Trebuchet Reassembly

Physics Club

History of the Trebuchet:

The Elon SPS uses a pumpkin-chunkin trebuchet for community outreach. We have been doing this community outreach since the fall of 2007. By inviting community members to bring their pumpkins the weekend after Halloween, and asking for a canned-food donation; the SPS provides fun and entertainment for the community, while collecting canned-food to distribute to needy members of the community.

I have worked on the trebuchet for the previous two years, with main collaboration from Jesse Clark. During the fall of 2010, we built the first incarnation of the current trebuchet, with some issues around structural integrity, and launch performance. Although it was a physically large, imposing trebuchet, ultimately launch performance was poor.

This year, we hoped to improve structural integrity with a much larger diameter pivot bar, requiring some rebuild of the trebuchet such that the larger diameter pivot bar did not break through the launch arm or supporting uprights. These modifications are shown in later PDF blueprints.

Assembly of the Trebuchet:

Blueprints are located in Appendix A, Italicized in the text

While the integrity of the trebuchet should be good, a careful check of all non-pressure treated pieces of lumber is important, as well as the galvanised steel tough-ties, to ensure safety.

The primary design consideration of the trebuchet was modularity. What this means for assembly is that there should be two pre-built sides to the trebuchet, requiring only cross bracing to stand the trebuchet back up, and side wings such that it stays standing despite side loads.

The *Basic Side* blueprint sheet shows the basic sides which should be fully assembled.

The *Cross Braces* blueprint shows the lower cross braces, these are 3 foot long, pressure treated 4x4s. They are mounted on the basic sides as shown in the *Cross Braces* blueprint, coincident to the diagonal braces. The right angle galvanized steel tough-ties are likely in poor condition, and will probably need to be replaced. These take much of the side load of the trebuchet. There is one side drilled out for the winch. Make sure this drilled out side is in the right place to allow the winch to pull on the longer side of the throw arm.

The alignment of the pivot arm should come next. It will require some wiggling of the trebuchet if the trebuchet is not on perfect flat ground, and this is very challenging to do once the upper cross brace and side bracing (from *Brace Wings* blueprint) have been mounted. The *Pivot Arm* blueprint shows the four elements needed, the steel pivot pipe, two PVC spacers, and the launch arm. This is a challenging operation since the pivot arm is located ten feet in the air, and the launch arm is very heavy. **BE EXTREMELY CAREFUL DOING THIS.** I recommend no less than four people present for this operation.

Be sure to tighten the bolts in the *Pivot Braces* once the launch arm is in place. You will probably need a ratchet and second wrench, due to use of locknuts.

Finally, the upper cross brace and side wings on the *Brace Wings* blueprint are mounted. This is an easy operation, but be sure the bottom of each side wing is flat on the ground before they are screwed in place so that it is properly supported.

Run steel cabling allowing the winch to pull the throwing arm down. It is useful to do this before putting the weights in place, such that once the weights are in place, the launch arm can be pulled back down.

Best of luck getting the weights in place. We have tried a number of techniques over time. Nothing has been a crashing success, but lifting the long side of the trebuchet up and lifting the weights up as high as it is safe to, onto a stable platform are relatively essential.

Cabling for the weights should have two wire cable clamps used anywhere two pieces of cabling meet. Use common sense, with 360lb of weights, be careful. Use one piece of cable, dont splice anything. The cabling is rated for over 1000lb, but ensure it is in good condition, this is the worst place to cut corners.

Mount the winch. There are bolt holes in one of the 4x4 cross braces. The old winch should bolt properly into place here. We have had acceptable success with this winch. It is not ideal, but for lack of a better option it is passable.

Future Modifications:

For future years, while the integrity of the trebuchet should be good, a careful check of all non-pressure treated pieces of lumber is important, as well as the galvanised steel tough ties, to ensure safety. Once that is verified to be in good condition, work to improve launch performance of the trebuchet should be a priority. It is likely not a viable option to increase launch weight, and while the launch arm is very heavy, a finite element analysis/solidworks simulation showed that lightening holes in the arm would have minimal benefits. (**Technical Analysis of Trebuchet Launch Arm**)

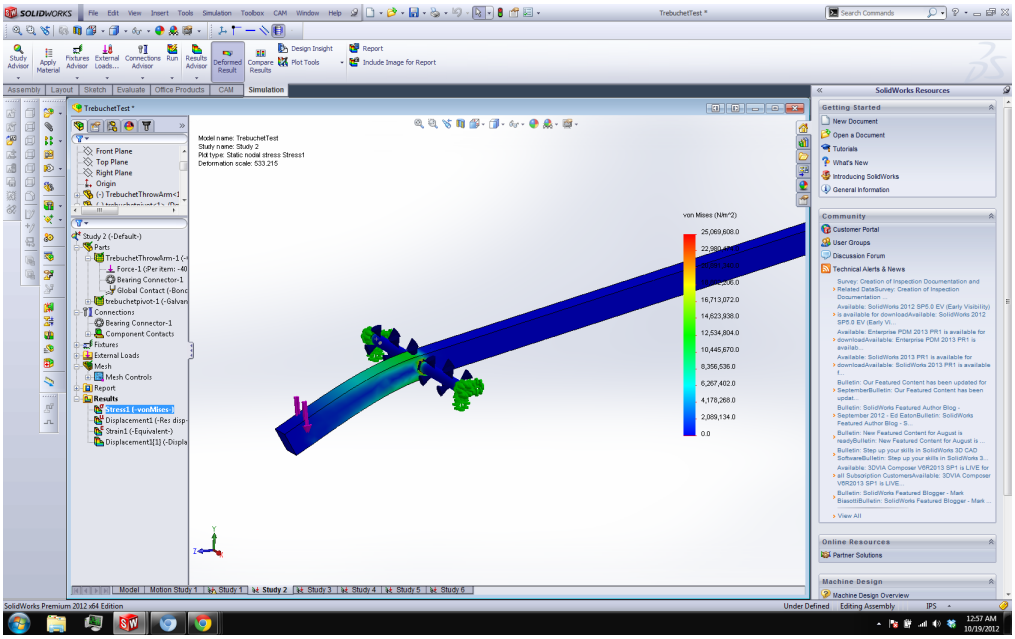
Discussion with Dr. DAmato suggested that increasing the launch moment, by lengthening the pivot-to-mass attachment distance could have good results. Current launch moment is shown on a PDF blueprint *Launch Arm*, along with one possible way of inexpensively increasing launch moment.

The winch (used to pull the arm back down after launch) has caused some difficulties, with high-friction and challenging cable routing, along with it being a workout to pull the winch back down. Given the low cost of upgrading/rebuilding the existing trebuchet, I recommend purchase of an electric, high-torque/low friction winch. It will improve ease-of-use, and safety of the trebuchet.

A sling. All traditional trebuchets used slings rather than a bucket like we have used. Elon SPS has done this in the past, but I do not know any specifics with regards to how it was designed or built. I recommend this as an upgrade, although research will have to be done in order to develop a functional sling.

Technical Analysis of Trebuchet Launch Arm

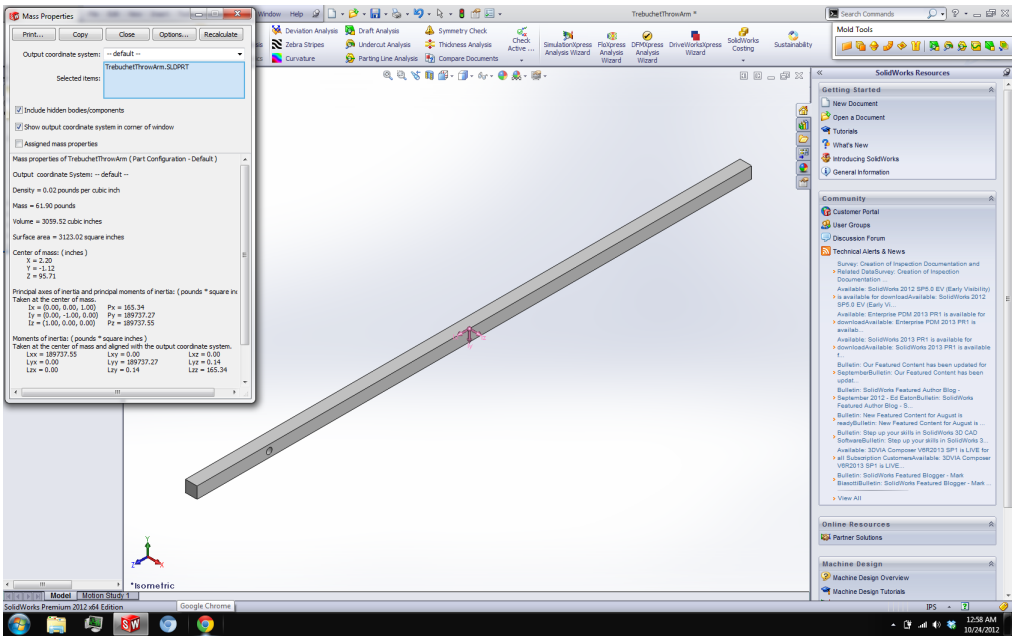
To determine feasibility of drilling out the trebuchet launch arm we consider first the structural feasibility of a larger pivot arm by applying force of 4000 newtons to a CAD model of the 16 foot throwing arm, at the location where our launch mass is attached to the throwing arm with our new 1.75" pivot hole modeled in place of the old .75" pivot hole.

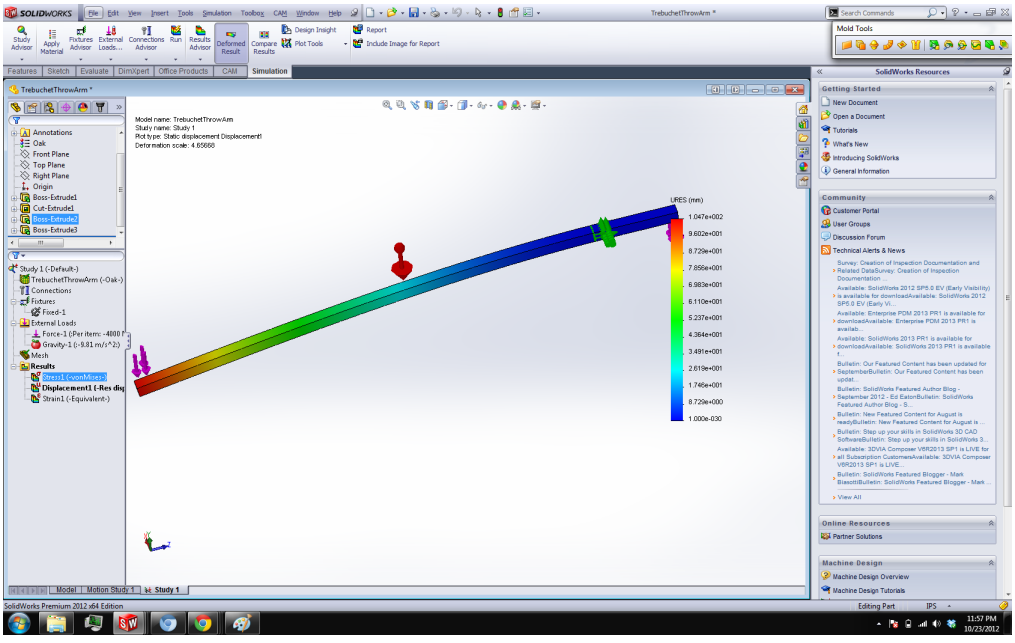


As a result of this large deflection we choose to support the new pivot hole with a large 4x4 brace and a smaller 2x4 brace on the bottom and a second smaller 2x4 brace on the top, bolted in place with 4 x 1/2" bolts. We choose the 6" of bracing on the bottom given the location and direction of the large displacement. This has shown to be sufficient support.

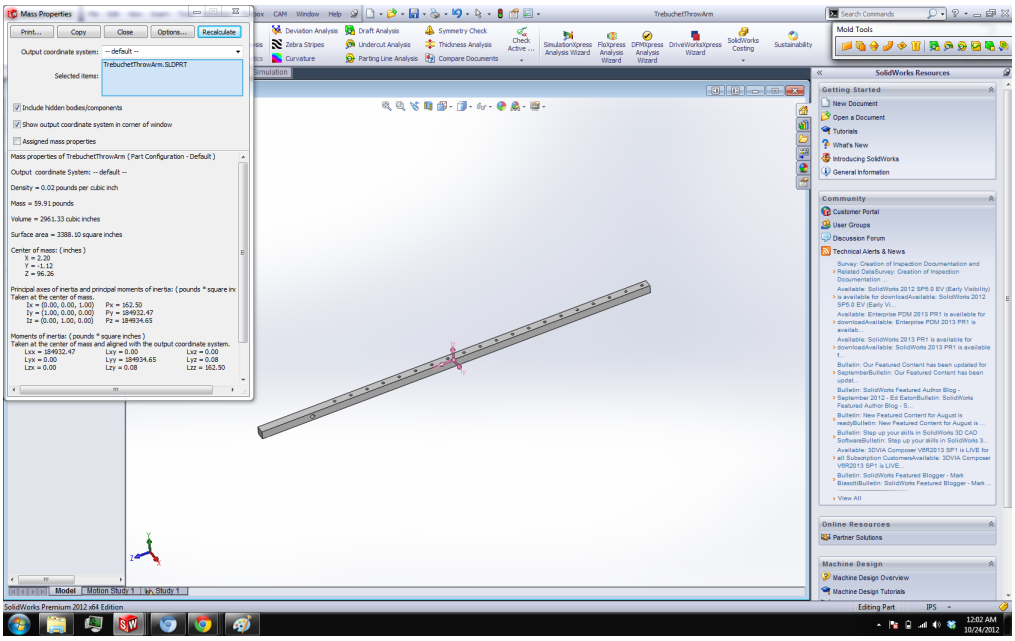
Due to the poor performance of the trebuchet last year, we consider reducing weight on the throwing side of the arm, i.e. the 12 foot section of 4x4 throwing arm between the launch basket and pivot arm. This is calculated by Solidworks to weigh roughly 60lb, and while this is probably inaccurate on density of material, since we choose to simulate pressure treated pine with the Solidworks "oak" material, by being consistent with material we can get an accurate idea of the effects which was sufficient in this model.

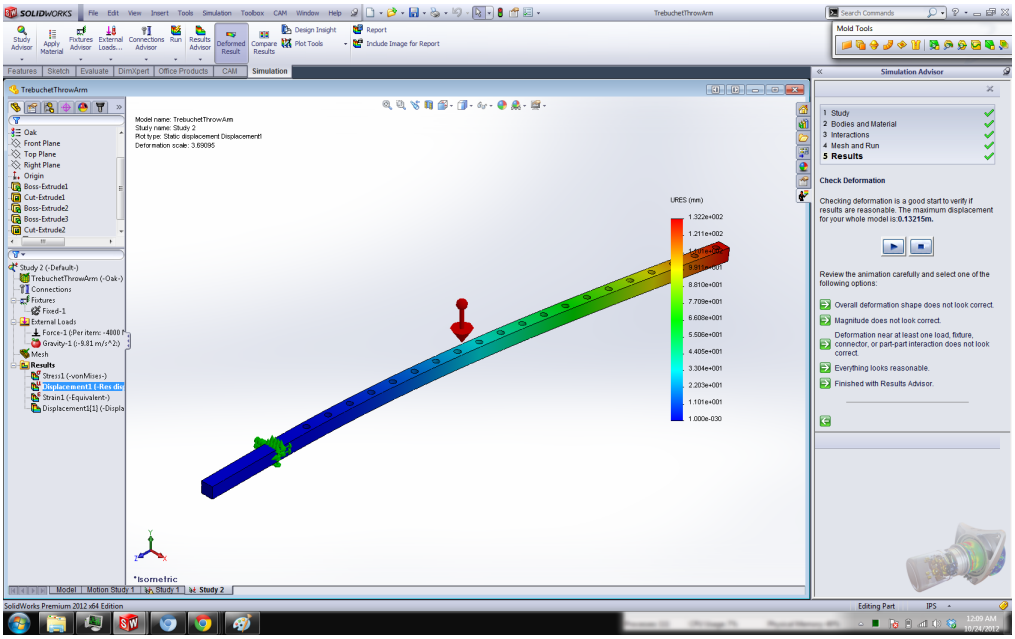
We start by modeling the arm with no lightening holes in the model for a baseline of deflection and mass that we can compare our later simulations to. With a fixed pivot and a force of 4000 newtons applied to the location our basket will be bolted to, and location of the launch mass on the throwing arm our initial mass is 61.9lb, with total deflection of 104cm.





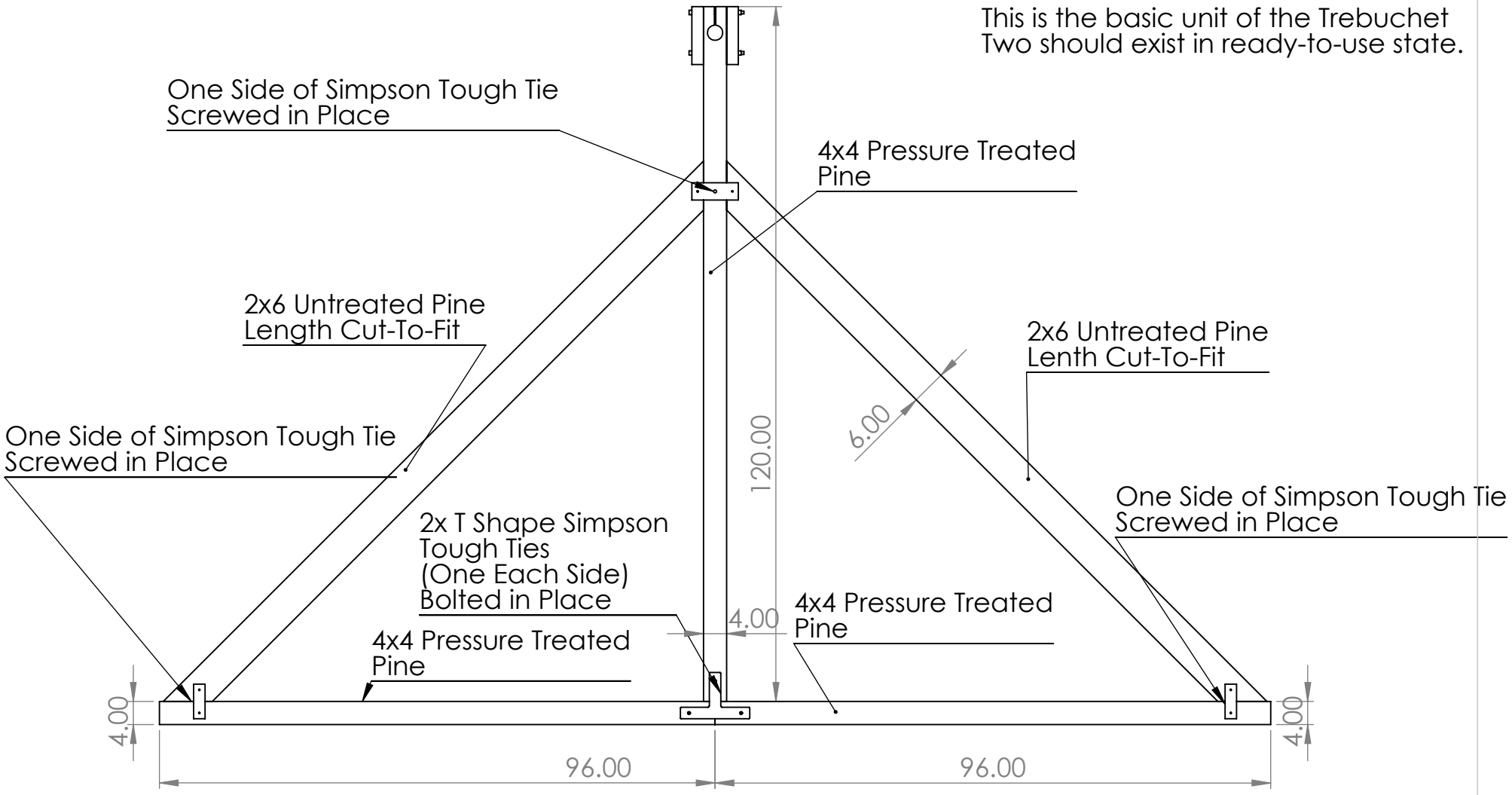
We again calculate mass and displacement of the throwing arm with our lightening holes. Keeping in mind that we do not have perfect simulation parameters in place, we find a mass of 59.91lb and displacement of 133cm.





This is a 25% increase in deflection for a 3% reduction in mass of the arm. There is no significant reduction of system mass with this modification while adding a significant increase in deflection of a critical system component. The safety of operation for this throwing arm is critical, as we are using a 400 lb counterweight in a public demonstration. Due to the large increase in deflection and negligible decrease in mass, this is not a reasonable modification to make.

This is the basic unit of the Trebuchet
Two should exist in ready-to-use state.



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Dimensions in Inches

TITLE:

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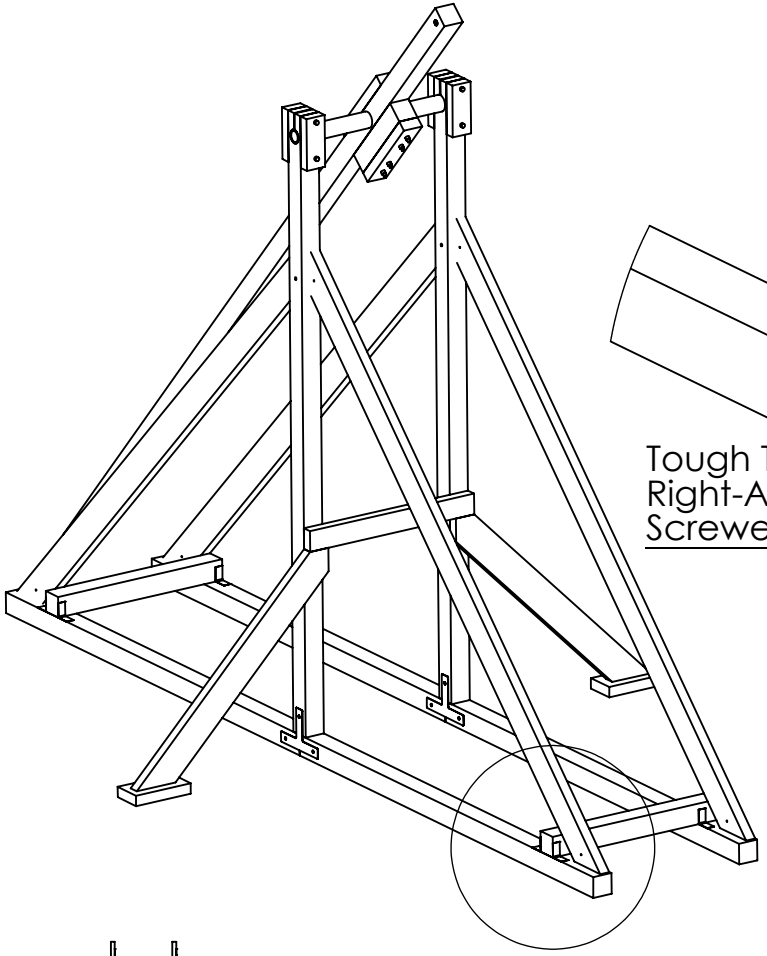
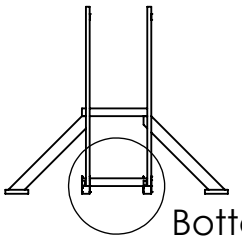
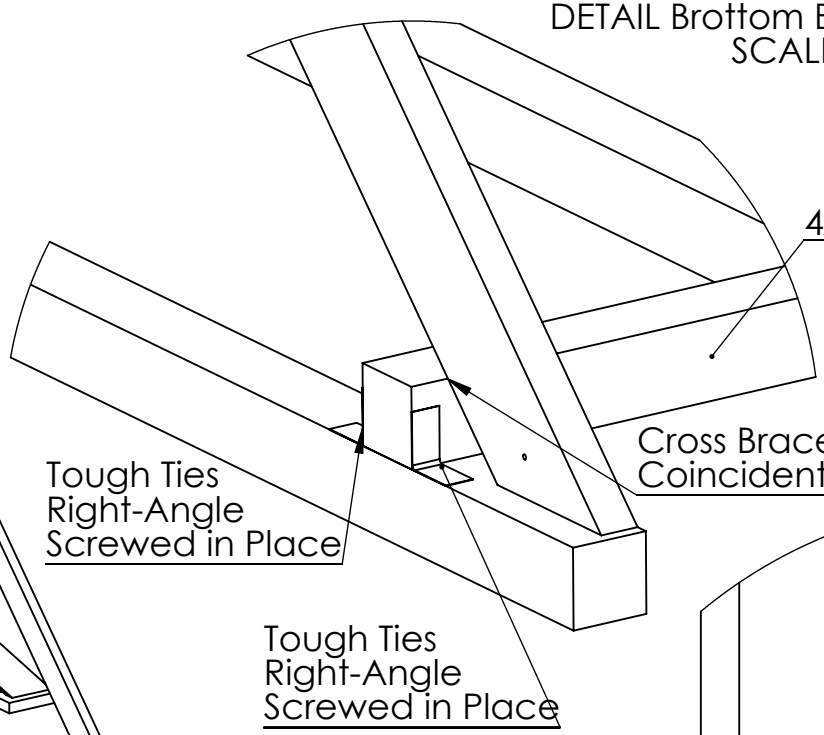


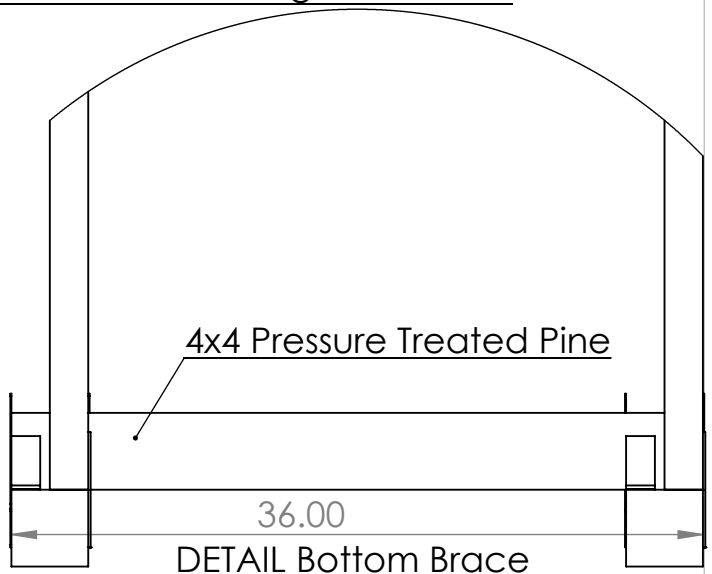
Brottom Braces Tough ties



Bottom Brace

DETAIL Brottom Braces Tough ties
SCALE 4 : 35





DETAIL Bottom Brace
SCALE 1 : 10

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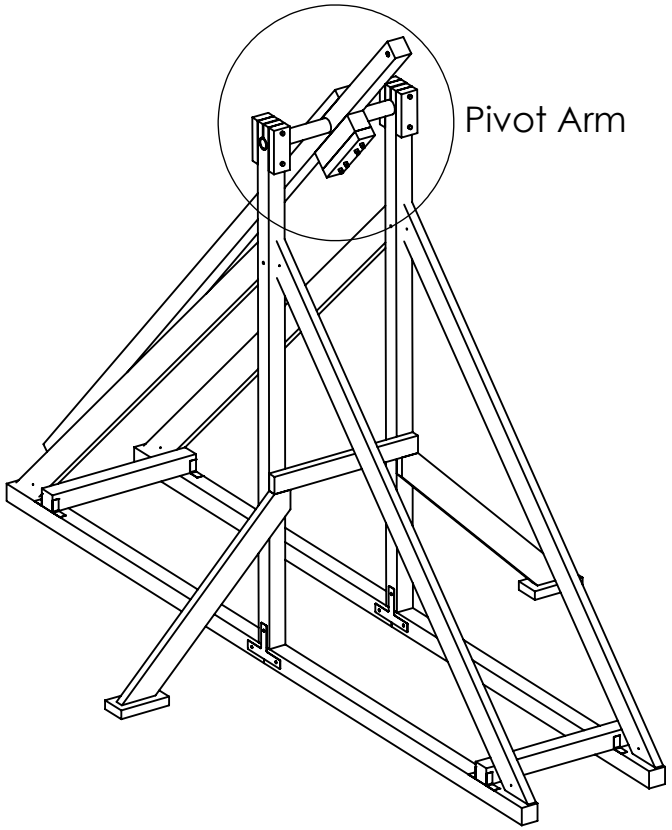

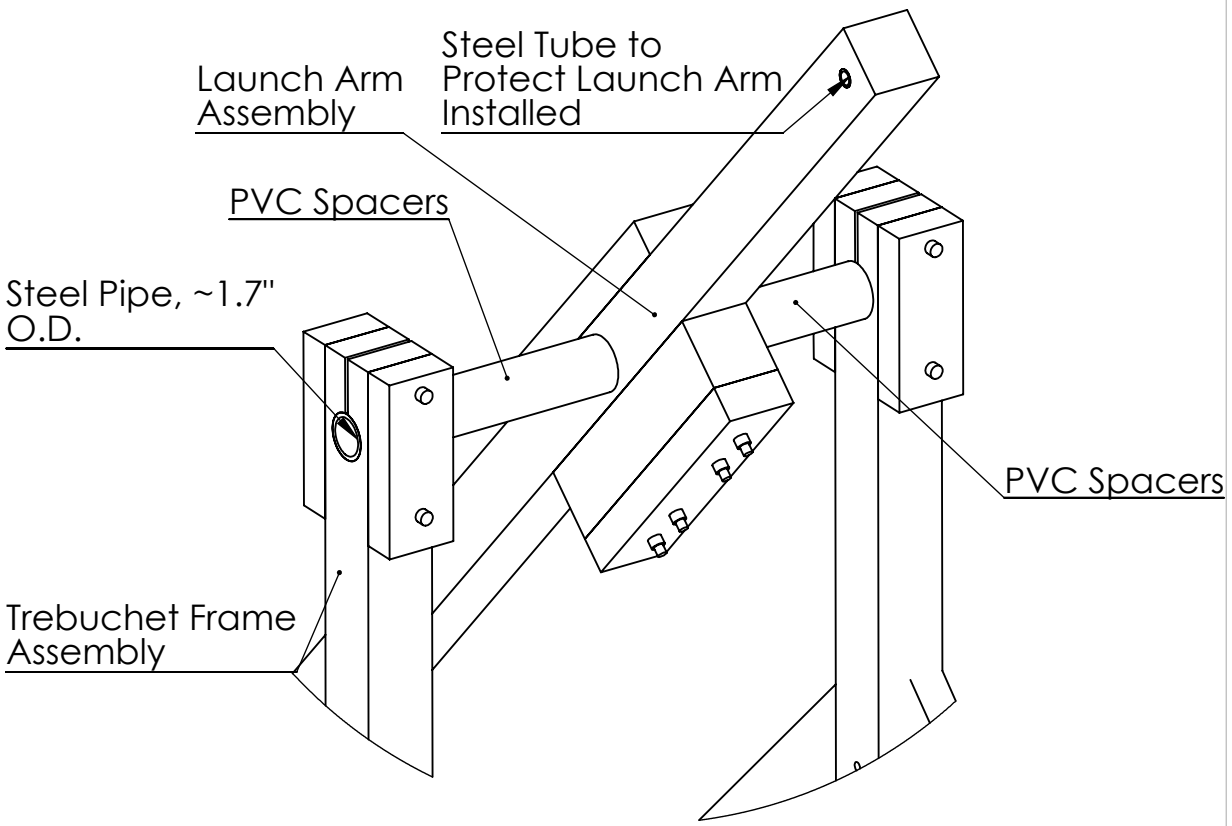

DETAIL Pivot Arm
SCALE 1 : 10

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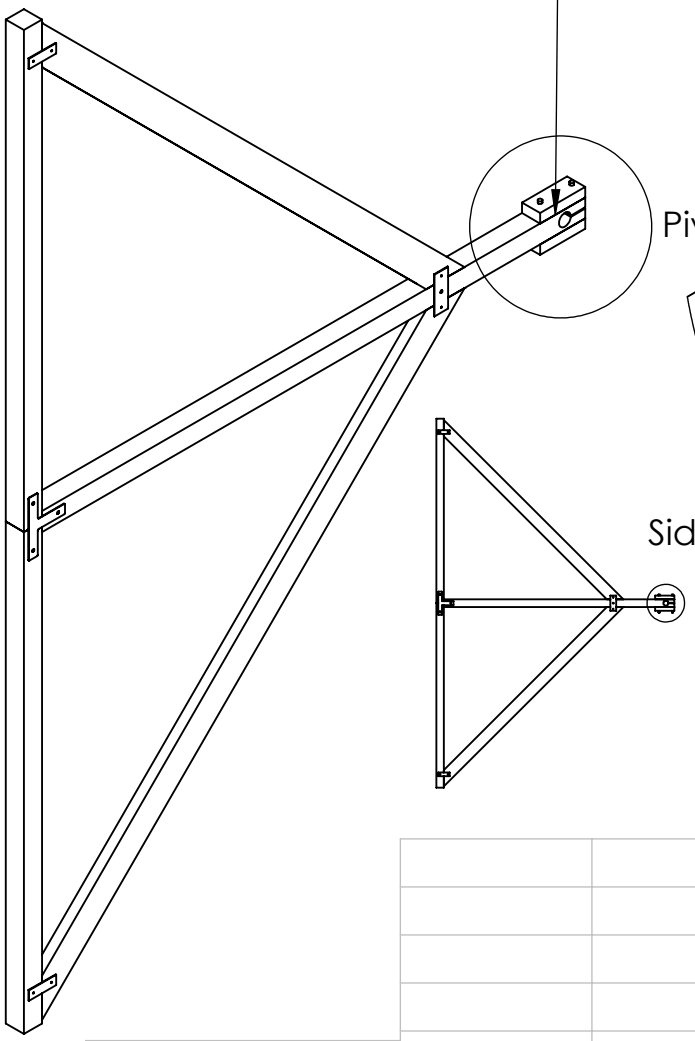
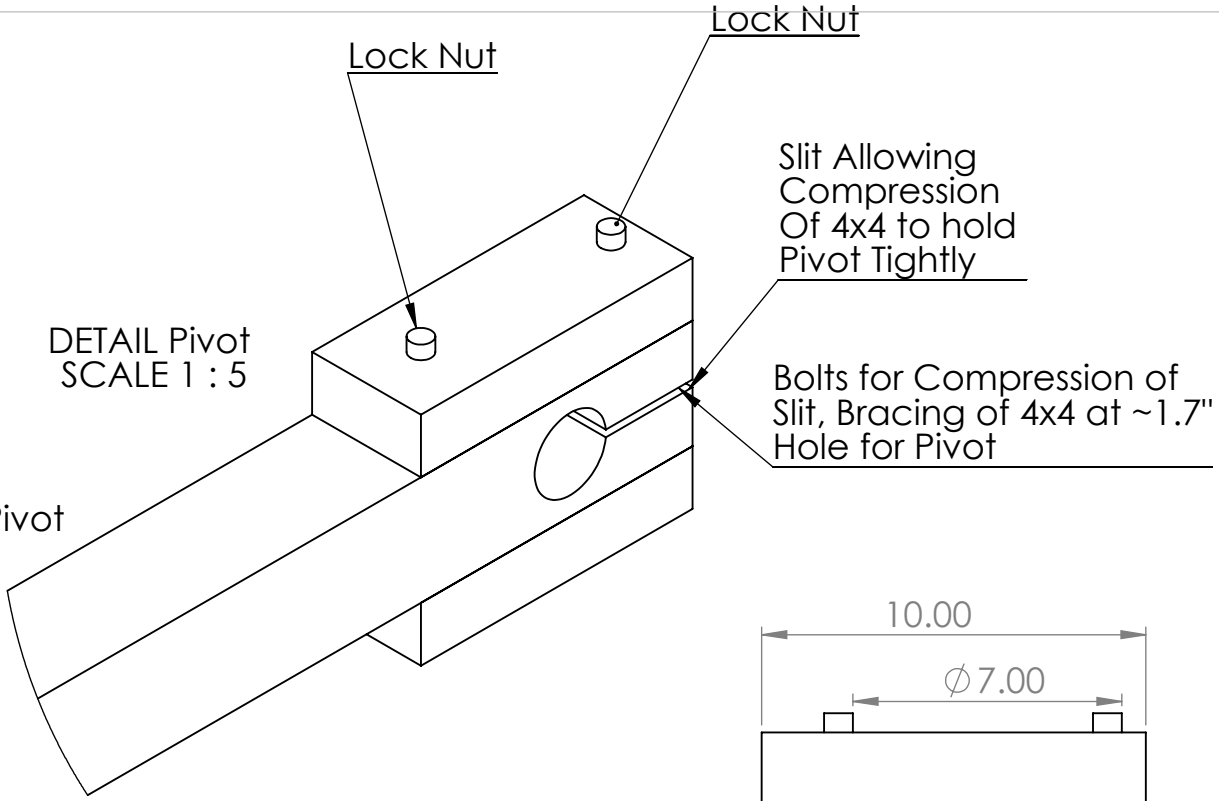
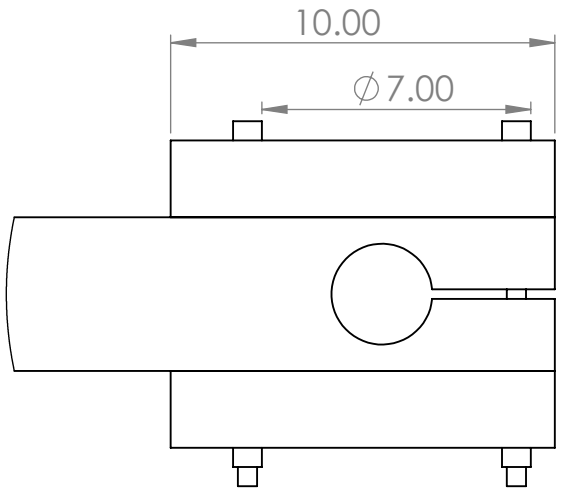




DETAIL Pivot
SCALE 1 : 5

Side View



DETAIL Side View
SCALE 1 : 5

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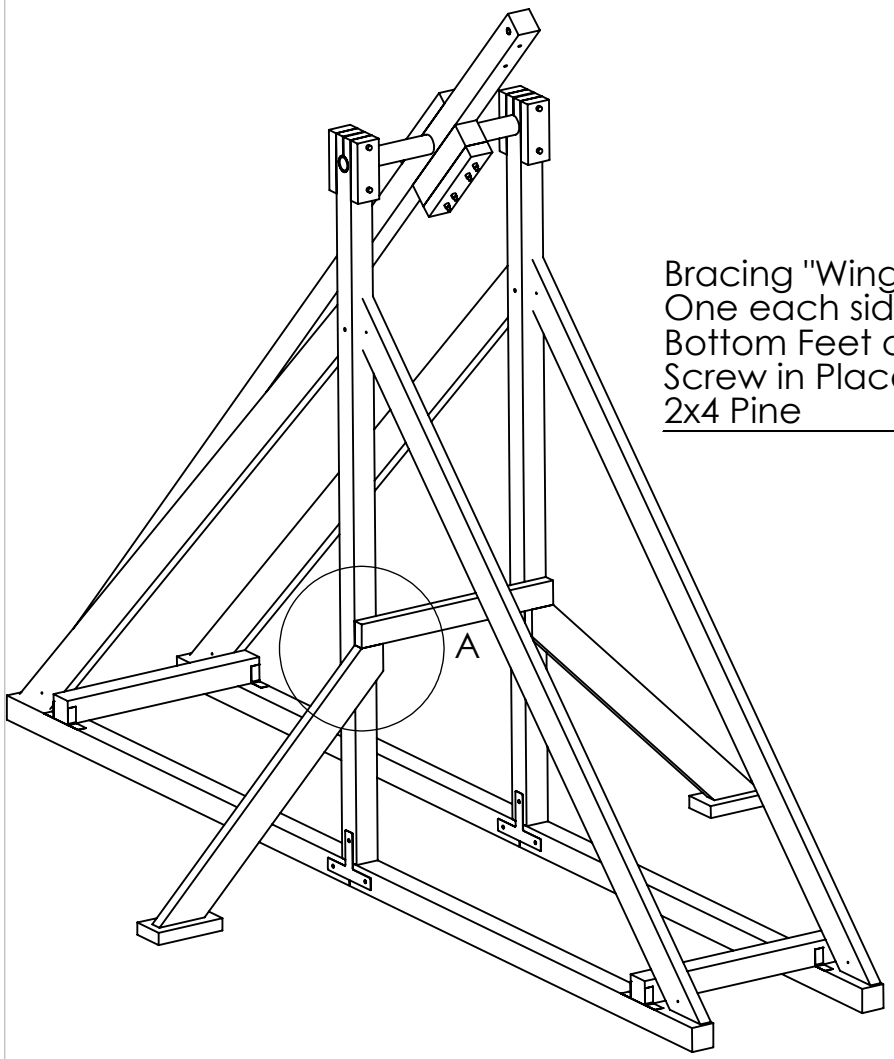
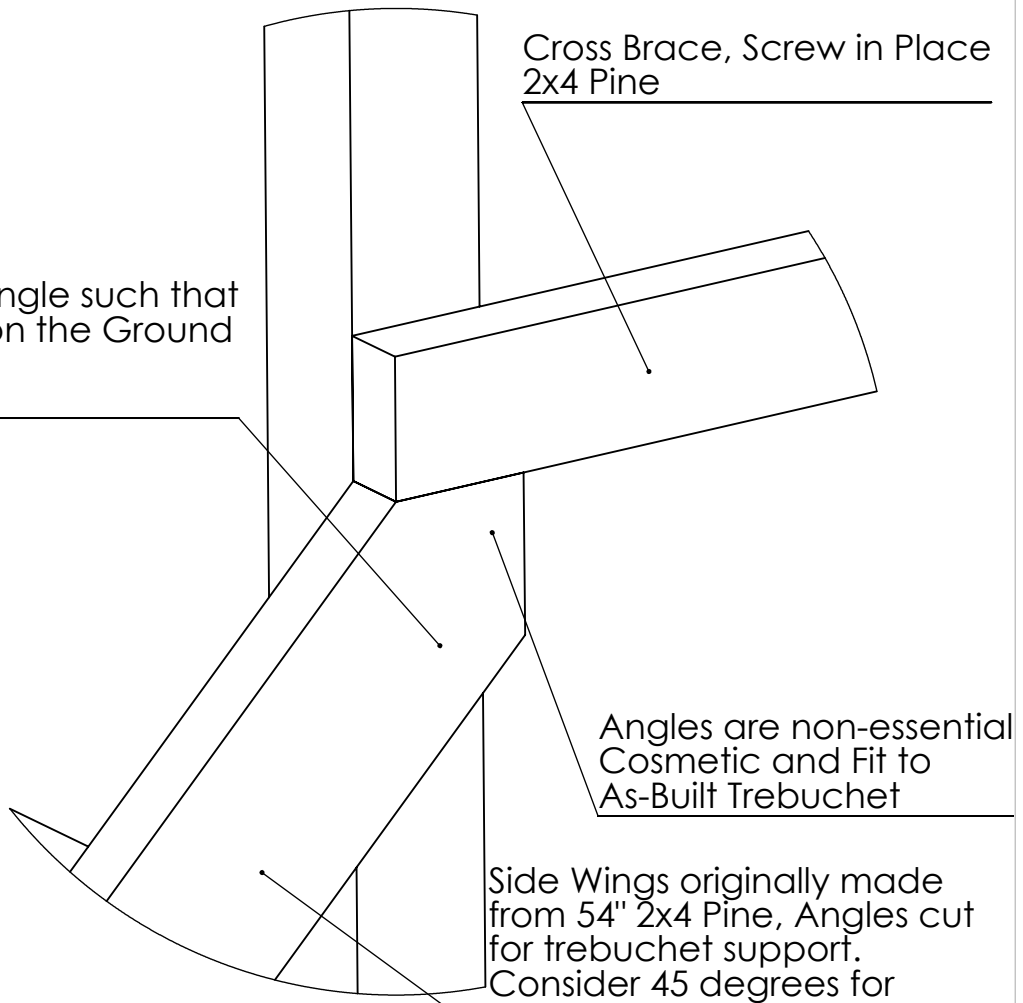


Bracing "Wings"
One each side, Angle such that
Bottom Feet are on the Ground
Screw in Place
2x4 Pine



Cross Brace, Screw in Place
2x4 Pine

Angles are non-essential
Cosmetic and Fit to
As-Built Trebuchet

Side Wings originally made
from 54" 2x4 Pine, Angles cut
for trebuchet support.
Consider 45 degrees for
ease of manufacture

DETAIL A
SCALE 1 : 5

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ABrace Wings

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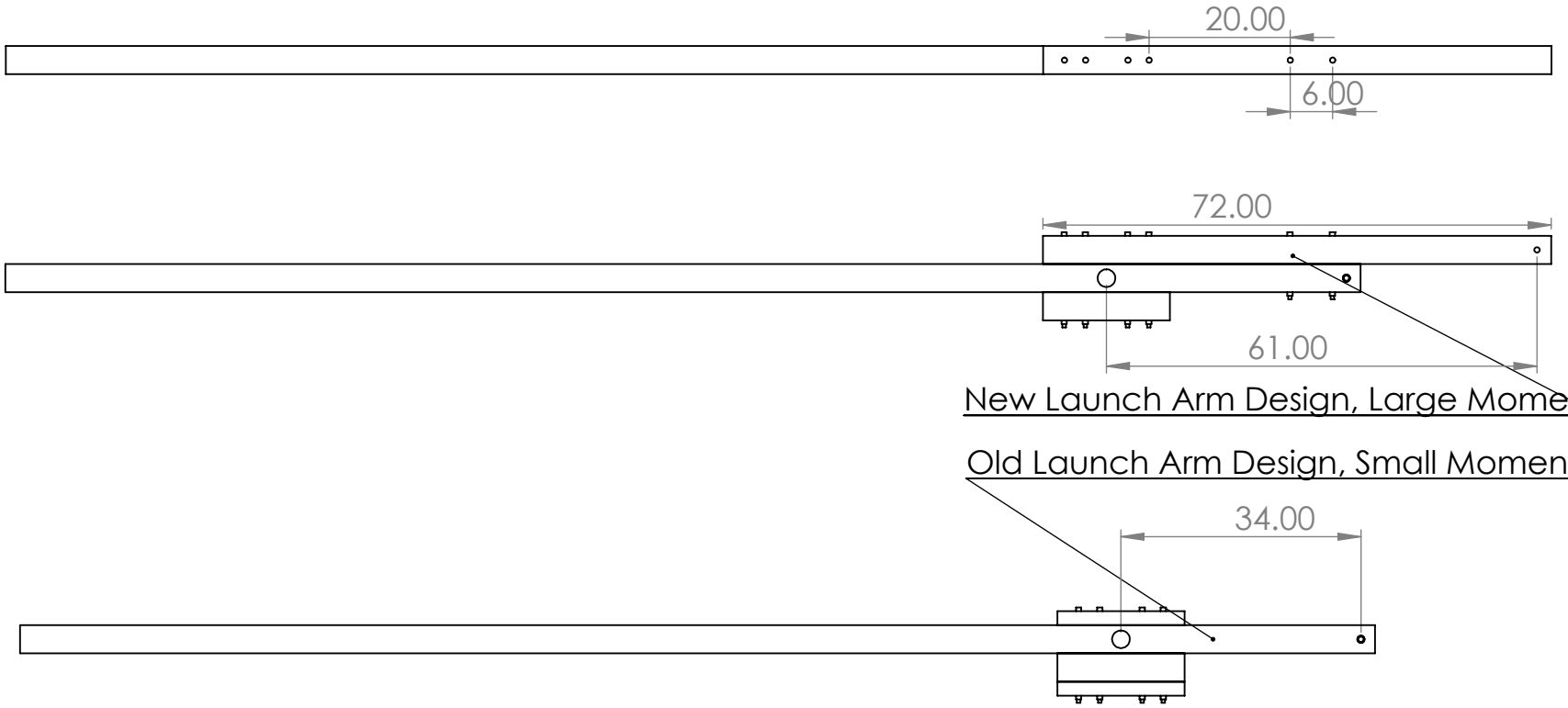

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ALaunch Arm

SCALE: 1:50 | WEIGHT: | SHEET 1 OF 1

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