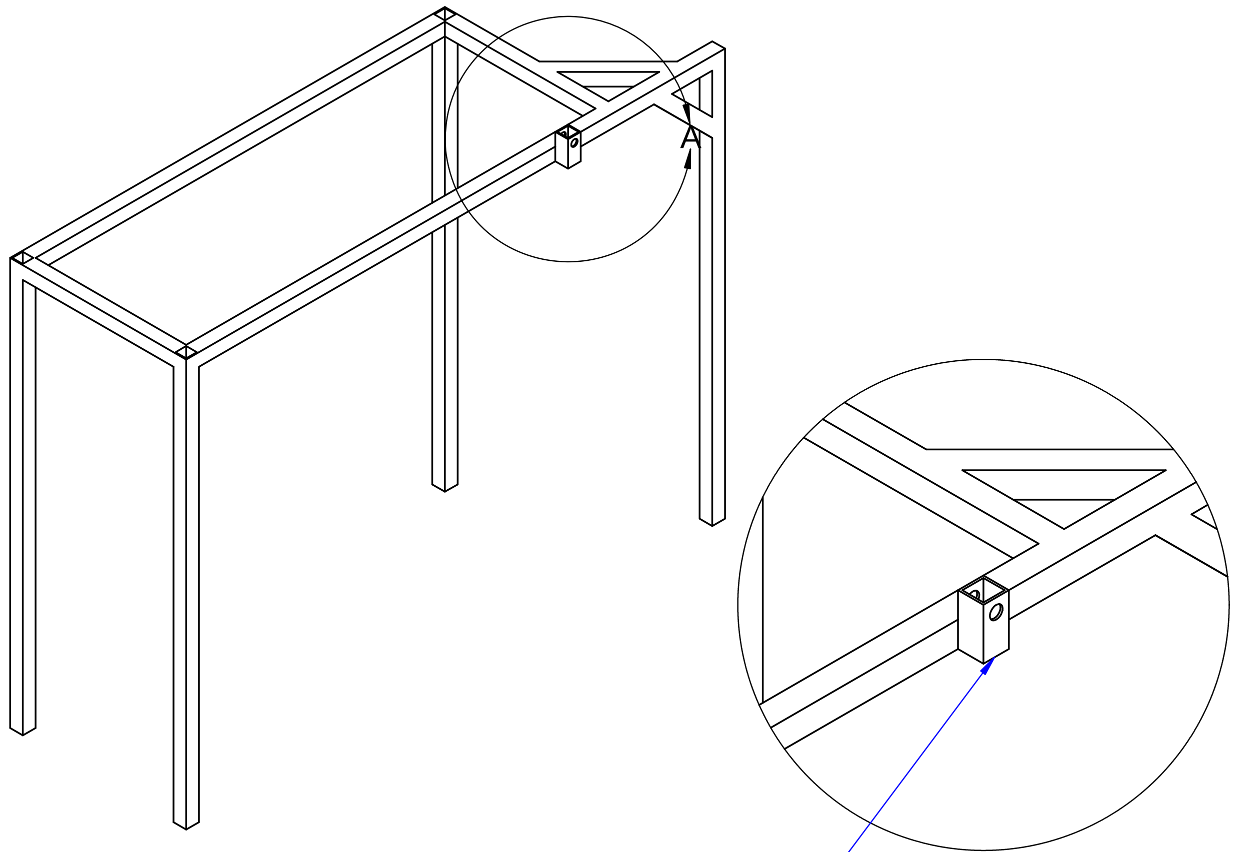
*ALL TUBING IS 1 3/4" X 1 3/4" X t 0.125" STEEL TUBING





		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	DCHAN		TITLE: FRAME SIDE WITH OUT THE COLLAR CONNECTORS
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
F001		MATERIAL	COMMENTS: ALL TUBING USED IS 1 3/4" X 1 3/4" X t1/8" TUING.			SIZE B DWG. NO. Frame Small REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:16 WEIGHT: SHEET 1 OF 1

UpperFrame Skeleton made from 1.5"x1.5"xt.125 tubing

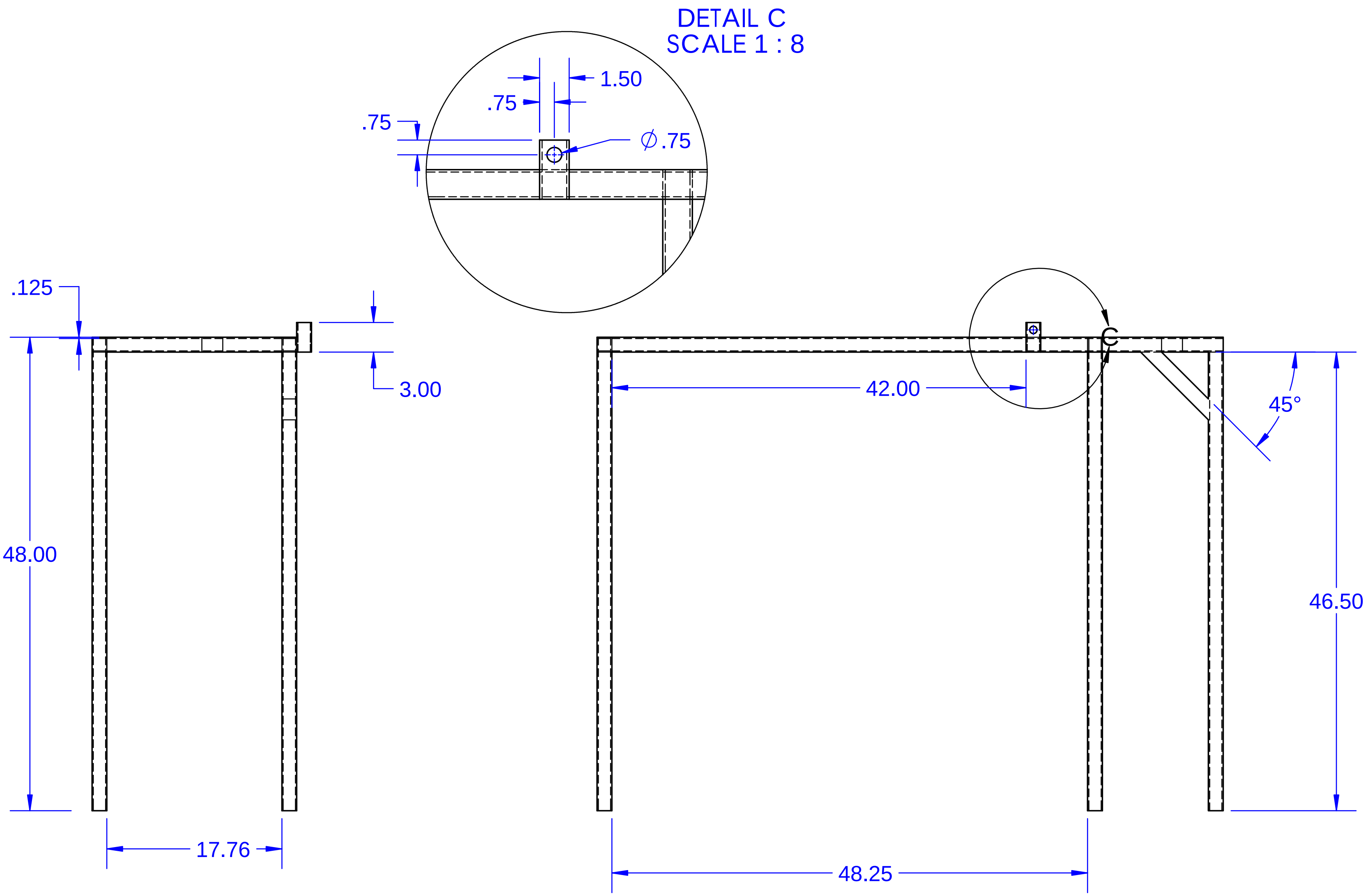


Ball Joint for Weight Assembly will be secured at this point

DETAIL A
SCALE 1 : 8

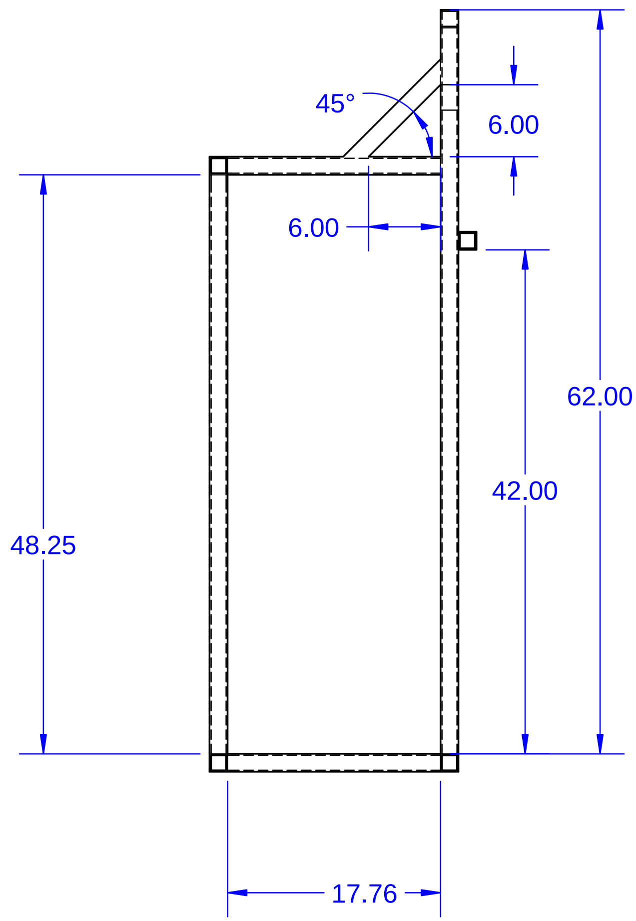
Ckd by:	Init:	Drawn By: DEREK CHAN	Init:
Next Assy: IS021	Units: INCHES	Material: STEEL	
Date: 4/20/12	Tolerance: ±1/8 IN	Group: BOARD BUSTERS	
Drawing #: UF001	Scale: 1 : 16	Title: UPPER FRAME ISOMETRIC	

Mechanical Engineering CAL POLY



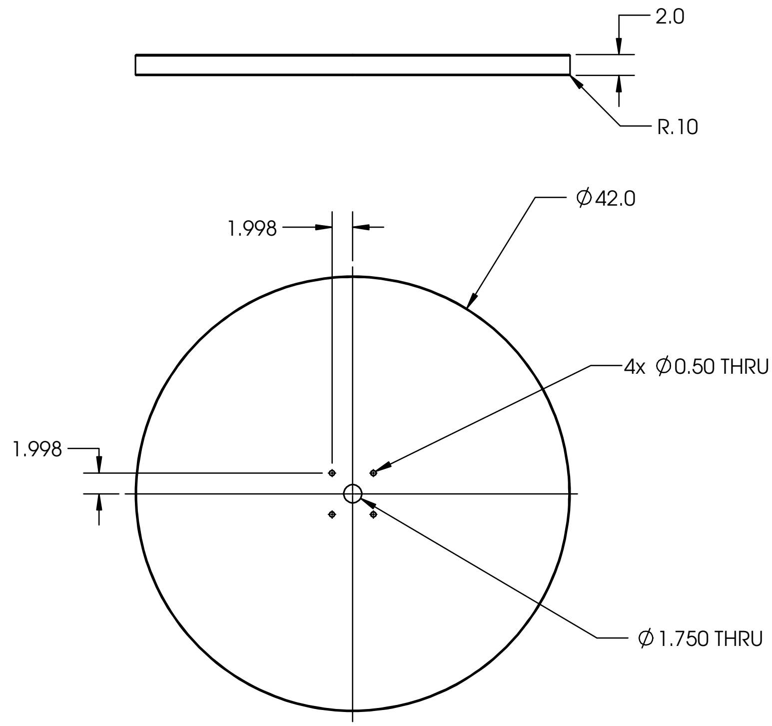
Ckd by:	Init:	Drawn By: DEREK CHAN	Init:
Next Assy: IS021	Units: INCHES	Material: STEEL	
Date: 4/20/12	Tolerance: ±1/8 IN	Group: BOARD BUSTERS	
Drawing #: UF001	Scale: 1 : 16	Title: UPPER FRAME FRONT & SIDE VIEW	

Mechanical Engineering CAL POLY



Mechanical Engineering
CAL POLY

Ckd by:	Init:	Drawn By: DEREK CHAN	Init:
Next Assy: IS021	Units: INCHES	Material: STEEL	
Date: 4/20/12	Tolerance: ±1/8 IN	Group: BOARD BUSTERS	
Drawing #: UF001	Scale: 1 : 16	Title: UPPER FRAME TOP VIEW	



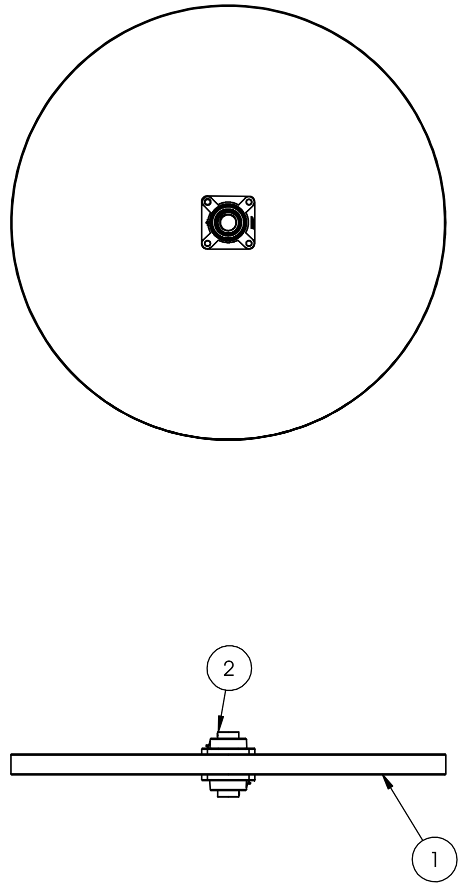
UNLESS OTHERWISE SPECIFIED:		
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±		
INTERPRET GEOMETRIC TOLERANCING PER:		
MATERIAL		
FINISH	NEXT ASSY	USED ON
DO NOT SCALE DRAWING	APPLICATION	

	NAME	DATE
DRAWN	C.H.	3/12/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

Maple Disk

SIZE	DWG. NO.	REV
B	D009	1A
SCALE: 1:12	WEIGHT:	SHEET 1 OF 1



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	D009	Maple Disk	1
2	FY_1_1_2_TF		2

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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

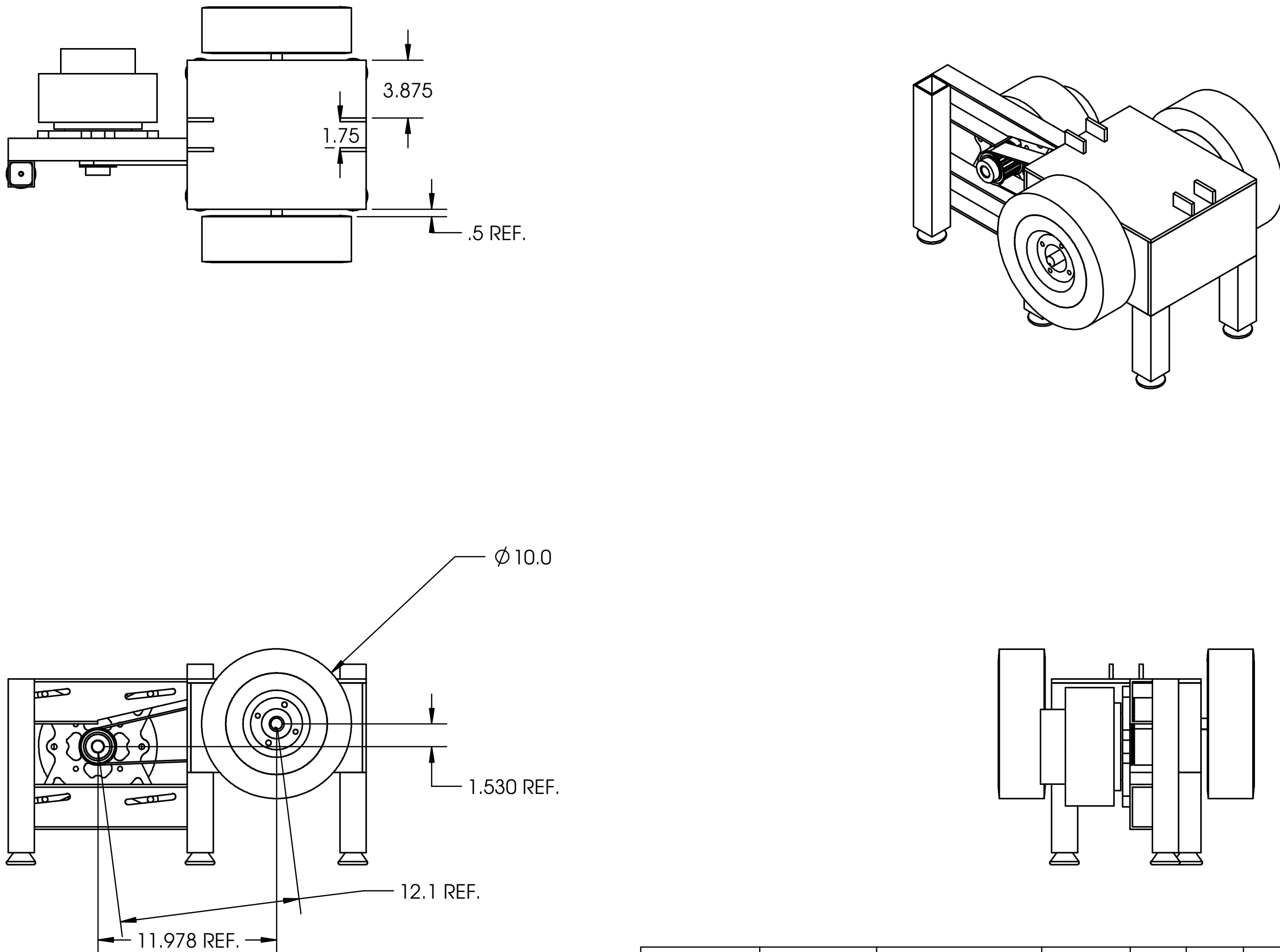
	NAME	DATE
DRAWN	C.H.	3/12/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

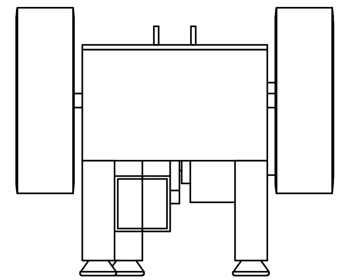
TITLE:

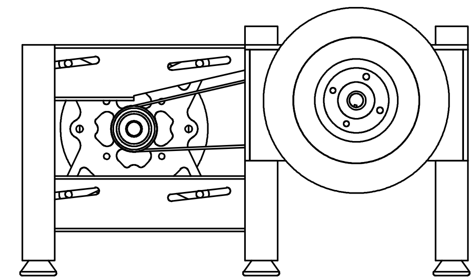
Disk Bearing Assy

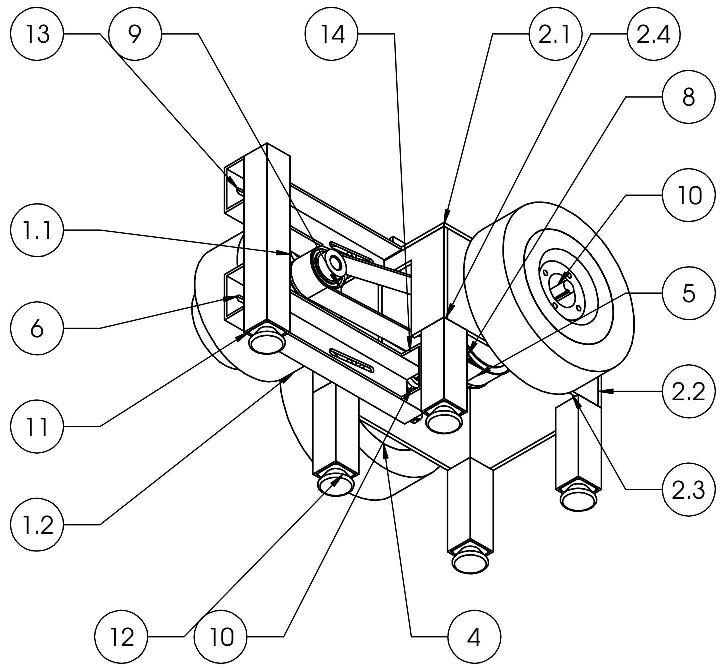
SIZE	DWG. NO.	REV
B	D011	1A
SCALE: 1:12	WEIGHT:	SHEET 1 OF 1

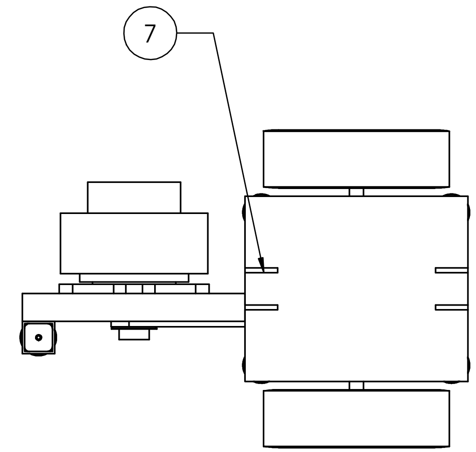


		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	C.H.	4/5/12	
			CHECKED			TITLE:
			ENG APPR.			Drivetrain Assy Dims
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE B DWG. NO. BBD024 REV 1B
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:8 WEIGHT: SHEET 1 OF 1









ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1.1	BB013	ETEK Motor Mount	1
1.2	BB014	ETEK Motor	1
2		Drivetrain Housing Assy	1
2.1	BB001	Drivetrain Top Plate	1
2.2	BB002	Drivetrain Plain Side Plate	1
2.3	BB003	Drivetrain Side Plate with Bearing Cutouts	2
2.4	BB004	Drivetrain Slotted Side Plate	1
2.5	BB019	Drivetrain Legs	4
10	BB007	Drivetrain Shaft	1
4	BB025	Wheel Assy	2
5	BB009	Drivetrain Belt	1
6	BB022	Motor Mount Lower Plate	1
7	BB017	Drivetrain to Frame Adapters	4
8	BB008	Shaft Side Pulley	1
9	BB010	ETEK Side Pulley	1
10	BB006	Drivetrain Bearings	2
11	BB020	Motor Mount Foot	1
12	BB021	Screw Feet	5
13	BB022	Motor Mount Lower Plate	1
[illegible]	[illegible]	[illegible] Plate Spacer	1

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	C.H.	4/20/2012
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

Drivetrain Assy

SIZE	DWG. NO.	REV
B	BB024(2)	1B

SCALE: 1:8 WEIGHT: SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	C.H.	4/5/2012
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

NEXT ASSY	USED ON
APPLICATION	

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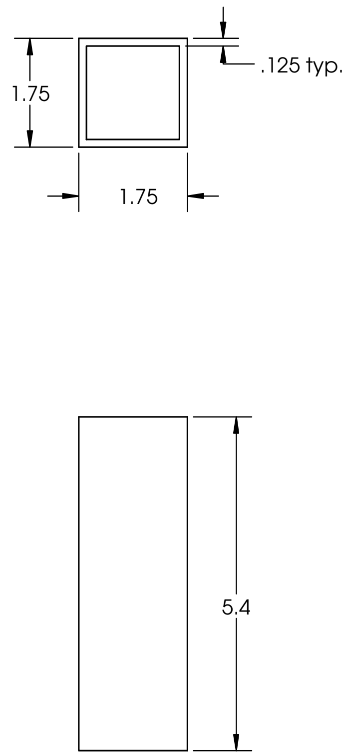
TITLE:

Drivetrain Housing Legs Assy

SIZE	DWG. NO.	REV
B	BBD	1B
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1



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NEXT ASSY	USED ON
APPLICATION	

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	C.H.	4/5/2012
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

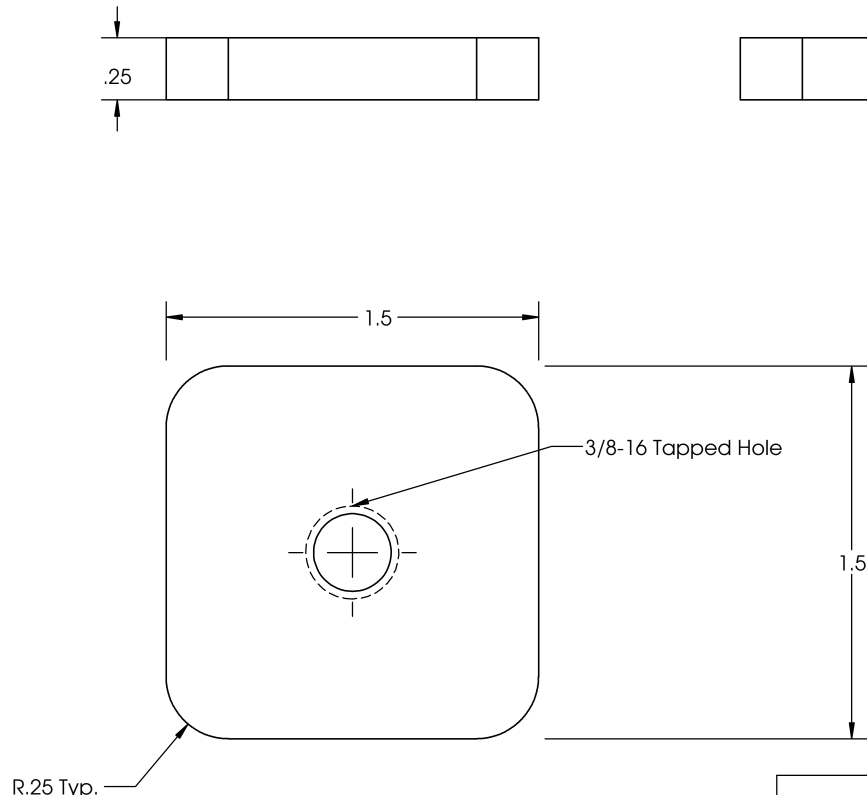
COMMENTS:

TITLE:

Drivetrain Housing Legs

SIZE	DWG. NO.	REV
B	BBD005	1B

SCALE: 1:2 WEIGHT: SHEET 1 OF 1



	NAME	DATE
DRAWN	C.H.	4/5/2012
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

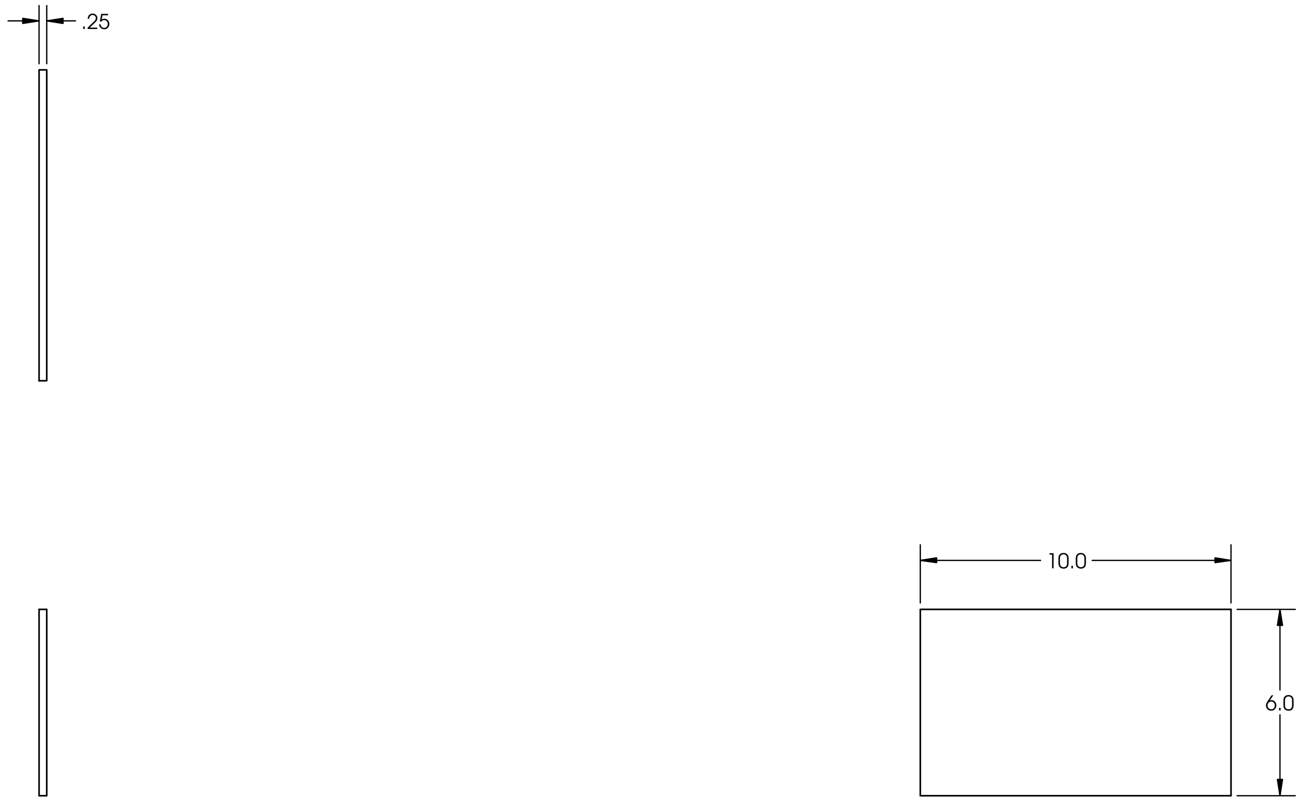
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

NEXT ASSY	USED ON
APPLICATION	

TITLE:
Drivetrain Leg Screw Feet Plates

SIZE **B** DWG. NO. BBD REV 1B

SCALE: 2:1 WEIGHT: SHEET 1 OF 1



	NAME	DATE			
DRAWN	C.H.	4/5/2012			
CHECKED					
ENG APPR.					
MFG APPR.					
Q.A.					

COMMENTS:

TITLE:

Drivetrain Plain Side Plate

SIZE: B | DWG. NO. BBD002 | REV 1B

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1

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

INTERPRET GEOMETRIC TOLERANCING PER:

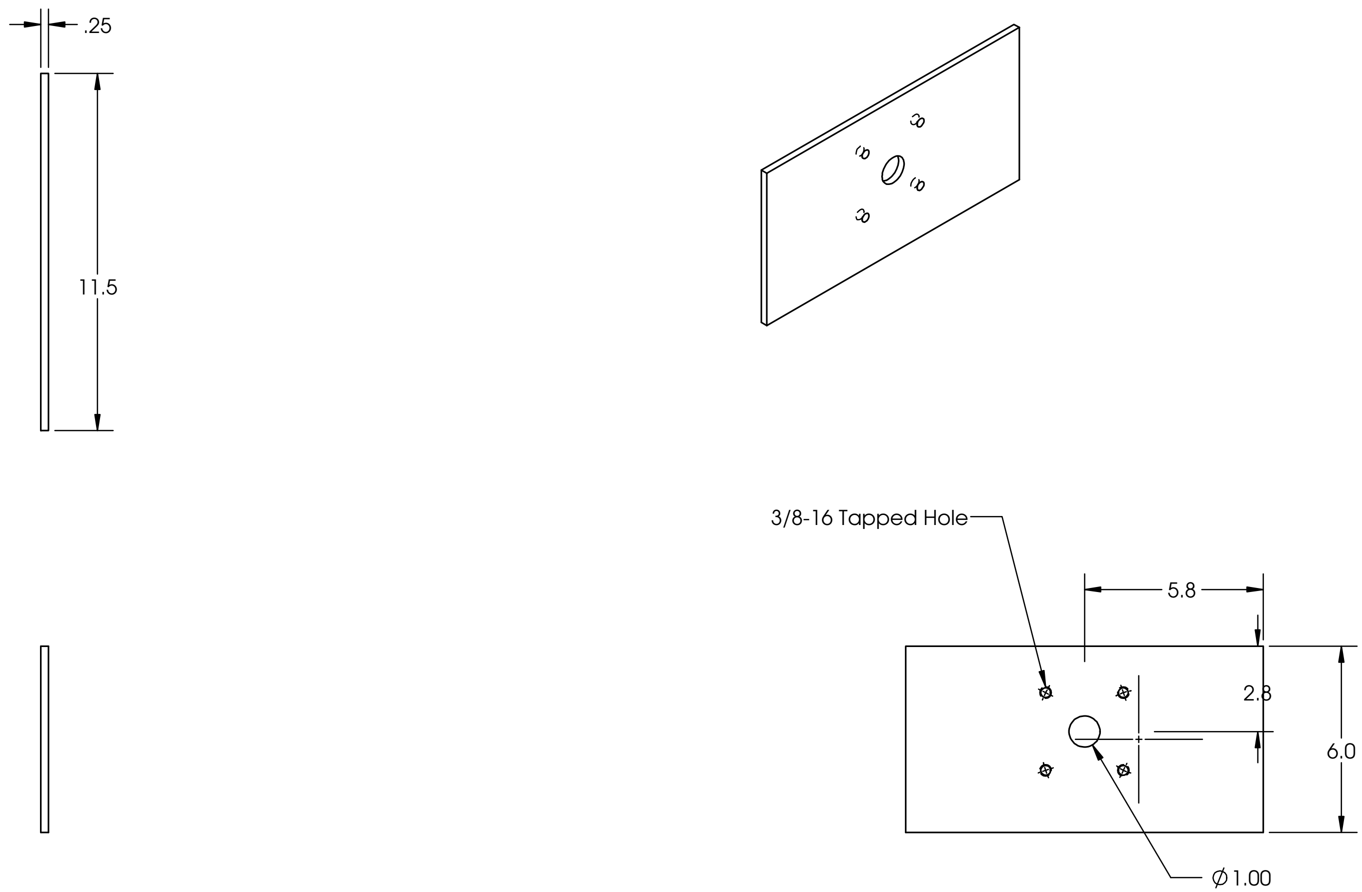
MATERIAL

FINISH

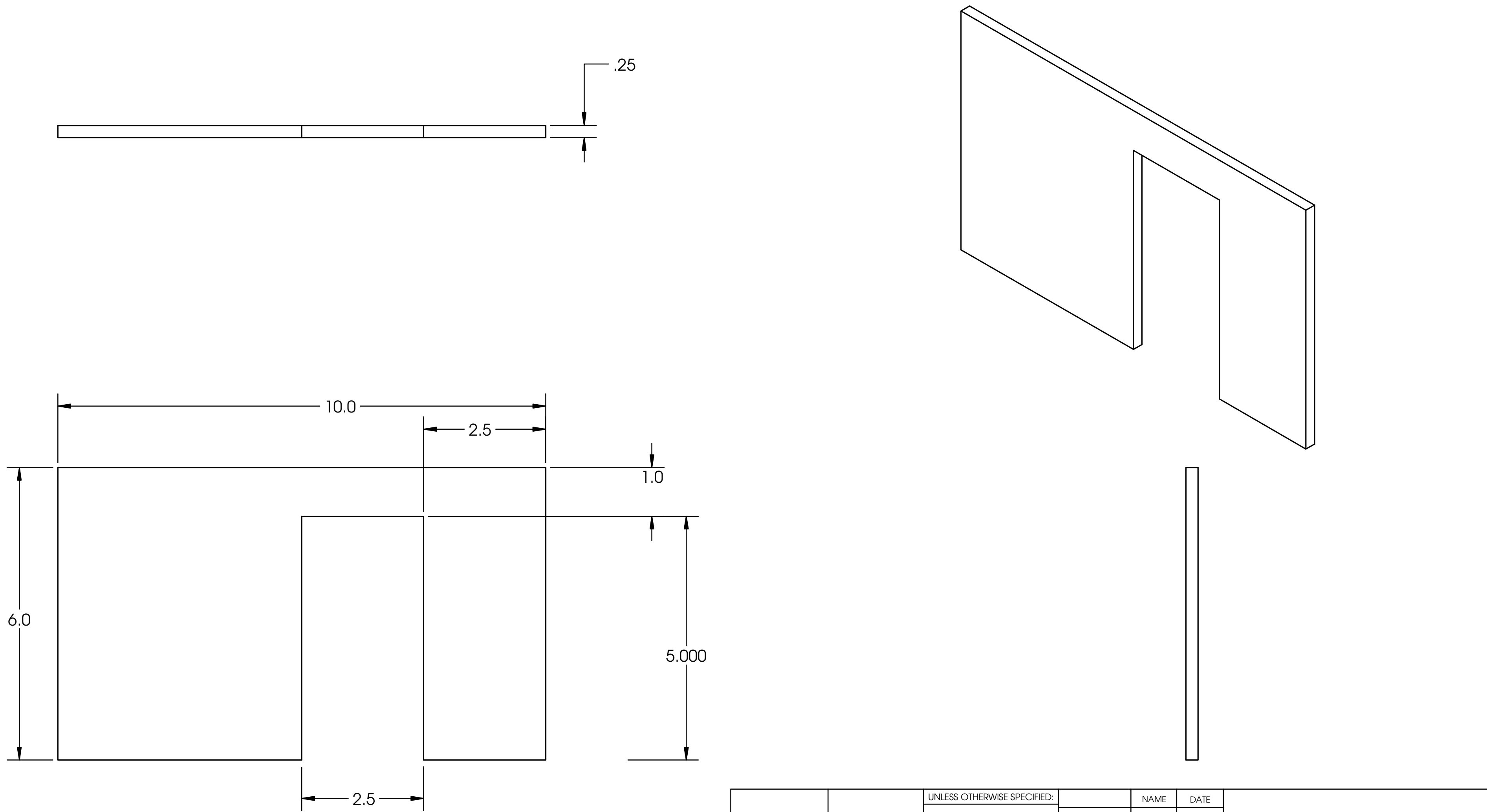
DO NOT SCALE DRAWING

NEXT ASSY | USED ON

APPLICATION



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	C.H.	4/5/2012	
			CHECKED			TITLE: Drivetrain Side Plate with Cutouts
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE B · DWG. NO. BBD003 · REV 1B
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:4 · WEIGHT: · SHEET 1 OF 1



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NEXT ASSY	USED ON
APPLICATION	

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

INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

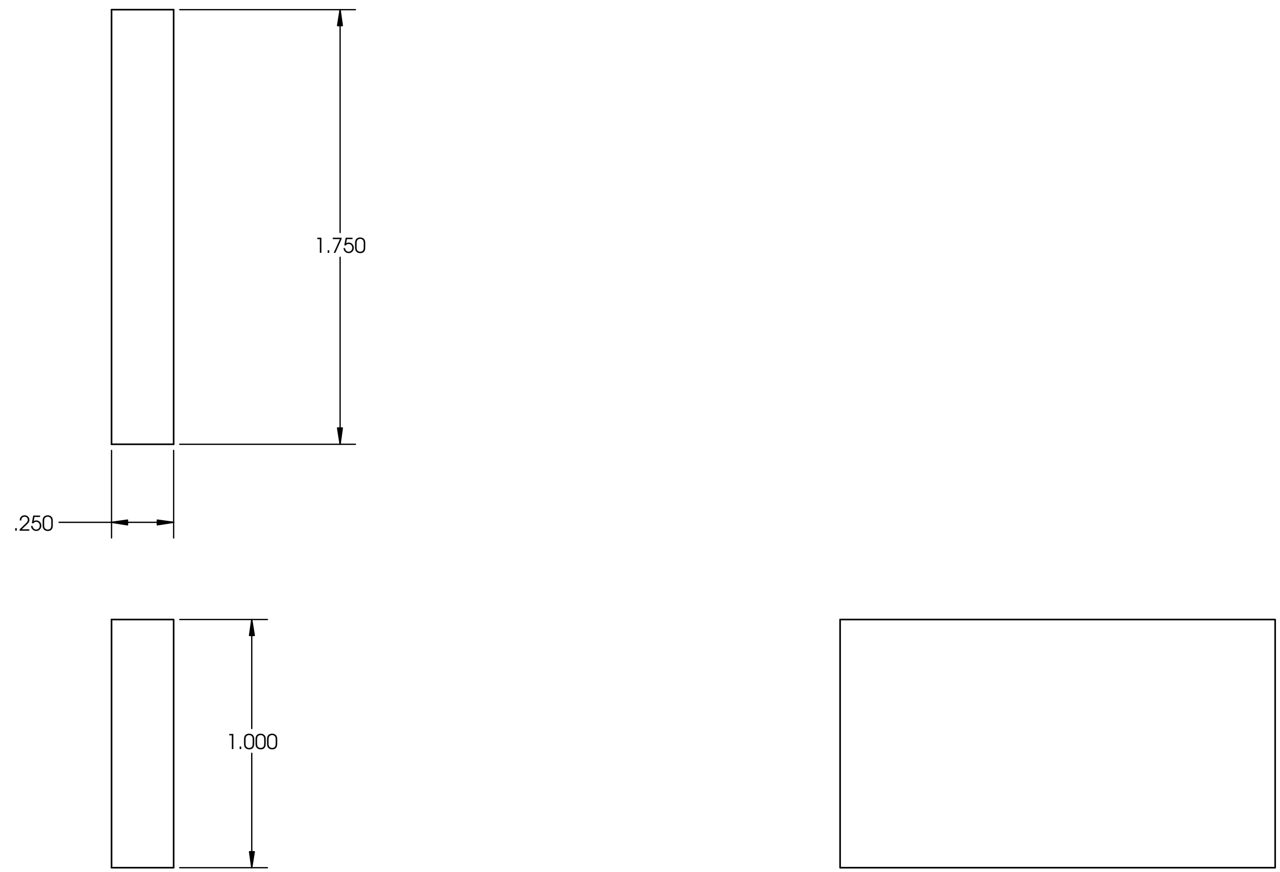
	NAME	DATE
DRAWN	C.H.	4/5/2012
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

Drivetrain Slotted Side Plate

SIZE	DWG. NO.	REV
B	BBD004	1B
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1



NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

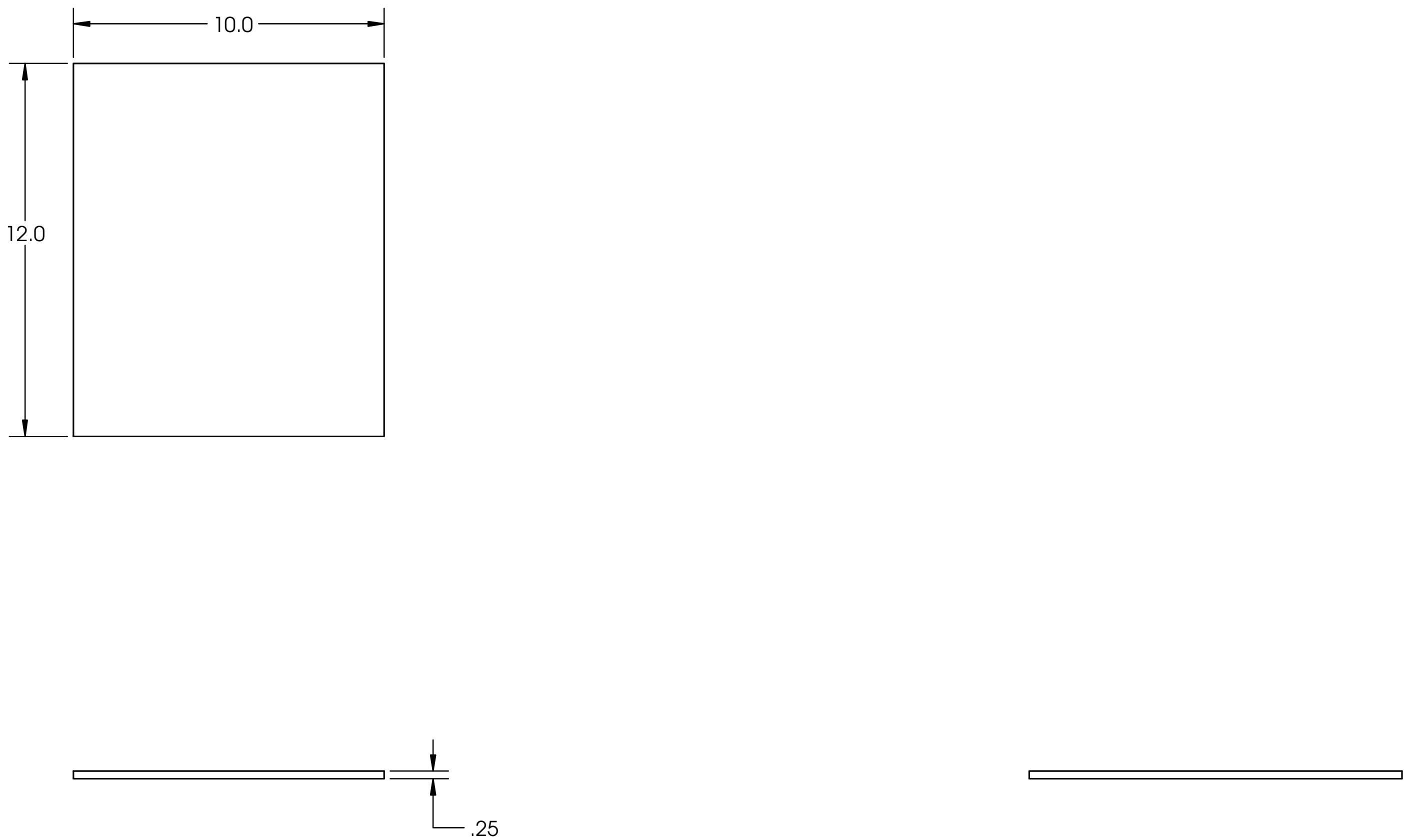
	NAME	DATE
DRAWN	C.H.	4/5/2012
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
Drivetrain to Frame Adapters

SIZE	DWG. NO.	REV
B	BB017	1B

SCALE: 2:1 WEIGHT: SHEET 1 OF 1



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NEXT ASSY	USED ON
APPLICATION	

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	C.H.	4/5/2012
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

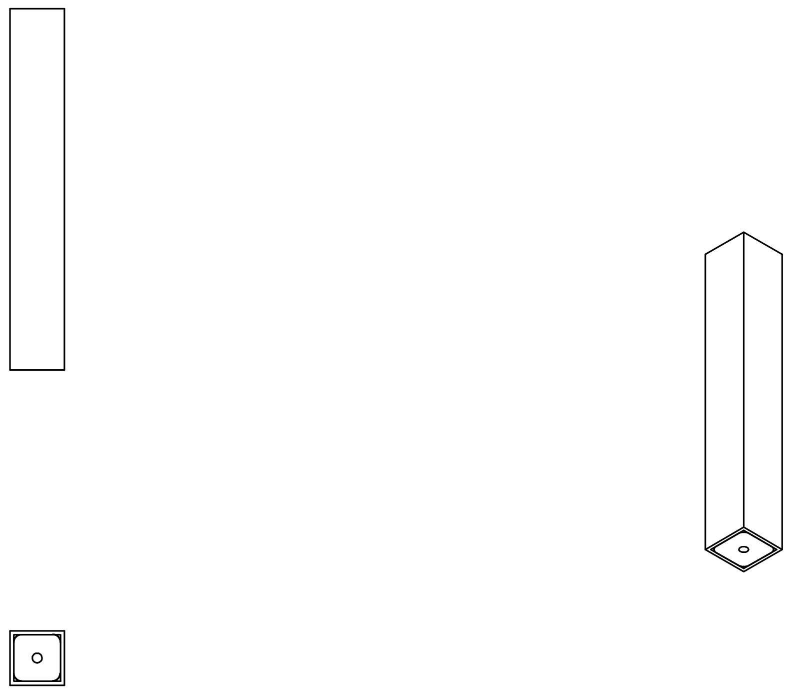
COMMENTS:

TITLE:

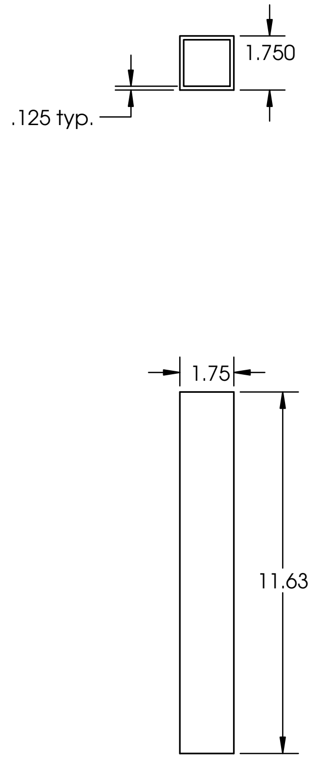
Drivetrain Top Plate

SIZE	DWG. NO.	REV
B	BBD001	1B

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	C.H.	4/5/2012	
			CHECKED			TITLE:
			ENG APPR.			Motor Mount Foot Assy
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE B / DWG. NO. BBD / REV 1B
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:4 / WEIGHT: / SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	C.H.	4/5/2012	
			CHECKED			TITLE:
			ENG APPR.			Motor Mount Leg
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE B · DWG. NO. BBD012 · REV 1B
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:4 · WEIGHT: · SHEET 1 OF 1

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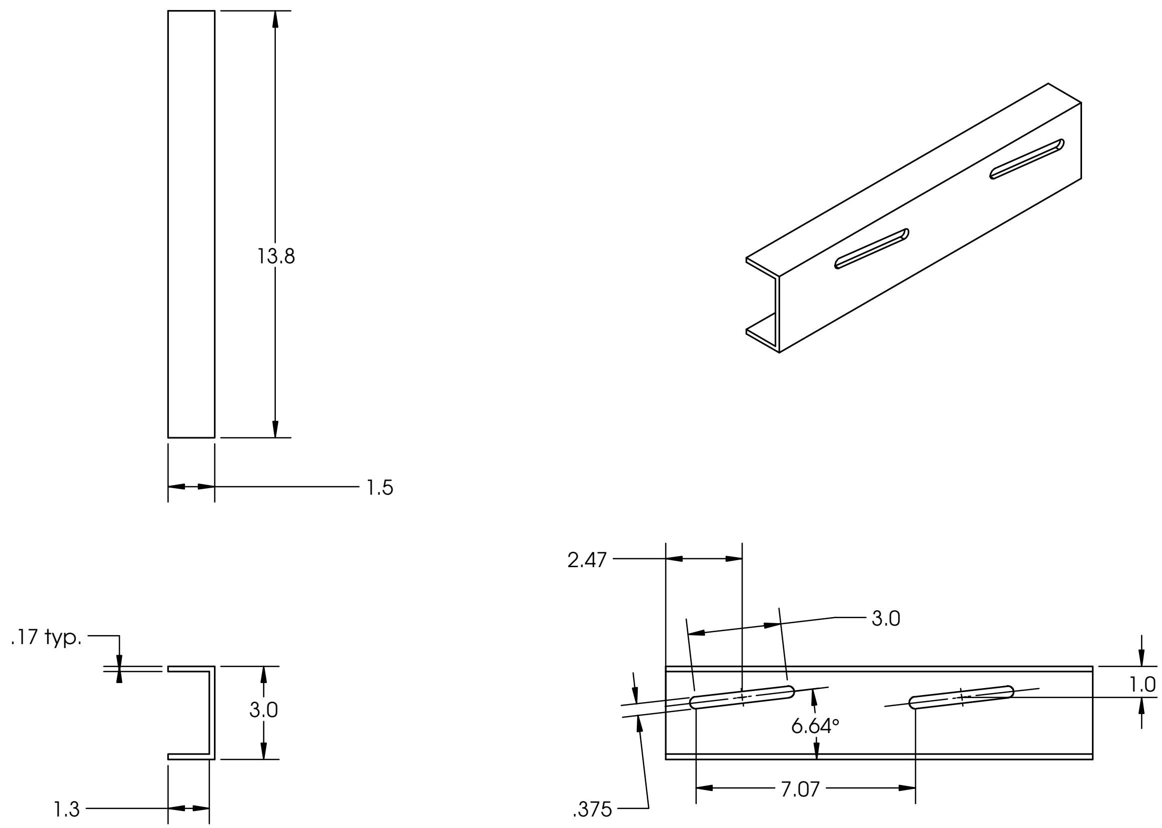

Note:
Standard C3X5 Steel Channel referenced here and may be used with slot and length modifications.

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NEXT ASSY	USED ON
APPLICATION	

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

INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

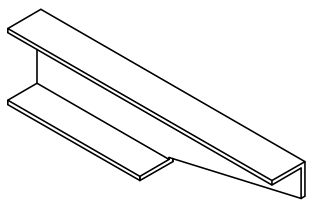
	NAME	DATE
DRAWN	C.H.	4/5/2012
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

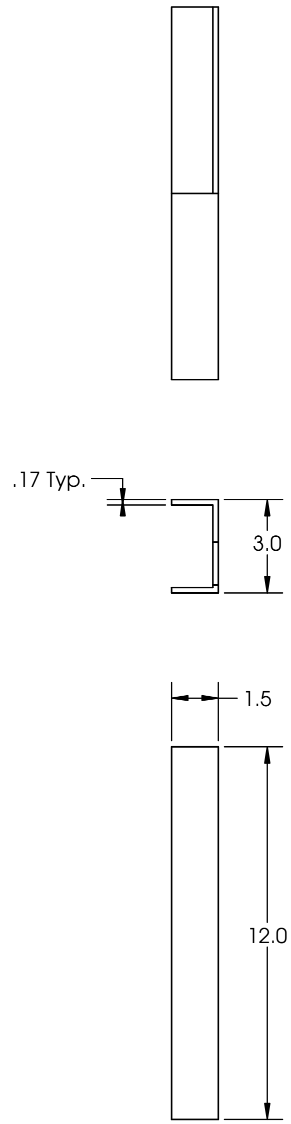
COMMENTS:

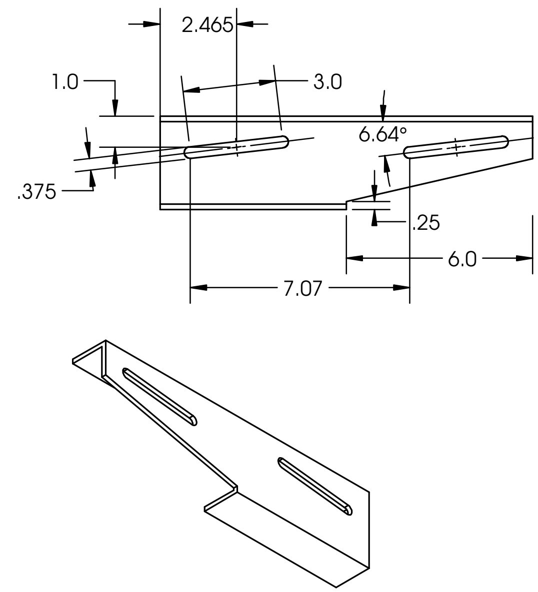
TITLE:
Motor Mount Plates

SIZE	DWG. NO.	REV
B	BBD011	1B

SCALE: 1:4 WEIGHT: SHEET 1 OF 1







Note:
Standard C3X5 Steel Channel referenced here and may be used with slot, angle, and length modifications.

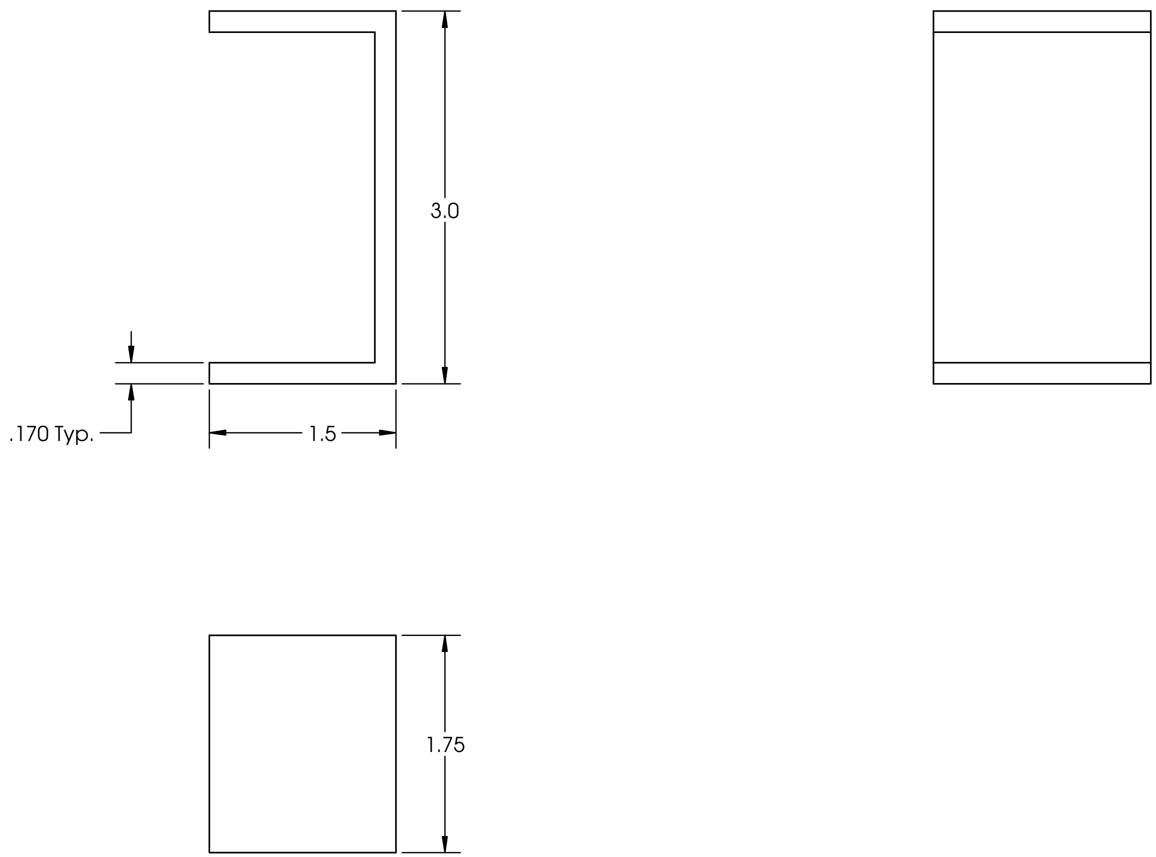
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	C.H.	4/5/2012
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:

Motor Mount Upper Plate

SIZE	DWG. NO.	REV
B	BBD	1B

SCALE: 1:4 WEIGHT: SHEET 1 OF 1



Note:
Standard C3X5 Steel Channel referenced here and may be used with length modifications.

PROPRIETARY AND CONFIDENTIAL

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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	C.H.	4/5/2012
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

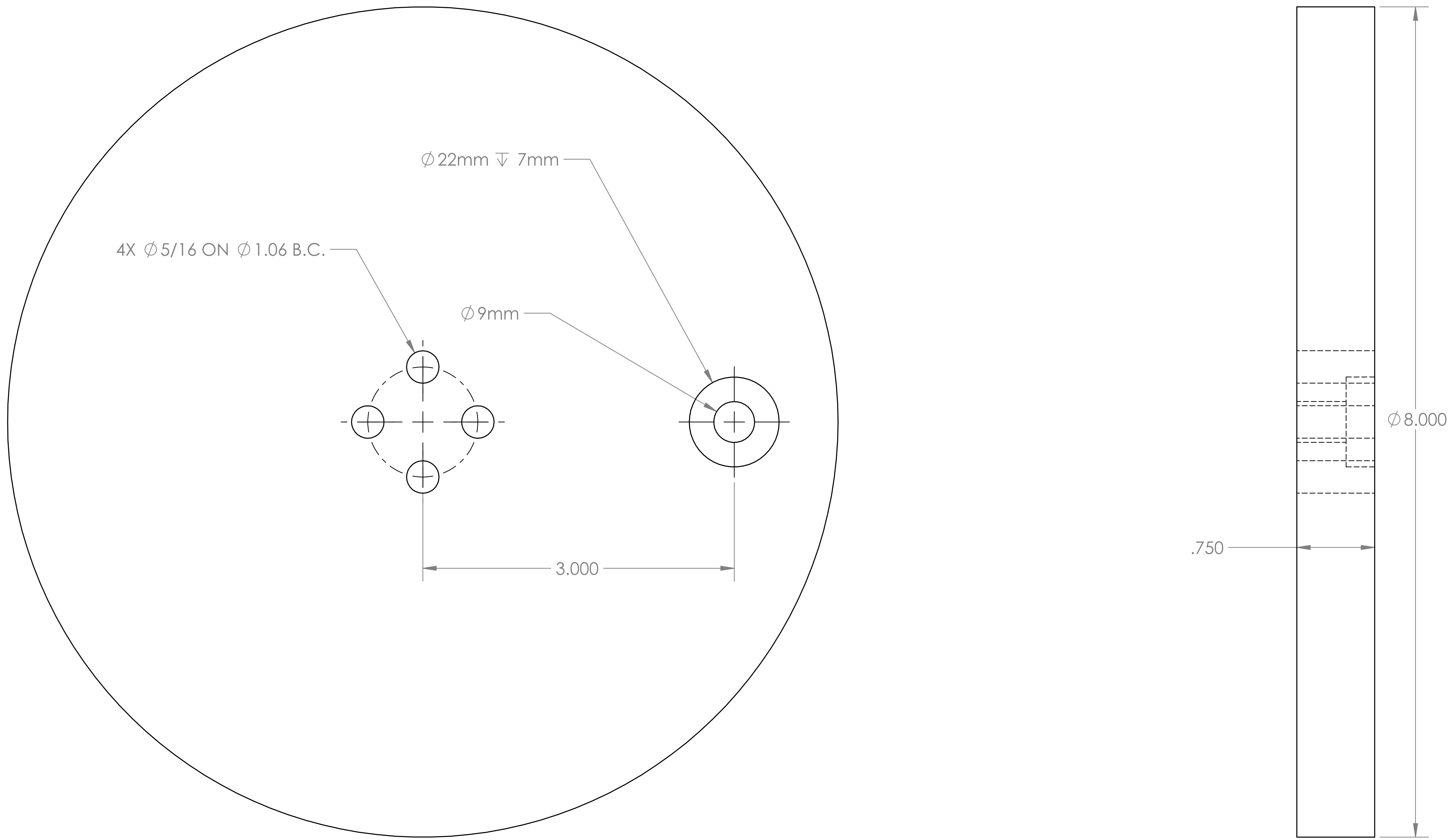
COMMENTS:

TITLE:

Mounting Plate Spacer

SIZE	DWG. NO.	REV
B	BBD	1B

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1



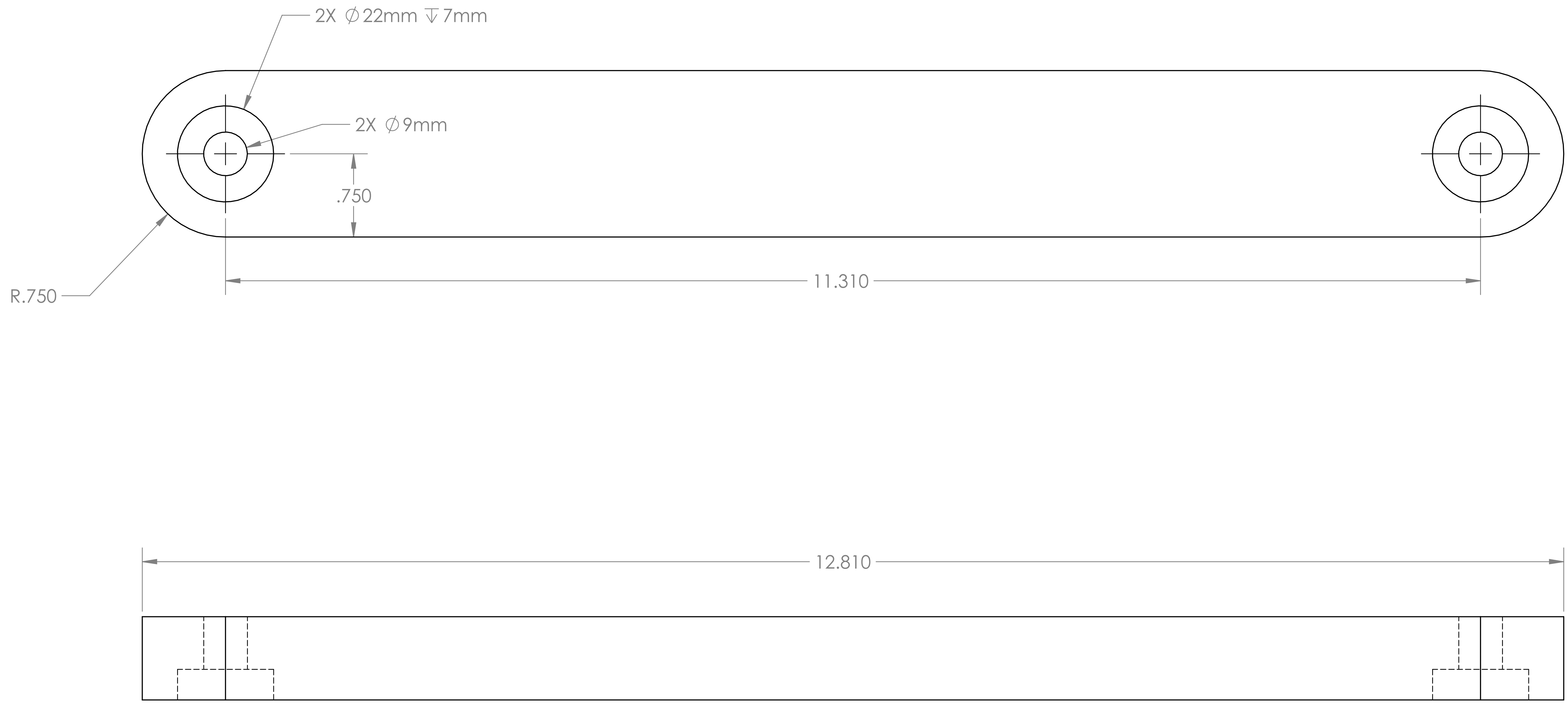
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	N.L.	4/24/12
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL: 6061 T6 ALUMINUM	COMMENTS: 22mm HOLES ARE MEANT FOR A TIGHT FIT WITH A 22mm BALL BEARING.		
FINISH			
DO NOT SCALE DRAWING			

NEXT ASSY: FB02	USED ON
APPLICATION	

TITLE:

Crank

SIZE	DWG. NO.	REV
B	FB01	1
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1



NEXT ASSY: FB02	USED ON
APPLICATION	

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 6061 T6 ALUMINUM

FINISH

DO NOT SCALE DRAWING

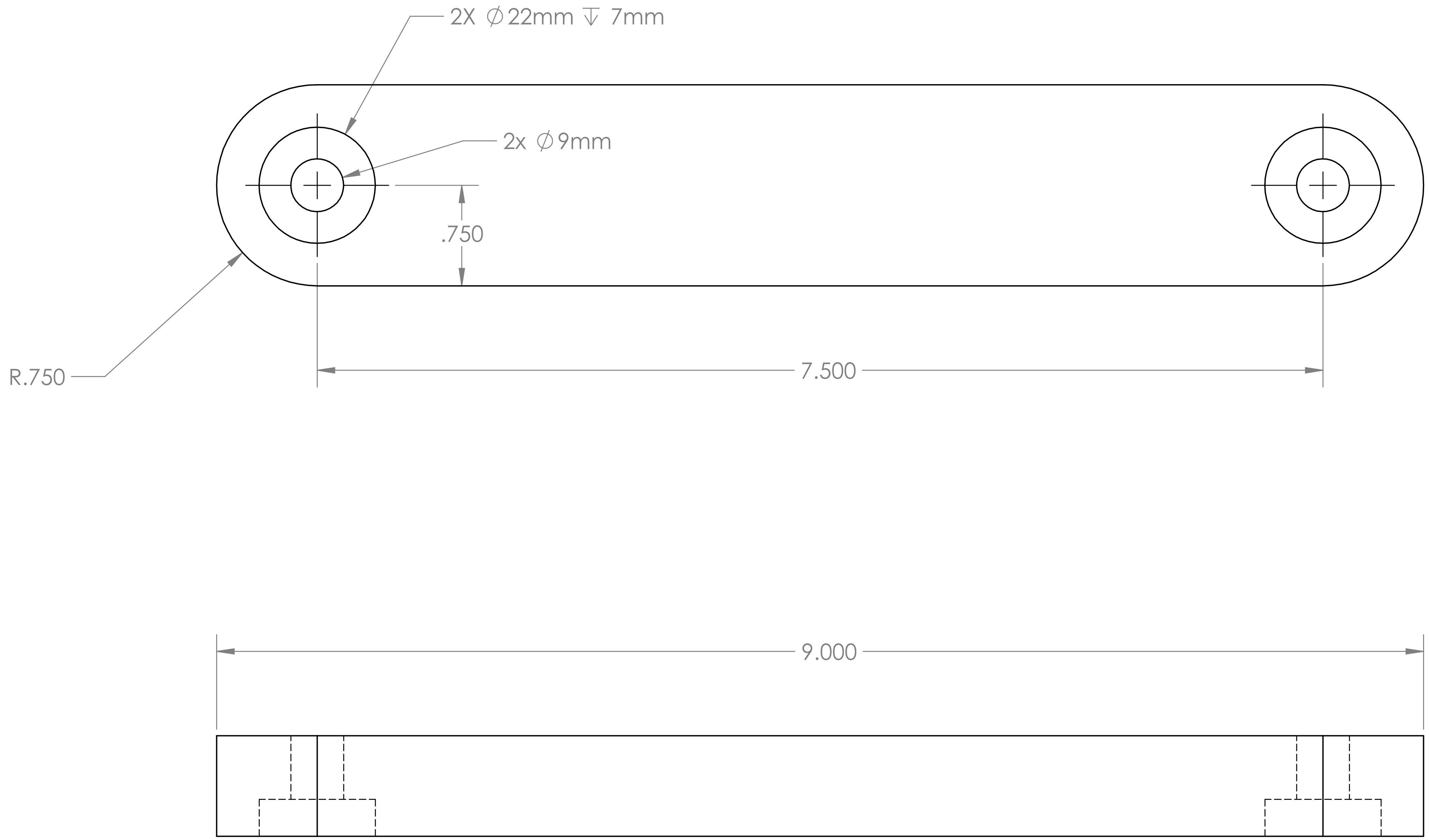
	NAME	DATE
DRAWN	N.L.	4/24/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS: 22mm HOLES ARE MEANT FOR A TIGHT FIT WITH A 22mm BALL BEARING.

TITLE:
Coupler

SIZE	DWG. NO.	REV
B	FB02	1

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



NEXT ASSY: FB02	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 6061 T6 ALUMINUM

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	N.L.	4/24/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

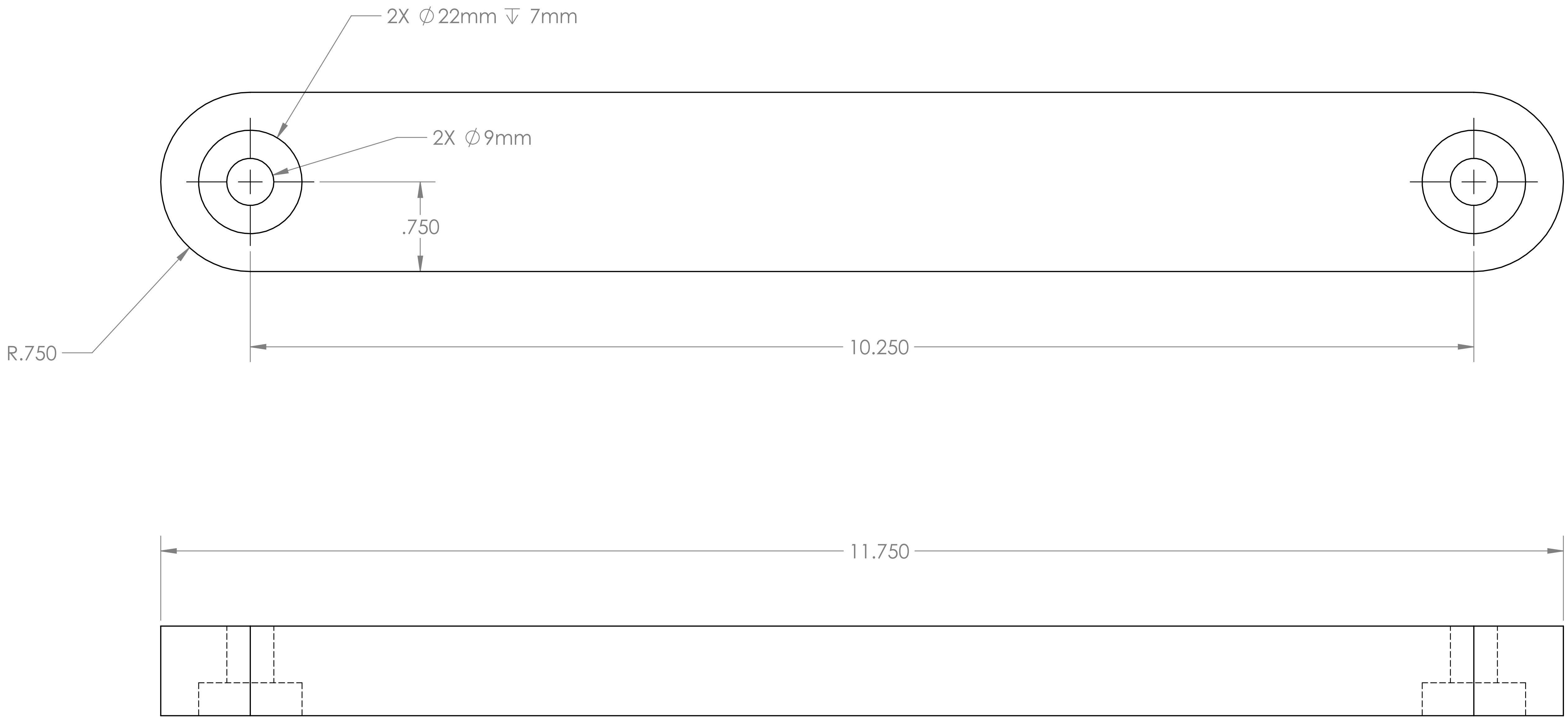
COMMENTS: 22mm HOLES ARE MEANT FOR A TIGHT FIT WITH A 22mm BALL BEARING.

TITLE:

Rocker

SIZE	DWG. NO.	REV
B	FB03	1

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



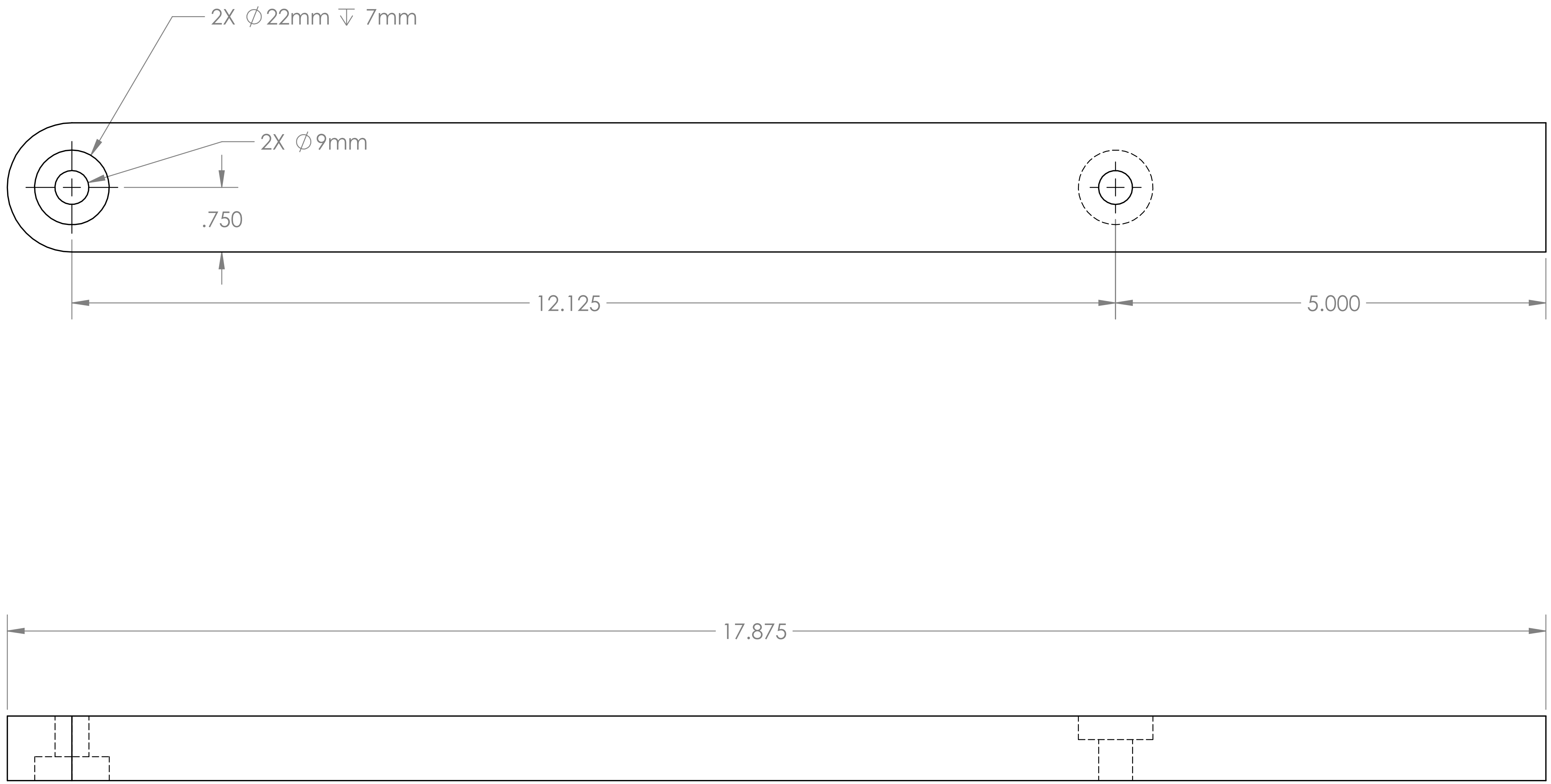
NEXT ASSY: FB02	USED ON	UNLESS OTHERWISE SPECIFIED:		NAME	DATE
APPLICATION		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	N.L.	4/24/12
		INTERPRET GEOMETRIC TOLERANCING PER:	CHECKED		
		MATERIAL: 6061 T6 ALUMINUM	ENG APPR.		
		FINISH	MFG APPR.		
		DO NOT SCALE DRAWING	Q.A.		

COMMENTS: 22mm HOLES ARE MEANT FOR A TIGHT FIT WITH A 22mm BALL BEARING.

TITLE:

Connector

SIZE	DWG. NO.	REV
B	FB04	1
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1



NEXT ASSY: FB02	USED ON
APPLICATION	

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 6061 T6 ALUMINUM

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	N.L.	4/24/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

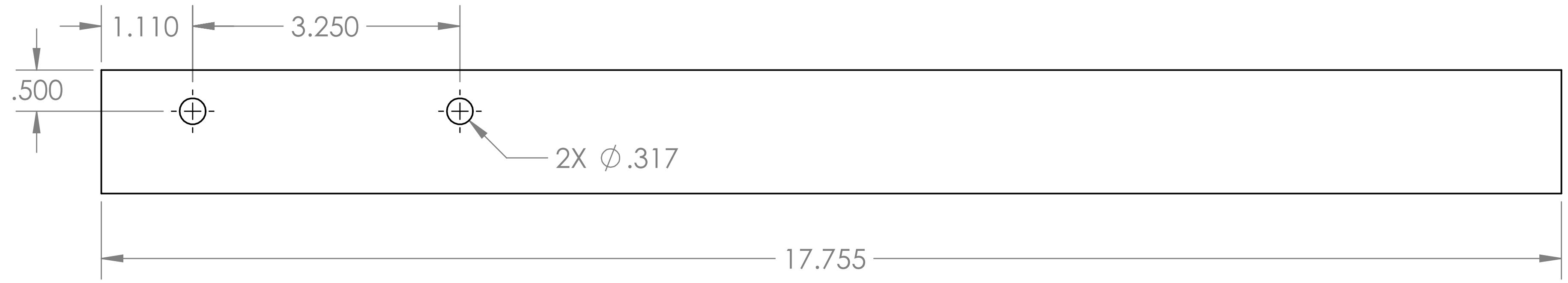
COMMENTS: 22mm HOLES ARE MEANT FOR A TIGHT FIT WITH A 22mm BALL BEARING.

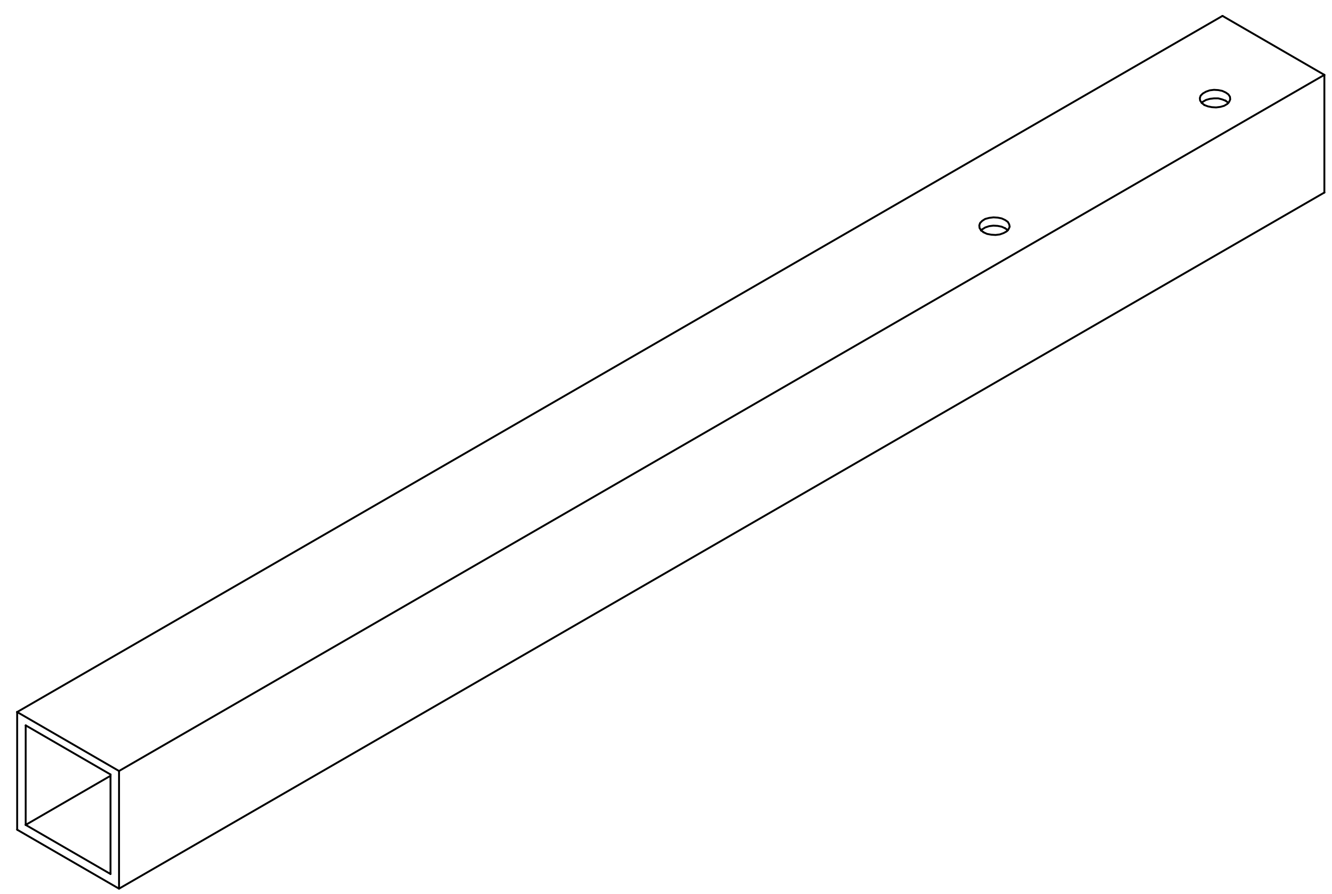
TITLE:

Moment Arm

SIZE	DWG. NO.	REV
B	FB05	1

SCALE: 1:2 WEIGHT: SHEET 1 OF 1





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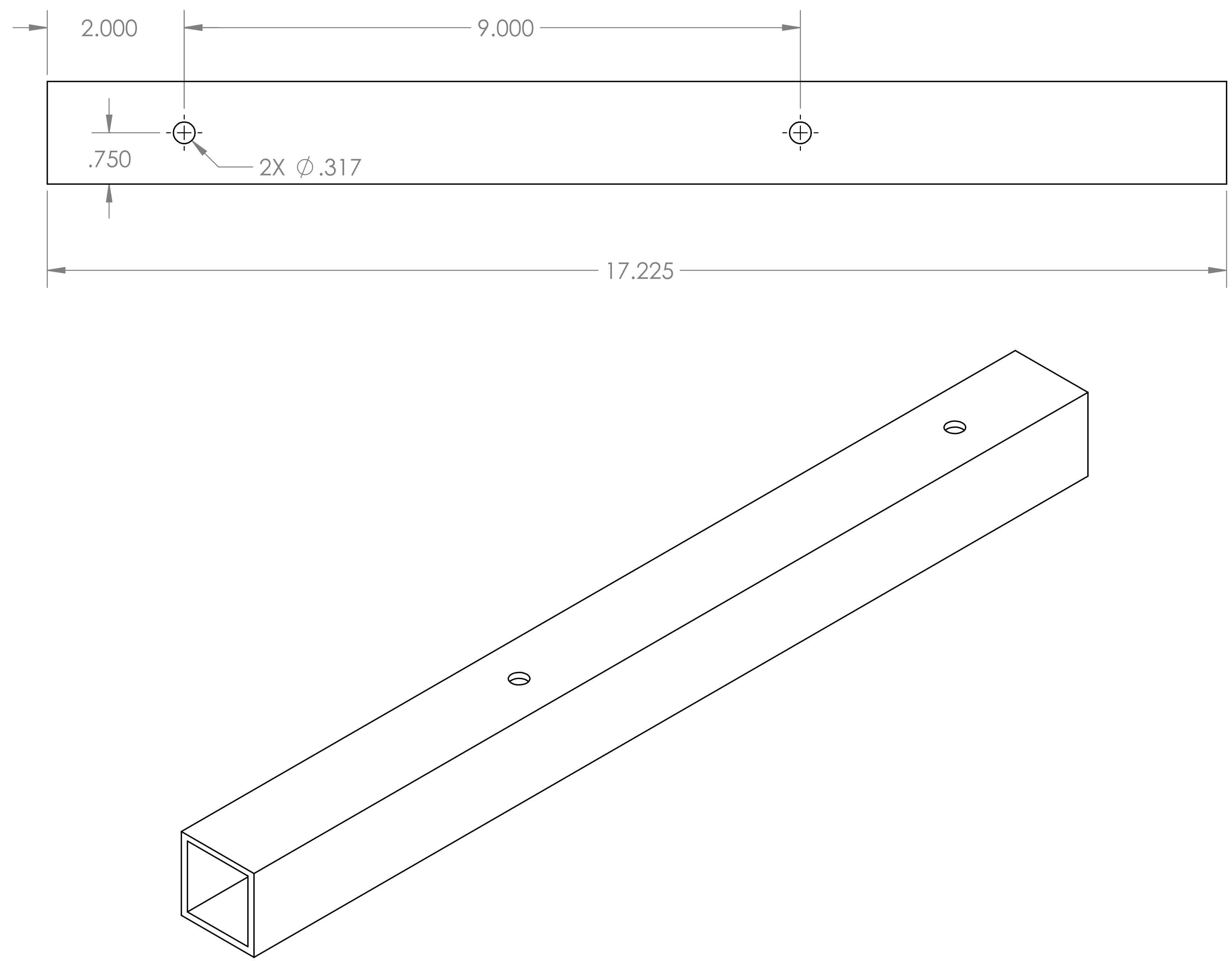
NEXT ASSY: N/A	USED ON	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±		NAME	DATE
APPLICATION		INTERPRET GEOMETRIC TOLERANCING PER:	DRAWN	N.L.	4/24/12
		MATERIAL: 1.5" SQAURE STEEL TUBE WITH .125" WALL THICKNESS	CHECKED		
		FINISH	ENG APPR.		
		DO NOT SCALE DRAWING	MFG APPR.		
			Q.A.		
			COMMENTS:		

TITLE:

Part #12

SIZE B | DWG. NO. FBM04 | REV 1

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1



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NEXT ASSY	USED ON
NEXT ASSY: FBM08	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 1.5" SQAURE STEEL TUBE WITH .125" WALL THICKNESS

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	N.L.	4/24/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

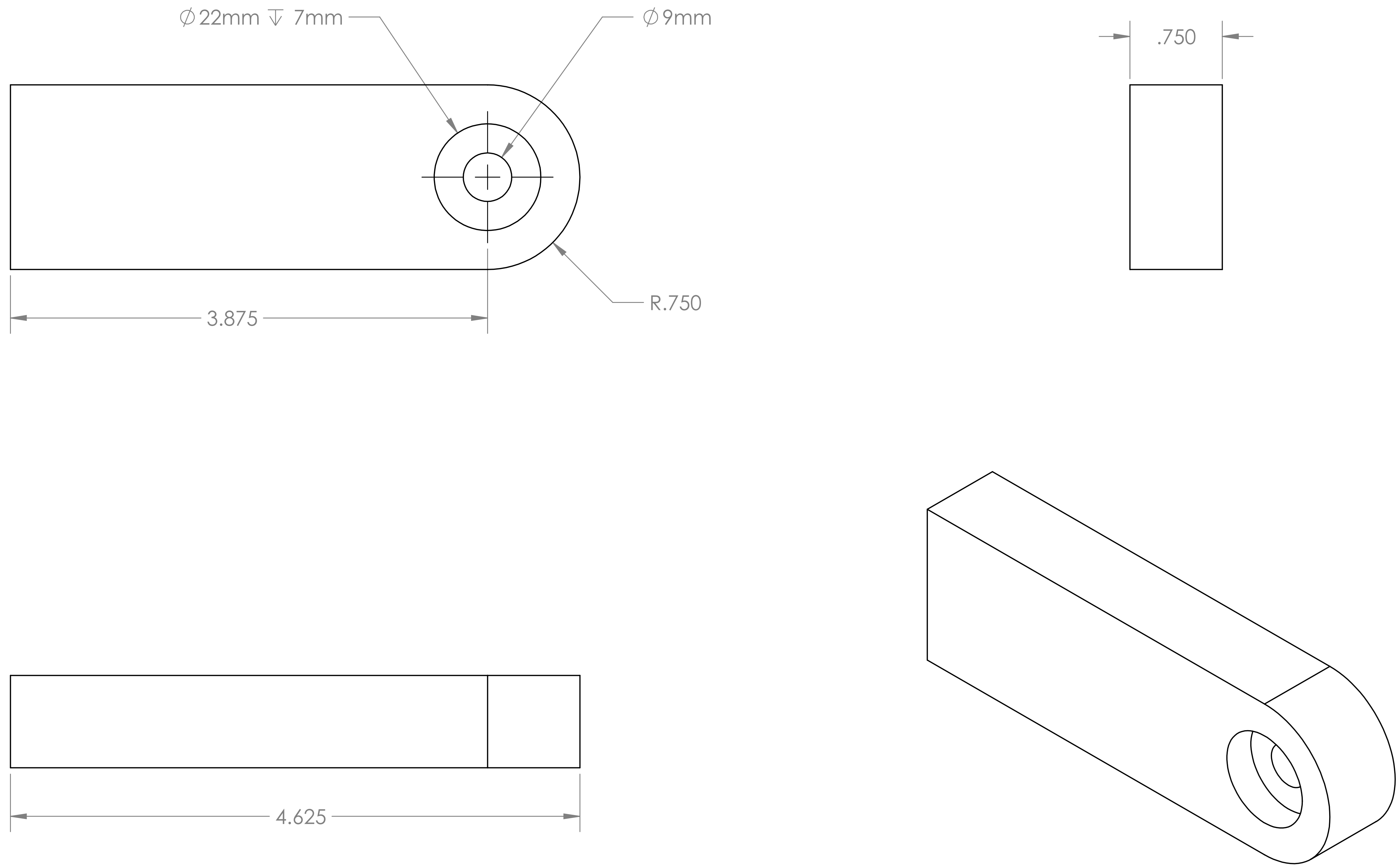
COMMENTS:

TITLE:

Part #5

SIZE	DWG. NO.	REV
B	FBM05	1

SCALE: 1:2 WEIGHT: SHEET 1 OF 1



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NEXT ASSY: FBM09	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: .75" x 1.5" STEEL RECTANGULAR BLANK

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	N.L.	4/24/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

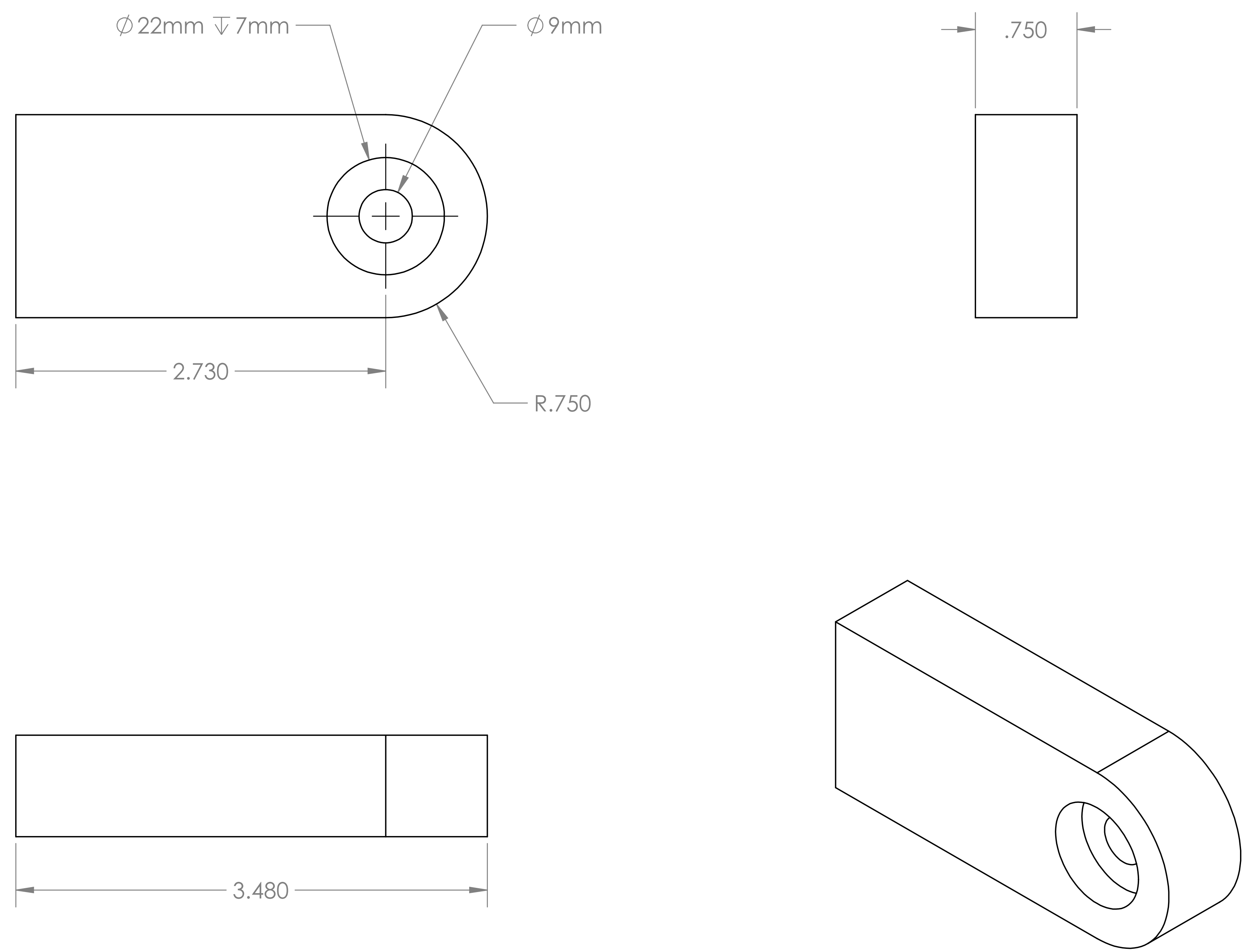
COMMENTS: 22mm HOLES ARE MEANT FOR A TIGHT FIT WITH A 22mm BALL BEARING. TOLERANCES ON ROUNDED END CAN BE LOW SINCE IT'S AESTHETICS.

TITLE:

Part #8

SIZE	DWG. NO.	REV
B	FBM08	1

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



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NEXT ASSY: FBM10	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: .75" x 1.5" STEEL RECTANGULAR BLANK

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	N.L.	4/24/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

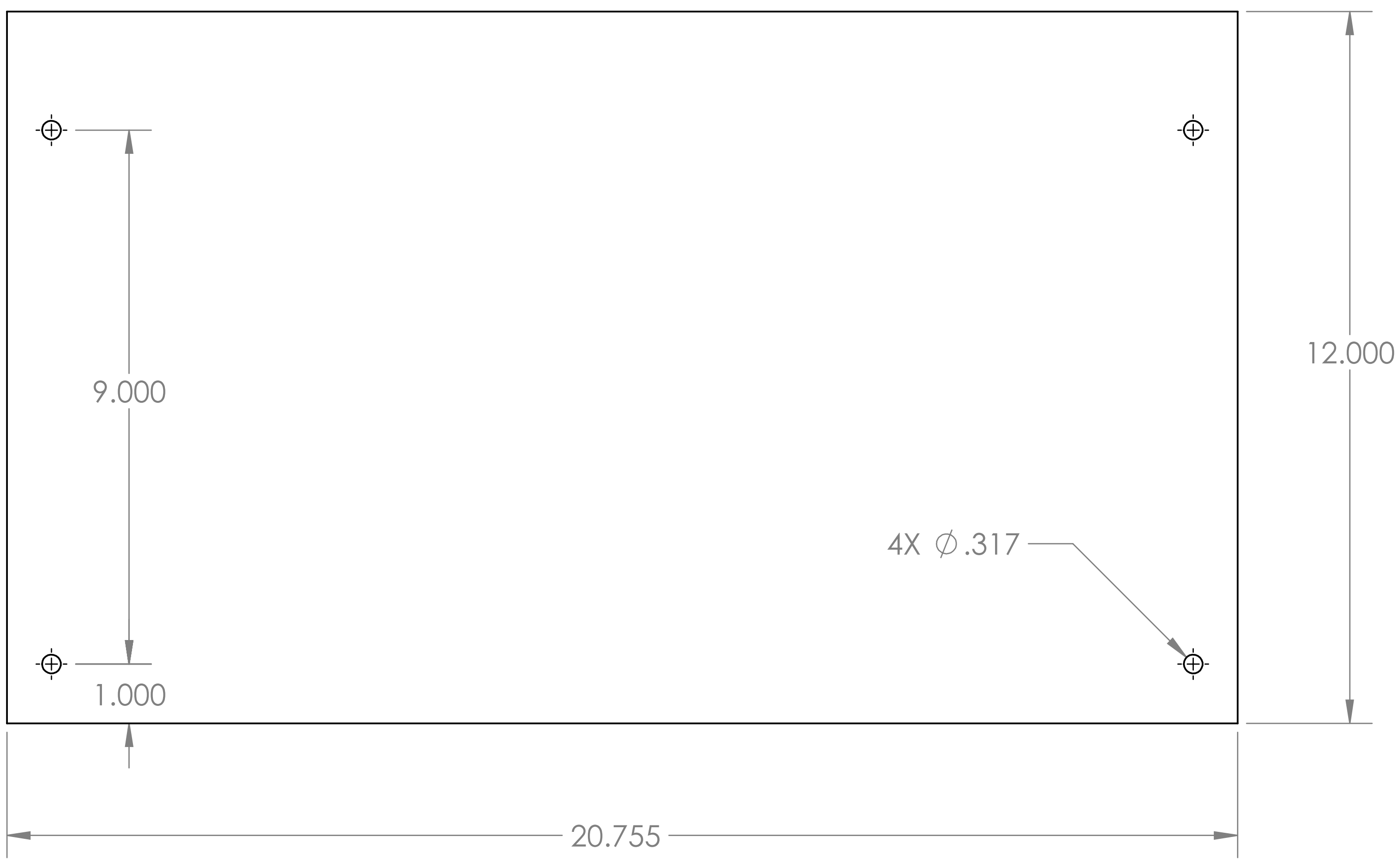
COMMENTS: 22mm HOLES ARE MEANT FOR A TIGHT FIT WITH A 22mm BALL BEARING. TOLERANCES ON ROUNDED END CAN BE LOW SINCE IT'S AESTHETICS.

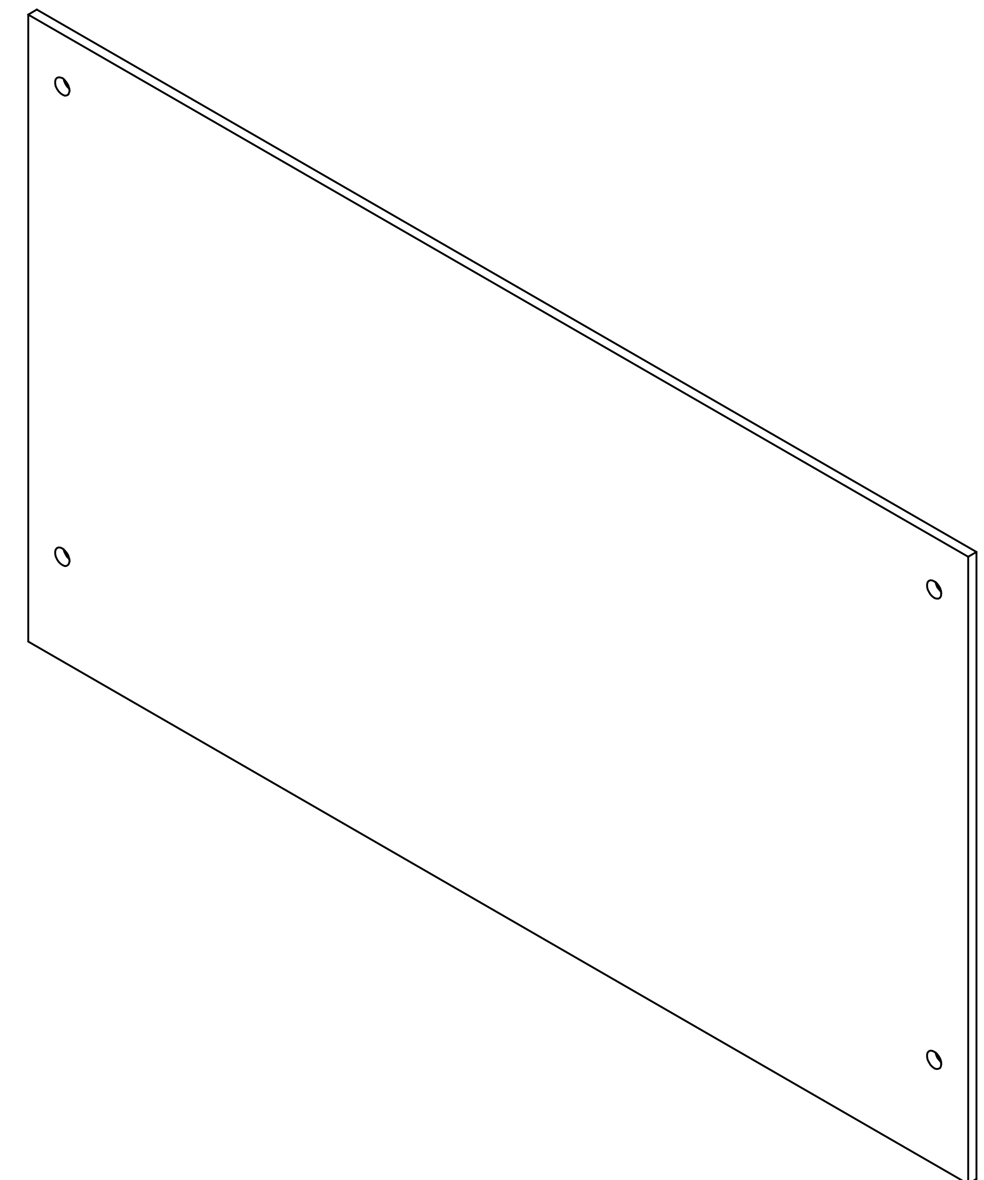
TITLE:

Part #9

SIZE	DWG. NO.	REV
B	FBM09	1

SCALE: 1:1 WEIGHT: SHEET 1 OF 1





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NEXT ASSY: FBM11 | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 3/16" A36 STEEL PLATE

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	N.L.	4/24/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

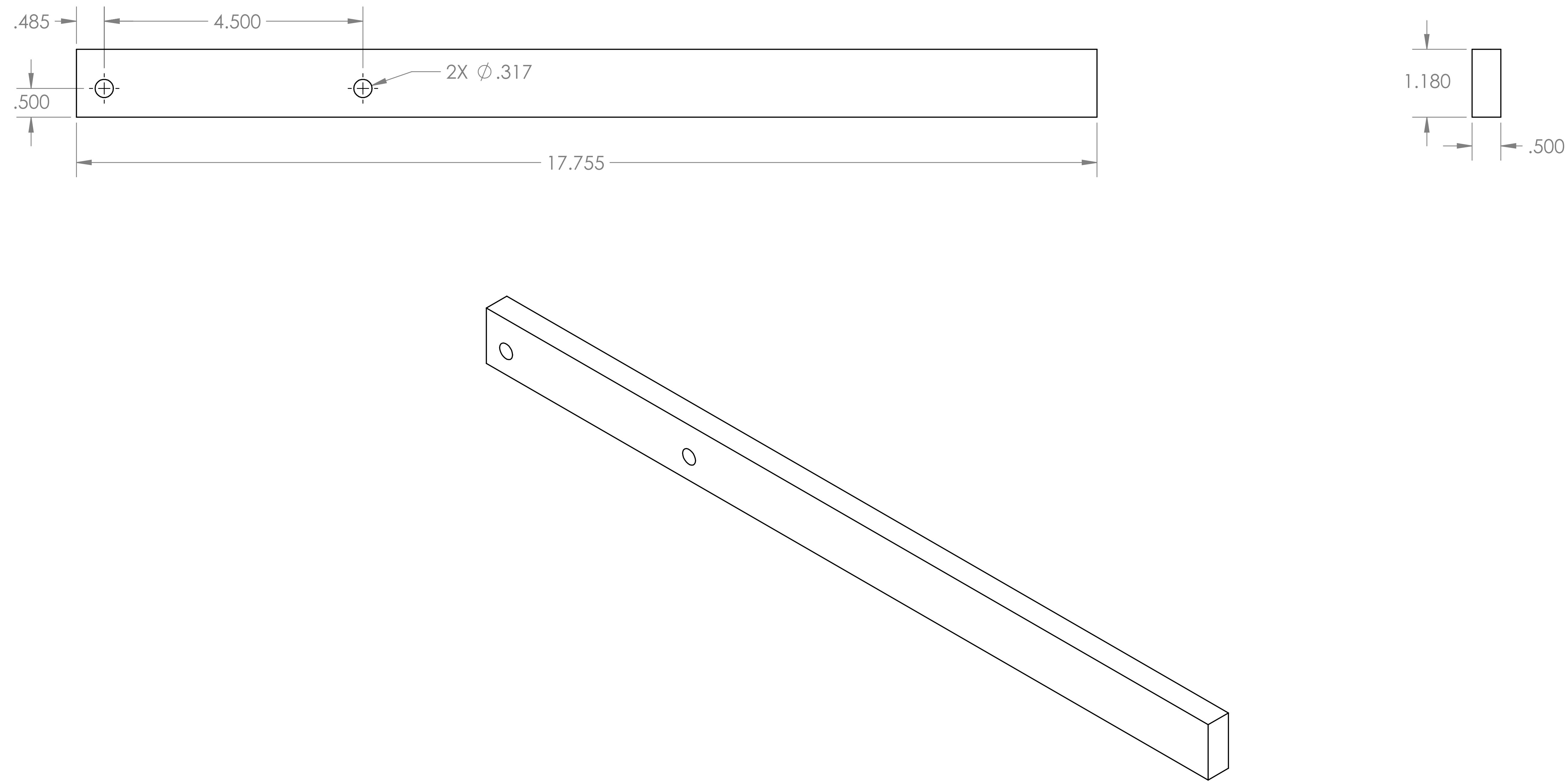
COMMENTS: THICKNESS IS NOT IMPORTANT SINCE THIS MEMBER WILL BE USED AS A REBOUND/STABILIZING PLATE. MATERIAL WAS CHOSEN TO REDUCE COST.

TITLE:

Part #10

SIZE	DWG. NO.	REV
B	FBM10	1

SCALE: 1:3 | WEIGHT: | SHEET 1 OF 1



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NEXT ASSY: FBM04 | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: RECTANGULAR STEEL BLANK

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	N.L.	4/24/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

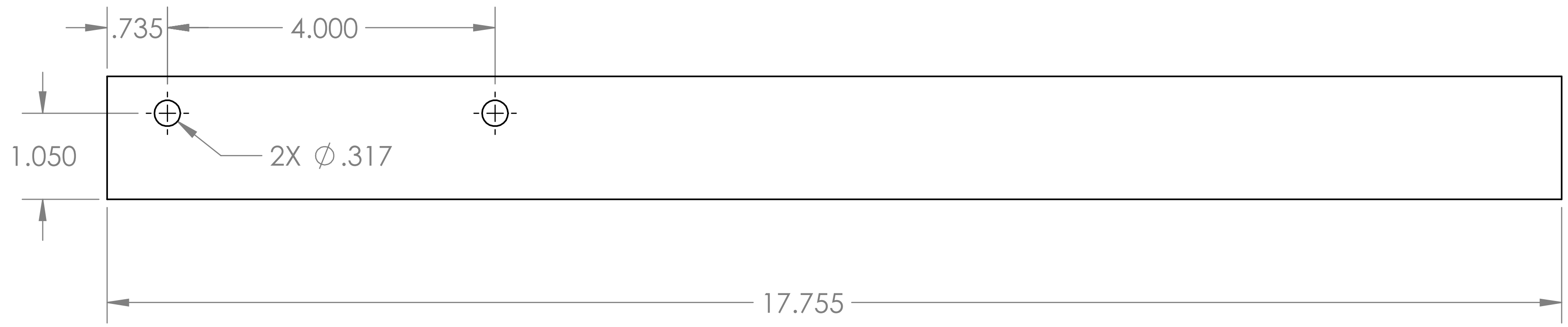
COMMENTS: THIS BRACKET IS DESIGNED TO FIT IN THE GROOVE ON THE BOTTOM SIDE OF THE NPC-T64 MOTOR. WHEN WELDING ONTO FBM04 MAKE SURE THAT BEAD DOES NOT INTERFERE WITH FITMENT.

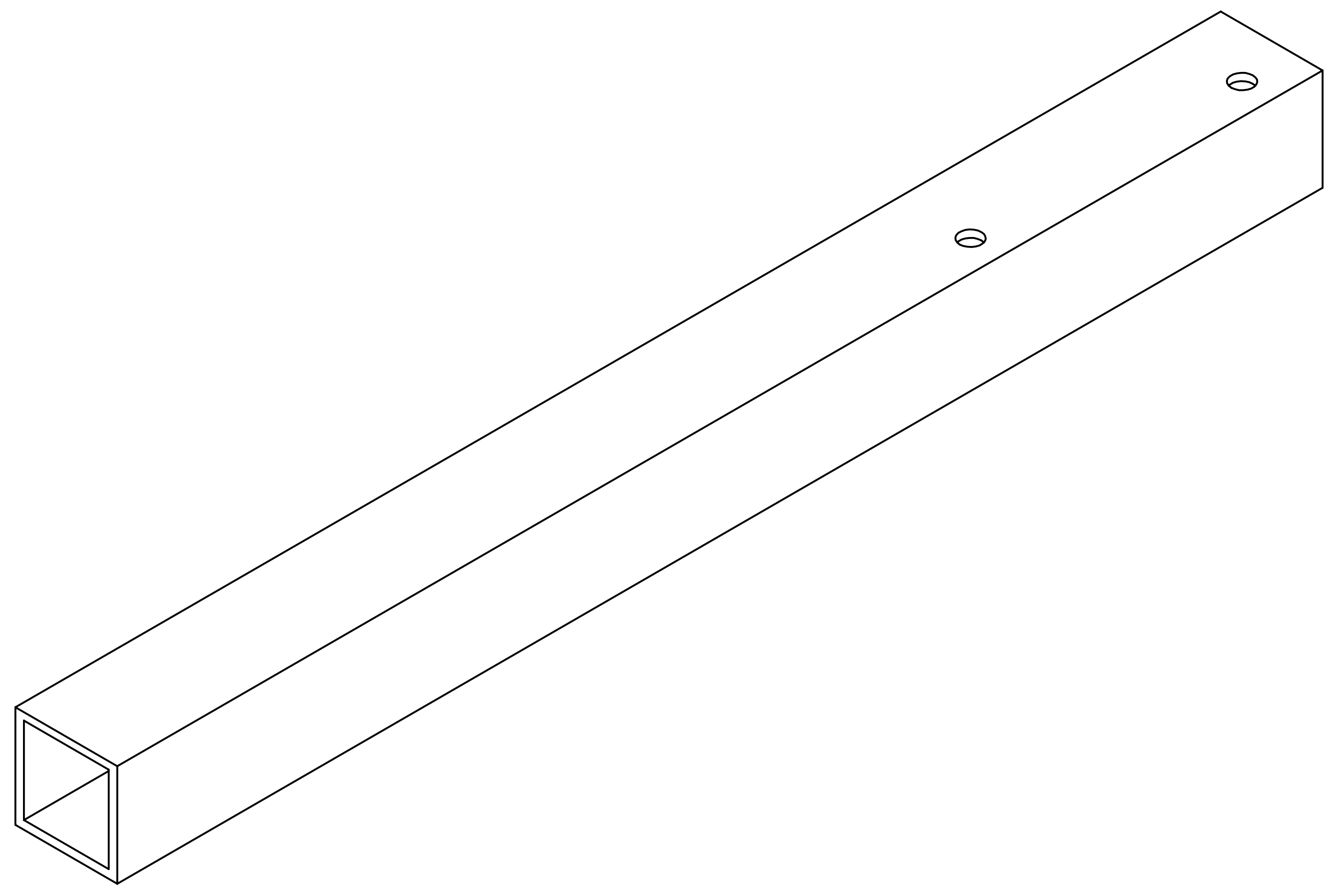
TITLE:

Part #11

SIZE **B** | DWG. NO. FBM11 | REV 1

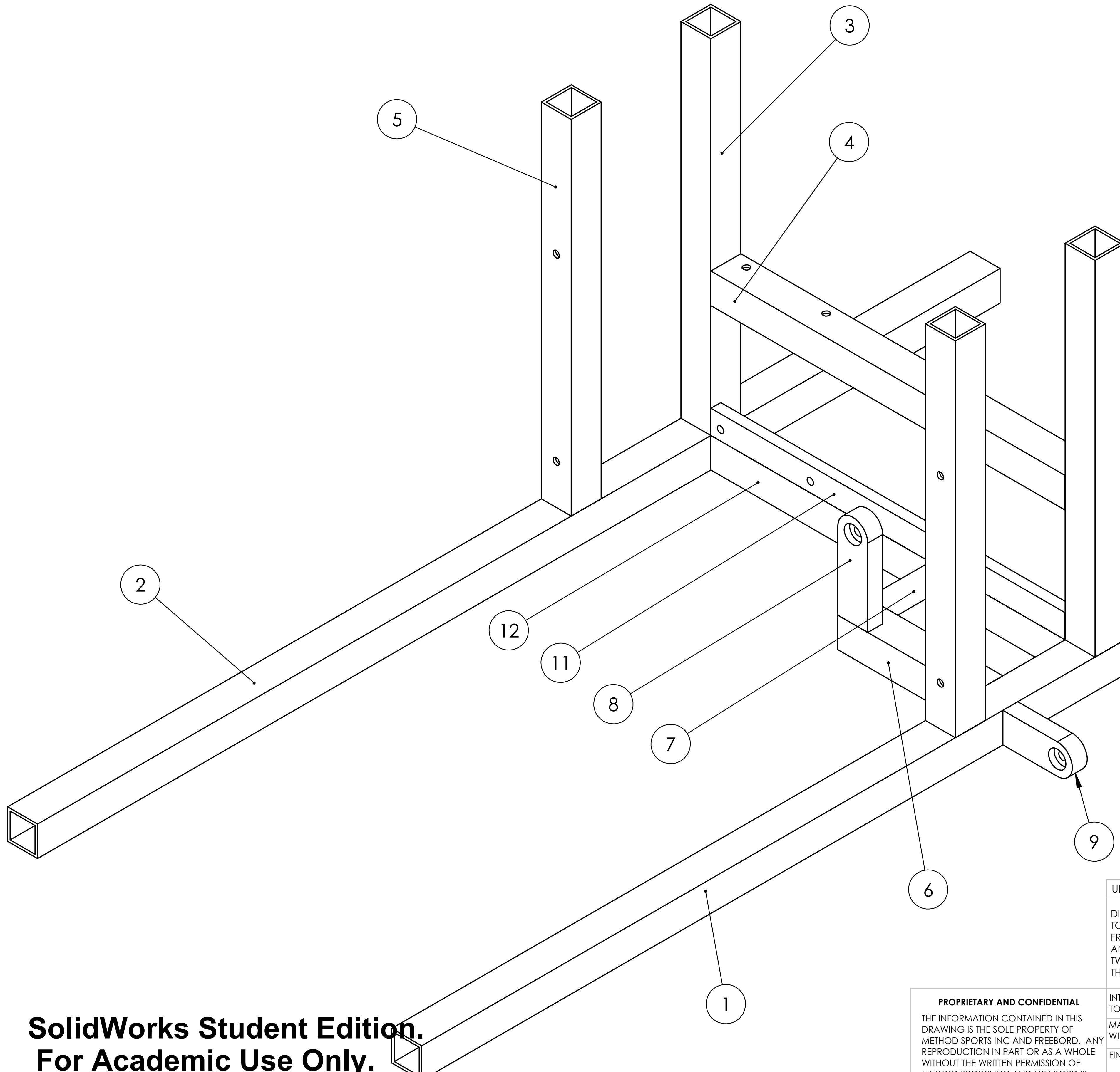
SCALE: 1:3 | WEIGHT: | SHEET 1 OF 1





		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	N.L.	4/24/12	TITLE: Part #4
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL: 1.5" SQAURE STEEL TUBE WITH .125" WALL THICKNESS	COMMENTS:			SIZE B DWG. NO. FBM12 REV 1
NEXT ASSY: FBM05	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2 WEIGHT: SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	FBM01	35.25"	1
2	FBM02	48.25"	1
3	FBM03	17.225"	2
4	FBM12	17.755" (SEE PART DRAWING FOR HOLE DIMENSIONS)	1
5	FBM05	17.755" (SEE DRAWING FOR HOLE DIMENSIONS)	2
6	FBM06	6.77"	1
7	FBM07	3.12"	1
8	FBM08	SEE PART DRAWING FOR DIMENSIONS	1
9	FBM09	SEE PART DRAWING FOR DIMENSIONS	1
10	FBM10	NOT SHOWN. SEE PART DRAWING FOR DIMENSIONS.	1
11	FBM11	SEE PART DRAWING FOR DIMENSIONS.	1
12	FBM04	17.755" (SEE PART DRAWING FOR HOLE DIMENSIONS)	1



UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 1.5" SQAURE STEEL TUBE WITH .125" WALL THICKNESS

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	N.L.	4/24/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

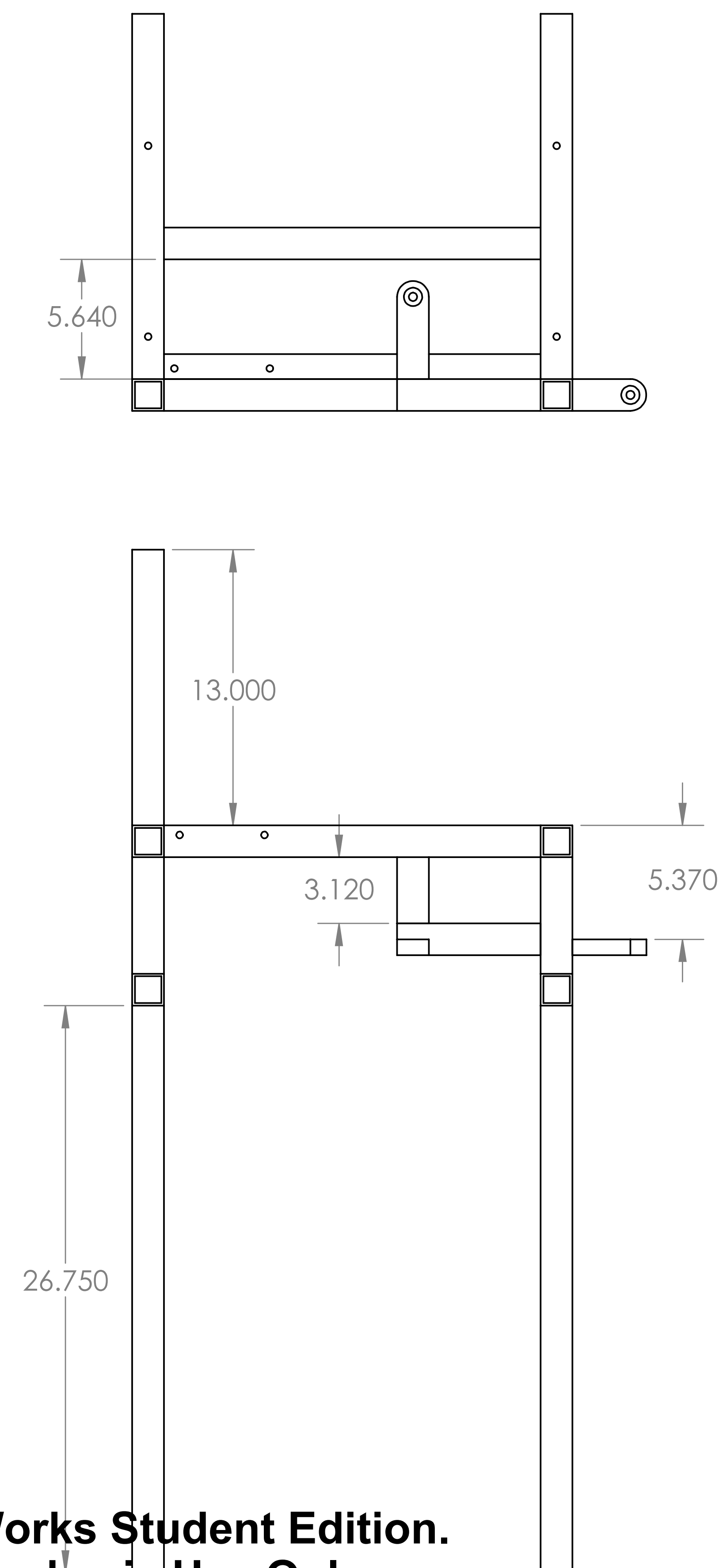
COMMENTS: ALL TUBING IS 1.5" STEEL SQUARE TUBE WITH .125" THICK WALLS. TUBE CUT LENGTHS ARE LISTED IN THE DESCRIPTION COLUMN OF THE BOM. MEMBERS 8 AND 9 WILL BE FABRICATED FROM .75" X 1.5" STEEL RECTANGULAR BLANKS.

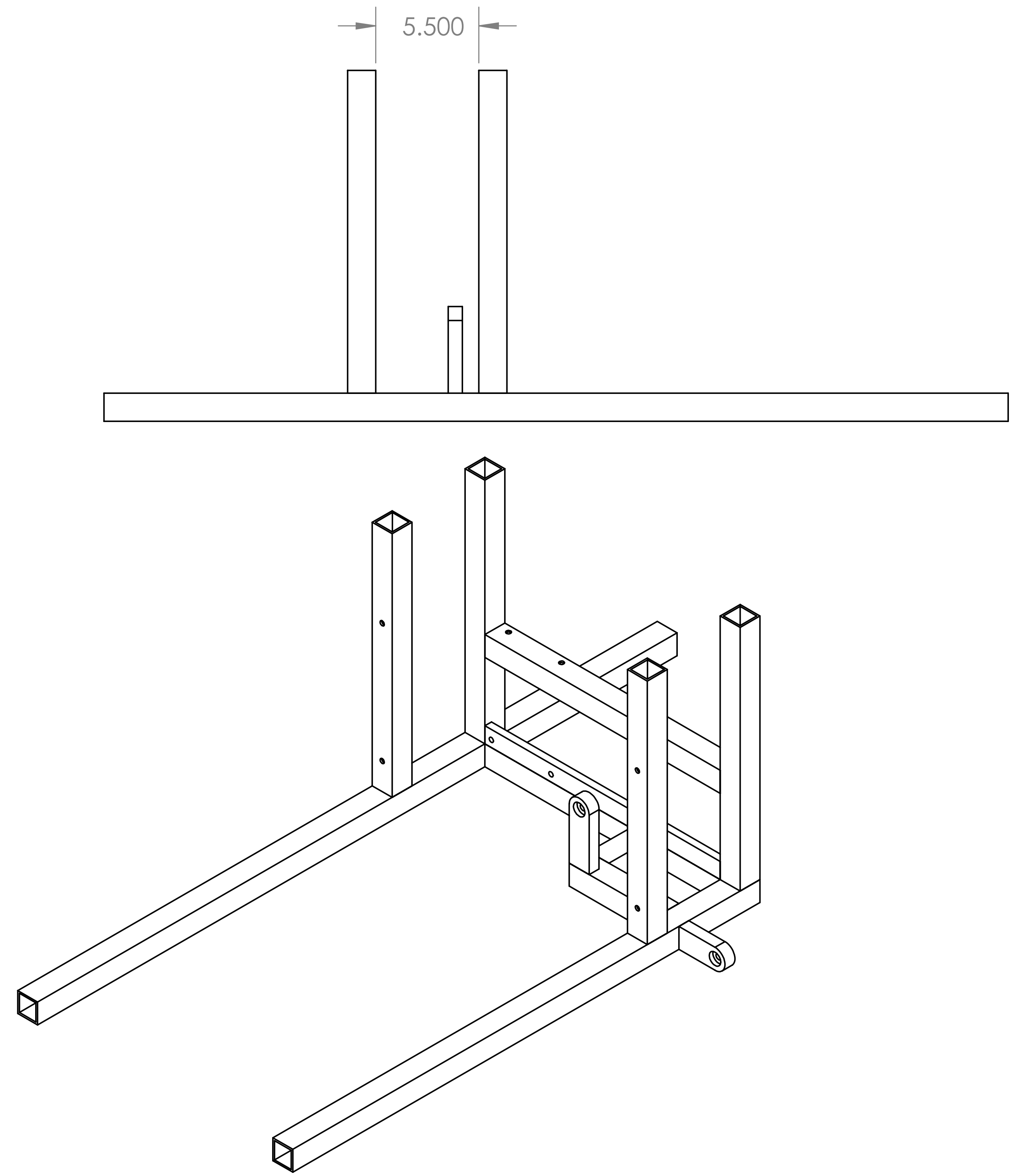
TITLE:

Four Bar Mount

SIZE **B** | DWG. NO. FBM | REV 1

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1





NEXT ASSY: | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 1.5" SQAURE STEEL TUBE WITH .125" WALL THICKNESS

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	N.L.	4/24/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

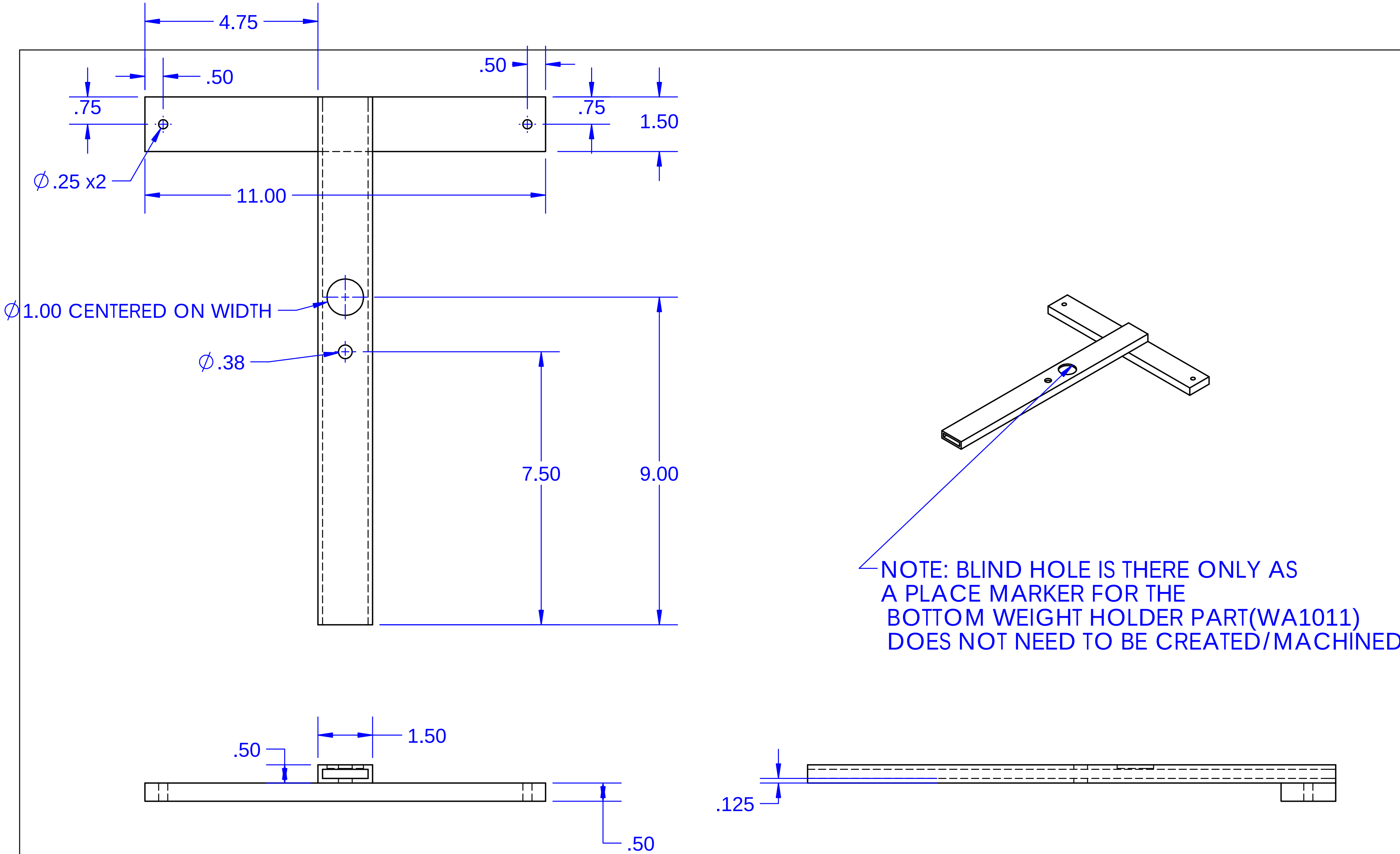
COMMENTS: DRAWING SHOWS THE DISTANCES THAT THE MEMBERS WILL BE WELDED.

TITLE:

Four Bar Mount

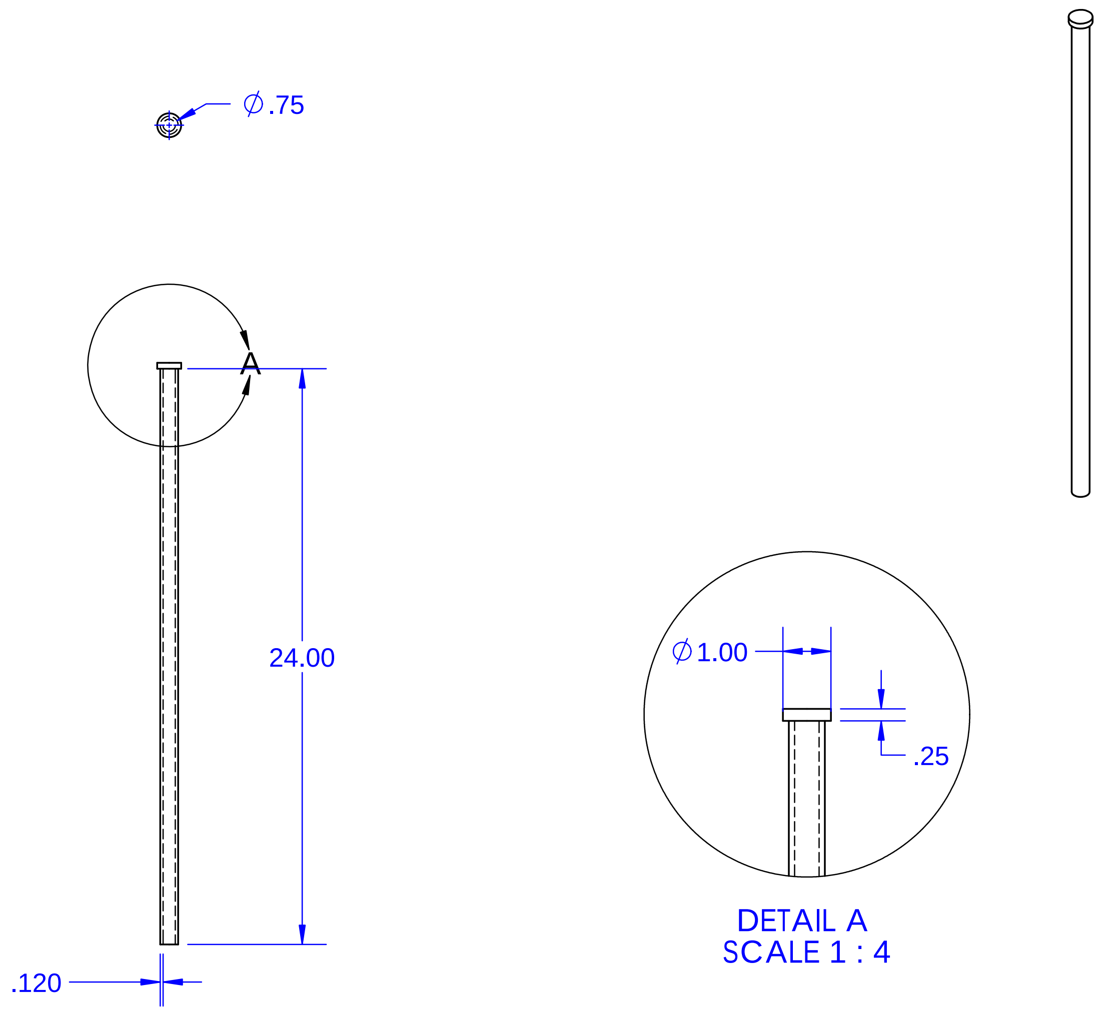
SIZE	DWG. NO.	REV
B	FBM	1

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1



Mechanical Engineering CAL POLY

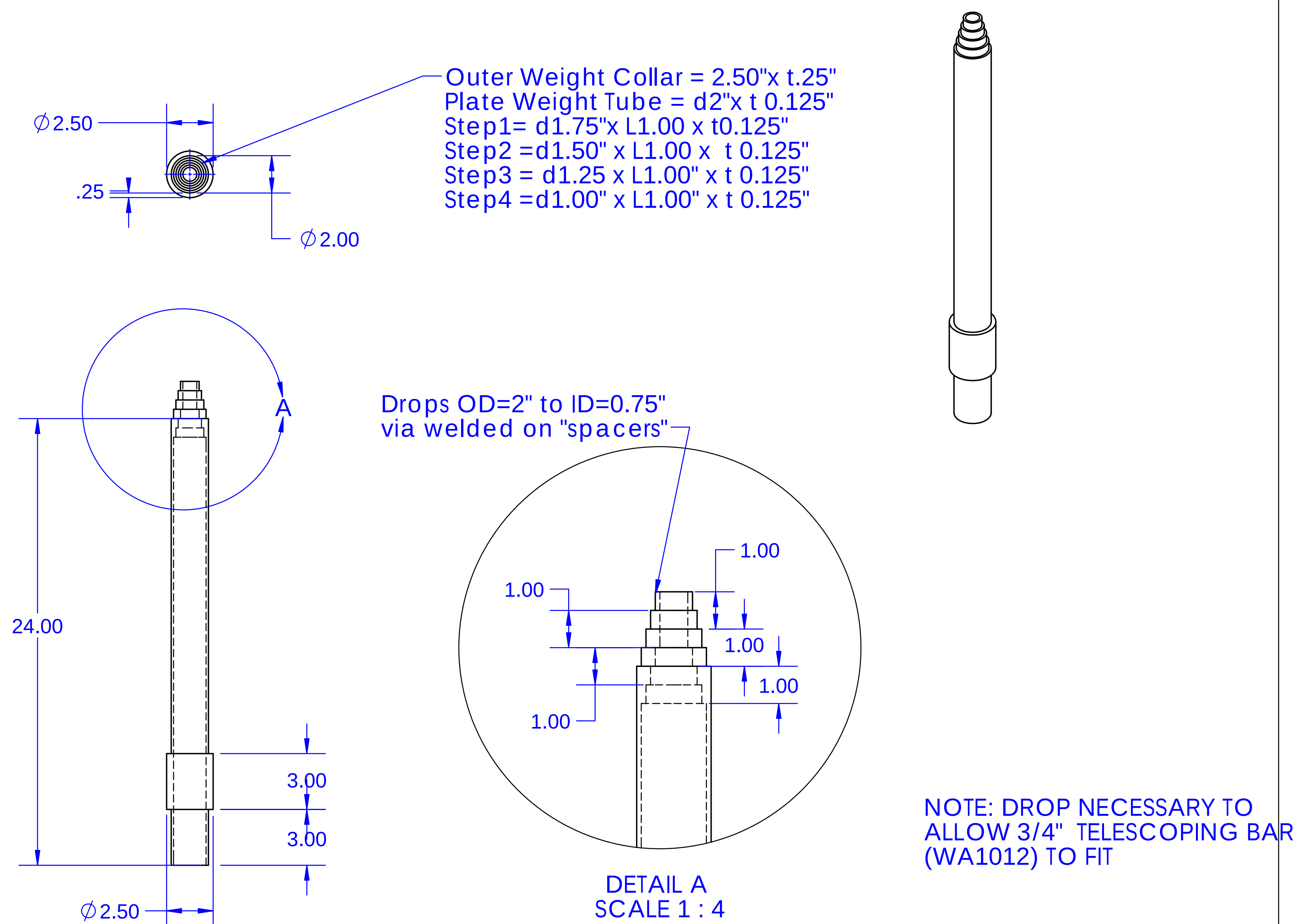
Ckd by:	Init:	Drawn By: DEREK CHAN	Init:
Next Assy: WA1001	Units: INCHES	Material: STEEL	
Date: 4/20/12	Tolerance: ±.1	Group: BOARD BUSTERS	
Drawing #: BS2001	Scale: 1 : 4	Title: BOARD SECURE LENGTH	



NOTE: MAIN TUBE IS MADE
OF 3/4" X t 0.120" TUBING

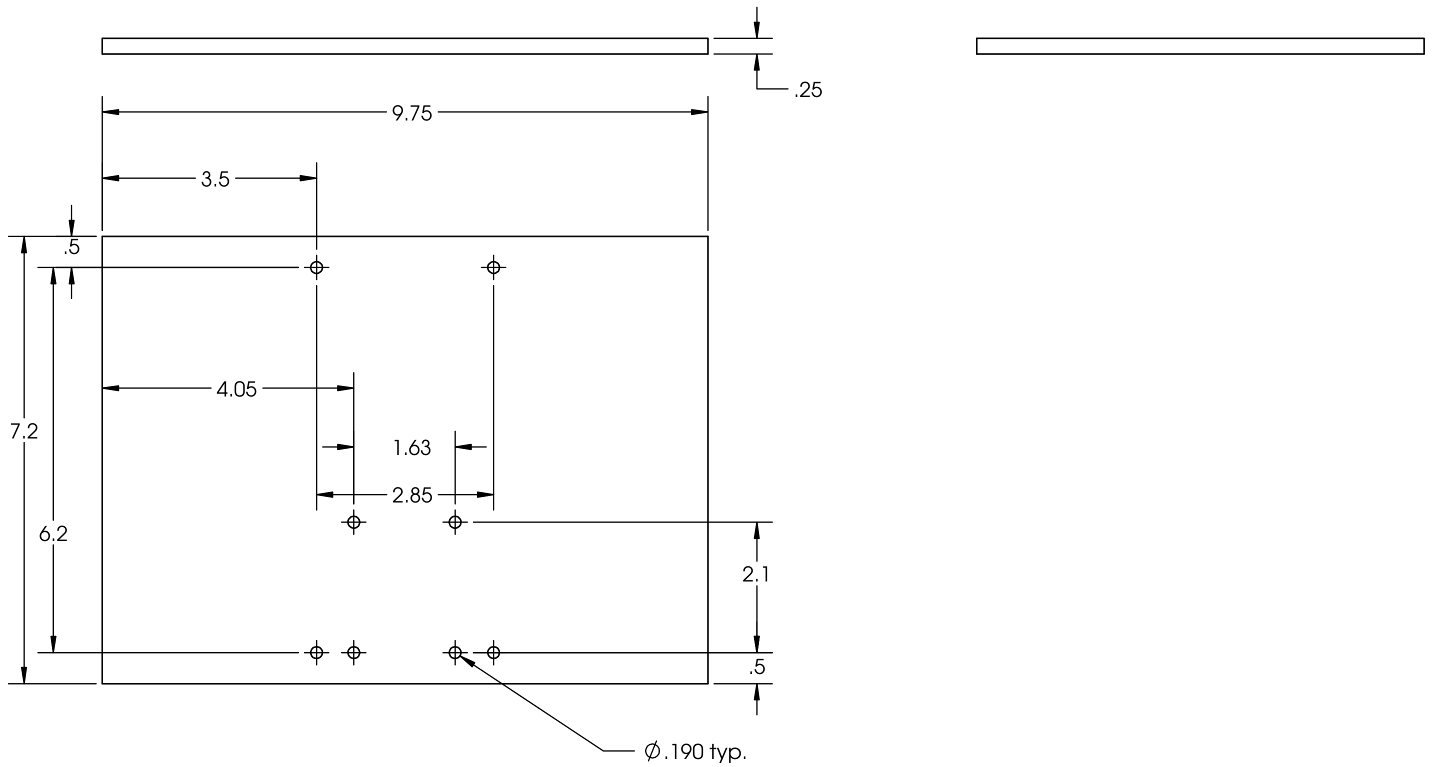
Mechanical Engineering CAL POLY

Ckd by:	Init:	Drawn By: DEREK CHAN	Init:
Next Assy: WA1001	Units: INCHES	Material: STEEL	
Date: 4/20/12	Tolerance: ±.1	Group: BOARD BUSTERS	
Drawing #: WA1012	Scale: 1 : 8	Title: TOP TUBE OF WEIGHT ASSEMBLY	

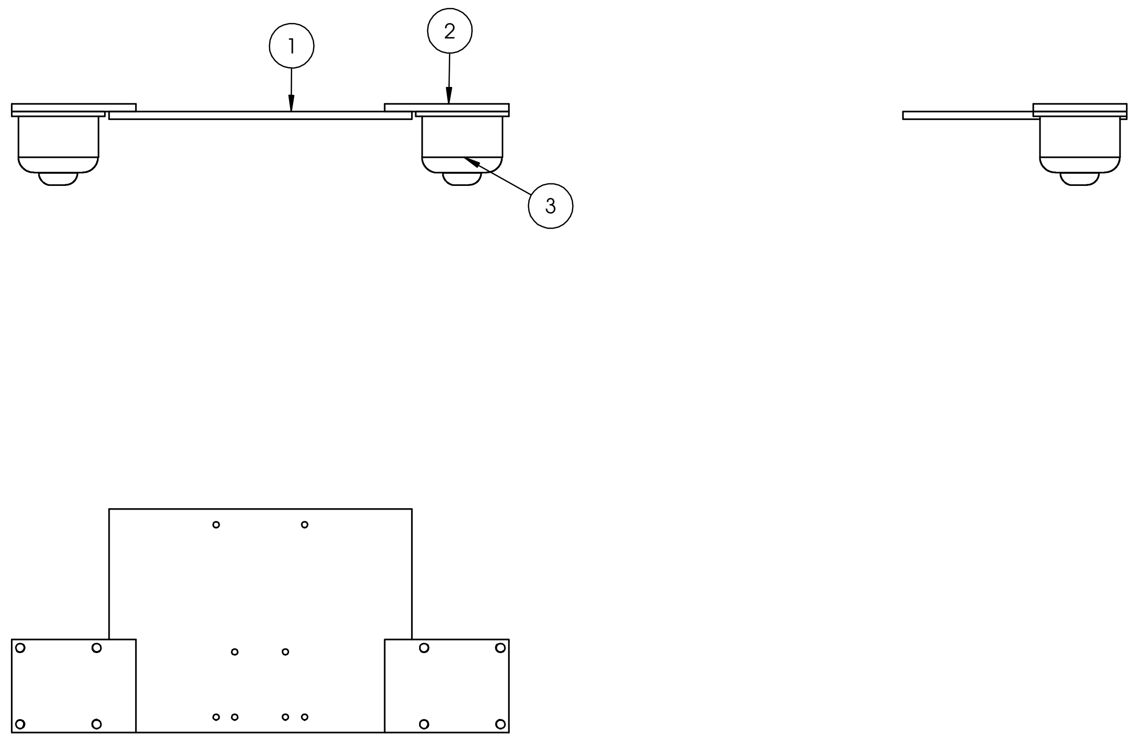


Mechanical Engineering CAL POLY

Ckd by:	Init:	Drawn By: DEREK CHAN	Init:
Next Assy: WA1001	Units: INCHES	Material: STEEL	
Date: 4/20/12	Tolerance: ±.1	Group: BOARD BUSTERS	
Drawing #: WA1011	Scale: 1 : 8	Title: BOTTOM WEIGHT HOLDER	



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	CH	4/20/2012	
			CHECKED			TITLE:
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE B | DWG. NO. BBS001 | REV 1A
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1



Note: Board Mount and Slider Side Plates welded together

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	BBS001	Board Mount	1
2	BBS002	Slider Side Plates	2
3	1-1/2 NEFMC	Nylon Ball Transfer	2

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

NEXT ASSY | USED ON

APPLICATION

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	C.H.	4/20/2012
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

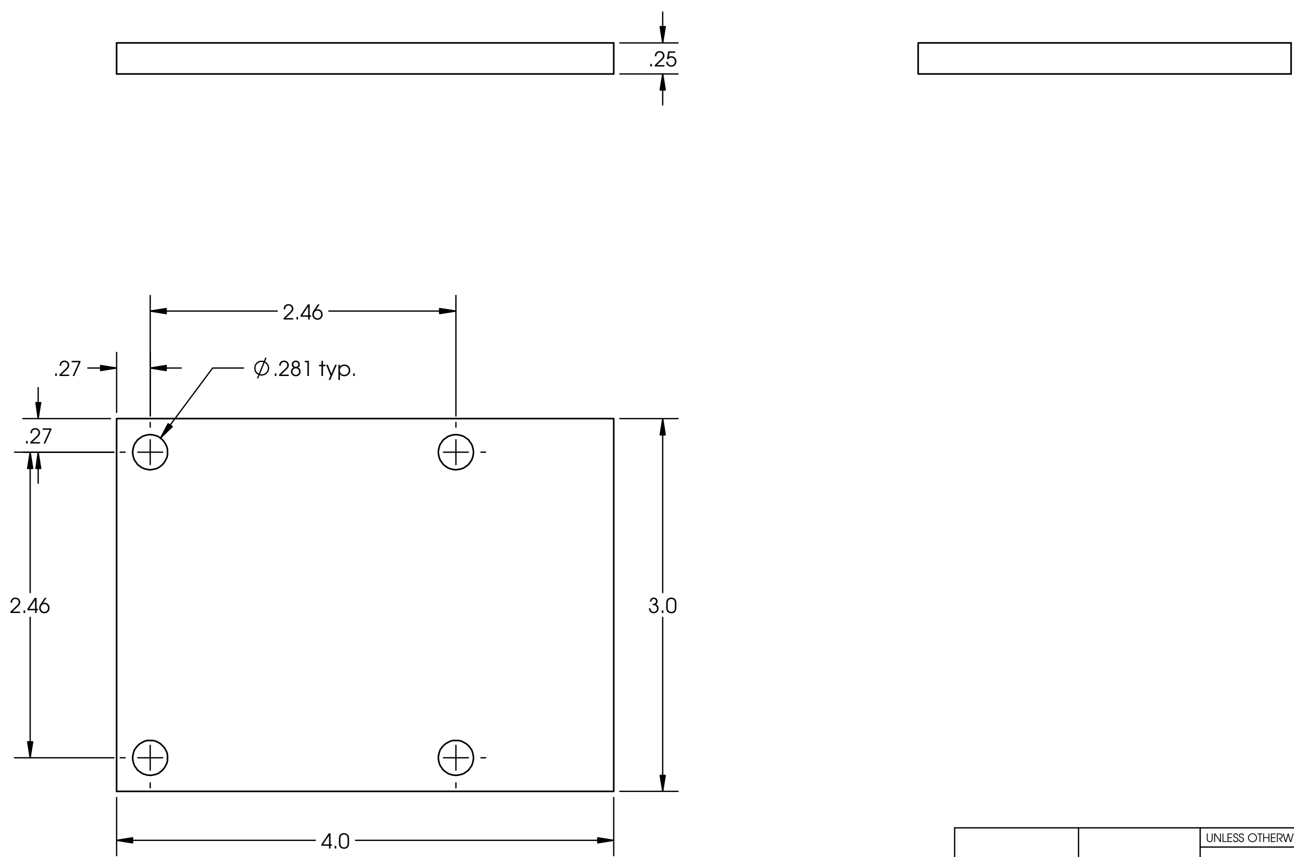
COMMENTS:

TITLE:

Slider Assembly

SIZE B | DWG. NO. BBSA001 | REV 1A

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1



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THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	C.H.	4/20/2012
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

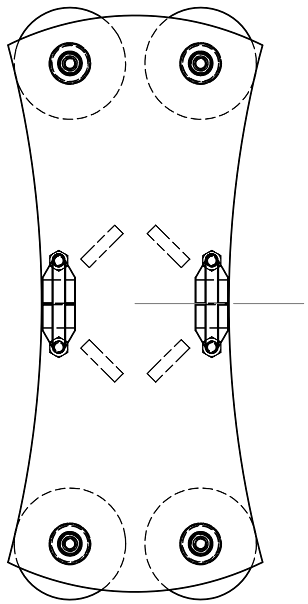
COMMENTS:

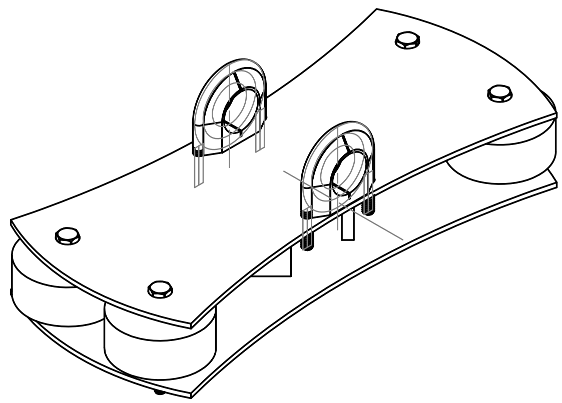
TITLE:

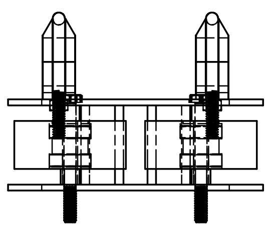
Slider Side Plates

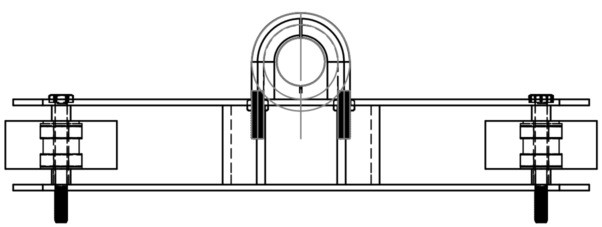
SIZE	DWG. NO.	REV
B	BBS002	1A

SCALE: 1:1 WEIGHT: SHEET 1 OF 1





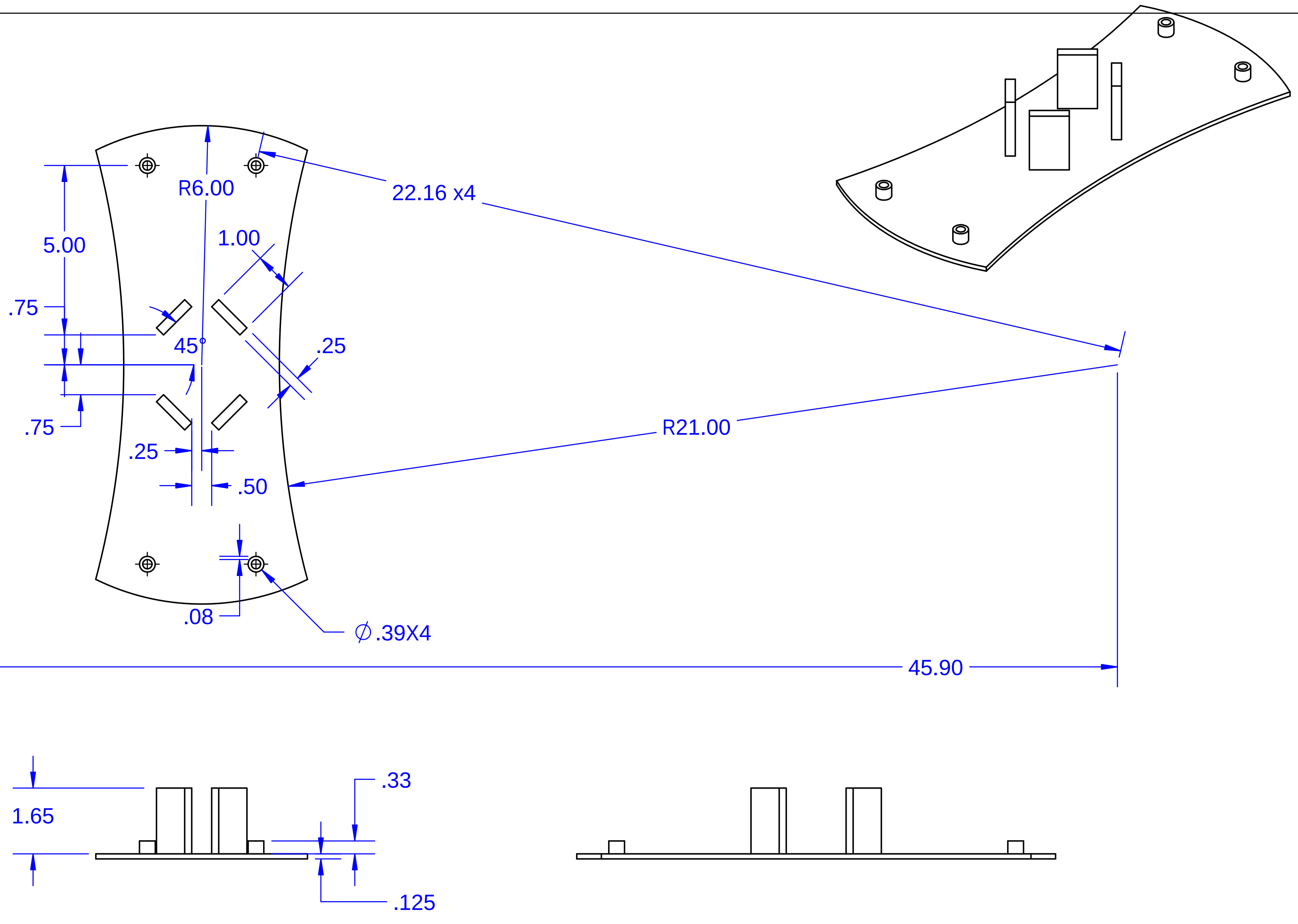




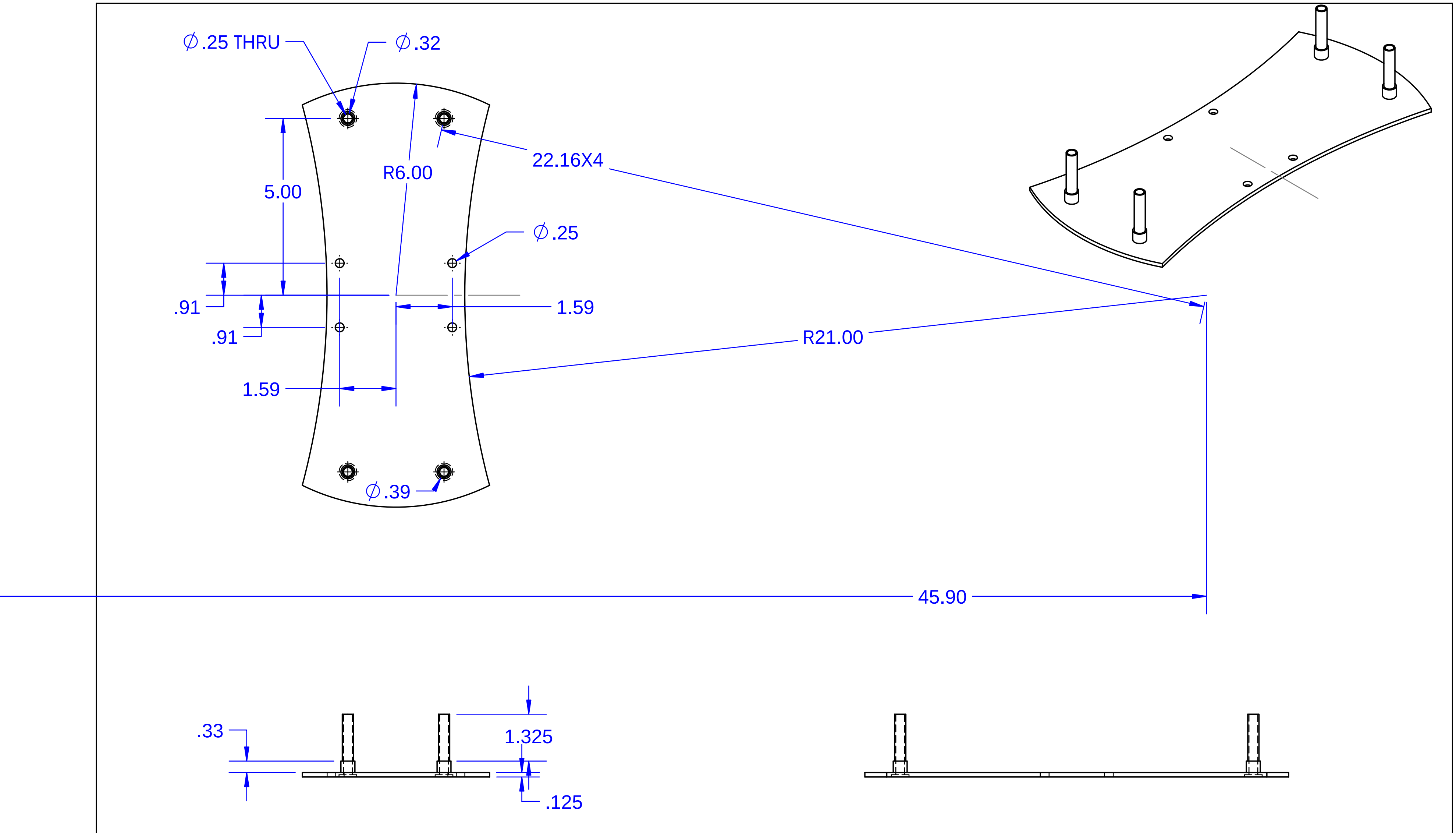
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
5	91247A552	1/4"-20xL2 1/2"Bolt	4
4	3176T46	1" Vibration-Damp U-bolt	2
3	WH021	Default	4
2	IS002	Default	1
1	IS001	Default	1

Mechanical Engineering CAL POLY

Ckd by:	Init:	Drawn By:	Init:
Next Assy: FA001	Units: INCHES	Material:	
Date: 3/13/2012	Tolerance:	Group: BOARD BUSTERS	
Drawing #: IS010	Scale: 1 : 4	Title: ISLAND ASSEMBLY	

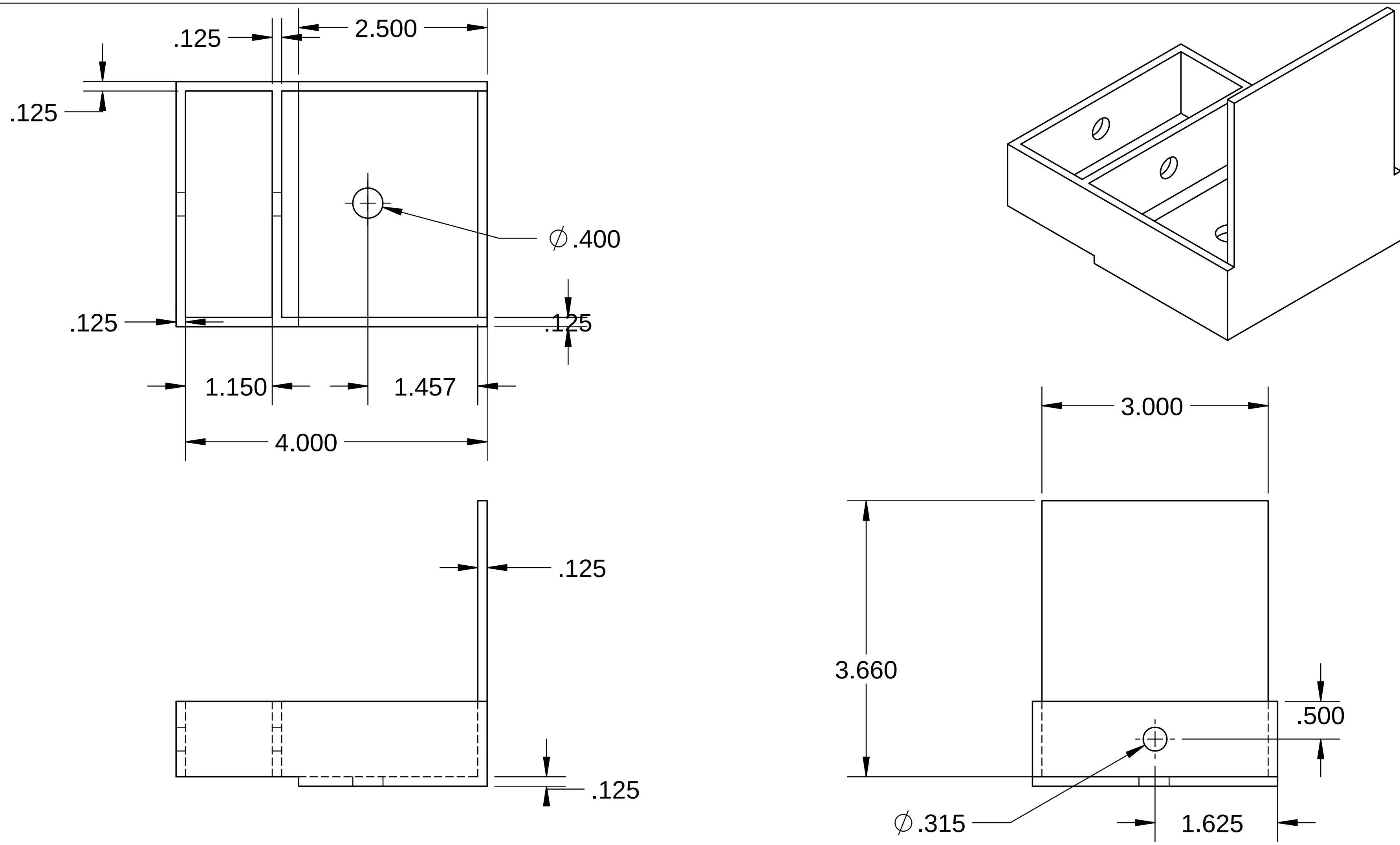


Ckd by:	Init:	Drawn By: DEREK CHAN	Init:
Next Assy: IS021	Units: INCHES	Material: STEEL	
Date: 3/13/12	Tolerance: ±.1	Group: BOARD BUSTERS	
Drawing #: IS001	Scale: 1 : 4	Title: ISLAND BOTTOM	



Mechanical Engineering CAL POLY

Ckd by:	Init:	Drawn By: DEREK CHAN	Init:
Next Assy: IS021	Units: INCHES	Material: STEEL	
Date: 3/13/12	Tolerance: ±.1	Group: BOARD BUSTERS	
Drawing #: IS002	Scale: 1 : 4	Title: ISLAND TOP	



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.1

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

NEXT ASSY

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

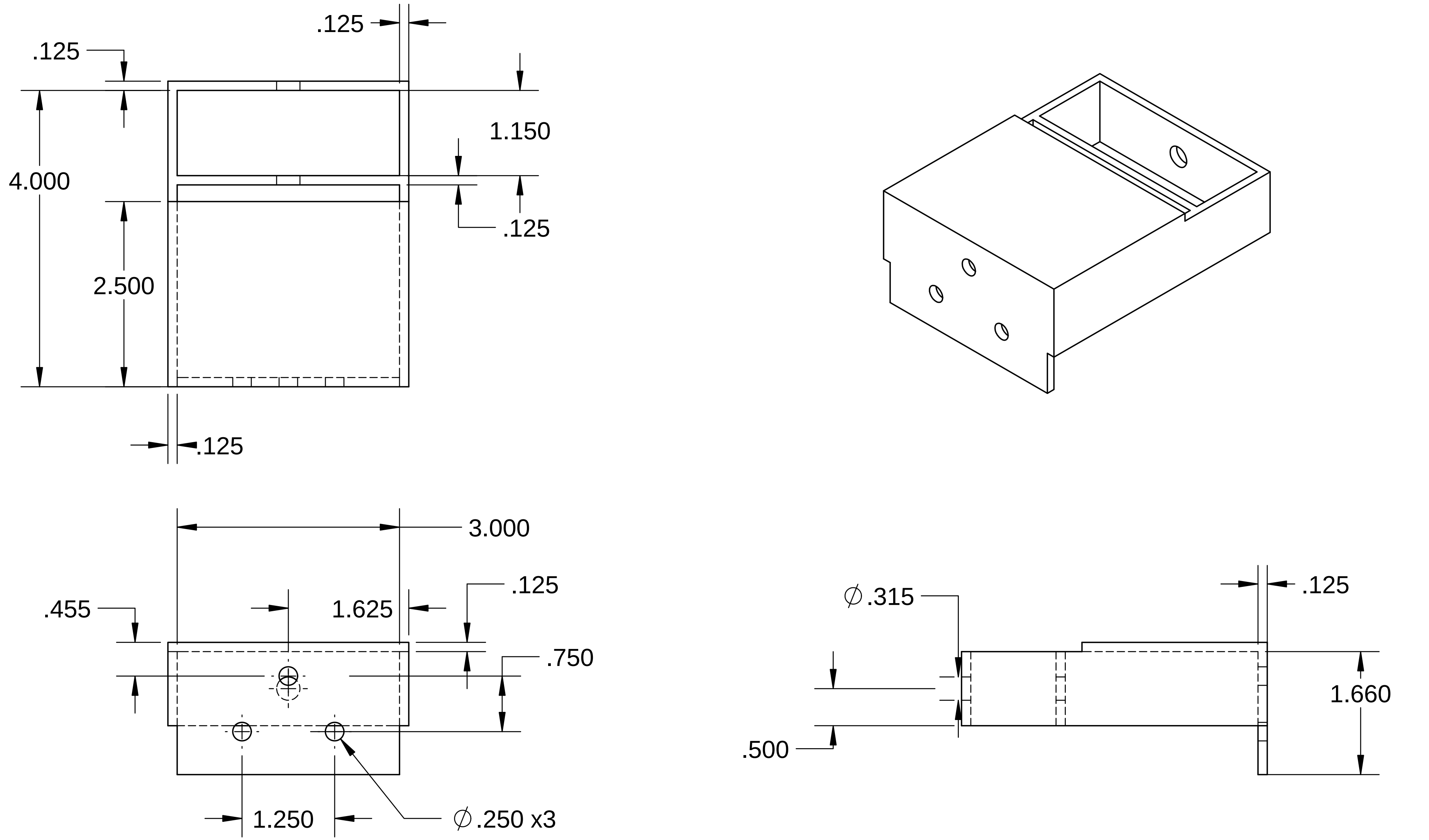
COMMENTS:

TITLE:
Lower disk stabilzer. To be welded on main lower frame

SIZE A | DWG. NO. Lower DS | REV

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

4 3 2 1



	UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
	DIMENSIONS ARE IN INCHES TOLERANCES: ±0.1	DRAWN			TITLE:
		CHECKED			Top Disk Stablizer
		ENG APPR.			
		MFG APPR.			
	INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
	MATERIAL	COMMENTS:			SIZE A · DWG. NO. TopDS · REV
NEXT ASSY	FINISH				
	DO NOT SCALE DRAWING				SCALE: 1:2 · WEIGHT: · SHEET 1 OF 1

4 3 2 1