



# Compact Portable Car Lift

FINAL REPORT

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## Purpose

The goal of this project was to design and build a compact portable car lift aimed at the home mechanic. This allows the user to perform maintenance and repairs in their own garage that they otherwise wouldn't be able to do.

## Initial Performance Specifications

- Each lift platform will be rated to lift 1500 lb. with a factor of safety of 2
- Size of each platform will be approximately 16" wide, 32" long, and 5" tall
- Lift platforms capable of accommodating 35" diameter tires for Jeeps with Rubicon off-road package
- Provision hydraulics for 4 possible lift platforms
- Be able to lift underside of vehicle at least 24" off of ground

## Design

Our project sponsor, Joe Joyner, frequently works on many vehicles of all sizes for family and friends in his garage. One tool almost every home mechanic wants, but cannot have for various reasons, is a car lift. These reasons frequently include; cost, lack of space in the garage, and ceiling height. For this project, we set out to design and build a car lift to address these issues.

We first looked on the internet for other car lifts on the market that set out to address the home mechanic. We found that all of them had a few areas that they ultimately failed our sponsor's or other home mechanics' needs.

Many took the route of the QuickJack™ system, which uses a hydraulic cylinder to rock the car back as it goes up. [1] These have the failing of not working well for users who have a shorter length garage and don't have the room to set the car back without the garage door open. This precludes using the car lift in the winter in many parts of the country. It also only has a single lift height, and wouldn't work well for vehicles like trucks and most SUVs as it can't reach the bottom of the vehicle without lift blocks. It also blocks access to the underside of the vehicle from the sides, which is the easiest exit point for removing parts like transmissions and drive shafts, not to mention the home mechanic on a creeper.

Others took the route of Central Hydraulics [2] with a scissor lift design placed under the center of the vehicle. This is a better design for space when in use, but it is a very large unit to store. However, unlike the first example it has the benefit that it can be raised to any height between 7 inches and nearly 5 feet. Also, it can lift nearly any size vehicle but has the failing of blocking removal of most drivetrain components as it is placed under the center of the vehicle.

During this research, we found many products that mostly followed these two styles with slight variations. Thus, we saw that there was an opening for a design that can take the best elements of all of these designs and eliminate most of their failings.

We decided on individual lift platforms for each tire to be able to gain extra lift height by using the vehicle's suspension to our advantage. We also decided on a scissor lift design to be out of the way of part removal and the user on a creeper when in use, and allow for a smaller area for storage when not in use. Also, the lift must be able to accommodate any size vehicle ranging from the sponsor's daughter's Ford Focus compact car, to his full size F-150, and his Jeep Wrangler with oversize tires for off-road use.

After researching the vehicles that were planned to be using this lift, we came to the conclusion that they collectively are a representative sample of nearly the entire automotive market. The heaviest vehicle, the full size pickup truck, became the basis of our maximum weight capacity of 6000 lbs., with our factor of safety of 2 being chosen after discussion with a design engineer that both Braxton and Jason both work with. The compact car, became the basis for the ramp angle and minimum height when collapsed as it has the lowest ground clearance and smallest approach angle. The Jeep Wrangler, became the basis for the lift platform length and width as it has the largest tires.

With this information in hand, we began roughing out our design. We decided hydraulics would be the best design route as they offer a simplicity and strength that can't be matched by other designs. We also decided to have the cylinder in a pulling configuration, rather than the more common pushing configuration to save space. This switch to an uncommon configuration led to a miscommunication and initially incorrect calculations of cylinder force. Because of this, the initial cylinder diameter had to be increased by nearly an inch which led to clearance issues that weren't recognized and corrected until initial fabrication had begun.

For a pump, an air over hydraulic pump was chosen as it is easy to operate and can be run off of any air compressor. Air compressors are one of the most common power tools used by home mechanics, so it was a safe assumption that most who would be interested in a car lift would already have an air compressor. This was important to the sponsor if a friend would borrow the lift for any reason that they would be able to run it.

We initially wanted a flat plate as the top of the platform, but after doing tests in Solid Edge the conclusion was reached that this design was both too heavy to be considered portable, and was not strong enough as there was permanent deflection as vehicle drove onto it. Thus, the design was changed to be made out of angle iron set at a 45 degree angle for better weight distribution and a lighter lift overall.

After having a rough design plan, and after consulting our sponsor, we were given the go ahead for a basic 4 lift system (one lift platform for each tire) run off of a single air over hydraulic pump. This project was to have a budget of \$1500 for a pair of lift platforms, with the understanding that two platforms would be built by the group members for initial testing for the senior design project, and that the other two platforms would be built at a later date by the sponsor once the design was finalized.

## Fabrication

Once the raw steel arrived at the build shop in South Bend, Jason spent the majority of the first build weekend preparing for the drilling and welding that was to be performed the following weekend. This involved cutting all of the 10' and 20' angle iron lengths for the frames to the proper lengths with the cutoff saw and abrasive blade as shown in Figure 1. After this, the ends of the 2" angle iron lengths were then cut at 45 degrees to aid with welding them into the rectangle frame shape.



*Figure 1: Cutting raw steel to length and proper angles*

## Frame Assemblies

The following weekend, the build started in earnest. The angle iron parts cut the previous weekend were deburred with an angle grinder, and passed to Andrew who drilled the holes in the frame parts for the scissor arm attachment points, hydraulic hose pass-through, and the lock pins.



*Figure 3: Deburring with angle grinder*



*Figure 2: Drilling holes in outer frame pieces*

Once a set of two short pieces and long pieces were drilled and deburred, Braxton then welded them together. Once cool, the welds were ground as smooth as possible with an angle grinder and die grinder.



*Figure 4: Welding outer frame assembly together*

To complete the top frame assemblies, the 1.5" angle tread bars were laid on scrap 2x4 pieces with the angle pointed up and the previously assembled outer frame laid on top of them. The 1.5" bars were then spaced evenly widthwise and tacked in place with the welder. Once tacked, the assembly was flipped upside down and the tread bars were finish welded to the outer frame assembly. The center tread braces were then welded into place centered lengthwise.

After that was complete, the back plates for the lock pins were welded into place, using a pin to maintain proper alignment. In the course of doing this, clearance for the lock pins past the back plates was neglected, and this had to be corrected with a cutting torch and die grinder later.



*Figure 5: Completed top assembly*

The bottom assemblies by comparison were much simpler. They followed the first steps of welding the outer frame together, and then the cylinder mounting assembly was welded into place opposite the hydraulic pass-through hole.

### Hydraulic Cylinder Mounts

The mounts for the base of the hydraulic cylinders are comprised of 5 components; two bracket side pieces that were cut on a CNC plasma table, one 2" x 2" x ¼" thick square tube, and two ½" thick booster plates for clearance between the cylinder and the ground. These are welded into a single sub-assembly that is in turn welded into the bottom frame assembly.

This same sub-assembly but with a different spacing between the two bracket pieces and without the booster plates is used for the rod end that is welded to the scissor arms.





Figure 6: Welding scissor arms to rod end hydraulic mount

## Wheel Fabrication

Each lift requires 4 wheels that allow the scissor arms to move. Upon research, we found that the type of wheels we needed, solid steel for strength and 1 inch wide, were not readily available for purchase. The wheels found were all of the cast variety, which did not have the weight capacity required. The decision was then made to fabricate the wheels ourselves from A36 round bar.

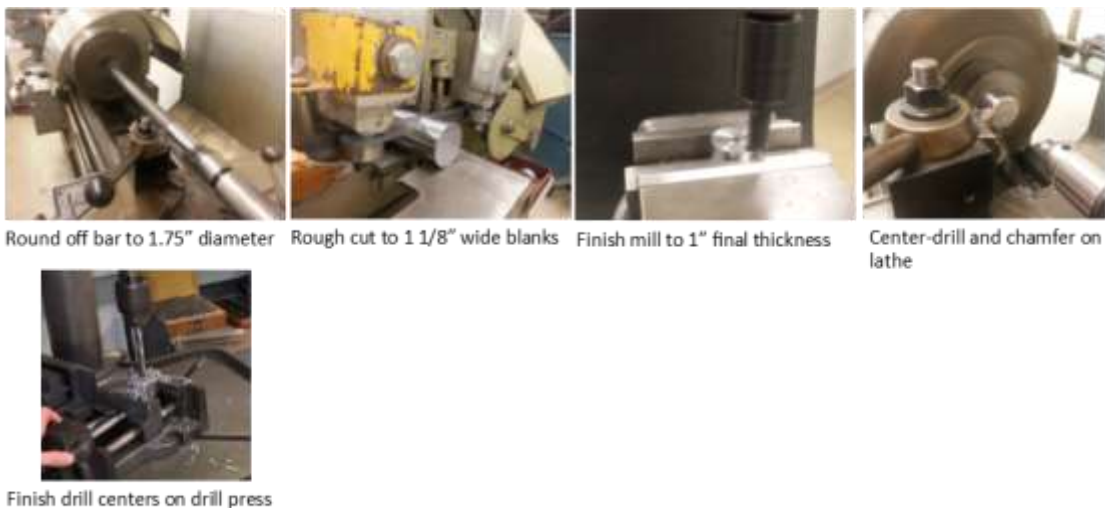


Figure 7: Wheel fabrication process

First, the round bar was rounded off by a few passes on the lathe and taken down to its final diameter of 1.75". Once the bar was verified as the proper diameter, it was taken to the band saw where it was cut into 1 1/8"



wide blanks. These blanks were then milled down to the final 1" thickness. Then the blanks were put back on the lathe, center-drilled, and had small chamfers added to each side. The blanks were then moved to the drill press for the final steps. The center axle hole was drilled, and then a countersink tool was used to add chamfers to either side of the center hole.

## Paint

Once part fabrication was complete, Andy took all of the frame assemblies and the scissors arms to his garage to be painted. After 2 coats, with each drying for 24 hours, this step was complete. All of the painted parts were painted with blue implement paint, which is designed to withstand the abuse of being used outdoors and being used roughly.



## Hydraulic Cylinder Modifications

During assembly for test fitting parts, it was discovered that the 90 degree fitting on the cylinder came into contact with the top frame when the lift platform was in the down position. As the vehicle would be driving on top of the platform and all of its weight would be pressing on this fitting, the fitting needed moved out of the way.

This problem was anticipated during the design phase, and the decision was made to find a hydraulic cylinder with the ports to the side which necessitated a cylinder with clevis end mounts so the cylinder could rotate relative to the rod end point. However, the necessity of a 3" bore x 8" stroke cylinder precluded this cylinder type, as none could be found matching the required specifications. A cylinder with fixed tube ends was chosen, with the hope there would be enough clearance.

Prior to purchase, the manufacturer was contacted and asked if they made a cylinder of the required size with ports to the side. The manufacturer replied that they currently don't make a cylinder like that needed, but if we ordered a minimum of 20 they could do a custom run for a small extra fee. Due to the scale of the project being a one off prototype system, this was determined to not be feasible.

To correct the clearance problem, the tube connector opposite the rod end was cut off using an angle grinder with a cut-off wheel. Both pieces were then ground smooth, and the tube end connection was welded back onto the cylinder tube at a 45 degree angle. After this was done, it was discovered the connection tube had gone out of shape due to the heat, and the inside diameter was widened with a Dremel rotary tool with a sanding wheel to once again accommodate the mounting pin.

## Test Fit Assembly & Troubleshooting

After fabrication, the lift platforms were assembled for test fitting. A problem was noted immediately that the wheels were not in contact with the bottom frame. This was due to the wheels being undersized during fabrication. The raw round bar the wheels were fabricated from, was not as round as required when received, so quite a bit more material was required to be removed on the lathe to make them perfectly round than initially anticipated. In hindsight, this could've been avoided by ordering a larger diameter bar.

To correct this, due to lack of time to order another round bar and have it shipped, one angle on the scissor arms was recut with an angle grinder and cut-off wheel until the wheel had enough clearance to roll on the frame.

Another problem discovered was the cylinder port clearance issue, which was anticipated in design, but we had no way to avoid this as the type of cylinder required does not currently exist on the market unless custom made. The process for correcting this was described in the previous section.

The third issue that was discovered was that the front of the lift platform is lower than the rear when the lift platform is in the lowered position. This was not anticipated in design, as the computer model did not take in to account gravity and this was not shown in modeling. This could easily be fixed however by welding a short length of steel tube about 3-4" long on either side on top of the cylinder mounting fixture on the bottom frame to act as a spacer.

Due to time constraints, this could not be fixed before the due date and to achieve function for testing this was temporarily corrected with wood spacer blocks. A more permanent design change to correct this will be made, although not implemented, during the week prior to presentation.

The fourth and final problem discovered, was that the holes for the upper locked position of the design are unusable as the scissor arms never fully pass the lock pin hole. This was caused by having to change to a larger cylinder than the initial design called for, and the inability to model the new cylinder without actually having the cylinder to measure until after fabrication had already begun. This is a relatively simple fix, and can be corrected by redrilling new holes in a more proper position. Again, due to time constraints this could not be finished before the due date and will be corrected in the coming weeks.

The full lift design calls for four lift platforms, although only two were actually built and budgeted for testing during this project. Using the lessons learned from the problems discovered by the fabrication of these two lift platforms, the design will be corrected and updated before the project sponsor fabricates the remaining two platforms himself. The two platforms already built will then be retrofitted to match the corrected design sometime after the completion of this course.





## Function Testing

Following our testing procedure, we first began testing the units individually unloaded first. This went well, although motion was improved by oiling the cylinder rods. When they were tested together however, the units would only lift one at a time sequentially, with one unit not moving at all until the other unit was fully extended. It was surmised that possibly a lack of weight was causing unequal fluid flow between the two units from the pump.

Concrete blocks were then added to each lift platform, and cycled up and down several times. All went well, however the units were still lifting sequentially. This is a problem that is still plaguing the design, and must be remedied, most likely with a flow control valve to be able to have consistent flow to each cylinder.



*Figure 8: Phase 2 of Testing, Concrete Blocks*

For the third phase of testing, a small car was driven onto the lift platforms and attempted to be lifted. A loud bang was heard after about 10 seconds as a 3/8" bolt snapped and the lift bound. All bolts were then upgraded to SAE Grade 8 bolts rated to 150,000 psi tensile strength as a precaution.

## Test Results vs. Design Goals

### Size of each platform will be approximately 16" wide, 32" long, and 5" tall

The size of the lift platforms is a little over what we initially wanted. The final dimensions are 16" wide, 39" long, and 6 inches tall. The final lift is 7" longer than our goal because we initially planned on having removable ramps, but this was determined to not be feasible. The permanent ramps account for all of this discrepancy in length. The lift is also one inch taller than planned, in order to reduce the force required by the cylinder to move the lift and allow us to use a 3" cylinder.

### Lift platforms capable of accommodating 35" diameter tires for Jeeps with Rubicon off-road package

With the final size, a 16" x 32" platform lift platform is more than enough to accommodate the 14" wide tires on the Jeep Rubicon.

### Provision hydraulics for 4 possible lift platforms

With the goal of eventually having a system of 4 lift platforms, the hydraulics at the first lift split off into a cross connector rather than a T to allow for the other 2 lifts to be connected. The pump reservoir is also large enough to accommodate all 4 lift platforms.

### Be able to lift underside of vehicle at least 24" off of ground

We nearly met our goal at 23" on a small sedan, although a truck or SUV would easily cross over the 24" threshold.



## Budget

After building two lift platforms, and provisioning the hydraulic system for the planned addition of two more lift platforms, the project came in a little over \$510 under budget or about 34% under budget. This is much less than expected, and from just the material costs in the lift platforms it is very likely that if time permitted we would've been able to build the entire system of four lift platforms within the allotted budget.

	Item	Rate	# units	Component Subtotal
STEEL COMPONENTS	2" x 2" x 1/8" angle x 45'	\$0.55	75.4	\$41.47
	1 1/2" x 1 1/2" x 1/8" angle x 28'	\$0.55	34.5	\$18.98
	1" x 1" x 1/8" angle x 10'	\$0.70	8	\$5.60
	3/8" x 2" flat x 10'	\$0.55	51	\$28.05
	2" x 2" x 1/4" square tubing x 6 1/4'	\$0.50	34	\$17.00
	1.75" diameter, 24" A36 round bar	\$50.43	1	\$50.43
<b>Category Subtotal:</b>				<b>\$161.53</b>

HYDRAULICS	AME 15924 5 Quart Titan Air Hydraulic Pump	\$293.48	1	\$293.48
	Double Acting 3" x 8" Hydraulic Cylinder	\$140.00	2	\$280.00
	Flow Control valve	\$17.69	1	\$17.69
	Hydraulic Fittings + shipping	\$68.98		\$68.98
	Hydraulic mounting brackets (custom on CNC plasma table)	\$7.00	8	\$56.00
	1/2" x 72" hose	\$25.67	1	\$25.67
	1/2" x 48" hose	\$19.25	1	\$19.25
	1/2" x 18" hose	\$10.67	2	\$21.34
	1" x 3 1/8" Pin	\$7.48	2	\$14.96
<b>Category Subtotal:</b>				<b>\$797.37</b>

FASTENERS	5/8" x 1" Shoulder Bolts	\$1.75	4	\$7.00
	3/8" x 1" Hex Bolts	\$0.14	4	\$0.56
	3/8" x 2 1/2" Hex Bolts	\$0.27	16	\$4.32
	3/8" Flat Washers	\$0.04	8	\$0.32
	3/8" Stop Nuts	\$0.14	16	\$2.24
	Axial Needle Thrust Roller Bearings (package 2)	\$7.92	2	\$15.84
<b>Category Subtotal:</b>				<b>\$30.28</b>

<b>Total Spent:</b>	\$989.18
<b>Budget:</b>	\$1,500.00
<b>Surplus/Deficit:</b>	<b>\$510.83</b>



## Conclusions

This was a large but rewarding project. We struggled to finish on time, as we chose a project that turned out to be vastly larger than we initially thought. However, we met most of our design goals and came vastly under budget. There were several flaws in our design that weren't apparent until we already had the project built, but we overcame most of those within the timeframe for the project and we have plans to fix several more in the next few weeks.

The biggest takeaway is that solid modeling and computer software can't beat what you learn from building a physical prototype. There were several things that looked fine in the software that came back to bite us, resulting in several days of headaches trying to figure out how to overcome them on time.

## References

- [1] Quick Jack USA, "Home Page," [Online]. Available: <http://www.quickjack.com/>.
- [2] Harbor Freight Tools, "Harbor Freight: Central Hydraulics Scissor Lift Listing," [Online]. Available: <http://www.harborfreight.com/automotive-motorcycle/lifts-stands/6000-lb-capacity-scissor-lift-91315.html>. [Accessed February 2016].
- [3] B. Dupen, Applied Strength of Materials for Engineering Technology v. 9, Fort Wayne, Indiana: Self Published, 2016.

## Appendix 1: Design Equations

### Cylinder Force Requirements

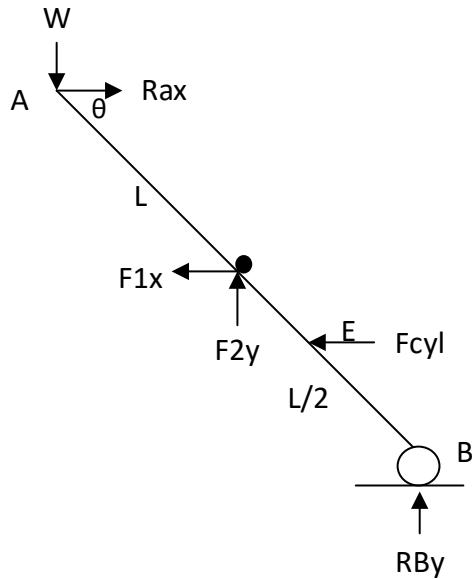
Assumed:

$$W = \frac{\text{lift rating per platform} * \text{Factor of Safety}}{\# \text{ of lift points}} = \frac{1500 \text{ lb} * 2}{4} \frac{3000 \text{ lb}}{4} = 750 \text{ lb.}$$

$$R_{AX} = 0$$

$$\Theta = 45 \text{ degrees (at Max. Lift Height)}$$

SIDE 1



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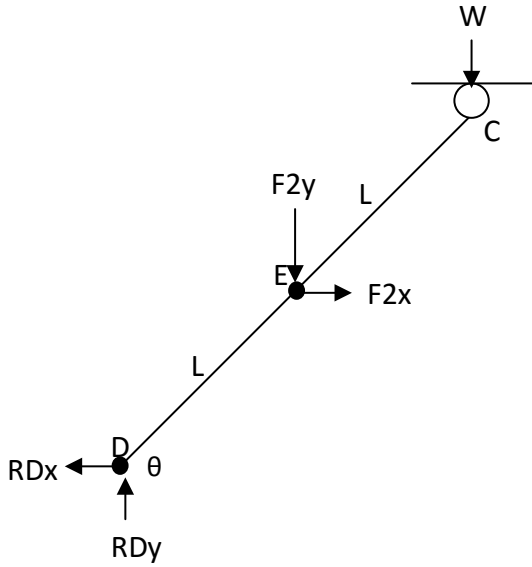
$$\sum F_X = 0 = R_{AX} - F_{1X} - F_{cyl}$$

$$\sum F_Y = 0 = -W + F_{1Y} + R_B$$

$$+ \sum M_A = 0 = -F_{1X} * L * \sin \theta + F_{1Y} * L * \cos \theta - F_{cyl} * 1.5L * \sin \theta + R_B * 2L * \cos \theta$$

$$+ \sum M_E = 0 = W * L * \cos \theta$$

Side 2:



$$\sum F_X = 0 = -R_{DX} - F_{2X}$$

$$\sum F_Y = 0 = -W + F_{2Y} + R_{DY}$$

$$+ \sum M_D = -F_{2Y} * L * \cos \theta - F_{2Y} * L * \sin \theta - W * 2L * \cos \theta$$

$$+ \sum M_E = 750 * L * \cos \theta - L * R_{DY} * \cos \theta - R_{DX} * L * \sin \theta = 0$$

$$R_{AX} = 0$$

$$R_{DY} = 2750 \text{ lbs.}$$

$$\Theta = 45 \text{ degrees}$$

$$R_{DX} = 2000 \text{ lbs.}$$

$$F_{1Y} = 2000 \text{ lbs.}$$

$$F_{2X} = 2000 \text{ lbs.}$$

$$R_B = -1250 \text{ lbs.}$$

$$F_{2Y} = 2000 \text{ lbs.}$$

$$W = 750 \text{ lbs.}$$

$$F_{1X} * L * \sin \theta + 1.5 * L * F_{cyl} * \sin \theta = 2 * R_E * L * \cos \theta + F_{1Y} * L * \cos \theta$$

$$0 = F_{2Y} * L * \cos \theta + F_{2X} * L * \sin \theta + 1500 * L * \cos \theta$$

$$750 * L * \cos \theta = L * R_{DY} * \cos \theta + R_{DX} * L * \sin \theta$$

$$F_{1X} * L * \sin \theta + 1.5 * L * F_{cyl} * \sin \theta = (1500 - 2 * F_{1Y}) * L * \cos \theta + F_{1Y} * L * \cos \theta$$

$$F_{1X} * L * \sin \theta - 1.5 * L * F_{1X} * \sin \theta = (1500 - 2 * F_{1Y}) * L * \cos \theta + F_{1Y} * L * \cos \theta$$

$$-0.5 * L * F_{1X} * \sin \theta = (1500 - 2 * F_{1Y}) * L * \cos \theta + F_{1Y} * L * \cos \theta$$

$$-0.5 * L * F_{1X} * \sin \theta = 1500 * L * \cos \theta - F_{1Y} * L * \cos \theta$$

$$F_{1Y} * L * \cos \theta = 1500 * L * \cos \theta + 0.5 * L * F_{1X} * \sin \theta$$

$$0 = F_{2Y} * L * \cos \theta + F_{2X} * L * \sin \theta + 1500 * L * \cos \theta$$

$$F_{2Y} * L * \cos \theta = -F_{2X} * L * \sin \theta - 1500L * \cos \theta$$

$$-F_{2X} * L * \sin \theta - 1500 * L * \cos \theta = 1500L * L * \cos \theta + 1.5L * F_{1X} \sin \theta$$

$$-3000L \cos \theta = 1.5L * F_{1X} \sin \theta$$

$$-2000 \cot \theta = F_{1X}$$

$$F_{1X} = -2000 \cot \theta^\circ$$

$$F_{1X} = -2000 \cot 45^\circ$$

$$F_{1X} = -2000 \text{ lb.}$$

$$750L \cos \theta = L * R_{DY} \cos \theta = L * R_{DY} \cos \theta + R_{DX} * L \sin \theta$$

$$L * R_{DY} \cos \theta = 750L \cos \theta - R_{DX} * L \sin \theta$$

$$R_{DY} = \frac{750L \cos \theta - R_{DX}L \sin \theta}{L \cos \theta} = \frac{750 \cos 45^\circ + 2000 \cos 45^\circ}{\cos 45^\circ}$$

$$R_{DY} = 2750 \text{ lb.}$$

$$750 + F_{2Y} = R_{DY}$$

$$F_{2Y} = R_{DY} - 750$$

$$F_{2Y} = 2750 - 750$$

$$F_{2Y} = 2000 \text{ lb.}$$

$$R_B = 750 - F_{1Y}$$

$$R_B = 750 - 2000$$

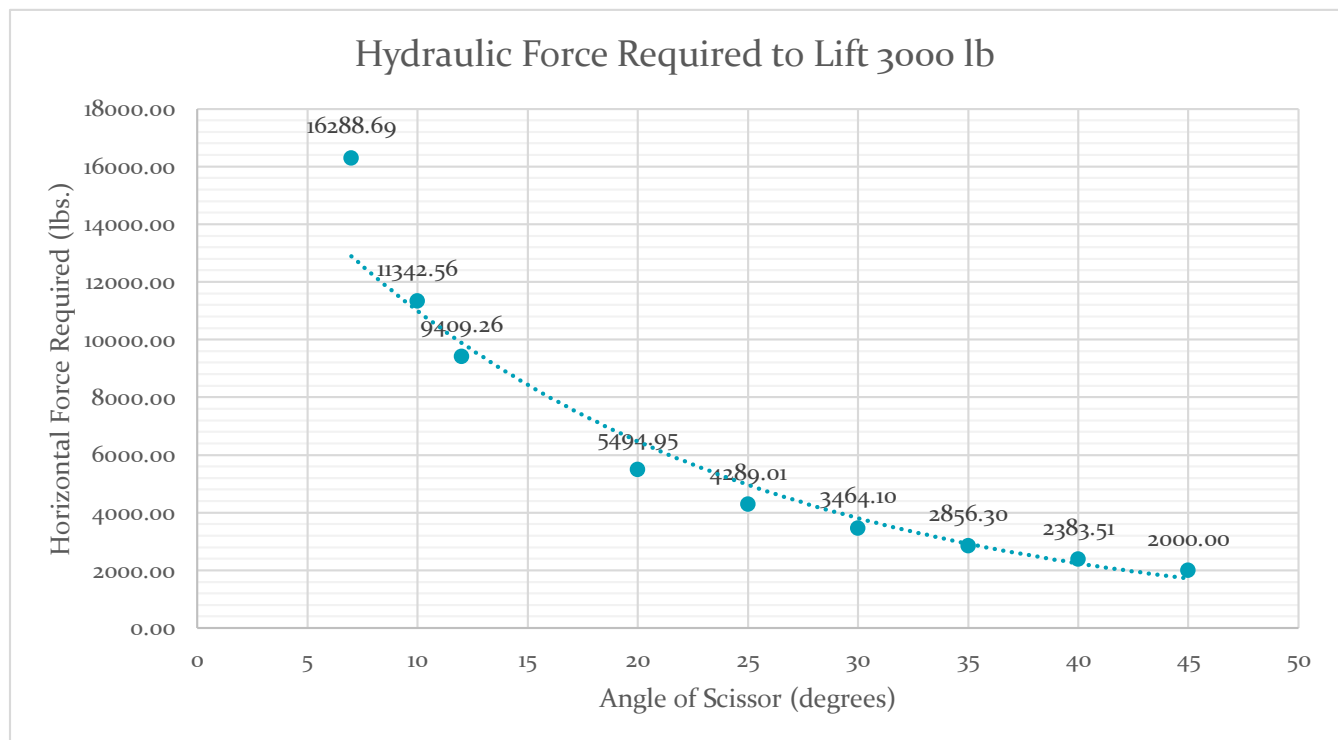
$$R_B = -1250 \text{ lb.}$$

$$-F_{cyl} = F_{1X}$$

$$F_{cyl} = -F_{1X} = -(-2000 \text{ lb})$$

$$F_{cyl} = 2000 \text{ lb.}$$

Thus, the force required for one platform to lift the 3000 lb. max capacity is 2000 lbs. Other angles can be seen on the graph below.



### Required Scissor Arm Thickness to Resist Buckling

#### Assumed:

$t_{req}$  = minimum required thickness of arm

$h$  = 2 in wide bar stock

$L$  = 26.25 in.



$K = 1$  (pinned)

$\sigma_{YS} = 36 \text{ ksi}$

$E = 30 \times 10^6 \text{ psi}$

$$r_{Gx} = \frac{h}{\sqrt{12}} = \frac{2 \text{ in}}{\sqrt{12}} = 0.5773 \text{ in}$$

$$r_{Gy} = \frac{t_{req}}{\sqrt{12}}$$

Use  $r_{GY}$  for slender equation because the thickness will be smaller than the width of the bar used.

Find maximum thickness to be considered as a slender column

$$\frac{KL}{r_G} \geq \sqrt{\frac{2\pi^2 E}{\sigma_{YS}}}$$

$$\frac{1 * 26.25}{r_G} \geq \sqrt{\frac{2\pi^2 * 30 * 10^6 \text{ psi}}{36000 \text{ psi}}}$$

$$\frac{26.25}{\frac{t_{req}}{\sqrt{12}}} \geq 128.25$$

$$\frac{26.25\sqrt{12}}{t_{req}} \geq 128.25$$

$$t_{req} \leq \frac{26.25 \sqrt{12}}{128.25}$$

$$t_{req} \leq 0.71 \text{ in.}$$

Maximum thickness to be considered as a slender column is 0.71 in. This is well above our ideal thickness when designing for weight, so we can consider the scissor arm as a slender column.

$$\sigma_{all} = \frac{\pi^2 E}{\left(\frac{KL}{r_G}\right)^2 FS}$$

$$\left(\frac{KL}{r_G}\right)^2 = \frac{\pi^2 E}{\sigma_{all} FS}$$

$$\frac{KL}{r_G} = \sqrt{\frac{\pi^2 E}{\sigma_{all} FS}}$$

$$r_G = \frac{KL}{\sqrt{\frac{\pi^2 E}{\sigma_{all} FS}}}$$

$$\frac{t_{req}}{\sqrt{12}} = \frac{KL}{\sqrt{\frac{\pi^2 E}{\sigma_{all} FS}}}$$

$$t_{req} = \frac{KL\sqrt{12}}{\sqrt{\frac{\pi^2 E}{\sigma_{all} FS}}}$$

$$t_{req} = \frac{1 * 26.26\sqrt{12}}{\sqrt{\frac{\pi^2 * 30 * 10^6}{\sigma_{all} * 2}}}$$

$$t_{req} = \frac{90.933}{\sqrt{\frac{1.481 * 10^8}{\sigma_{all}}}}$$

**Find allowable stress. Use W as allowable force for worst case.**

$$P_{all} = 0.525\sigma_{all}A$$

$$\sigma_{all} = \frac{P_{all}}{0.525 * A} = \frac{W}{0.525 * A}$$

$$\sigma_{all} = \frac{750 \text{ lb}}{0.525 * 2 \text{ in.} * t_{req}}$$

$$\sigma_{all} = \frac{750 \text{ lb}}{0.525 * 2 \text{ in.} * t_{req}}$$

$$\sigma_{all} = \frac{714.286}{t_{req}}$$

**Substitute allowable stress into  $t_{req}$  equation**

$$t_{req} = \frac{90.933}{\sqrt{\frac{1.481 * 10^8}{\frac{714.286}{t_{req}}}}}$$

$$t_{req} = \frac{90.933}{\sqrt{\frac{1.481 * 10^8 * t_{req}}{714.286}}}$$

$$t_{req} = \frac{90.933}{\sqrt{207339.92 * t_{req}}}$$

$$t_{req} = \frac{0.199701}{\sqrt{t}}$$

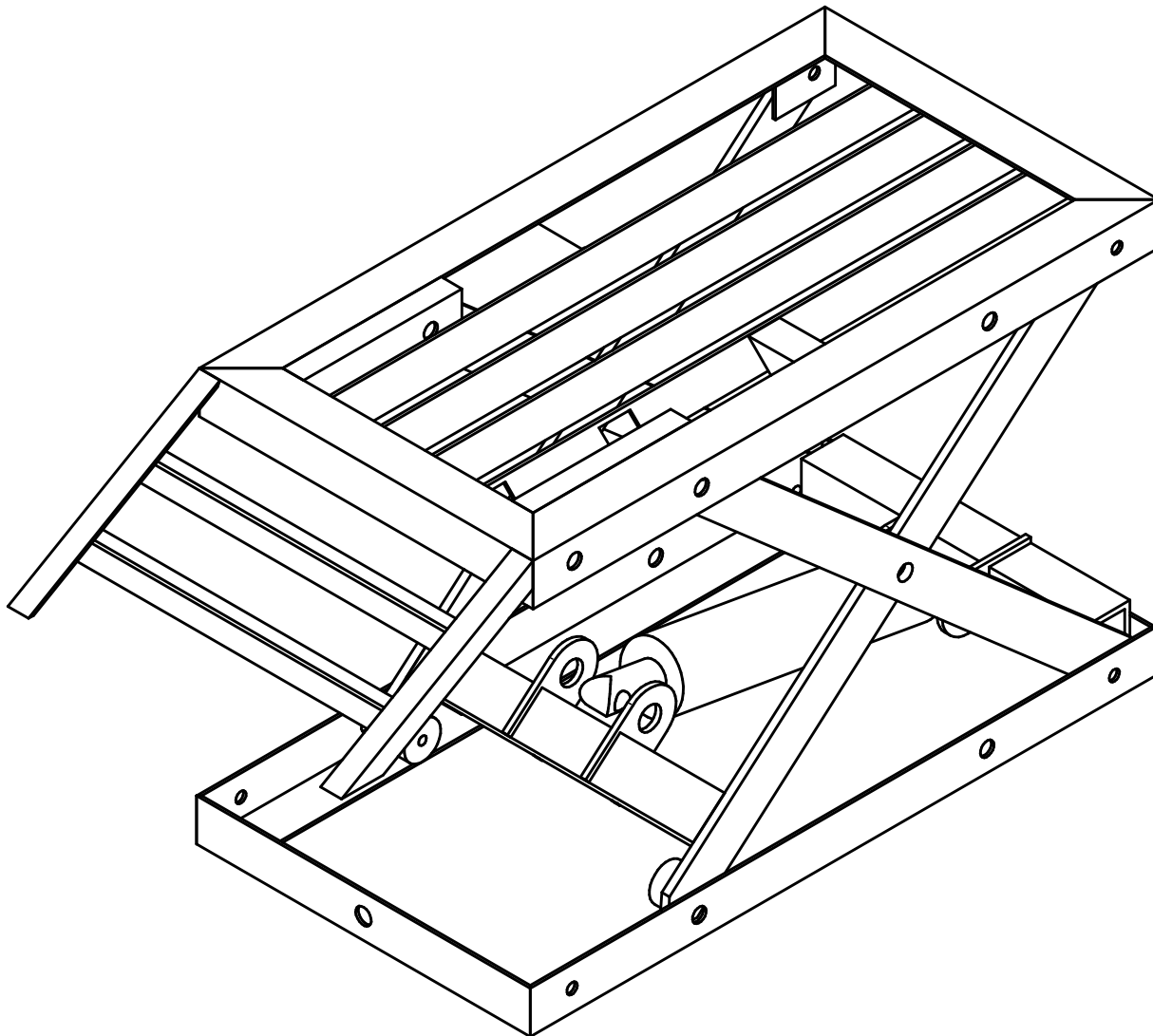
$$t_{req}^{\frac{3}{2}} = 0.199701$$

$$t_{req}^3 = 0.0398805$$

$$\sqrt[3]{t_{req}^3} = \sqrt[3]{0.0398805}$$

$$t_{req} = 0.341 \text{ in}$$

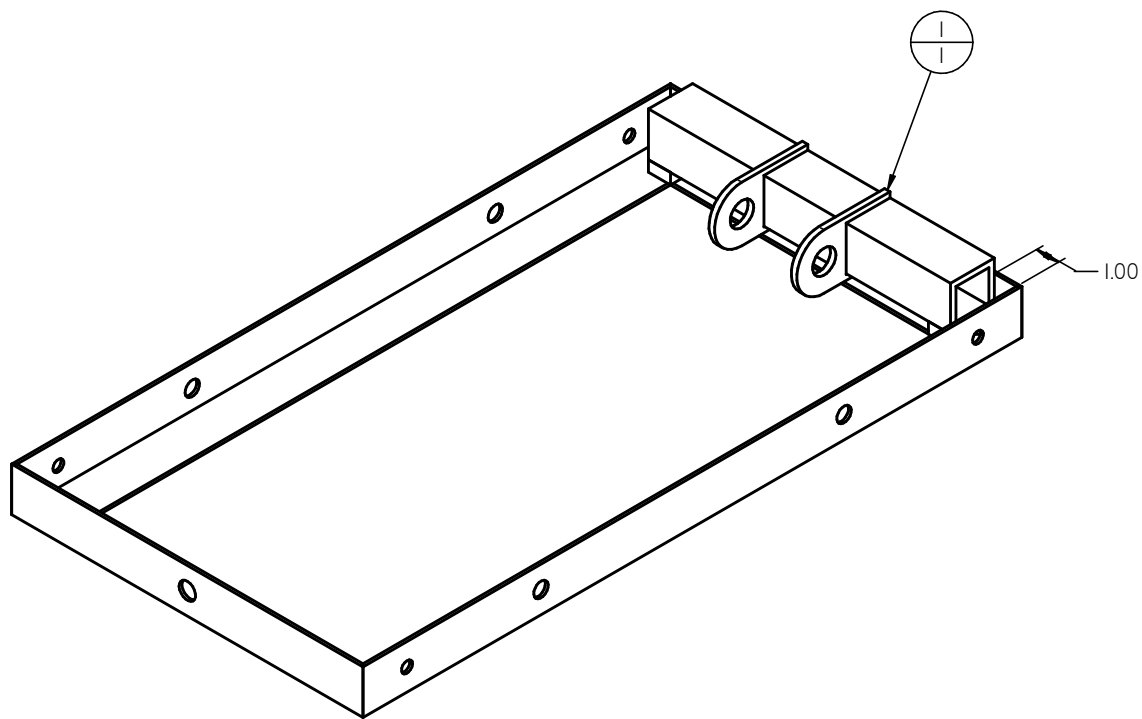
As the minimum required thickness to prevent buckling under maximum load is 0.341 inches, the closest standard thickness able for purchase for the scissor arms is 0.375 inches, or 3/8".



REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
			FULL LIFT ASSEMBLY	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES $\pm 1.0^\circ$ 2 PL $\pm 0.06$ 3 PL $\pm 0.001$			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT:
			SHEET 1 OF 25	

SOLID EDGE ACADEMIC COPY

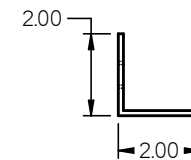
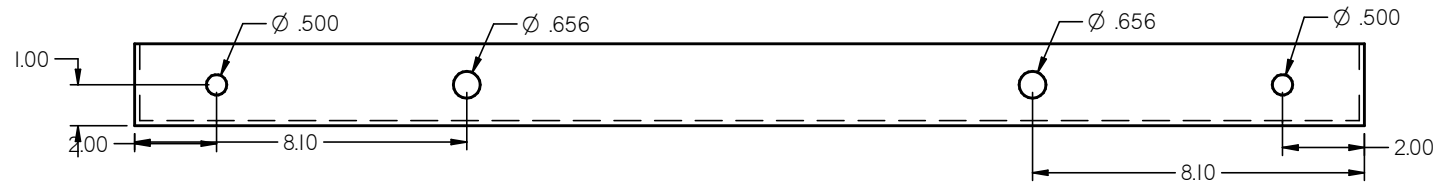
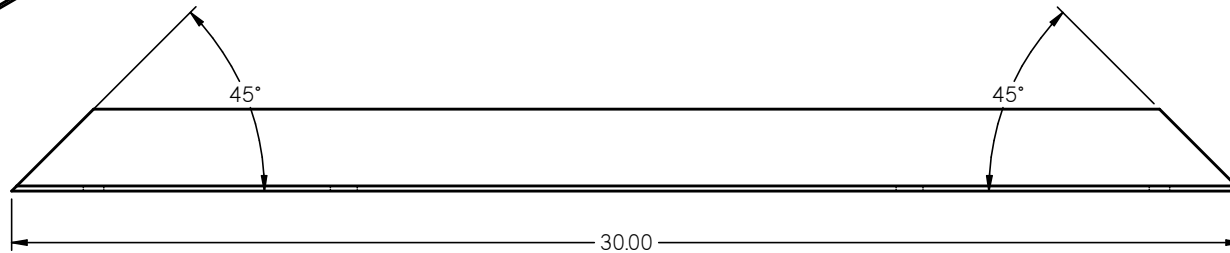
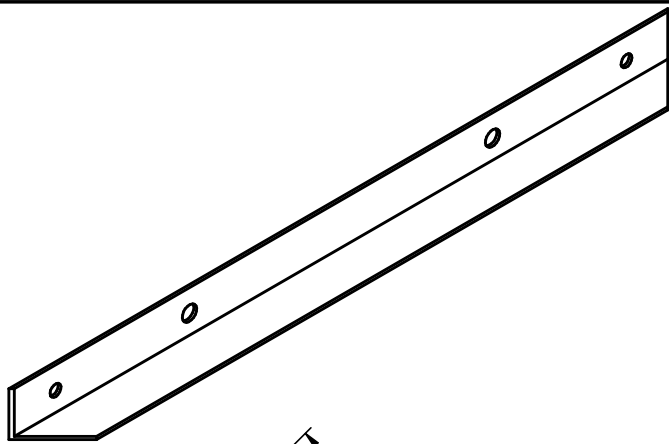


REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

SOLID EDGE ACADEMIC COPY

	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
			BOTTOM FRAME ASSEMBLY	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT:
			SHEET 2 OF 25	



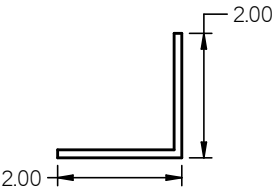
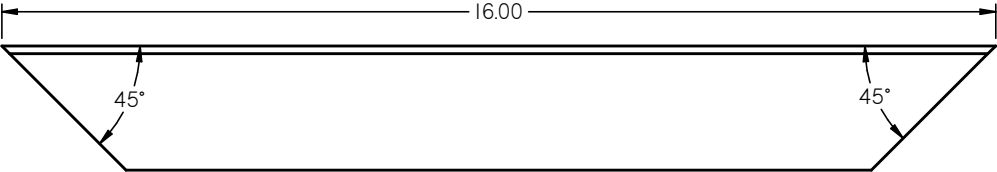
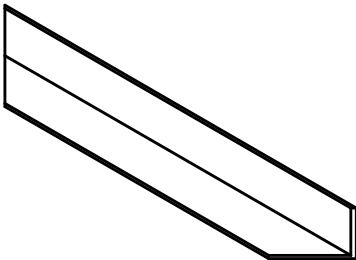


REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE BOTTOM FRAME LENGTH	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	REV
			SCALE:	WEIGHT:
				SHEET 3 OF 25

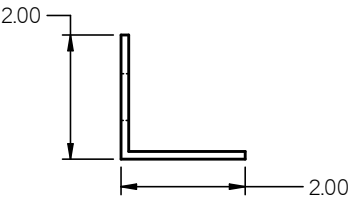
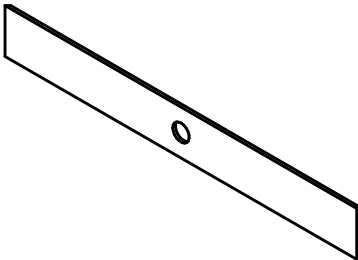
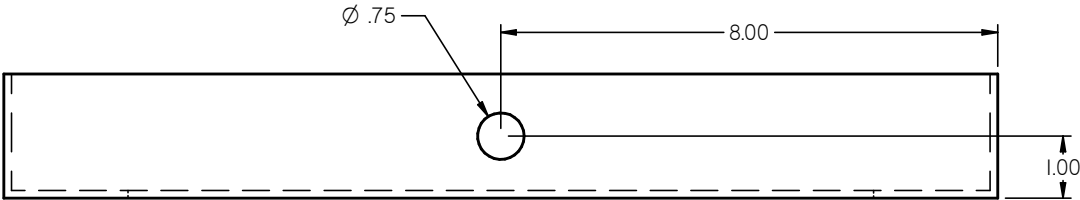
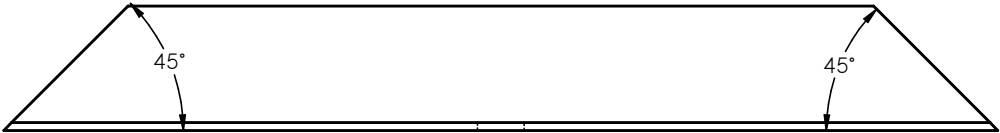
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REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
			BOTTOM FRAME WIDTH	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT:
			SHEET 4 OF 25	

SOLID EDGE ACADEMIC COPY

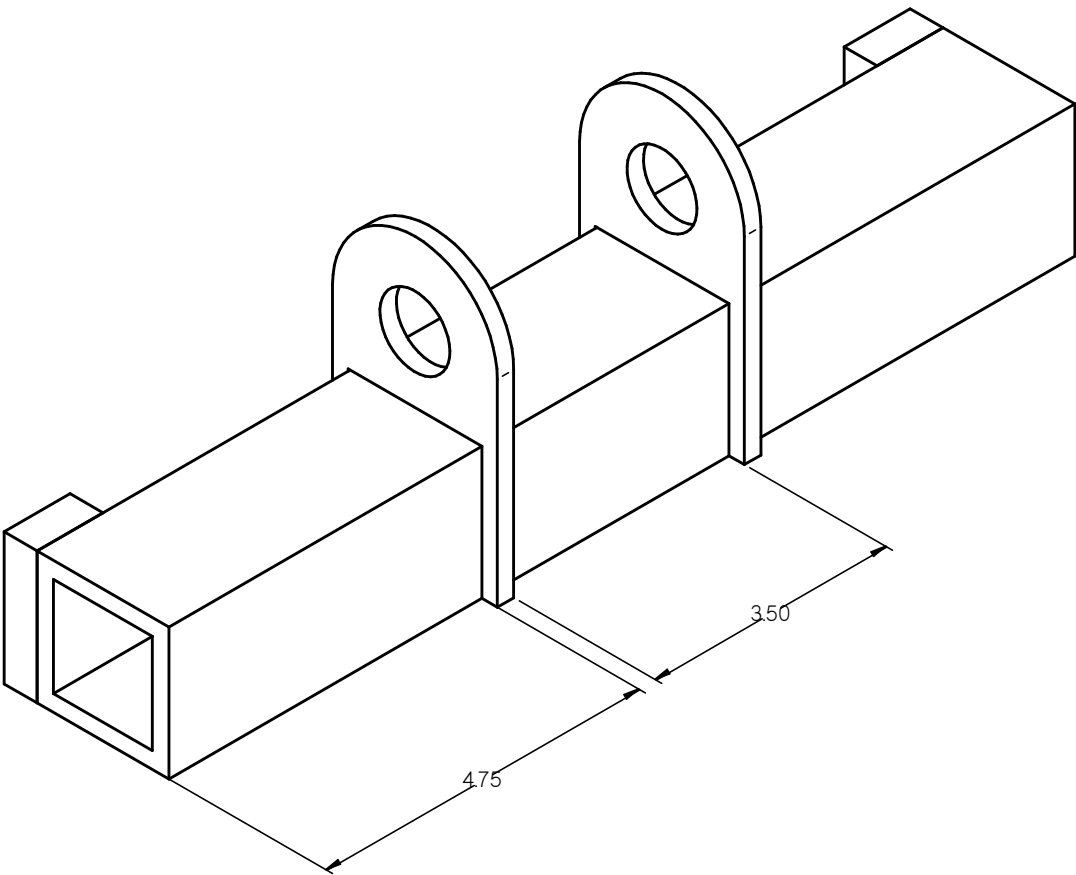


REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

NAME	DATE	Solid Edge	
DRAWN J. Joyner	04/25/16		
CHECKED			
ENG APPR			
MGR APPR		TITLE BOTTOM FRAME WIDTH with PASSTHROUGH	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES $\pm 1.0^\circ$ 2 PL $\pm 0.06$ 3 PL $\pm 0.001$		SIZE B	DWG NO
		FILE NAME: Lift Assembly Design Package.dft	
		SCALE:	WEIGHT:
		SHEET 5 OF 25	

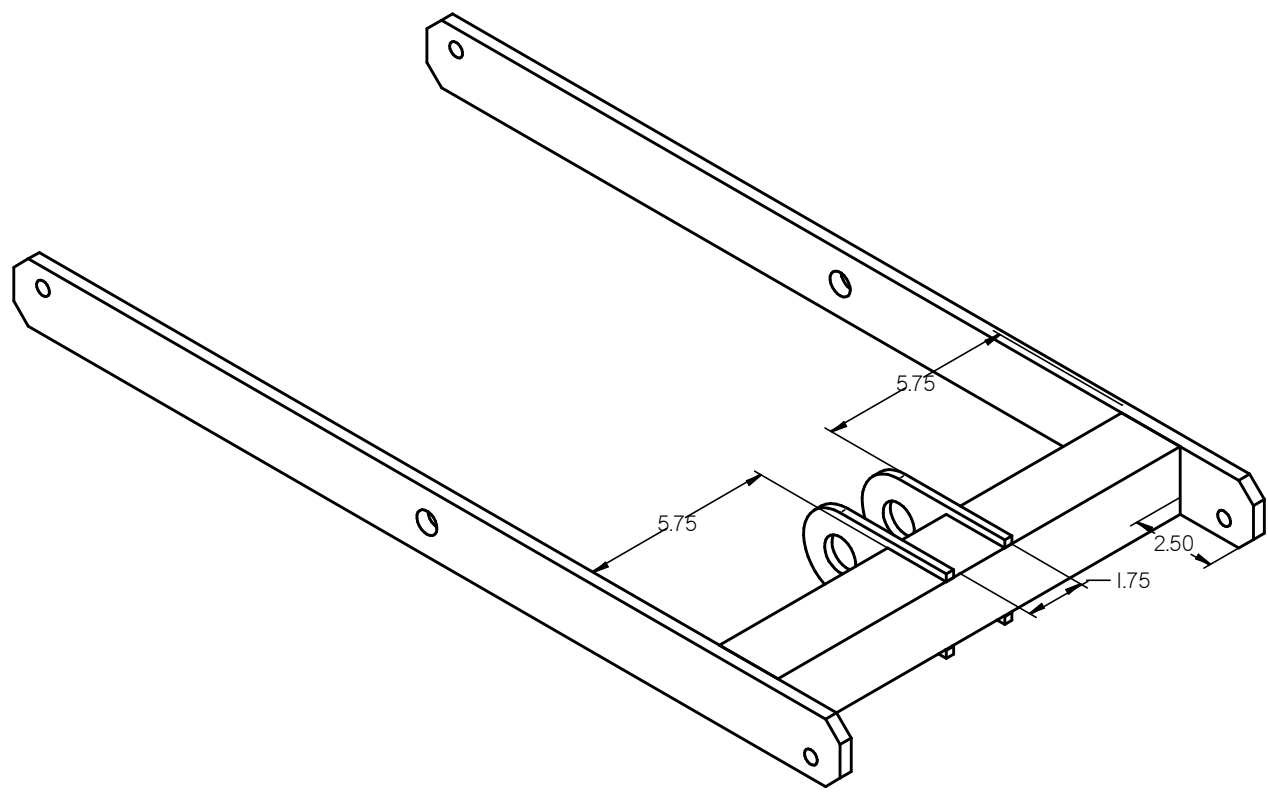
SOLID EDGE ACADEMIC COPY



REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE HYDRAULIC MOUNT BASE END ASSEMBLY	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	REV
			SCALE:	WEIGHT:
			SHEET 6 OF 25	

SOLID EDGE ACADEMIC COPY

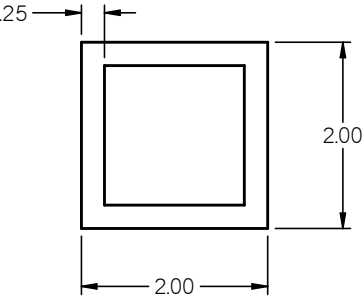
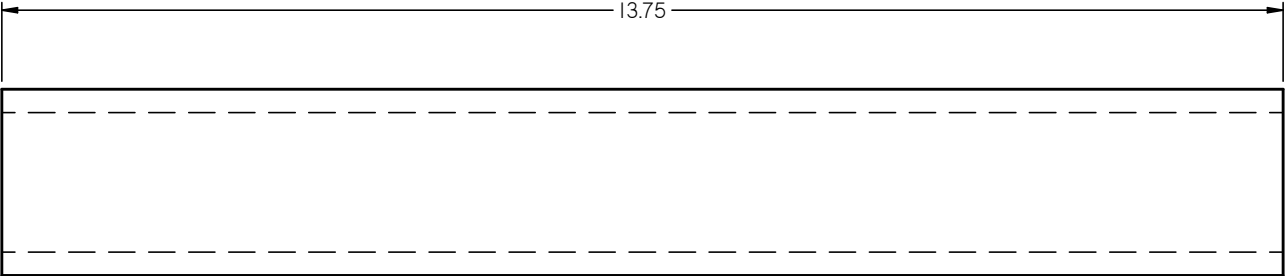


REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

SOLID EDGE ACADEMIC COPY

	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED			TITLE	
ENG APPR				
MGR APPR			HYDRAULIC MOUNT ROD END ASSEMBLY	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	REV
			SCALE:	WEIGHT:
				SHEET 7 OF 25

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

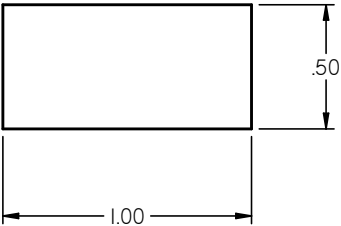
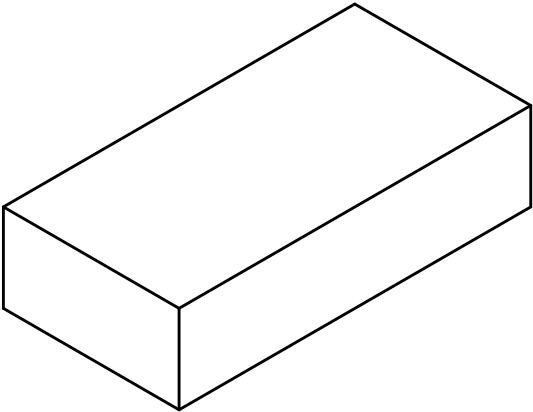
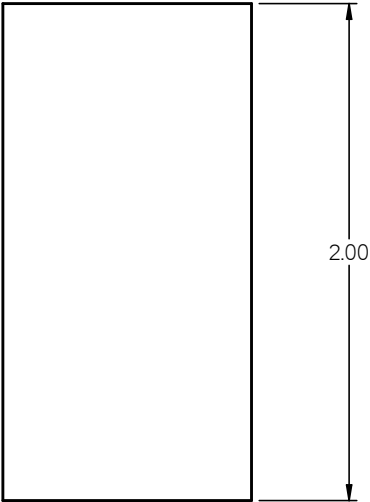


	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
			HYDRAULIC MOUNT BRACE	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT:
			SHEET 8 OF 25	

SOLID EDGE ACADEMIC COPY



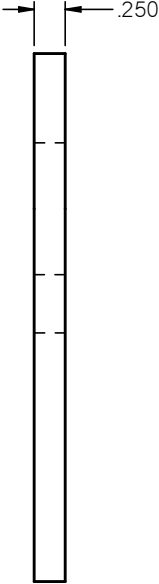
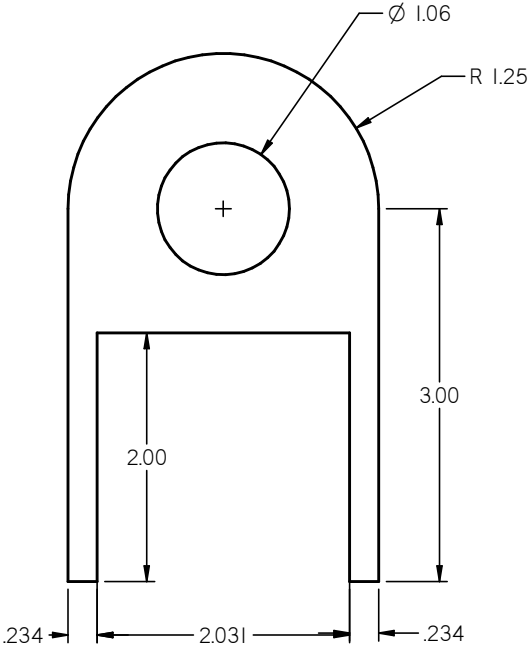
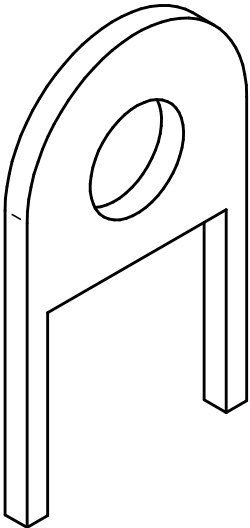
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			HYDRAULIC SPACER BLOCK	
			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT:
			SHEET 9 OF 25	

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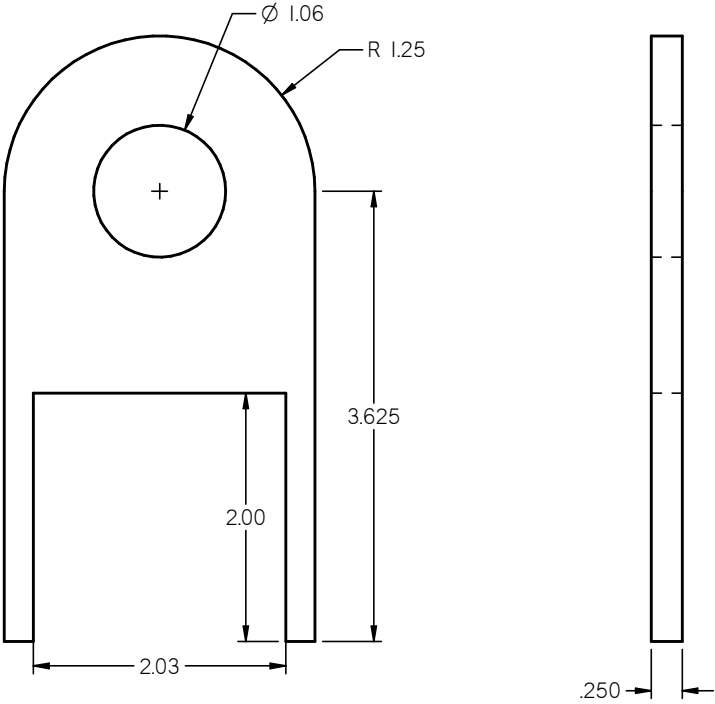
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
			HYDRAULIC BRACKET BASE END	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES $\pm 1.0^{\circ}$ 2 PL $\pm 0.06$ 3 PL $\pm 0.001$			SIZE B	DWG NO REV
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT: SHEET 10 OF 25

SOLID EDGE ACADEMIC COPY

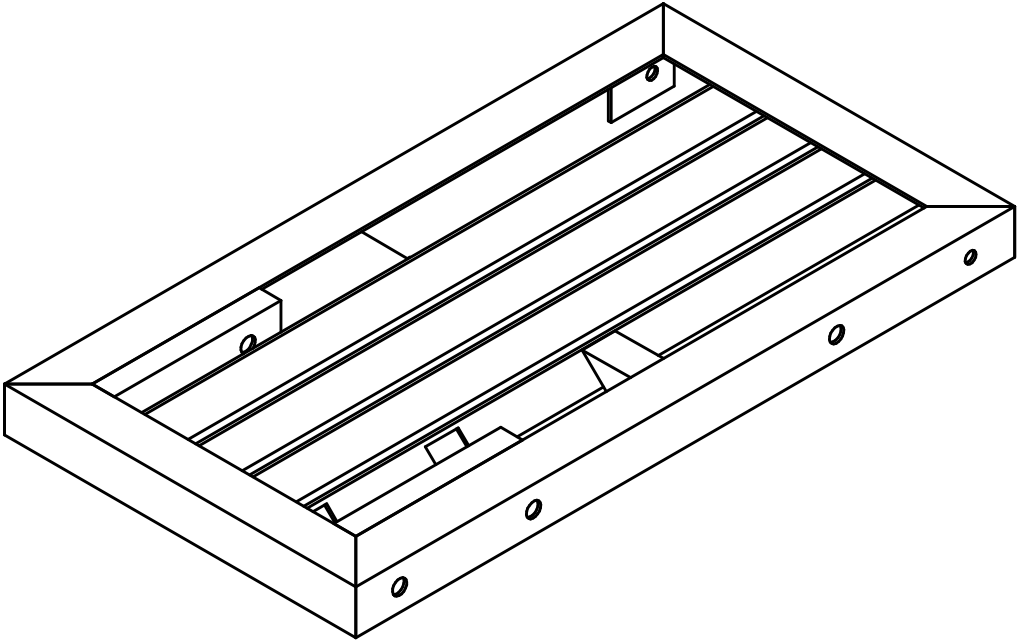
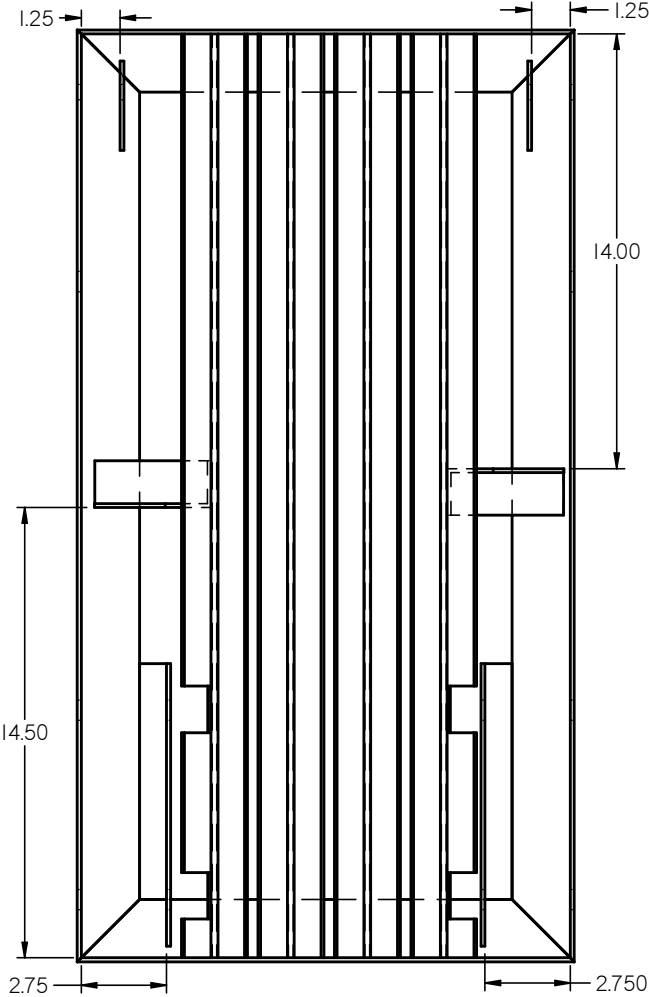
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
			HYDRAULIC BRACKET ROD END	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			REV	
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT:
			SHEET 11 OF 25	

SOLID EDGE ACADEMIC COPY

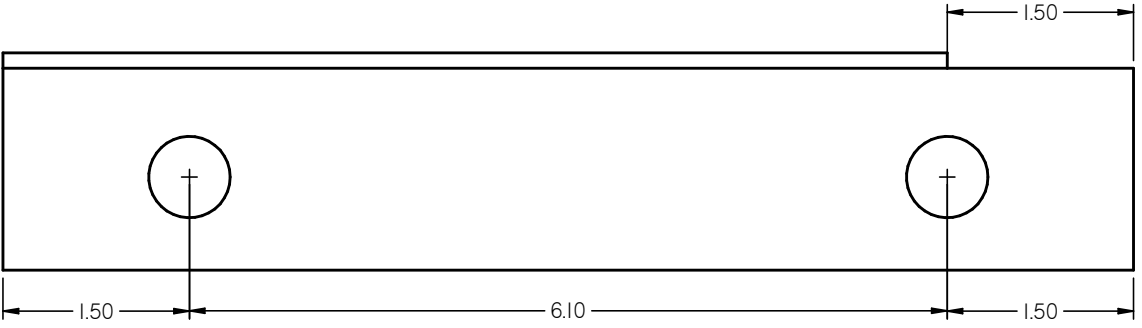
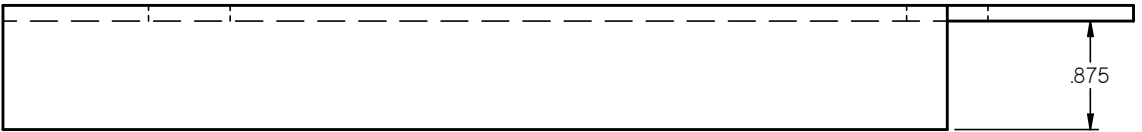
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



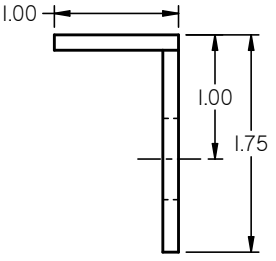
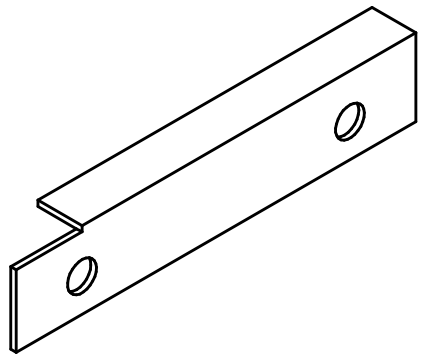
NOTE: TREAD BARS SHOULD BE SPACED EVENLY WIDTHWISE

	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE: TOP ASSEMBLY	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	REV
			SCALE:	WEIGHT: SHEET 12 OF 25

SOLID EDGE ACADEMIC COPY



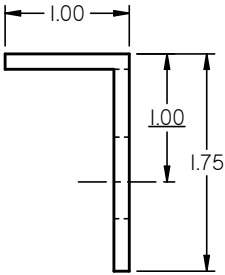
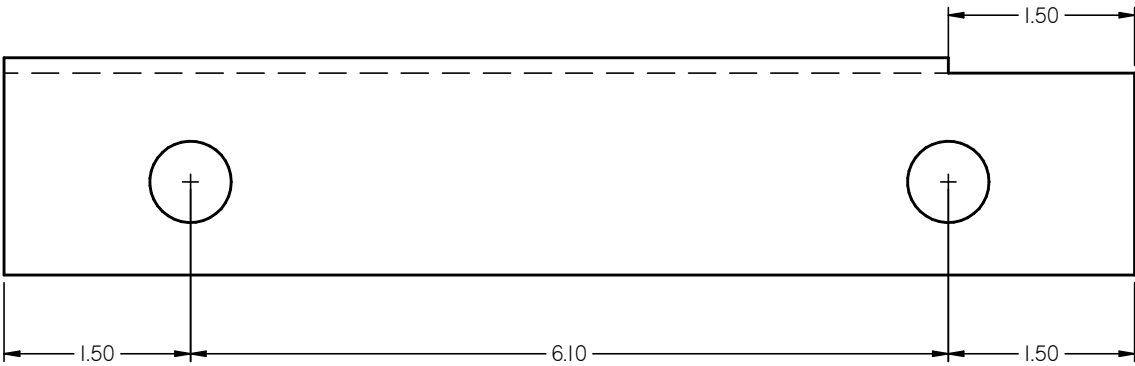
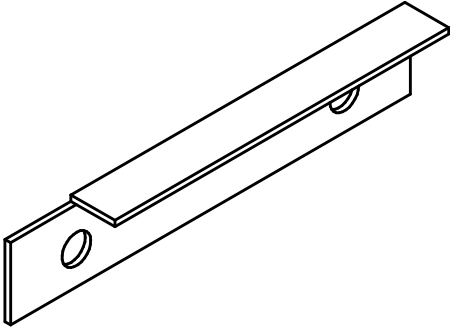
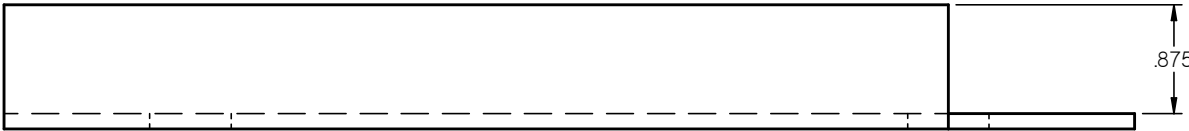
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE	Solid Edge		
DRAWN	J. Joyner	04/25/16			
CHECKED					
ENG APPR					
MGR APPR			TITLE		
			LEFT LOCK PIN INSIDE		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO	REV
			FILE NAME: Lift Assembly Design Package.		
			SCALE:	WEIGHT:	SHEET 13 OF 25

SOLID EDGE ACADEMIC COPY

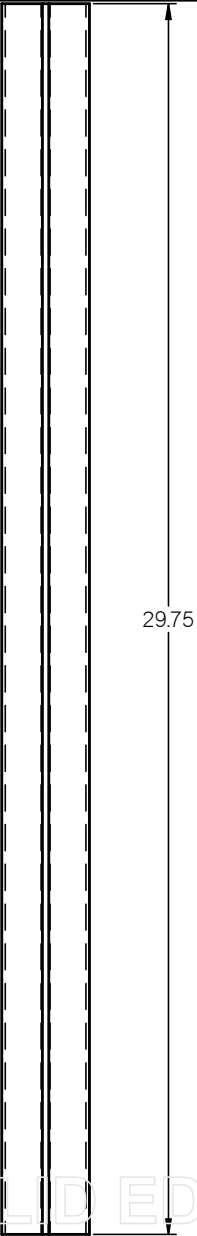
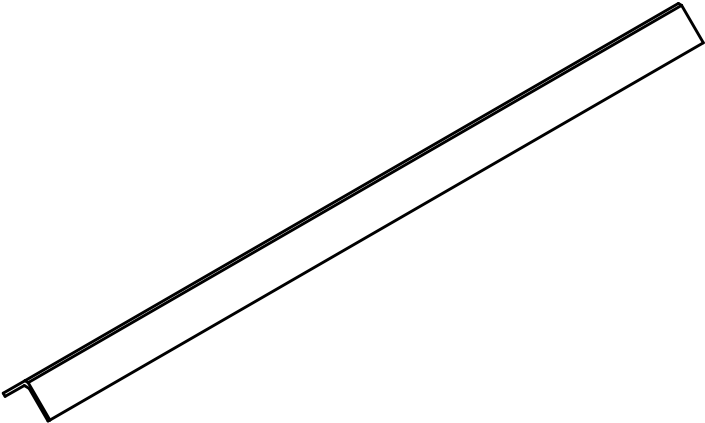
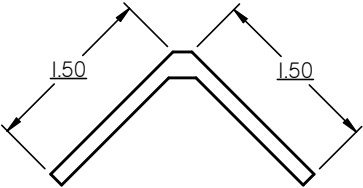
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



NAME	DATE	Solid Edge	
DRAWN J. Joyner	04/25/16		
CHECKED			
ENG APPR			
MGR APPR		TITLE	
		RIGHT LOCK PIN INSIDE	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES $\pm 1.0^\circ$ 2 PL $\pm 0.06$ 3 PL $\pm 0.001$		SIZE B	DWG NO
		FILE NAME: Lift Assembly Design Package.dft	
		SCALE:	WEIGHT:
		SHEET 14 OF 25	

SOLID EDGE ACADEMIC COPY

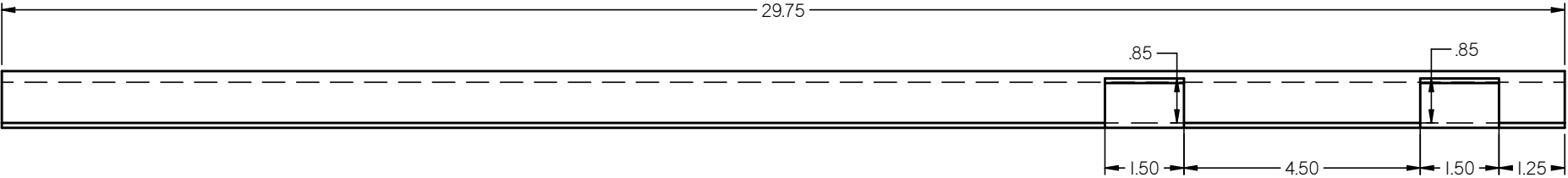
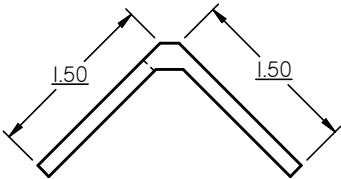
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE CENTER TREAD BAR FOR TOP ASSEMBLY	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	REV
			SCALE:	WEIGHT: SHEET 15 OF 25

SOLID EDGE ACADEMIC COPY

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

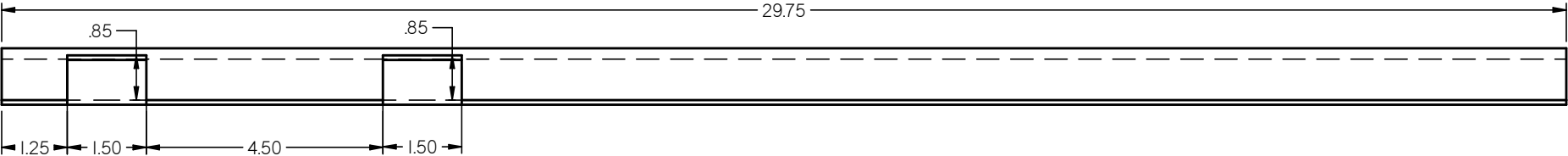
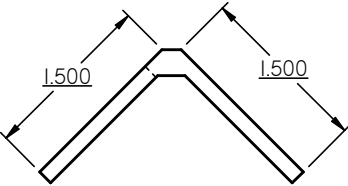


	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
			LEFT TREAD BAR FOR TOP ASSEMBLY	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO REV
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT: SHEET 16 OF 25

SOLID EDGE ACADEMIC COPY



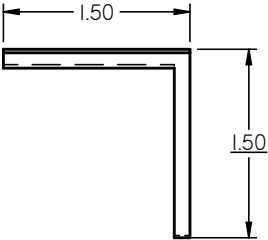
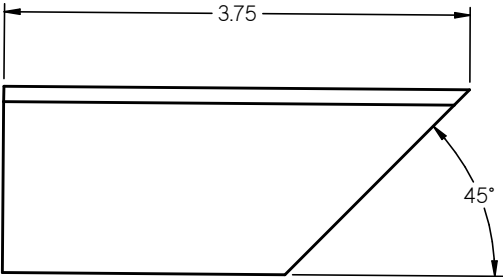
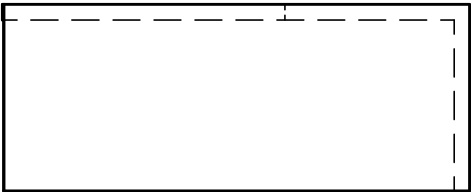
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE	Solid Edge				
DRAWN	J. Joyner	04/25/16					
CHECKED							
ENG APPR							
MGR APPR			TITLE				
			RIGHT TREAD BAR FOR TOP ASSEMBLY				
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO		REV	
			FILE NAME: Lift Assembly Design Package.				
			SCALE:		WEIGHT:	SHEET 17 OF 25	

SOLID EDGE ACADEMIC COPY

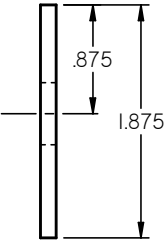
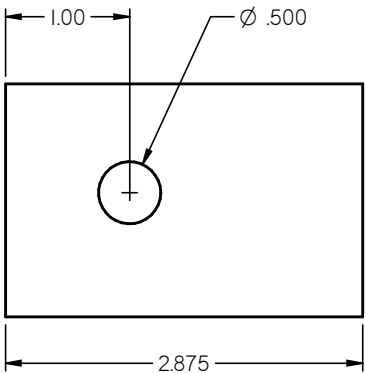
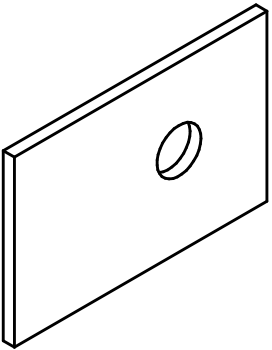
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE TREAD CENTER BRACE FOR TOP ASSEMBLY	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	REV
			SCALE:	WEIGHT:
			SHEET 18 OF 25	

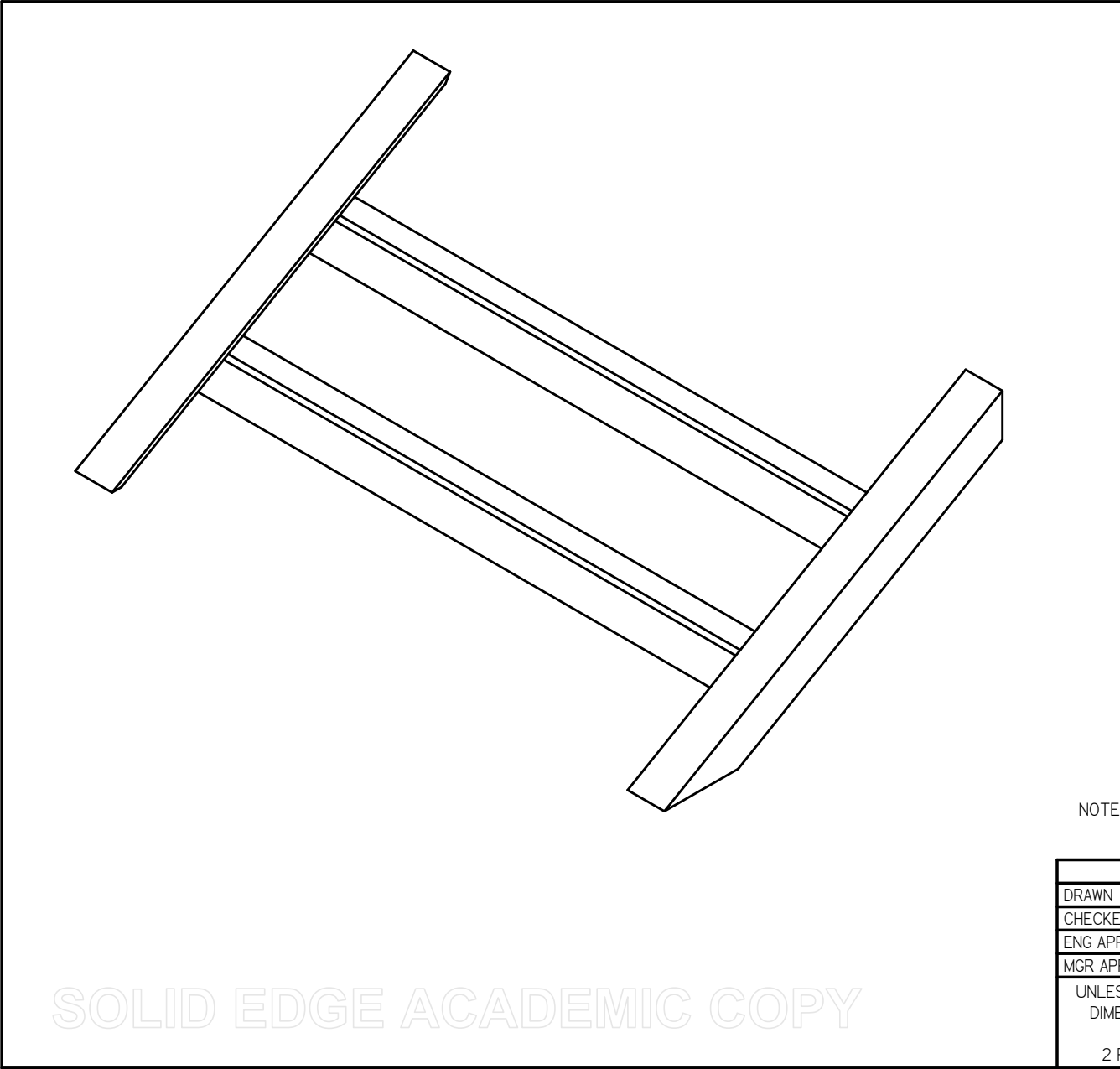
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REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE SCISSOR ARM BACKPLATE FOR TOP ASSEMBLY	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			REV	
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT: SHEET 19 OF 25

SOLID EDGE ACADEMIC COPY

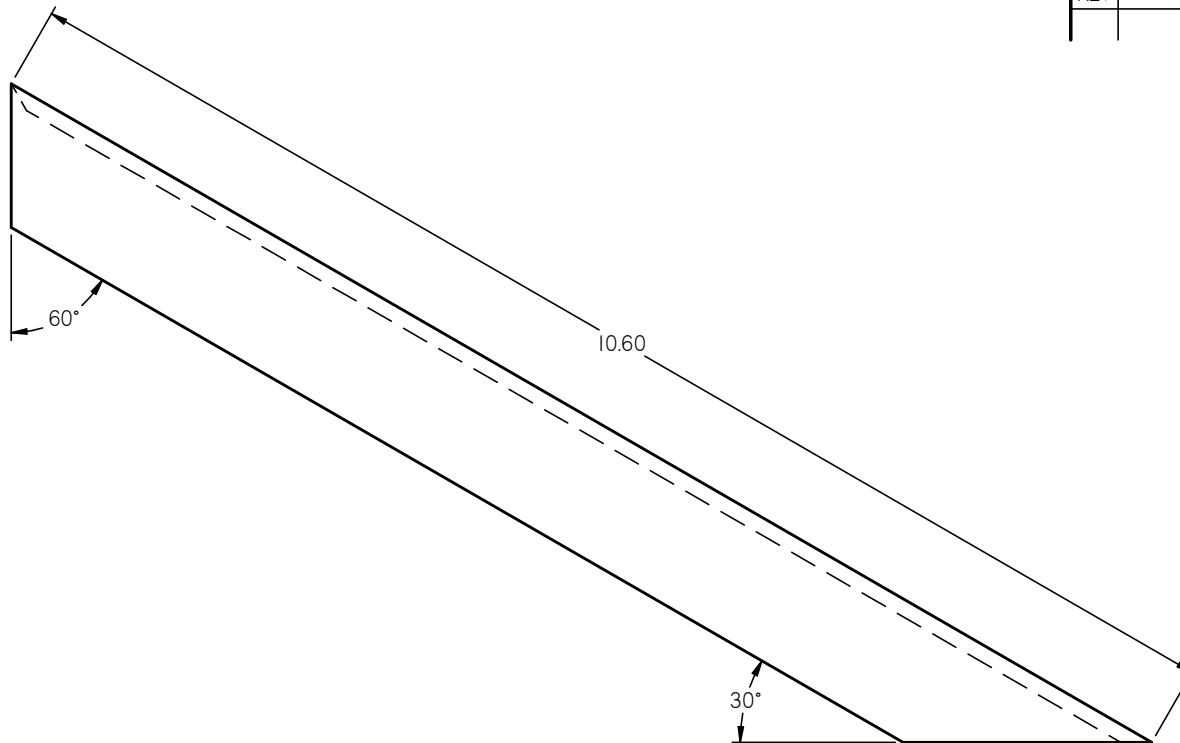


REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

NOTE: SPACE TREAD BARS EVENLY ALONG LENGTH OF RAMP SIDES

	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT:
			SHEET 20 OF 25	

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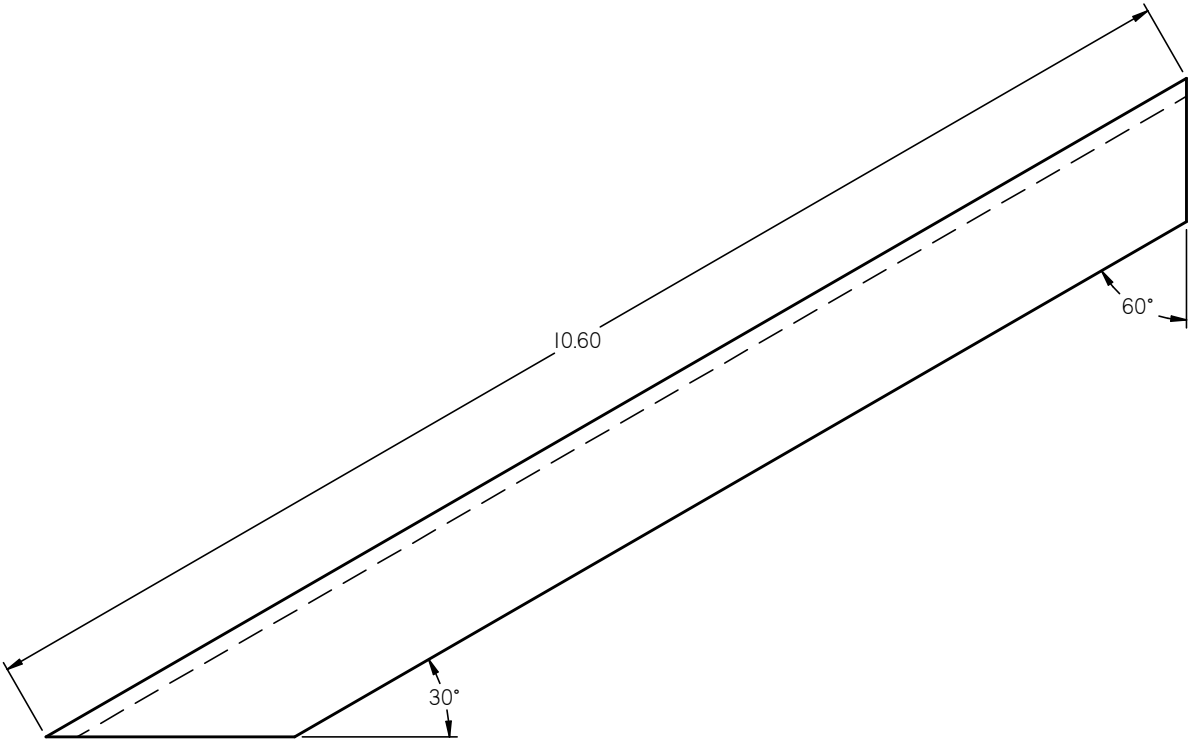
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

MAKE OUT OF 1" X 1" ANGLE IRON

	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE LEFT SIDE RAMP	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	REV
			SCALE:	WEIGHT:
			SHEET 21 OF 25	

SOLID EDGE ACADEMIC COPY

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

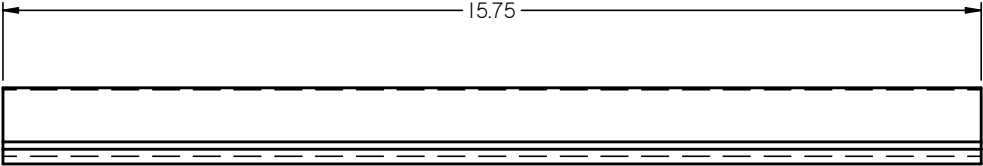


MAKE OUT OF 1" X 1" ANGLE IRON

	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT:
			SHEET 22 OF 25	

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REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

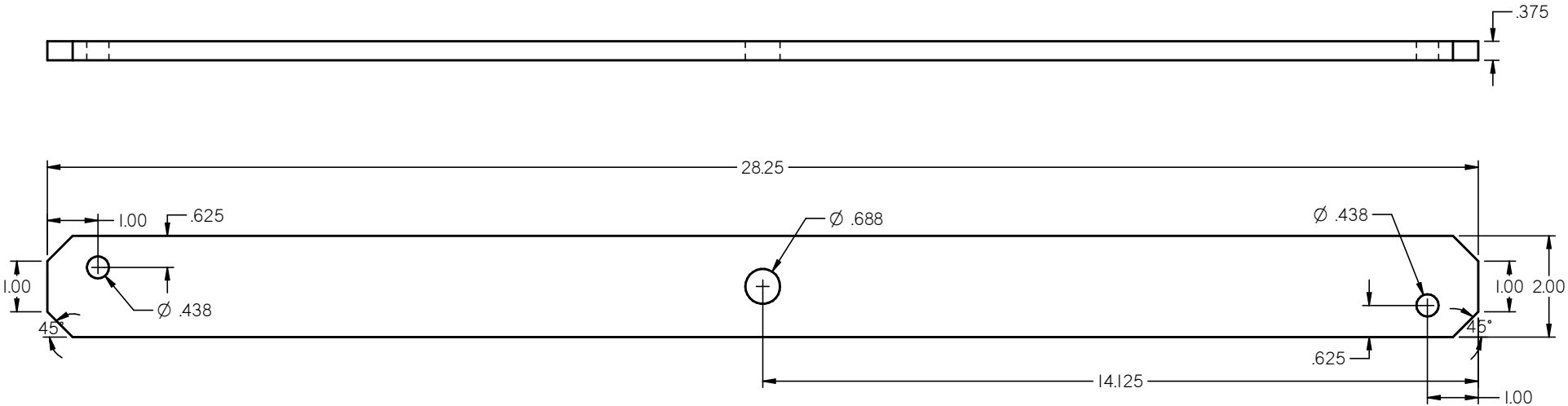


MAKE OUT OF 1" X 1" ANGLE IRON

	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE RAMP TREAD BAR	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT: SHEET 23 OF 25

SOLID EDGE ACADEMIC COPY

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

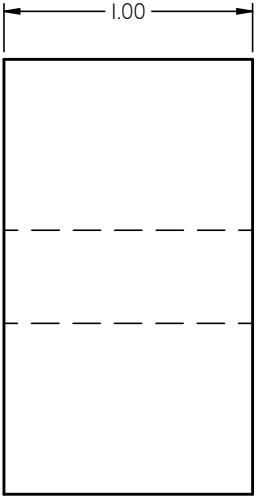
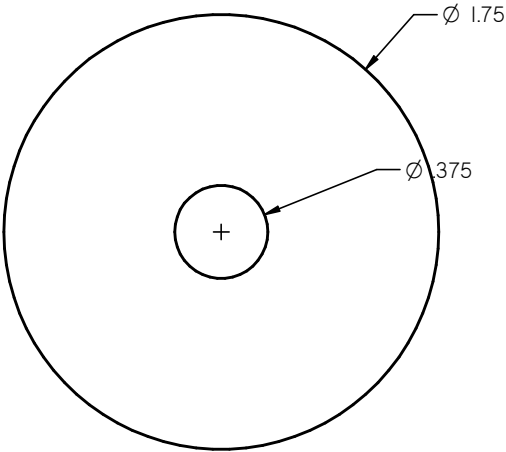


	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
			SCISSOR ARM	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT:
				SHEET 24 OF 25

SOLID EDGE ACADEMIC COPY



REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE	Solid Edge	
DRAWN	J. Joyner	04/25/16		
CHECKED				
ENG APPR				
MGR APPR			TITLE	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±1.0° 2 PL ±0.06 3 PL ±0.001			SCISSOR WHEEL	
			SIZE B	DWG NO
			FILE NAME: Lift Assembly Design Package.dft	
			SCALE:	WEIGHT:
			SHEET 25 OF 25	
			REV	

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