Summer 2016

ATV Rack Extension

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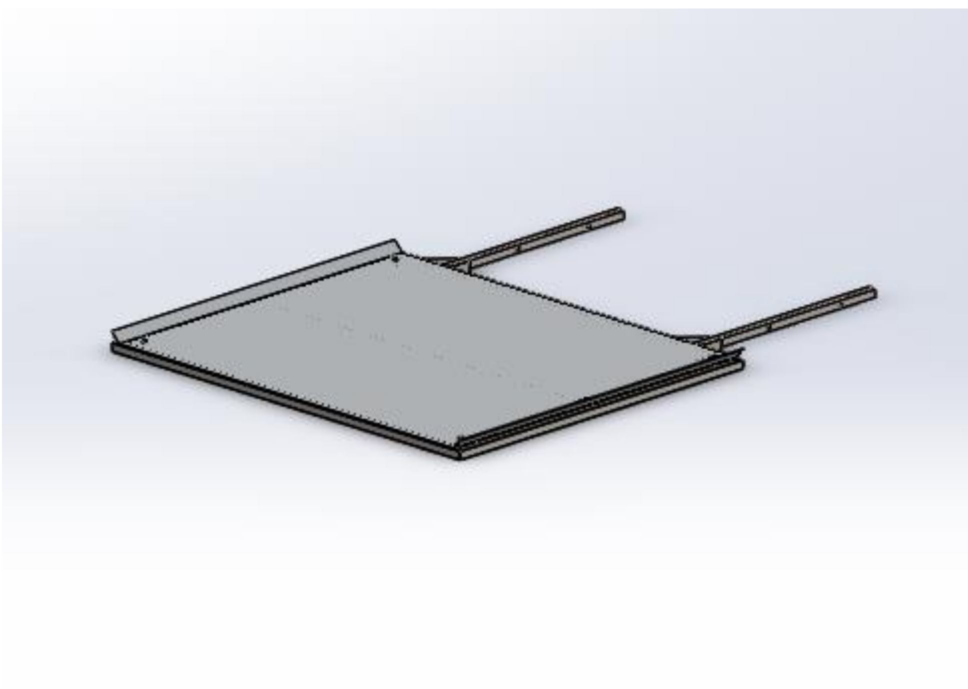
By:

Trista Smith



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Introduction

Motivation: The motivation behind this project consists of an issue that my family had ten or so years ago when we were trying to take our three ATV's to Florence Oregon to the sand dunes. We have a rack that is capable of holding two ATV's on the truck bed while still pulling the trailer. We wanted to add a third quad on the tailgate somehow but we were never successful on finding a way to do that safely. That is how I came up with the idea to make a rack extension that can be put on the tailgate of the truck that can carry that third ATV. A completely new ATV rack that will hold more than two ATV's would cost too much and isn't needed for this case.

Function Statement: A device is needed for the tailgate of the truck that extends from the existing vehicle rack to accommodate a third ATV.

Requirements: The following is a list design requirements that go along with this project:

- Rack needs to be able to hold the load of a 400lb ATV.
- Large enough to fit an ATV that is 48" x 63".
- Cost less than $500.
- The rack extension needs to weigh less than 100lbs.
- Rack Max dimensions cannot exceed 60" x 72" x 4".
- Pin cannot exceed the diameter of 0.5".

Engineering Merit: The Engineering merit comes from the rack that currently exists that is being used. The rack that is being built this year needs to be detachable from the existing rack so that the original rack can still be used by itself.

Scope of Effort: The scope of this effort will be focused on the new rack extension. The only minor changes to the original rack will be made to help secure the new rack to the original rack and the truck. No other changes to original rack will be made.

Success Criteria: The criteria of this project depends on the following:

- Supports the weight of the ATV.
- Attach and detach from original rack with minimum effort.
- Rack has fixtures to fasten the ATV to the rack securely.

This rack will be successful with these three scenarios because of the ability to be economical for the users of this device by the weight restrictions that were given and the minimum effort to use this rack.

Design and Analysis

Approach: This ATV rack extension will be manufactured off of the original rack that is owned. This rack will help stabilize the new rack and will hopefully take some of the ATV weight off of the tailgate and be distributed to the inner of the bed of the truck. The original rack for the ATV's have been modeled and are shown in Appendix B part a.

Some of the parameters of the new rack consists of dimensions requirements of the ATV being about 68" x 46" and needs to hold a weight up to 300lbs. These are the two most important requirements because the rack will fail if it is not with in these two specific parameters.

Design Description: There are two different designs that were being worked with and analyzed. For Design number one (Appendix B, part 2) shows the two long bars that stick out that have a lip on it. The lip and bar is to be under the original rack so that the weight of that rack and ATV's will help keep the new rack in place. The lip is there so that the new rack won't slide off the truck. If there is a pin placed there on both bars then that will keep it locked in place as well.

Design option number two is represented in a quick sketch in Appendix B part 3. Instead of sliding a bar under the original rack it shows that two bars are slide around the legs of the original rack and then pinned to all four legs for extra support.

For design number three, number two was taken and was changed a bit. Instead of two long beams to be on each leg, the decision has been made to use the square tubing to extend into the bed of the truck and attach to the base of the original rack. Since the square tubing is a bit larger in width than the bar would be, it would be necessary to try and find a hitch pin to connect to the existing rack. This would ensure that the pin wouldn't shear. In Appendix part 4 shows the current design for the rack extension. The design has also been changed to make the diamond plating be the whole length and width of the rack so that when the ATV is loaded on to the rack it will be easier to rotate it to be in the position where it will be tied down. The number of attachments (QTY 4) will be different because it wouldn't be necessary to have it connected in eight placed when there will be tubing under the diamond plating to support it as well.

Benchmark: The problem that is being solved is similar to the problem of the original rack, and the design will be similar and serve a purpose that is similar as well. Except that the rack will be on the tail gate of the truck and hold one ATV instead of being in the bed of the truck. Solution will consist of using similar materials and look to make it so that the two racks will match. But the function and weight constraints will be different.

Performance Predictions: Some of the performance predictions that are given are the size and weight predictions. The weight of the rack itself needs to be less than 100lbs so one man can place on the truck if need be. The rack will be able to with stand the weight of a 400lb ATV while going 70mph down the freeway on a flat plane or incline.

Description of Analyses: A few things that need to be analyzed are the pins that will be attached to the original rack. Some of the calculations done are listed as followed:

- Max Moment and Shear For each Tubing
- Weld Width
- Force on each Pin
- Pin Diameter
- Tubing Deflection

Scope of Testing and Evaluation: The testing will take place in a parking lot or drive way that has enough space to move around two racks and three ATVs. The testing will consist of loading up the racks the way they are assembled and then loading the ATV's. Once the third ATV that will be on the rack being manufactured for this project is loaded then the truck will be driven at multiple speeds and for a certain amount of time to make sure that there is no problems with the pins breaking. Time that the ATV is on the rack will be another means of data, to make sure that the rack can with stand the load for long periods of time.

Analysis: The analysis that were done are represented in Appendix A. in part one of the appendix the calculations for the square tubing were done. The Methods of sections were used for this set of calculations. The max shear and max moments was able to be calculated for each tubing used. Some tubing has multiple tubes with the same length so only one calculation was done to represent both of them. For section A-A the max shear was about 200lb and the max moment was about 3122lb-in. For section B-B Shear was 200lb and max moment was 2400lb-in. For section C-C the shear was about 400lb and moment was 6000lb-in.

The max moment was then able to be used to calculate the welding width at each of those end of tubes, this is represented in part two of appendix A. The S_w needed to be calculated since the tubing is bending. This equated to about 2.08in^2. Then for each section the welding force and then weld width could be calculated. The welding width of the A-A section was about 0.156in. B-B section was about0.12in and the C-C section was about 0.3in. For the section A-A and B-B the weld width is okay for the tubing, but the C-C section the weld width is too high. So it was determined to add gussets to each of the tubes that will be connected to the original rack for extra weld support.

Next the force on each pin was then calculated. This is represented in appendix A part 3. The force on pin 1 was 1300lb and the force on pin 2 was 1700lb. Then the diameter of the pin was able to be calculated. The diameter of pin 1 to with stand the force acting on that pin equated to 0.2in and the diameter of pin 2 was 0.24in. This means that the pin diameter used needs to be larger or equal to 0.24in. So a pin diameter of 0.5in was chosen. The deflection of the rack without a tailgate was also calculated. The deflection would be about 2.64in. The deflection should not reach this number because there will be a tailgate of extra support to help carry the load.

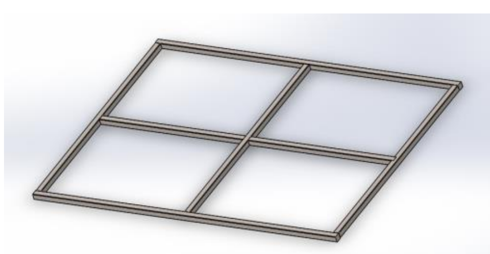
The next set of calculation that were done to partially include the fact that the tailgate will be supporting about half of the ATV. So the deflection of the rack extension was then calculated again but only used about half the weight because only half of the ATV will be hanging over the edge. This time the deflection was calculated to be about 0.17in. Then the shear fail was calculated to be about 18,000 psi, and then a shear allowable was chosen to be about 6,000psi because the out of all the forces calculated it shouldn't exceed the 6,000psi. These two numbers then were used to calculate a safety factor of 3.0. These calculations are in appendix A.

Design: The look of this design will consist of being rectangular shaped as a whole. The hollow beams that will be used for assembly will be about 1.25" x 1.25" and welded together because that is preferred for the final look. Pins and nuts and bolts will be used when needed. The plates that the ATV will be sitting on will be diamond plating. If time is available the steel beams may be powder coated to match the original rack.

Calculated Parameters: One of the calculated parameters for this project is the diameter of the pin. The pin needs to be able to with stand the forces that will be applied to these pins. As stated above the pin needs to be at least 0.24in and the pins that were chosen will be 0.5in.

Device: The device purpose will be to hold a 300 to 400lb ATV and be easily detached from the original rack. This will be able to happen by attaching the part with four pins that will be able to handle the force of the truck in acceleration and incline.

Device Assembly: The devise starts with a steel beam structure that will be the support of the weight of the quad. This will consist of about seven beams that will be in the shape of a rectangle. The picture below shows the structure discussed. The dimensions of the structure is 45" x 68" to ensure the ATV fits on the rack.



The diamond plating that the ATV tires will be sitting on, are the same width, length and thickness. The thickness of the diamond plating to match the original rack needs to be 1/8" thickness, and has to be about 68" long. The width of the diamond plating will vary a little depending on the tire width and keeping to whole numbers for easier cuts as well.

There will be two bars that are connected to the main structure that will extend into the bed of the truck to connect to the legs or the original rack. These bars will connect to the legs of the rack by pins for easy attach and detach. This is for extra support of the rack and to stabilize it so that the rack doesn't slide forward or backward off the tailgate of the truck.

Tolerances, Kinematic, Ergonomic, etc.:

Tolerances:

- Steel Structure=0.005"
- Diamond Plating=0.10"

Ergonomics:

- Weight= 100lbs so one man/women can lift on own if need be.

Methods and Construction

Construction: The construction of this project will take place over the time period of winter quarter. The bracket attachments will have to be cut and shaped to the drawing and drilled as well as cutting the square tubing to length first. The holes will then be drilled into the two pieces of tubing that will slide into the bed of the truck and attached to the other rack is drilled before the pieces will be welded on. The steel hollow beams, brackets, and gussets are welded together on campus by a few friends. The diamond plating will then need to be ordered to length and bent per engineering. The diamond plating will then be attached with nuts and bolts on campus to the steel frame. The holes will be match drilled onto the diamond plating from the brackets to ensure that the holes will concentric with each other. There will be four places total that the diamond plating will be bolted onto the steel frame. The ATV rack extension will then be able to be pinned to the existing rack. The two bars that will be welded to the steel frame will need to be drilled as well.

Description: This project will consist of the main assembly that will be welding the square hollow beams together so that they have a nice uniform look and stability. The diamond plating will be bolted to the beam assembly to ensure that there is no movement between the two. The beam assembly with the brackets will be the support to the diamond plating that will be holding and supporting the weight of the ATV.

Each part number with in this assembly will be numbered. A-001 is an example of how the beams will be numbered with in the sub assembly. Then the brackets and diamond plating will have their own number such as B-001 or C-001. Some of the parts within this final assembly have duplicate parts that are exactly the same. Above the title of that part will say how many of that part will be manufactured. The parts that with in the subassembly will be in the A group.

The parts that are attached in the final assembly will be a part of the B group. The sub assembly and final assembly will be part numbered in the C group.

Drawing Tree: In part five of appendix B shows the drawing tree that shows how the rack extension is built and the parts with in their assemblies. The green represents the final assembly. The blue represents the sub assembly, and the parts are represented with the color purple on the drawing tree. The drawing tree also represents and correlates with the way that the parts are numbered as well. There have been no changes to the parts.

Parts list and labels: In appendix C, the parts list shows that there is a need for square tubing (steel), bars made of steel A36, and diamond plating. The cost of the diamond plating will be dependent on when the order take place, currently it is on sale for significantly cheaper than it normally is selling for. The bolts have to be determined for a size and same with the pins that will be used. Parts list to be updated when more information is determined.

Manufacturing issues: Some of the manufacturing issues that may be of concern are listed below:

- Welding callouts need to be called out correctly on all drawings, because one beam may get welded to the wrong location or wrong part.
- Plasma Cutter and not exact holes.
- Hole match up with bracket and diamond plating
- The holes for the pins wrongly located on new rack or original rack.

Like it was stated above these manufacturing issues have been resolved during the manufacturing process. For example the plasma cutter was having issues with cutting the hole in the brackets, because of the female, and male cuts were either significantly larger or significantly smaller. Lots of time working with the machine the plasma cutter was able to make a direct cut and only be about 0.020 off of the hole which is okay because there will be a bolt going through that hole.

The hole match up with the bracket and diamond plating was fixed by match drilling to the diamond plating from the bracket to ensure hole location is correct.

Testing Method

Introduction: The testing section of the ATV rack extension project consisted of two major tests. One test included placing sand bags weighing about 60lbs onto the rack one at a time to measure the amount of deflection. The second test this included measuring the strain on the side of the rack on the square tubing.

The sands bags were placed on the rack one at a time. At the time there were only four sand bags available so a person weighing about 160lbs took care of the rest of the weight. The data that was collected was the deflection of the rack that is over hanging the tail gate and the strain that is being applied to the rack where it will bend.

Method/Approach: The two testing methods that will be used are discussed in the following:

1. The first method that was used to test the new rack extension was making sure that 400lbs of weight can be tolerated by the rack and the tailgate could with stand at least 400lbs worth of weight. To test this the rack extension it was placed on the truck with the original rack and ATVs, and secured the rack extension. The rack was secured to the rack with four hitch pins. Then sand bags and a person was continuously placed on the rack extension until the weight limit of 400lbs is reached. This was a way to slowly test the weight compatibility without putting the ATV right on the truck and hoping that it doesn't buckle or break.
2. The second approach to testing the new rack extension was to place a strain gage on the side where the square tubing is parallel with the truck. The strain gage was placed on the bottom of the square tubing where the most bending would occur. The same process of the weight being applied to the rack extension was used but this time taking the measurement of strain instead.

The testing will take place off campus since ATV's are not allowed on the premises. So the testing will take place in Bonney Lake so that the ATV's can be properly stored and moved when needed for the first part of the testing. The second half of the testing will take place on 167 and Hwy 410 near Bonney Lake, WA so that the truck and ATV rack will be able to reach the proper testing speeds and incline.

There will be multiple parts that will be needed for both sections of the testing. They are as follows:

- Ford F-150 Truck with Speedometer
- Original ATV Rack
- New ATV Rack
- 4 x Hitch pins and Cotter pins
- 3 x ATV's
- Lifting Weights (at least 400lbs worth)
- Extra Vehicle
- Go-Pro Video Camera (2 if possible)
- Excel Document to keep track of comments and weights
- Ratchet Straps (at least twelve are needed)
- Dial Indicator

Test Procedure: As stated above there are two testing methods for this project. Below are the procedures to each testing method.

Procedure for Test #1 and #2: Deflection and Strain

1. Place original rack in the truck bed and secure rack and truck bed together.
2. Place new rack extension on tailgate of truck and ensure that the pin holes align.
3. Place hitch pins into the square tubing that slid into the bed of the truck, parallel with the original rack. Pin these hitch pins so they won't slip out.
4. Let the rack sit on truck tailgate to ensure the tailgate can support the weight of the rack. (Safety is a very big factor in this testing).
5. Next lift the truck up and place onto jack stands. Ensure that jack stands are places on the frame of the truck to ensure that the measurements take for deflection will not include the suspension movement of the truck.
6. Set up the strain gage on the right or left side of the rack extension. The strain gage needs to be place on the bottom side of the square tubing to ensure that the strain will be measured where the most bending will occur. Follow the instructions that are provided with the strain gage for proper set up.
7. Next place the dial indicator on the sturdy plat form that can reach the square tubing of the rack extension. The dial indicator needs to be placed at the end of the rack extension where the most deflection would occur.
8. Now place 60lbs (one sand bag) on the new rack extension. Even though the load that will be on the rack will be distribute throughout the whole rack, place sand bags on the edge that overhangs from the tail gate for best results.
9. Record the deflection of the rack if any movement occurs, and the strain on excel spreadsheet.
10. Repeat steps eight and nine with an additional 60lbs (one sandbag at a time) each time until at least 400lbs worth is tested.

Deliverables: The deliverables for the testing stages of this projects will be answering simple questions on an excel sheet that state whether the rack was able to withstand a certain amount of weight and the deflection and strain will be recorded as the procedure is done. The example of spreadsheet represented in appendix G and the testing report with results is in appendix I.

Budget/Schedule/Project Management

The proposed budget for this project is located in Appendix D. This is also referencing the parts cost for this project as well in Appendix C.

The main parts for this assembly will be purchased through Haskins Steel so that the CWU discount can be received so that the project will cost less money. In doing research this can save a couple hundred dollars when receiving this discount. The other parts for this assembly will be purchased online through McMaster Carr because they have a good variety and can do one shipment instead of multiple shipments through multiple companies. This will save money in shipping in handling as well.

Some of the buying issues will be waiting for the parts to arrive. The school received shipments through Haskins twice a week so that shouldn't be a problem getting the bigger parts to the school in a decent matter. The pins and fasteners will be ordered online and will need to be shipped, this will have to be ordered in advance so that the shipment can arrive when the final assembly will be put together.

Labor for this project will is estimated on the schedule for each task that is being done. The Labor for the winter quarter of building is estimated to be about 52 hours give or take. The manufacturing of this project will be done in house and so will the welding but by another student in this program.

The estimated total cost of this project is about $350.00. This is an estimate from the budget in Appendix D. This number was raised about fifty dollars because the rhino paint and the fasteners have not been estimated for a total cost yet and will be added when the number is known.

The funding of this project will be from Trista Smith or her parents, Owen and Kristin Smith. They are supporting this project and will help with the costs when needed.

Proposed Schedule: The schedule for this project is located in Appendix E. Within Appendix E, it shows all three quarters that this project will be worked on and accomplished during.
During Fall quarter you can see that the project proposal will be finished by November 23, 2015, this will be considered the first draft. The second draft will be due three weeks later. Then the final draft will be due the first week of winter quarter.

Winter quarter will consist of many miles stones. This is there so that the ordering for parts can be done at the right time as well as the completion of each part can be manufactured in a timely manner as well. Parts need to be delivered by week two of the quarter and the parts need to be cut and ready for welding by week three. Week four and five are set out for time for welding the steel square tubing together for the base of the final assembly. Then there will be paint so that the new rack can look similar to the original rack. While the base is drying that week the fasteners and pins will be arriving from the supplier so that the next week the diamond plating can be fastened to the steel structure. The final assembly will be finished with two weeks of the quarter left to spare. This will give extra time to fix what needs to be worked on and also work on the website and getting ready for the testing stage.

Spring quarter will have multiple weeks for each testing stage. Testing stage one will need to be done before testing stage two, test one will be done by the fourth week of the quarter and then test two will begin and have another three weeks to complete.

Project Management: One big consideration in this project will be safety. This is because of multiple reasons. One because this project requires some welding to be done for the structure of the rack. Safety precautions will have to be made so that the person welding the structure will not get hurt of any sort while performing this task. One safety precaution will be masks and gloves to be worn while welding the steel. Also two people in the room at all time to make sure the safety of the welder. The second safety caution for this project is when the final product is finished it will have to be tested on the tailgate of the truck will weight also being applied to the rack. Test one is a safety test to ensure that the amount of weight desired to be held on the rack extension will be met before placing an ATV on top of the tailgate and rack extension. Testing equipment that is listed in the testing sections will be provided throughout the testing period by Trista Smith and will be available throughout the spring quarter when needed.

Discussion

Design Evolution: Before the analysis began there was a general idea of what the design of this project would be, this is where the design evolution began. The general design was that there needed to be enough surface area for an ATV to sit on the structure, which sits on the tailgate of the truck and connect to the original rack. The steel square tubing will be 1 ¼" by 1 ¼" to match the original rack. The length and width of the rack extension was also known as well because that ATV has to be able to fit on the extension.

There have been multiple design that were stated above that involve being connected to the rack in various ways. The first one included that the steel bar would slide under the original rack and have a lip on the end that would help the new rack not slide out of the truck, but since the original rack needs to sit flat on the truck bed, that design wouldn't work. The second design consisted of the steel bars that would slide down and be pinned to the each leg of the original rack. This idea would work just fine but the design seems to be over engineered, and can be made more simple. Then the next design became two steel square tubing that would slide next to the original rack and be pinned together.

The next design consisted of changed the size of the diamond plating because when the ATV is loaded on to the new rack extension it will have to be loaded on the back and cannot be driven up the side of the rack because of the cord that is the backup piece that helps hold the load of the tailgate to the truck when it is open. Making the diamond plating the whole length and width of the rack will make it so that when the ATV is loaded on the back, the ATV can be rotated in to the position that it will be secured down in. So for safety reasons it is better to have a full plate rather than holes that could cause an accident. The thickness of the diamond was known when the measurements of the original rack was done. The thickness will match the original rack diamond plating and is an 1/8".

Project Risk analysis: The risk that is the big part of this project is making sure that the welding of the steel square tubing can be done for a decent price or on campus by another student. The Other students that are willing to do the welding have all the necessary tools to get the project done, but they are both seniors as well and have their own other projects to complete as well. The risk of relying on them for the welding part of this project is that they will have time to get the welding done right and in a decent time frame.

Next phase: The next phase of this project will be ordering all the materials that will be needed to manufacture this project. Once the material is shipped and received then the material can be cut and trimmed to the engineering. The sooner that the material is cut the sooner that the two seniors can start the welding. To manufacture this project, the welding part of the project will take the longest amount of time. This will be because the welding of the steel structure needs to be done accurately and correctly so that the welds hold.

Conclusion

The motivation of this project came close to home with the arising issue from eight years ago. This rack extension will give people the chance to carry three ATV's on the bed of the truck instead of just two. This rack extension also meets the requirements in:

- Size of ATV of 48" X 63"
- Weigh less than 100lbs
- Cost let than $500
- Safety Factor of 3.0

This project will succeed because of the ability to manufacture this device in a timely manner, but yet manufacture to the engineering and specs that are discussed in this paper. This includes welding and fastening the necessary parts into a final product that will change the way you transport ATV's.

Acknowledgements:

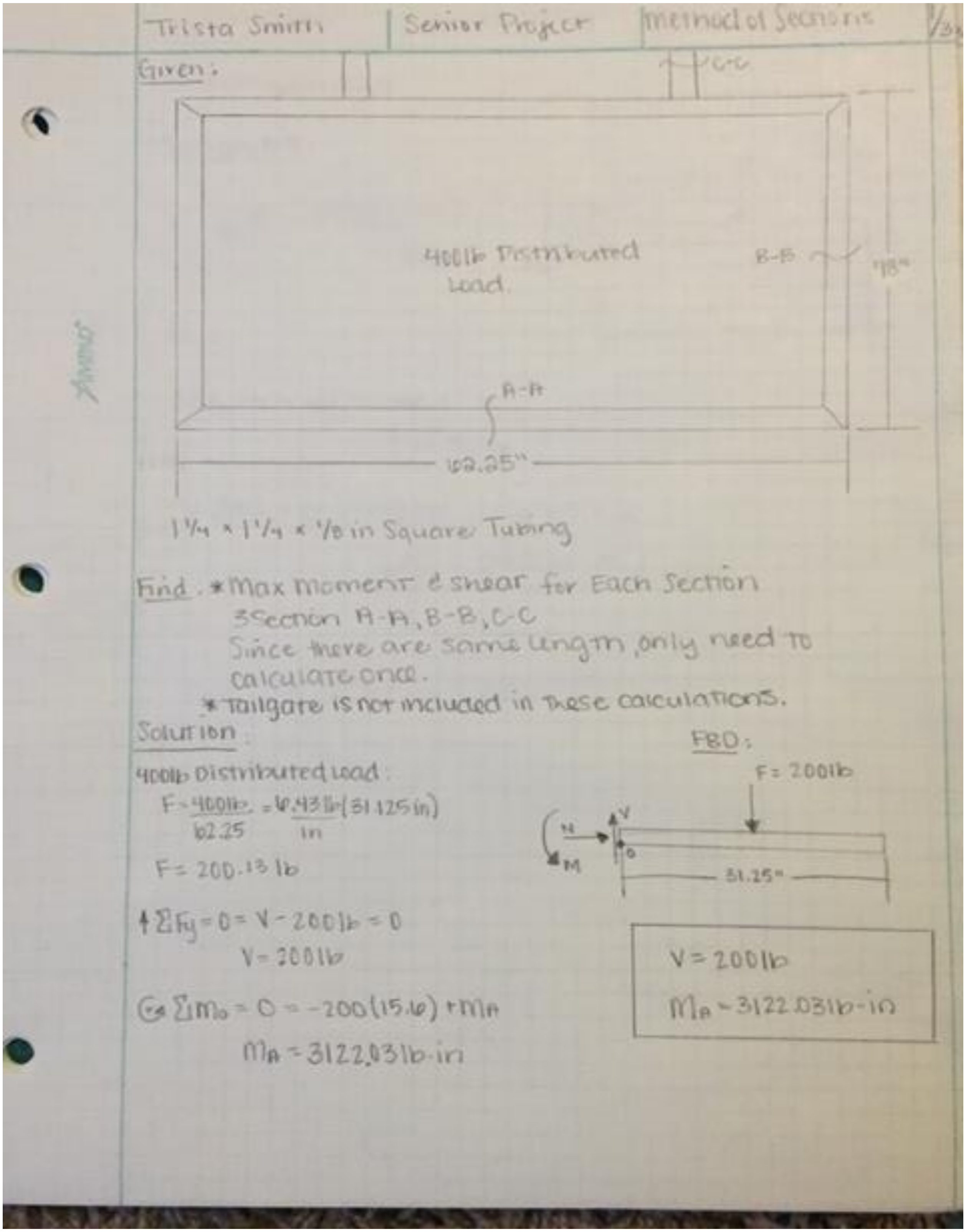
Owen Smith: For helping with the funding and the project build and the testing itself.
Charles Pringle: Calculations and design.

References:

Statics Textbook
Technical Dynamics Textbook
Machine Elements in Mechanical Design Textbook

Appendix A:

1. Methods of Section:



Trista Smith | Senior Project | Method of Sections | 1/3

Given:

1 1/4 × 1 1/4 × 1/8 in Square Tubing

Find: * Max moment & shear for Each Section
3 Section A-A, B-B, C-C
Since there are same length, only need to calculate once.
* Tailgate is not included in these calculations.

Solution:

400lb Distributed Load:

$F = \frac{400lb}{62.25} = 6.43\frac{lb}{in}(31.125in)$

$F = 200.13\ lb$

FBD:

$+\uparrow \Sigma F_y = 0 = V - 200lb = 0$

$V = 200lb$

$\Sigma M_o = 0 = -200(15.6) + M_A$

$M_A = 3122.03lb\text{-}in$

$V = 200lb$

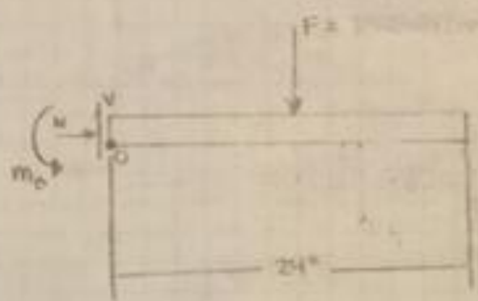
$M_A = 3122.03lb\text{-}in$

Solution Continued:

Section B-B:

$$F = \frac{400lb}{48in} = 8.33 lb/in \times 24in = 200lb$$

$F = 200lb$



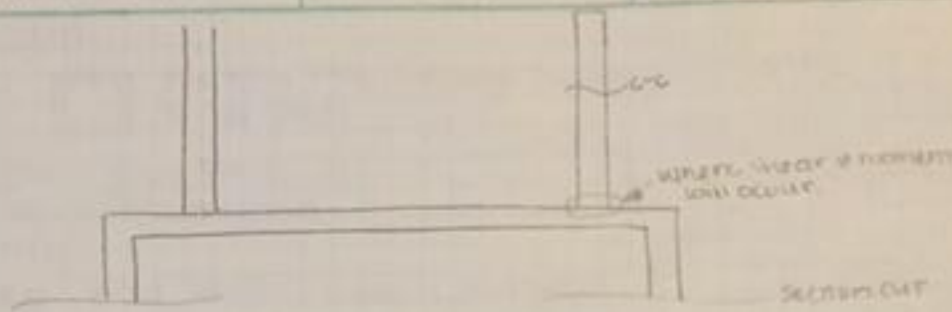
$N = 0$

$\uparrow \sum F_y = 0 = V - 200lb$

$$\boxed{V = 200lb}$$

$\circlearrowleft \sum M_o = 0 = -200lb \cdot (12in) + M_B$

$$\boxed{M_B = 2400lb \cdot in}$$



Section C-C

Calculated @ the extreme

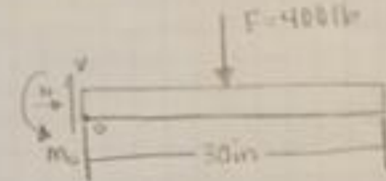
$N = 0$

$+\uparrow \Sigma F_y = 0 = -400lb + V$

$V = 400lb$

$\circlearrowleft + \Sigma M_o = 0 = M_c - 400lb(15in)$

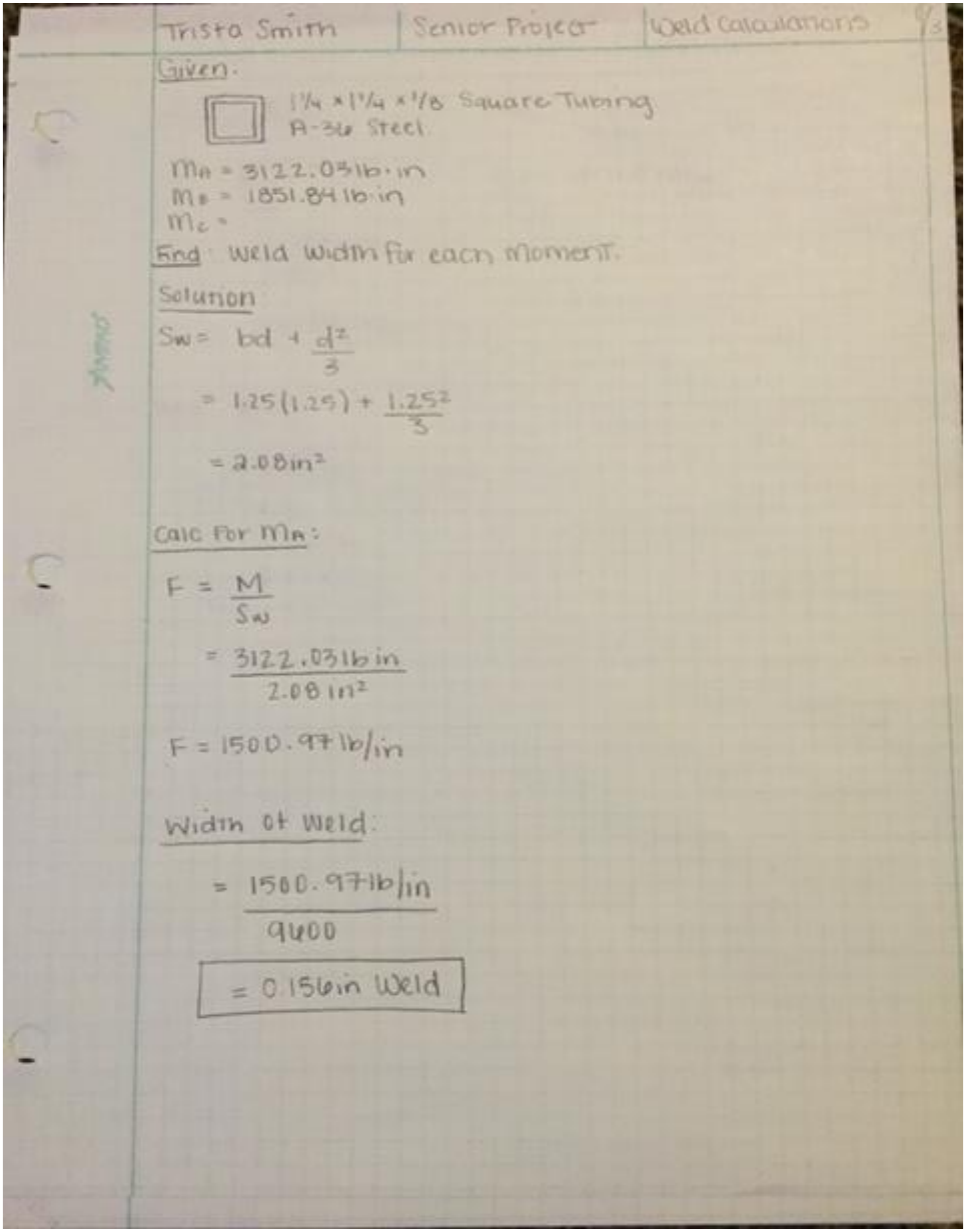
$M_c = 6000lb\text{-}in$



$V = 400lb$

$M_c = 6000lb\text{-}in$

2. Welding Width Calculations:



Trista Smith | Senior Project | Weld Calculations | 1/3

Given:

$1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{8}$ Square Tubing
A-36 Steel

$M_A = 3122.03\ lb \cdot in$
$M_B = 1851.84\ lb \cdot in$
$M_C =$

Find: Weld width for each moment.

Solution

$$S_w = bd + \frac{d^2}{3}$$

$$= 1.25(1.25) + \frac{1.25^2}{3}$$

$$= 2.08\ in^2$$

Calc for M_A:

$$F = \frac{M}{S_w}$$

$$= \frac{3122.03\ lb\ in}{2.08\ in^2}$$

$$F = 1500.97\ lb/in$$

Width of Weld:

$$= \frac{1500.97\ lb/in}{9600}$$

$$= 0.156\ in \text{ Weld}$$

Trista Smith | Senior Project | Weld Calculations 2/3

Calc. For M_B:

from $S_w = 2.08\,in^2$ Previous Page

$M_B = 1851.84\,lb/in$

$$F = \frac{M}{S_w}$$

$$= \frac{2400\,lb \cdot in}{2.08\,in^2}$$

$$= 1153.84\,lb/in$$

Weld width

$$\frac{1154.84\,lb/in}{9600}$$

$$\boxed{= 0.12\,in}$$

Trista Smith | Senior Project | Weld Calculation 3/3

Calc. For M_c:

M_c = 6000 lb·in from methods of section

$$F = \frac{M}{S_w}$$

$$= \frac{6000\,lb \cdot in}{2.08\,in^2}$$

$$= 2884.6\,lb/in$$

Weld width:

$$= \frac{2884.6\,lb/in}{9600}$$

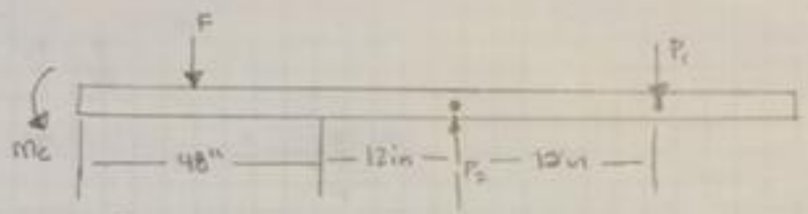
= 0.3in which is large for Square Tubbing

* So I will add 2 gussets on each leg to help support the ATV.

3. Diameter and Deflection Calculations:

Trista Smith | Senior Project | Diameter & Deflection | 1/3

Given: moment taken from Section C-C because that is where the pins will be on that tubing.



$M_c = 6000\,lb \cdot in$

$F = 400\,lb$

Find: a) Forces @ P_1 & P_2

b) Pin diameter for P_1 & P_2

c) Tubing deflection

Solution:

a) Forces in each pin (P_1 & P_2):

$$\circlearrowleft + \sum M_{P_2} = 0 = 6000\,lb\,in + 400\,lb(24in) - P_1(12in)$$

$$P_1 = \frac{6000\,lb\,in + 400\,lb(24in)}{12in}$$

$$P_1 = 1300\,lb$$

$$\uparrow \sum F_y = 0 = -400\,lb + P_2 - 1300\,lb$$

$$P_2 = 1700\,lb$$

$P_1 = 1300\,lb$

$P_2 = 1700\,lb$

b) Pin diameter for P_1 & P_2:

* For stainless steel 18-8, γ = 38KSi

- For P_1 = 1300lb:

$$\sigma = \frac{F}{A}$$

$$38{,}000\,lb/in^2 = \frac{1300\,lb}{\frac{\pi d^2}{4}}$$

$$38000\,lb/in^2 = \frac{1655.2}{d^2}$$

$$d = \sqrt{\frac{1655.2}{38000}}$$

d = 0.2in * diameter for P_1 Needs to be equal or greater than 0.2in

- For P_2 = 1700lb:

$$\sigma = \frac{F}{A}$$

$$38000\,lb/in^2 = \frac{1700\,lb}{\frac{\pi d^2}{4}}$$

$$3800\,lb/in^2 = \frac{2164.5}{d^2}$$

$$d = \sqrt{\frac{2164.5}{38000}}$$

d = 0.238

d = 0.24in * diameter For P_2 Needs to be equal or greater than 0.24in

c) Deflection of Rack:

From page 740 Table A14-1 part f, we will use the equation for the end of Beam @ D.

$$Y = \frac{-Wa^3}{24EI}(4L + 3a) \qquad w = \frac{400 lb}{48 in} = 8.33 lb/in$$

$$I = \frac{HB^3 - hb^3}{12} = \frac{1.25(1.25)^3 - 1(1)^3}{12}$$

page 720 Hollow rectangle

$$I = 0.120 in^4$$

$$E = 29 \times 10^6 psi$$

So,

$$Y = \frac{-Wa^3}{24EI}(4L + 3a)$$

$$= \frac{-8.33 lb/in (48 in)^3}{24(29 \times 10^6)(0.120)}[4(24) + 3(48)]$$

$$= -0.01103(240)$$

$$Y = -2.64 in$$

The Rack will deflect about 2.64 in downwards.

4. Deflection with Tailgate & Safety Factor:

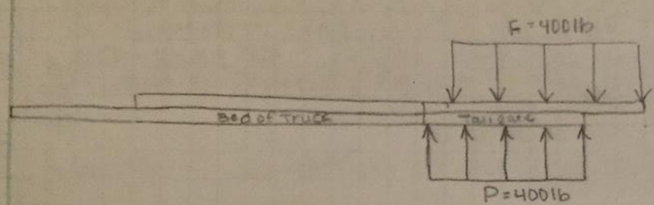
Trista Smith | Senior Project | Tailgate | 1

Given: distributed load $w = 400$ lbs
Tailgate weight load 400lbs
E =

From Section B-B on previous calcs.

Find: Shear (V), Moment (M), τ_{fail}, deflection (y), & Safety Factor.

Solution:

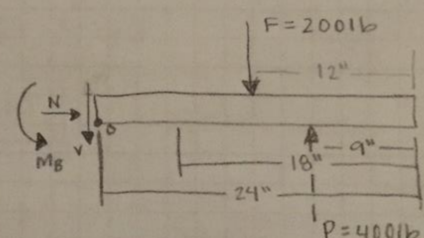


I am assuming the Tailgate to be able to withstand 400lb because I do not have a certain spec to show. The Tailgate is supported by the two cords holding the tailgate in the down position. The cords are then supported by some sort of pin or fastener.

Section B-B:

$F = \frac{400lb}{48''} = 8.33 lb/in \times 24in$

$F = 200lb$



N = 0

$\uparrow + \Sigma F_y = 0,\ V - 200lb + 400lb = 0$

V = -200lb switch arrow direction.

V = 200lb

$\circlearrowleft + \Sigma M_o = 0.\quad 400lb(15in) - 200lb(12in) + M_B = 0$

$M_B = 200(12) - 400(15)$

$M_B = -3600 lb \cdot in$ switch arrow direction.

$M_B = 3600 lb \cdot in$

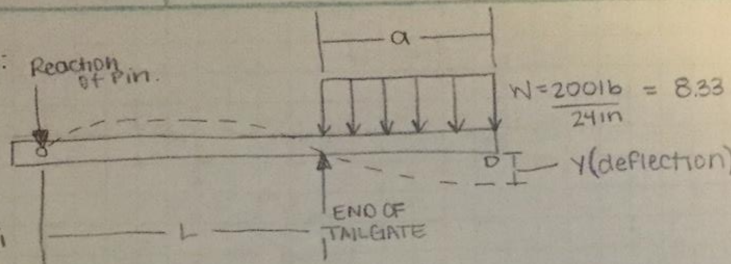
Deflection:

L = 12in

a = 24in

$E = 29 \times 10^6$ psi

$I = 0.120 in^4$



The weight of the distributed load is split in half this time because half of the load will be on the tailgate which will be supporting that part of the load. That is why the arrow going up is placed their. The arrow in downward direction is representing one of the pins.

Equation for deflection at the end @ point D:

$$y = \frac{-Wa^3}{24EI}(4L + 3a)$$

$$y = \frac{-(8.33 lb/in)(24in)^3}{24(29 \times 10^6 lb/in^2)(0.120 in^4)}\left[4(12in) + 3(24in)\right]$$

$$= -0.00137 \times 120$$

$$\boxed{y = 0.1644 \text{ in}}$$

Equations Used:

$$\tau_{fail} = \tau_{yield} = 0.5\,S_y$$

$$F.S. = \frac{\tau_{fail}}{\tau_{allow}}$$

$\tau_{fail} = 0.5\,S_y$ S_y for A36, $S_y = 36\text{ksi}$

$\tau_{fail} = 0.5(36{,}000\text{psi}) = \boxed{18{,}000\text{ psi}}$

Choose $\tau_{allowable}$ to be $6000\text{psi} = \tau_{allowable}$

$$F.S. = \frac{\tau_{fail}}{\tau_{allowable}} = \frac{18{,}000\text{ psi}}{6{,}000\text{ psi}}$$

Factor Safety = 3.0

5. Material Amount Calculations:

Tnsta Smith | Senior Project | Material Amount — Square Tubing | 1/1

Given:

① 2 x 62.5in

② 2 x 48in

③ 1 x 45.5in

④ 2 x 29.25in

⑤ 2 x 30in

20ft. x 12in = 240in

Find amount of square Tubing Needed

*can only order in Lengths of 20 feet.

Solution:

① 62.5" x 2 = 125"

② 48" x 2 = 96"

→ 221" — 1 Tube

③ 45.5"

④ 29.25" x 2 = 58.5"

⑤ 30" x 2 = 60"

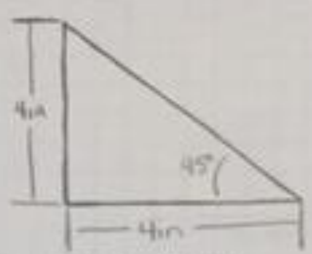
→ 164" — 1 Tube

2 Tubes of 20'

Trista Smith | Senior Project | Material Amount Bracket & Gussets

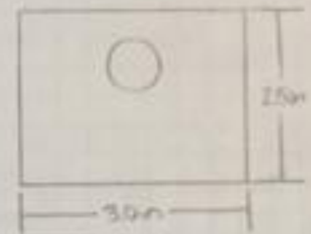
Given:

① Gusset Design:



Thickness = 0.25"

② Bracket Design:



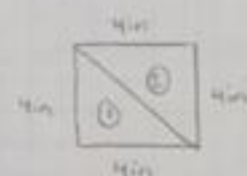
Thickness = 0.25"

Find The amount of material Needed for:
- 4 Gussetts
- 4 Brackets

Solution:

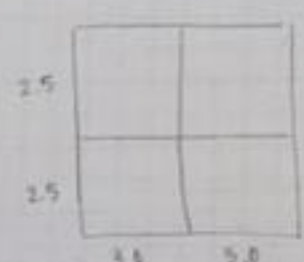
a) 4 Gussetts:

2Gussets =



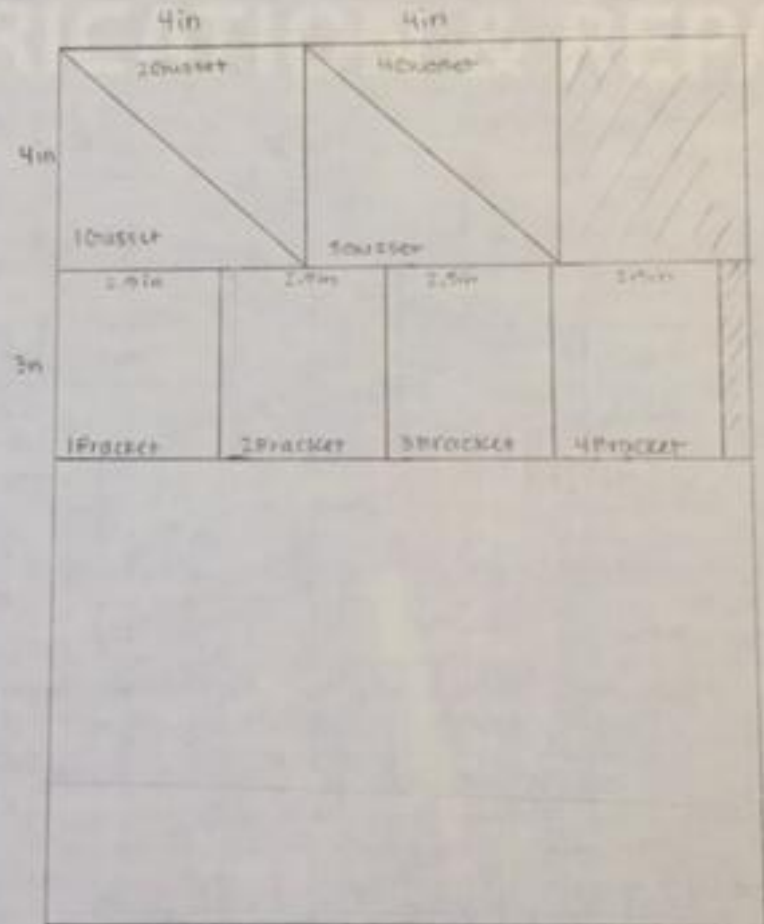
x2 for 2 more Gussetts

b) 4 Brackets



Trista Smith | Senior Project | material Bracket & Gusset | 1/2

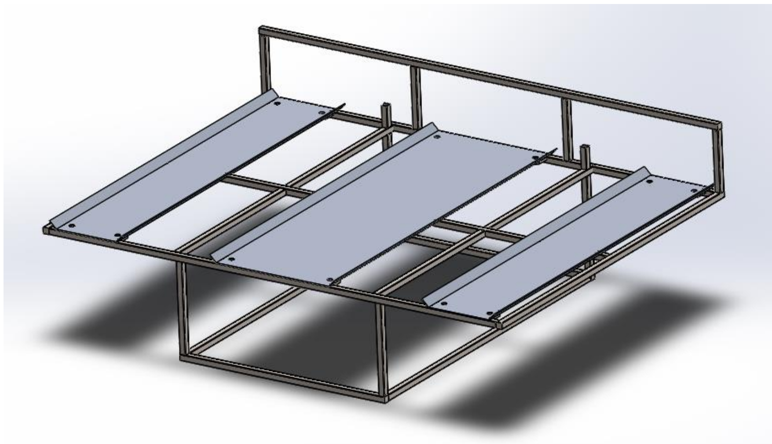
Parts Can Be Seperated by more space,
To count for the Cutter



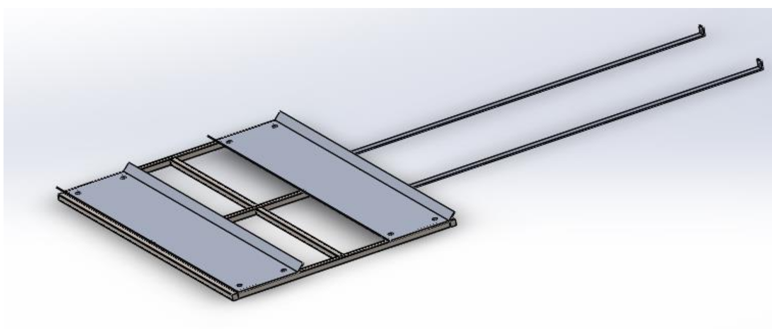
A 12in x 8in Plate $t = 0.250in$ will be enough.
with extra for just in case.

Appendix B

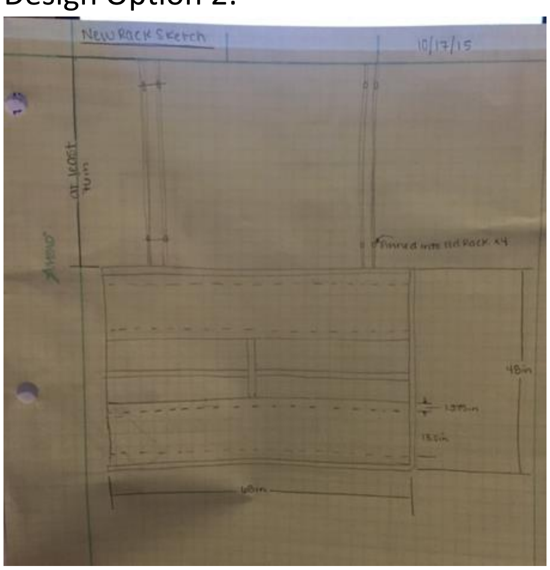
1. Existing Rack:



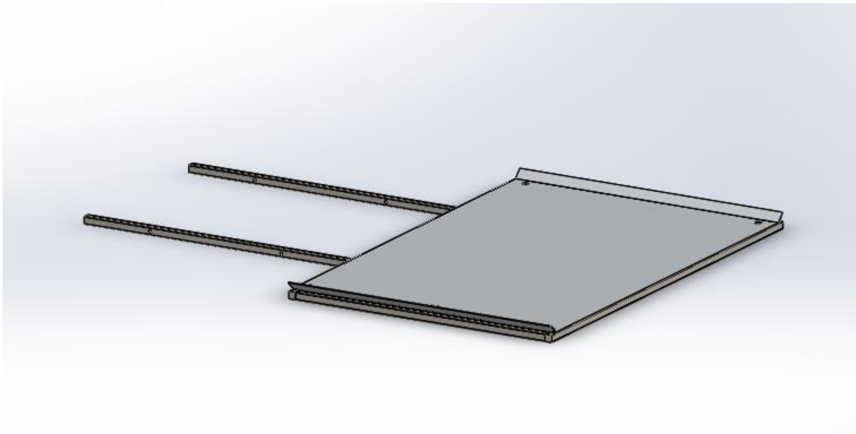
2. Design Option 1:



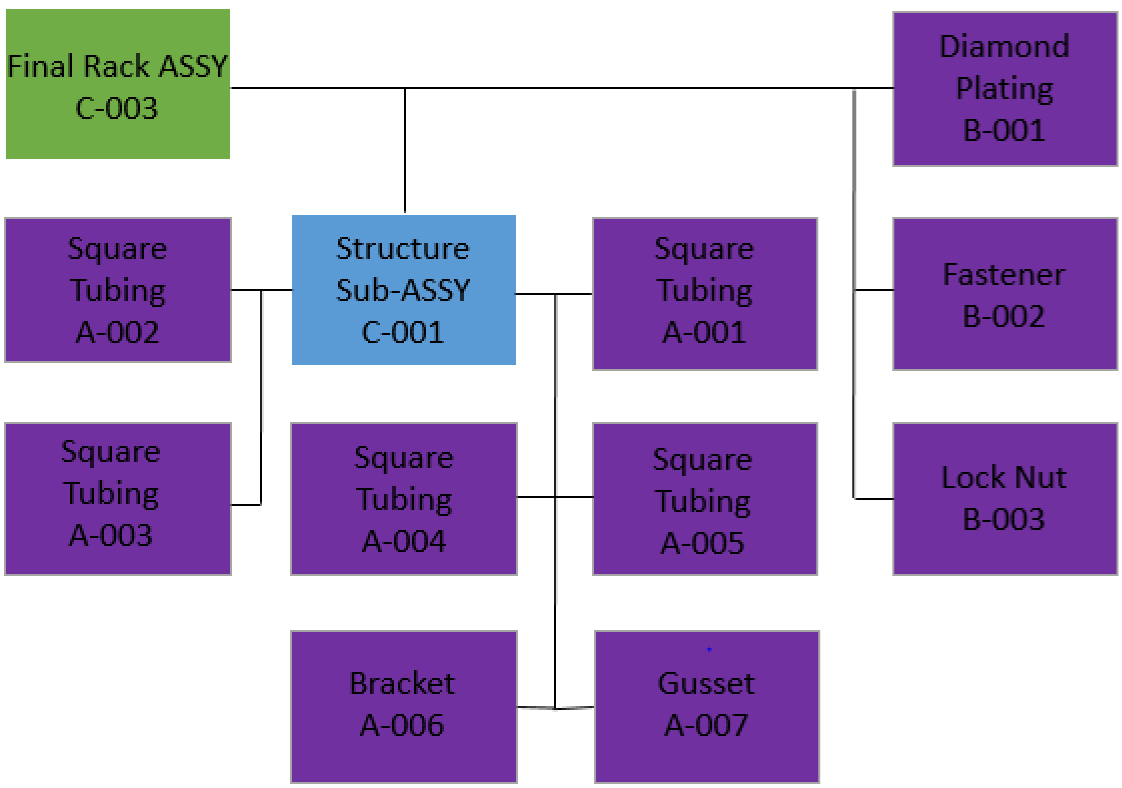
3. Design Option 2:



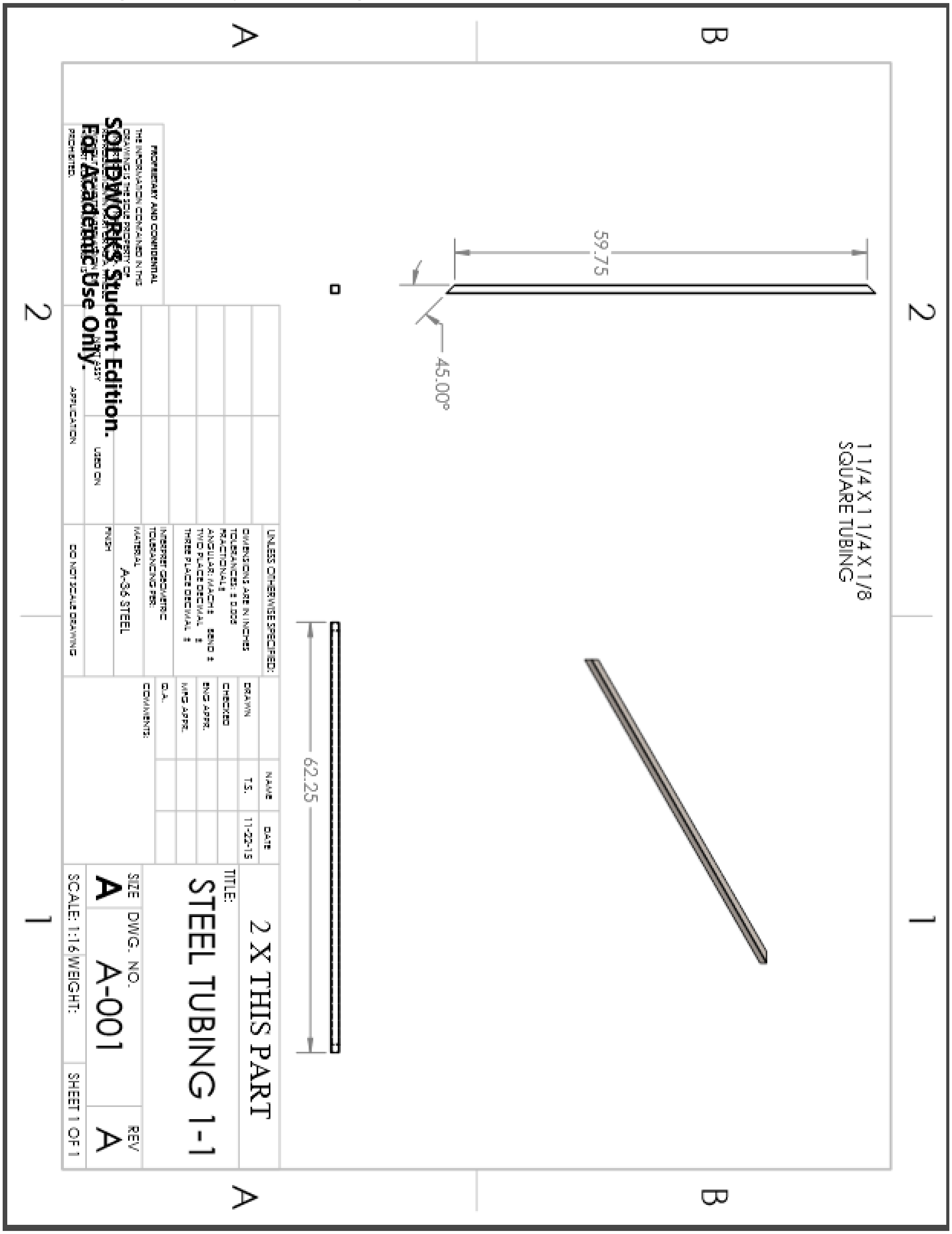
4. Design Option 3:



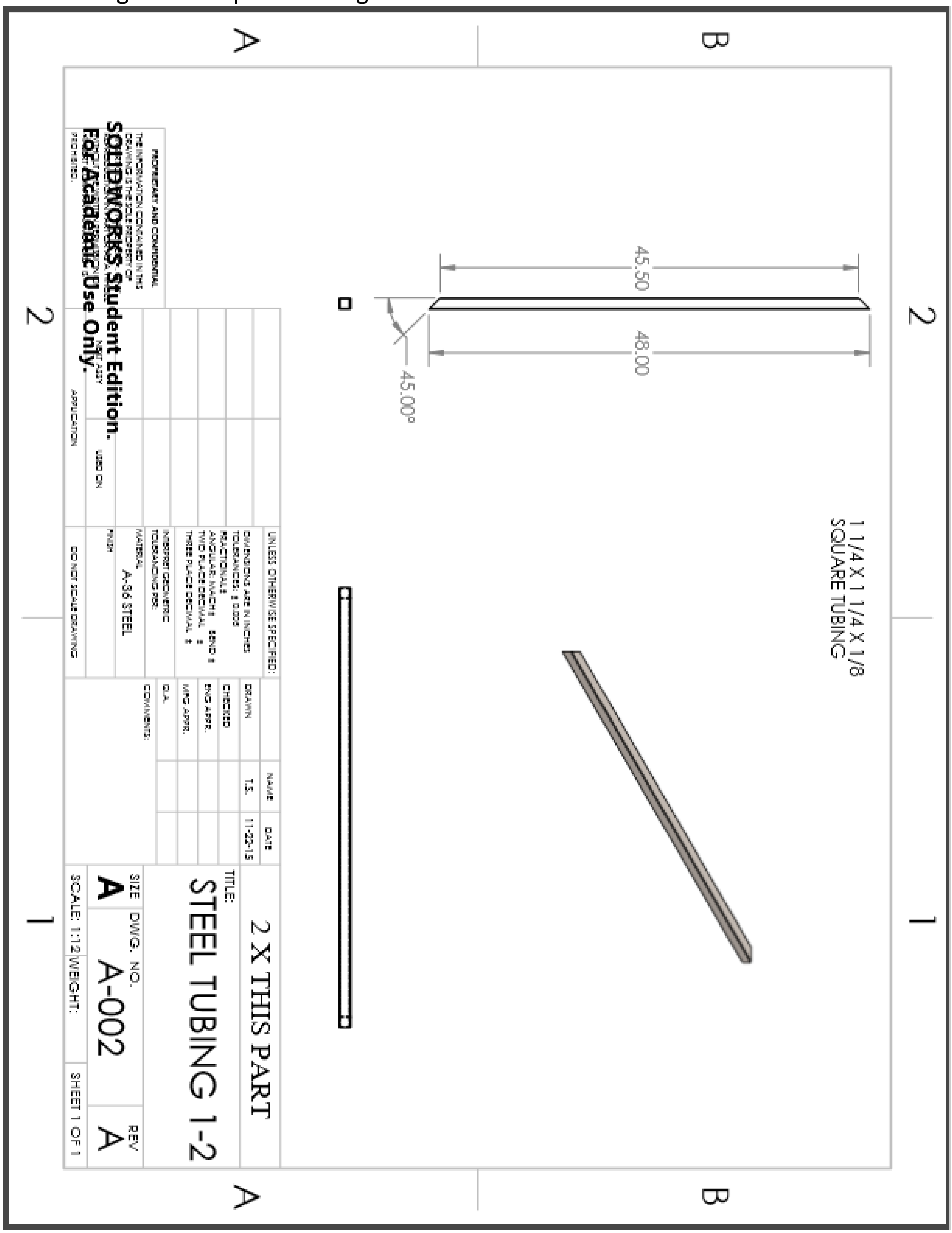
5. Rack Extension Drawing Tree:



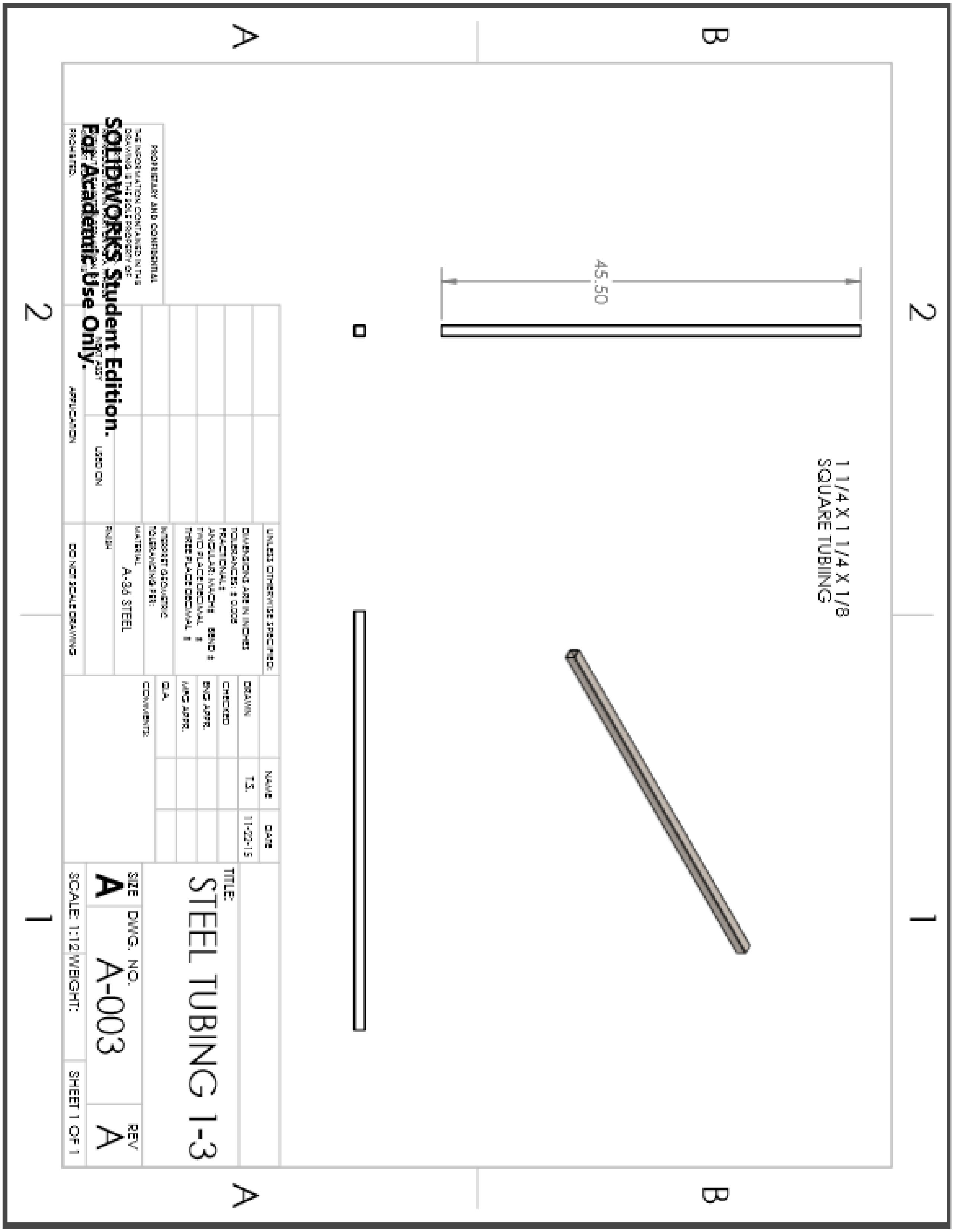
6. Drawing A-001: Square Tubing



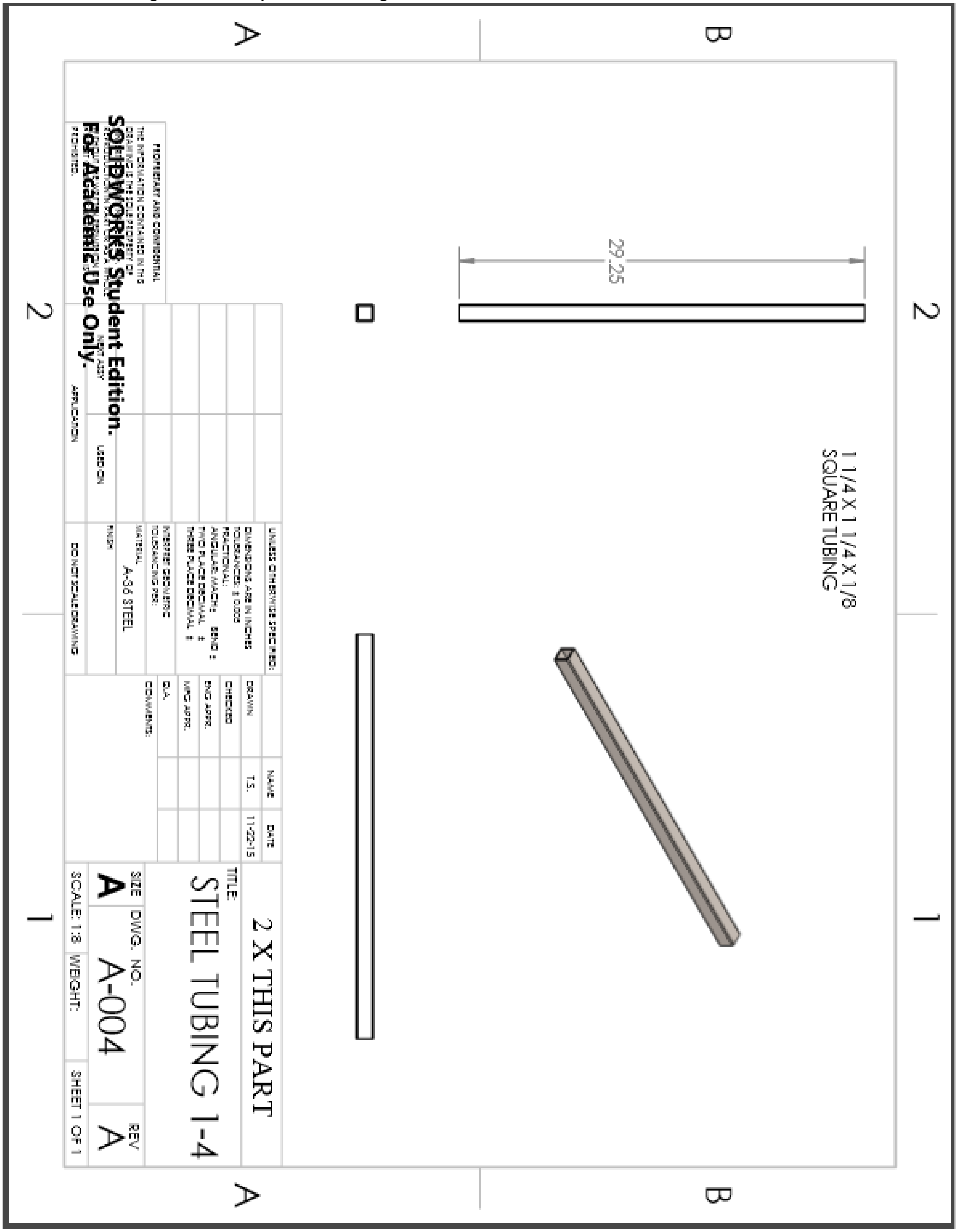
7. Drawing A-002: Square Tubing



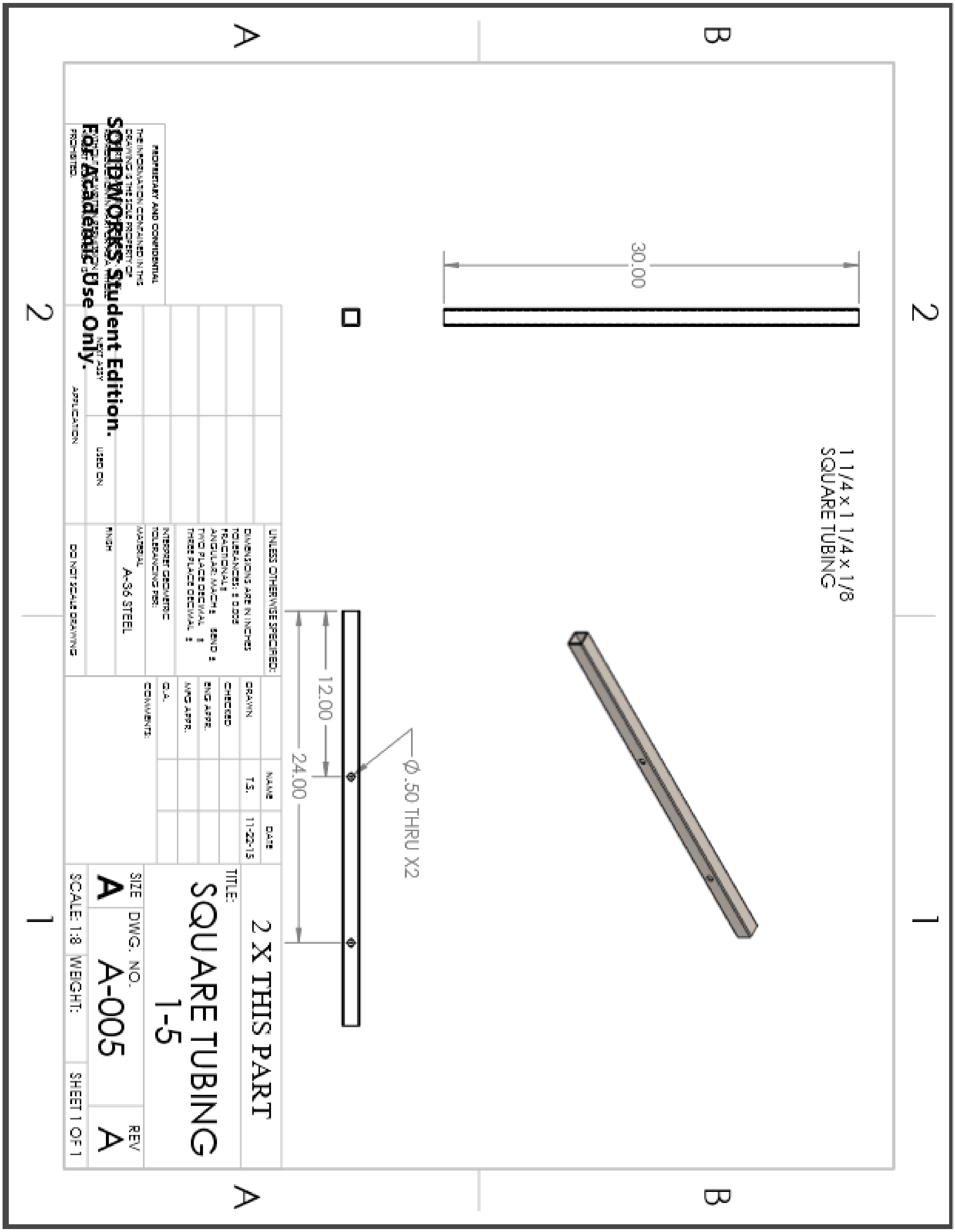
8. Drawing A-003: Square Tubing



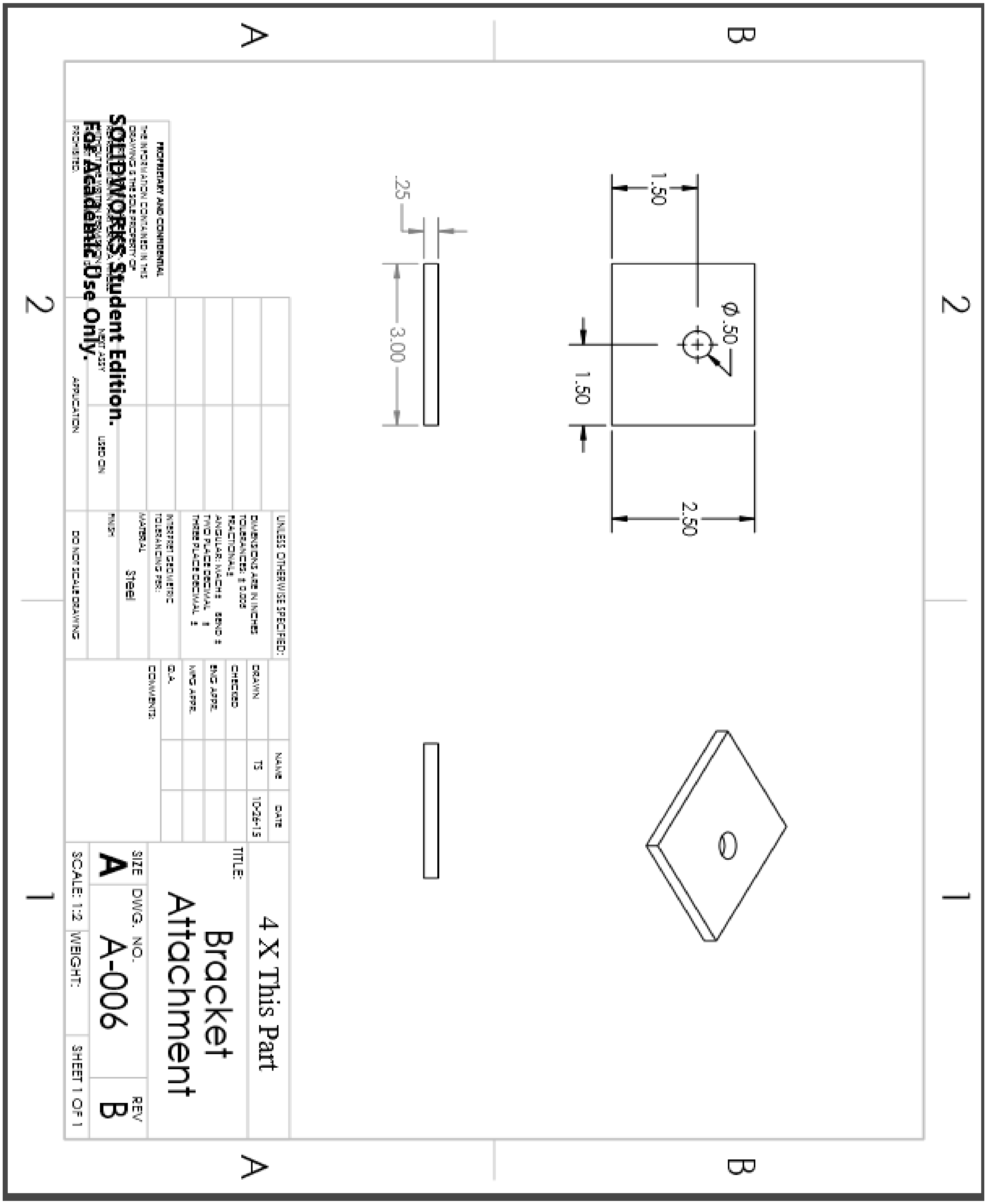
9. Drawing A-004: Square Tubing



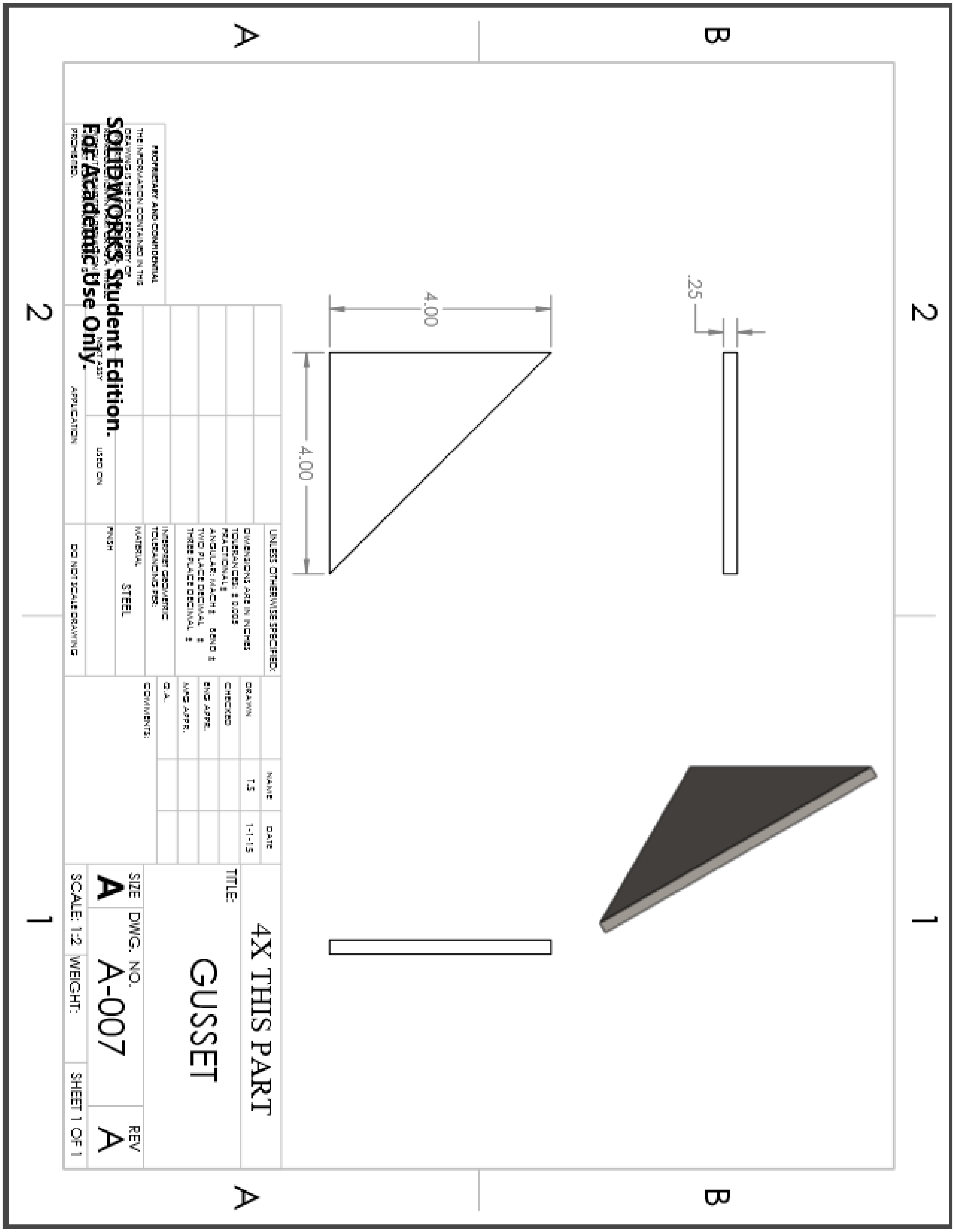
10. Drawing A-005: Square Tubing



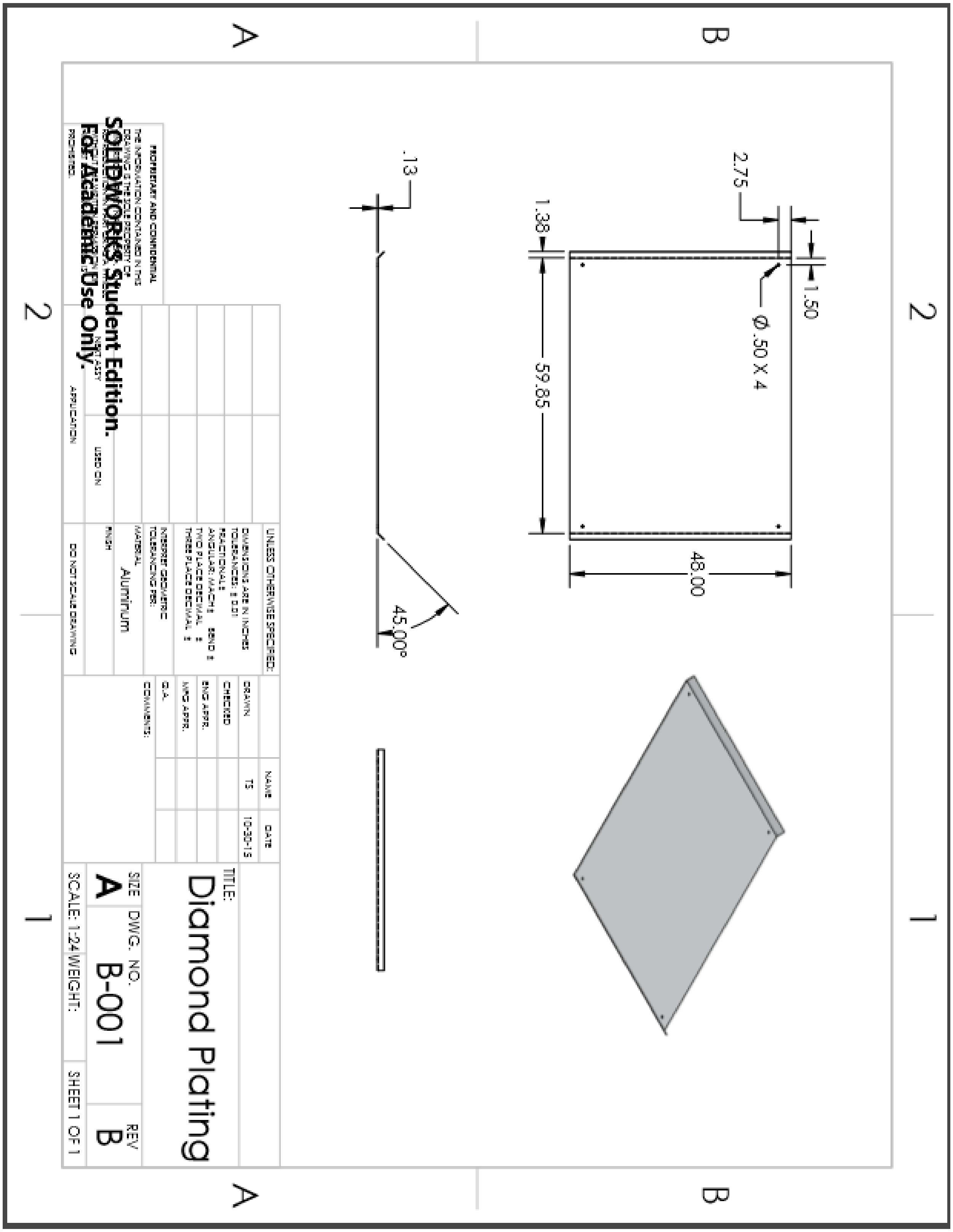
10. Drawing A-006: Attachment Plate



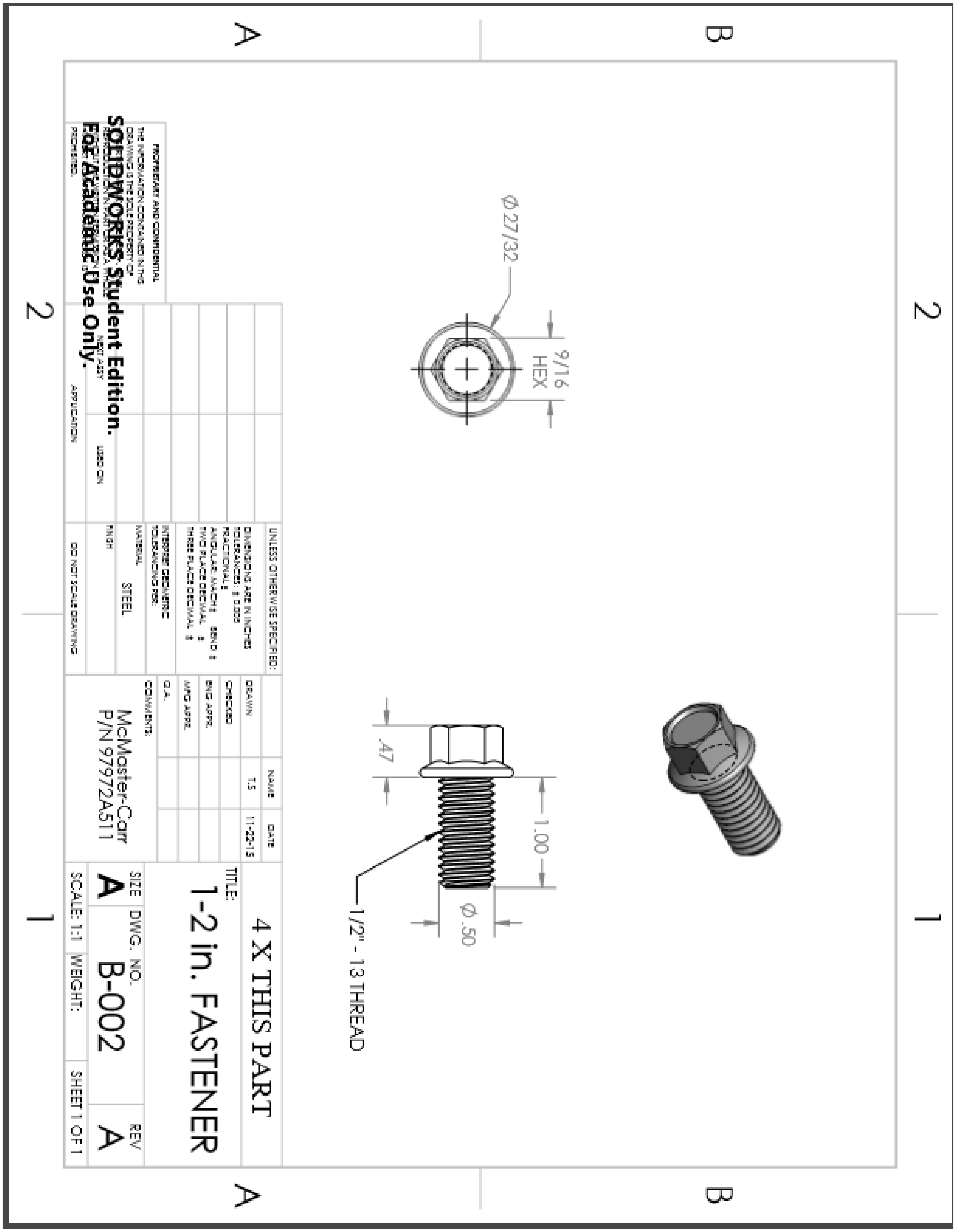
12. Drawing A-007: Gusset



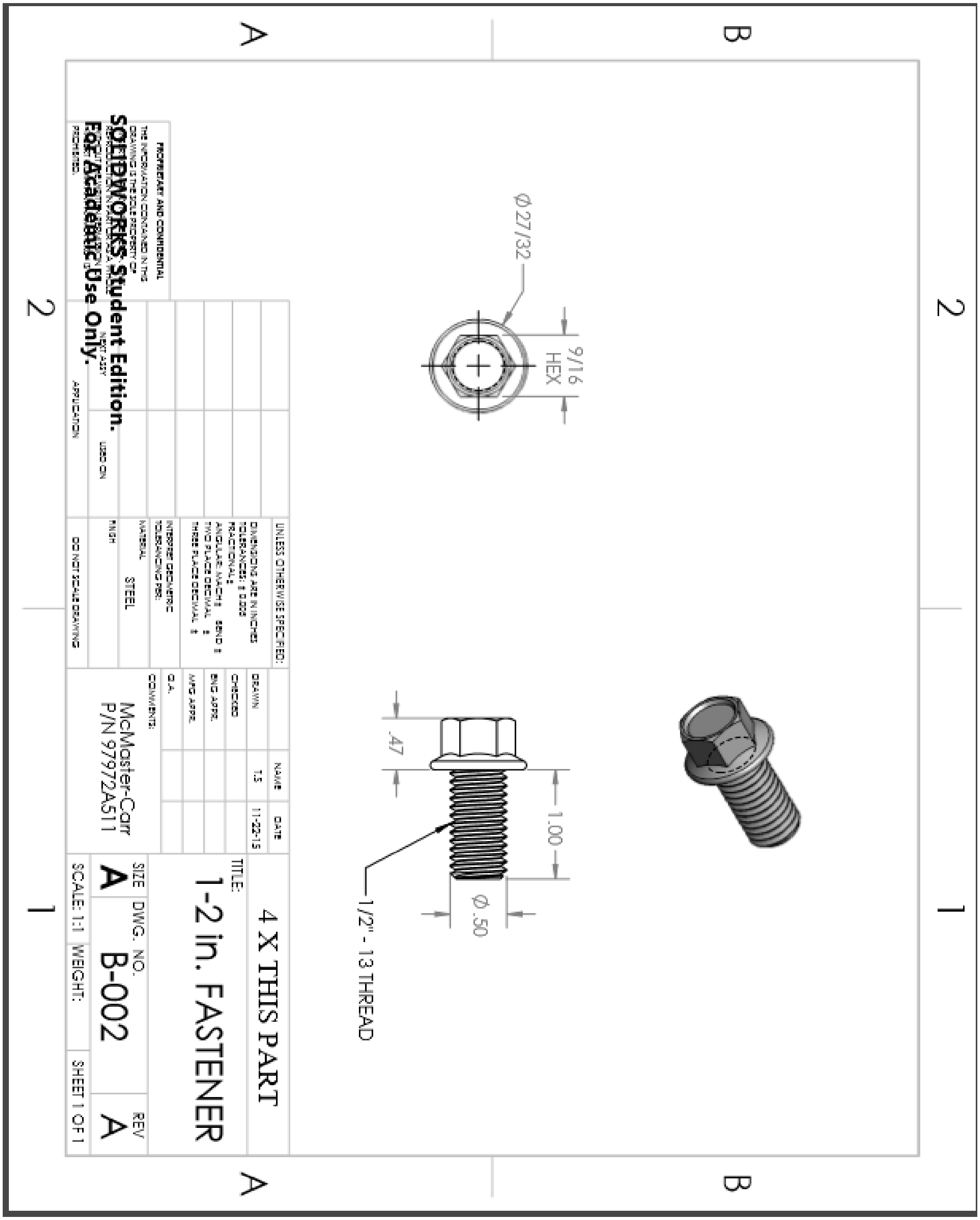
11. Drawing B-001: Diamond Plating



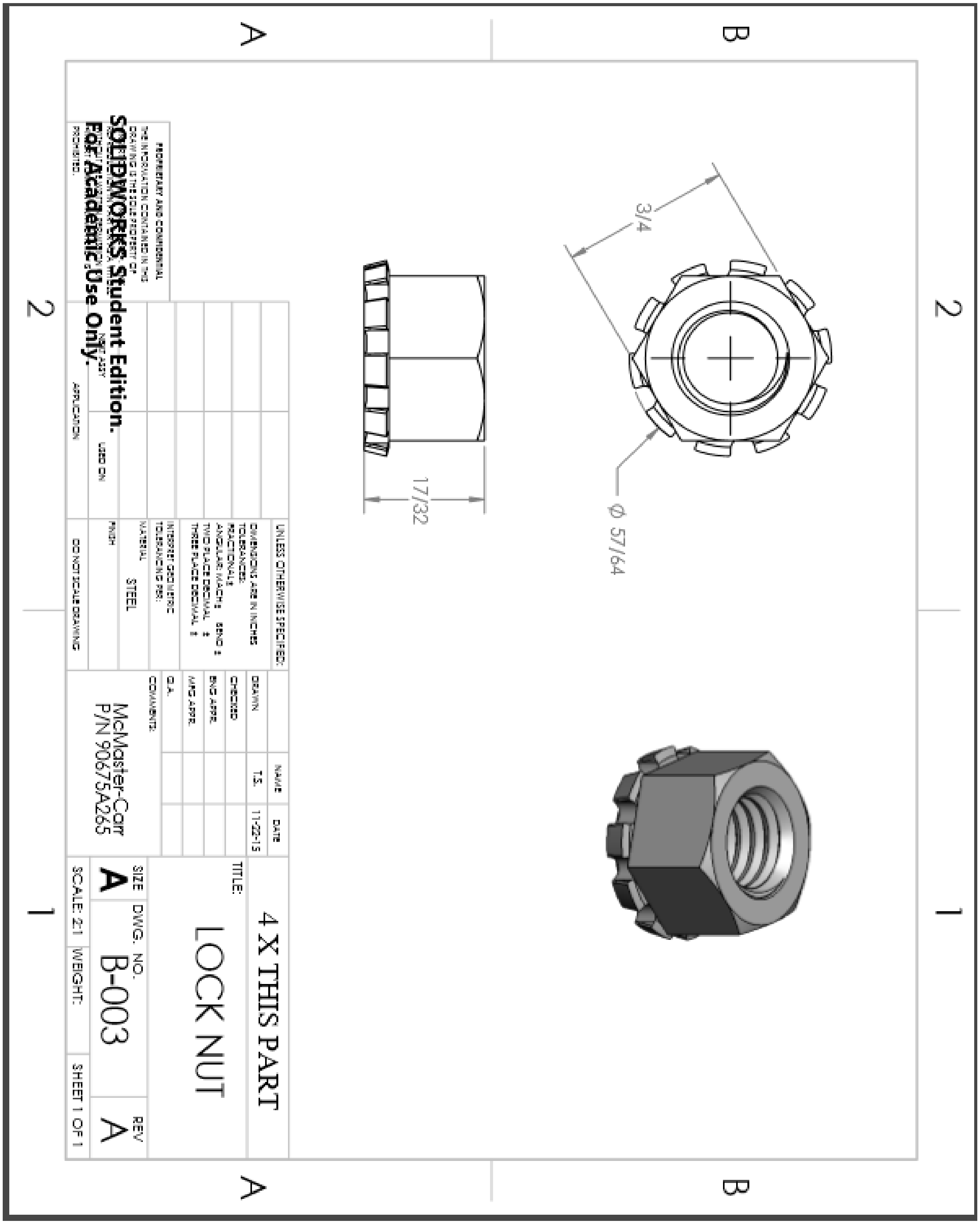
12. Drawing B-002: Fastener



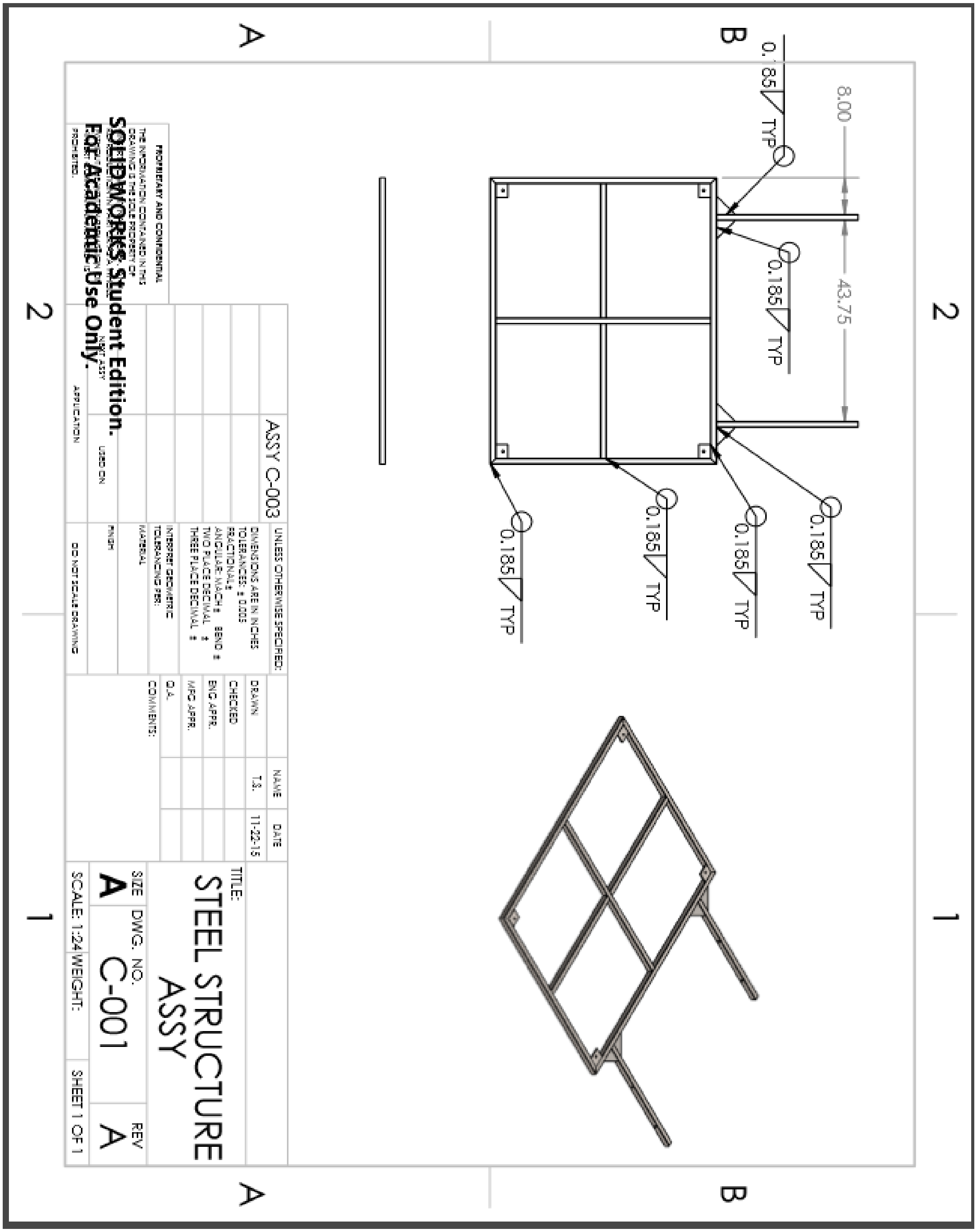
13. Drawing B-002: Fastener



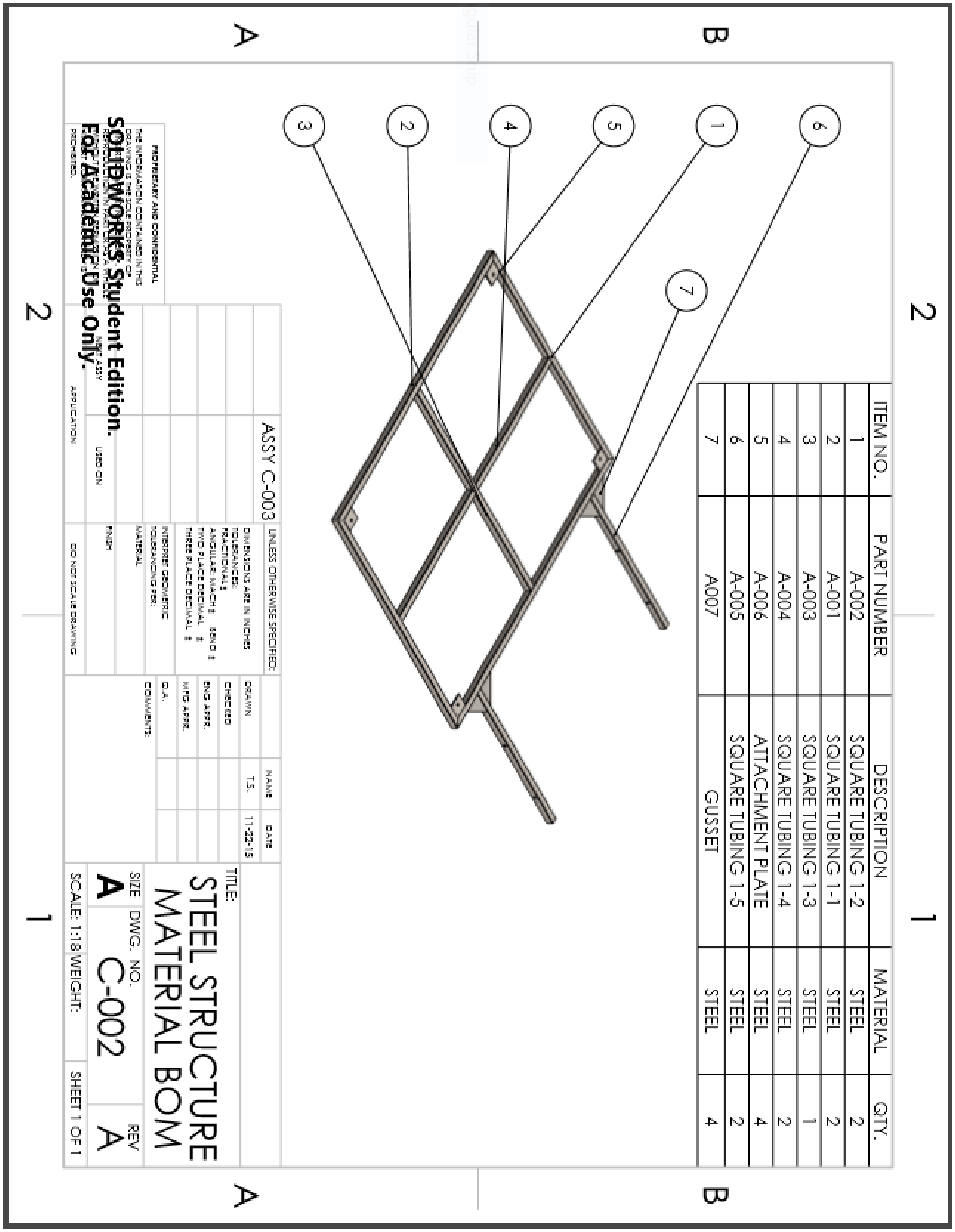
14. Drawing B-003: Lock Nut



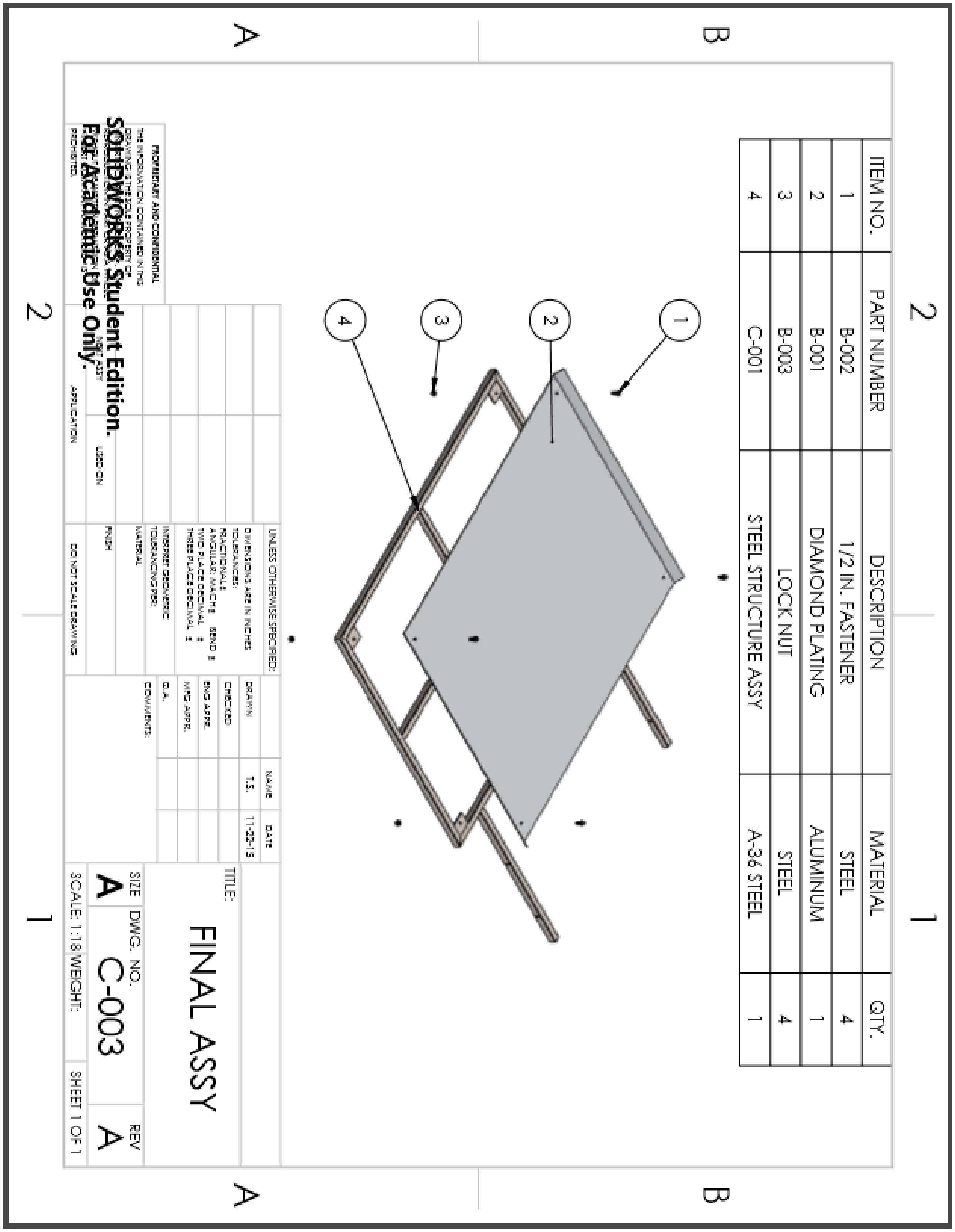
15. Drawing C-001: Weld Call Outs



16. Drawing C-002: Sub-ASSY BOM



17. Drawing C-003: Final ASSY BOM



Appendix C - Parts list and Costs

ATV Rack Extension Parts List:								
Part Name:	**Supplier:**	**Material:**	**Model #:**	**Size:**	**QTY:**	**Est. Cost:**	**Actual Cost:**	**Comments:**
Diamond Plating	Haskins Steel	Aluminum	0.125" tk	4' x 8'	1	138.38	120.00	
Square Tubing	Haskins Steel	Steel	1-1/4 x 1-1/4	20ft	2	80.69	55.00	
Steel Plate	OnlineMetals.com	Stainless Steel		t=0.25 12x8in	1	53.76	15.00	
Bent Hitch Pin w/Reusable Cotter Pin	McMaster-Carr	Stainless Steel 18	94563A811	1/2" x 3"	4	31.72	31.72	7.93 Each
Hex Nut with Lock washer	McMaster-Carr	Steel	90675A265	1/2" dia.	1 pkg	9.34	10.00	1 pkg. = 10
Head Cap Screw	McMaster-Carr	Steel	97972A511	1/2" dia.	4	16.56	25.00	4.17 each
Total:						330.45	256.72	

Appendix D - Budget

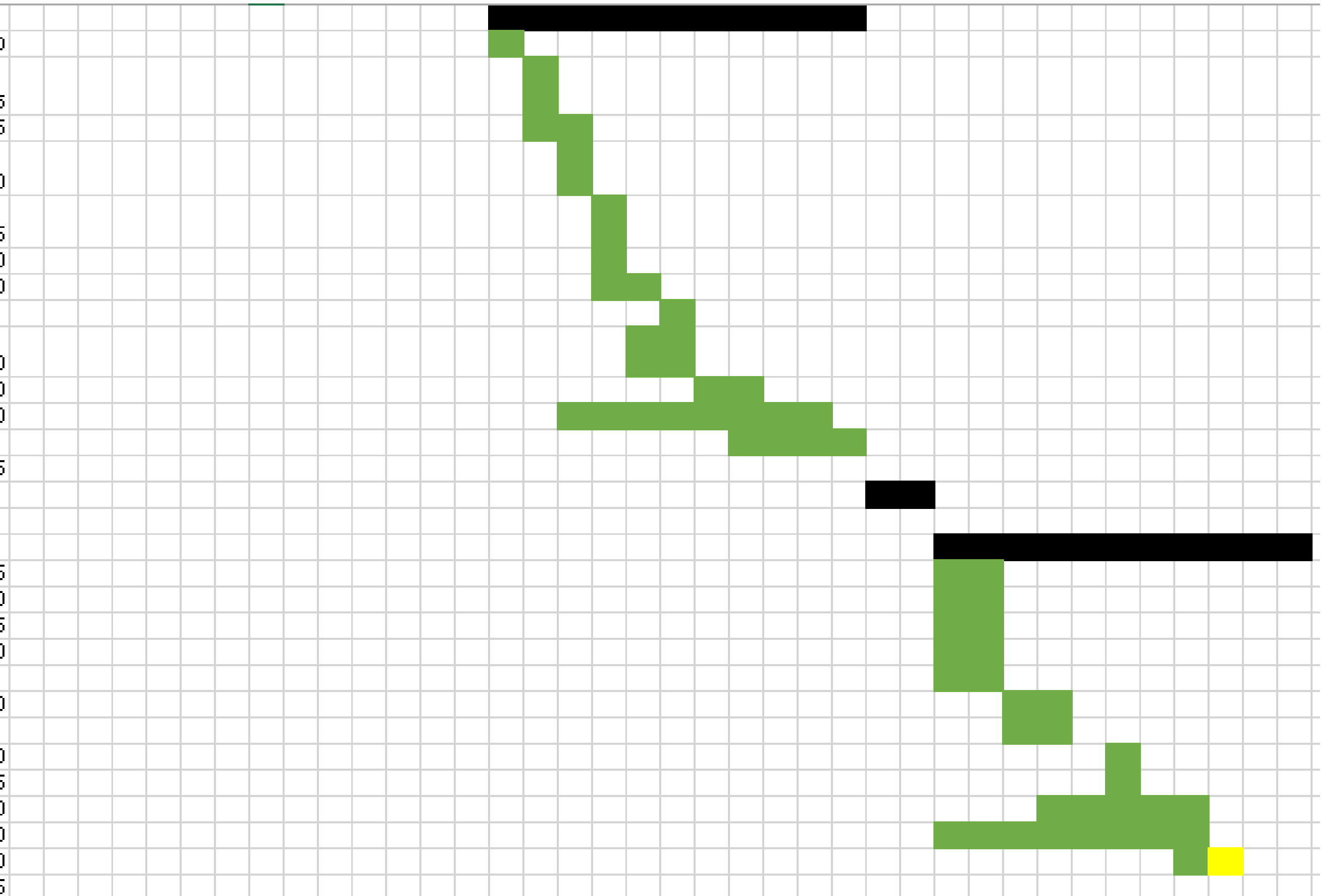
Budget ATV Rack Extension:	
Parts Listed:	**Cost:**
Structure ASSY	
Square Tubing	$80.69
Steel Bar	$55.89
Final ASSY	
Diamond Plating	$138.38
Hitch Pins	$31.72
Fasteners	
Rhino Spray Paint	
Total Cost:	**$306.68**

Appendix E – Schedule

ATV Rack Extension Senior Project Schedule

			September- October					November					December				January				February					March				April				May					June	
Section	Task	EST. Labor	9/28/2015	10/5/2015	10/12/2015	10/19/2015	10/26/2015	11/2/2015	11/9/2015	11/16/2015	11/23/2015	11/30/2015	12/7/2015	12/14/2015	12/21/2015	12/28/2015	1/4/2016	1/11/2016	1/18/2016	1/25/2016	2/1/2016	2/8/2016	2/15/2016	2/22/2016	2/29/2016	3/7/2016	3/14/2016	3/21/2016	3/28/2016	4/4/2016	4/11/2016	4/18/2016	4/25/2016	5/2/2016	5/9/2016	5/16/2016	5/23/2016	5/30/2016	6/6/2016	6/13/2016
1.00	**Fall Quarter**																																							
1.01	Project Idea																																							
1.02	Function Statement	0.5																																						
1.03	Requirements	0.5																																						
1.04	Introduction	2.0																																						
1.05	Analysis	6.0																																						
1.06	Designs	10.0																																						
1.07	Parts List	2.0																																						
1.08	Drawing Tree	2.0																																						
1.09	Methods & Construction	5.0																																						
1.10	Testing Method	1.5																																						
1.11	Testing Procedure	1.5																																						
1.12	Testing Deliverables	1.5																																						
1.13	Budget	1.0																																						
1.14	Schedule	2.0																																						
1.15	Project Management	2.0																																						
1.16	Discussion	1.0																																						
1.17	Conclusion	1.0																																						
1.18	First Draft																																							
1.19	Second Draft																																							
1.20	**Winter Break**																																							
1.21	Winter Labor Total:	39.5																																						

2.00	**Winter Quarter**		
2.01	Final Draft Turn In	10.0	6.0
2.02	Order Tubing/Plate/Diamond Plate (P/N: A-001 - A-007, B-001)	0.5	0.5
2.03	Material Received	0.5	0.5
2.04	Cut Tubing/Steel Plate (P/N: A-001 - A-007)	6.0	6.0
2.05	Order Fasteners/Pins (P/N B-002 - B-003)	0.5	0.5
2.06	Drill Holes in A-005, & A-006	2.0	1.0
2.07	Welding Frame ASSY C-001	15.0	8.0
2.08	Painting Frame ASSY C-001	5.0	
2.09	Receive Fasteners/Pins (P/N B-002 - B-003	0.5	1.0
2.10	Add Diamond Plating To ASSY C-0	3.0	3.0
2.11	Webpage Updated	5.0	6.0
2.12	Finished Product ASSY C-003		
	Spring Labor Total:	48.0	32.5
	Spring Break		
3.00	**Spring Quarter**		
3.01	Abstract For SOURCE	2.0	1.5
3.02	Test Plan	2.0	2.0
3.03	Create LinkedIn Acct.	0.5	0.5
3.04	Test 1	2.0	3.0
	Weight Check		
3.05	Test 2	2.0	3.0
	Strain		
3.06	Test Report	1.5	1.0
3.07	Webpage Update	3.0	2.5
3.08	Prepare for Final Presentation	5.0	3.0
3.09	Prepare for SOURCE	5.0	5.0
3.10	Final Project report	3.0	1.0
	Spring Quarter Labor	18.5	22.5



Black: Time Frame for that Section

Red: Final Required for Task

Green: Task Tentative Completion Date

Appendix F

Some help that was received was from Matt Burvie for supplying tools and the machine shop when it was needed. Trevor Reher and Jason Moore welded the square tubing and gussets together for the manufacturing quarter of this project.

The Mechanical Design textbook was a big resource for analysis and design changes to this project. As well as help from Charles Pringle and Daryl Fuhrman for calculations questions.

Appendix G

The Testing data will be represented in tables that are shown below. All data will be taken in the measured boxes and compared to the calculated.

Deflection		
Weight (lbs):	**Calculated:**	**Measured:**
60	0.0297931	
120	0.05958621	
180	0.08937931	
340	0.16882759	
420	0.20855172	

				Caluclated	**Measured**
Weight (lbs):	**Force (lb):**	**Moment (lb-in):**	**Stress (psi):**	**strain**	
60	30	360	1687.5	0.0000582	
120	60	720	3375	0.0001164	
180	90	1080	5062.5	0.0001746	
340	170	2040	9562.5	0.0003297	
420	210	2520	11812.5	0.0004073	

	REQUIR'D	**ACTUAL**
WEIGHT:	100LBS	

Appendix H

The data that is represented below is the final data for testing that was measured compared to calculated requirements.

Deflection		
Weight (lbs):	**Calculated:**	**Measured:**
60	0.0297931	0.177
120	0.05958621	0.334
180	0.08937931	0.342
340	0.16882759	0.613
420	0.20855172	0.756

				Caluclated	Measured
Weight (lbs):	Force (lb):	Moment (lb-in):	Stress (psi):	strain	
60	30	360	1687.5	0.0000582	0.000062
120	60	720	3375	0.0001164	0.000129
180	90	1080	5062.5	0.0001746	0.000186
340	170	2040	9562.5	0.0003297	0.000311
420	210	2520	11812.5	0.0004073	0.00032

	REQUIR'D	ACTUAL
WEIGHT:	100LBS	82LBS

Appendix I

Testing Report:

Introduction:

The testing section of the ATV rack extension project consisted of two major tests. One test included placing sand bags weighing about 60lbs onto the rack one at a time to measure the amount of deflection. The second test this included measuring the strain on the side of the rack on the square tubing.

The sands bags were placed on the rack one at a time. At the time there were only four sand bags available so a person weighing about 160lbs took care of the rest of the weight. The data that was collected was the deflection of the rack that is over hanging the tail gate and the strain that is being applied to the rack where it will bend.

The required value for the deflection was that the rack deflect not more than 0.25". The predicted performance was that the rack would only deflect about 0.21". The required and calculated value for the strain was that at the most weight being applied (400lbs) the values be less than 407με.

The testing took place all at once because it was more convenient to be back at home one time. The Gantt chart for spring quarter that is shown in the appendix shows that the testing took place throughout the month of April. The actual date of the tests was April 24.

Method/Approach:

Below describes the two testing methods that were used for this project:

3. The first method that was used to test the new rack extension was making sure that 400lbs of weight can be tolerated by the rack and the tailgate could with stand at least 400lbs worth of weight. To test this the rack extension it was placed on the truck with the original rack and ATVs, and secured the rack extension. The rack was secured to the rack with four hitch pins. Then sand bags and a person was continuously placed on the rack extension until the weight limit of 400lbs is reached. This was a way to slowly test the weight compatibility without putting the ATV right on the truck and hoping that it doesn't buckle or break.
4. The second approach to testing the new rack extension was to place a strain gage on the side where the square tubing is parallel with the truck. The strain gage was placed on the bottom of the square tubing where the most bending would occur. The same process of the weight being applied to the rack extension was used but this time taking the measurement of strain instead.

The materials that was needed for testing is stated below:

- Ford F-150 Truck with Speedometer
- Original ATV Rack
- New ATV Rack
- 4 x Hitch pins and Cotter pins
- Sand Bag (at least 400lbs worth)
- Go-Pro Video or Cell phone for video/pictures
- Excel Document to keep track of comments and weights

- Strain gage
- Dial Indicator

The data was represented in an excel spreadsheet and then placed into graphs to see the trends of weight vs deflection, and weight vs. strain. The precision will be to three decimal places to ensure that the deflection is represented properly. The data that was gathered was compared to the calculated results of deflection and strain at each amount of weight used.

Test Procedure:
These two tests occurred on April 24th and were done simultaneously. Since the tests were done at the same time the procedure below represents both tests. The location of these test will be in Bonney Lake, WA where the truck and ATV racks are located.

Test 1 & 2 Procedure:

11. Place original rack in the truck bed and secure rack and truck bed together.
12. Place new rack extension on tailgate of truck and ensure that the pin holes align.
13. Place hitch pins into the square tubing that slid into the bed of the truck, parallel with the original rack. Pin these hitch pins so they won't slip out.
14. Let the rack sit on truck tailgate to ensure the tailgate can support the weight of the rack. (Safety is a very big factor in this testing).
15. Next lift the truck up and place onto jack stands. Ensure that jack stands are places on the frame of the truck to ensure that the measurements take for deflection will not include the suspension movement of the truck.
16. Set up the strain gage on the right or left side of the rack extension. The strain gage needs to be place on the bottom side of the square tubing to ensure that the strain will be measured where the most bending will occur. Follow the instructions that are provided with the strain gage for proper set up.
17. Next place the dial indicator on the sturdy plat form that can reach the square tubing of the rack extension. The dial indicator needs to be placed at the end of the rack extension where the most deflection would occur.
18. Now place 60lbs (one sand bag) on the new rack extension. Even though the load that will be on the rack will be distribute throughout the whole rack, place sand bags on the edge that overhangs from the tail gate for best results.
19. Record the deflection of the rack if any movement occurs, and the strain on excel spreadsheet.
20. Repeat steps eight and nine with an additional 60lbs (one sandbag at a time) each time until at least 400lbs worth is tested.

The testing occurred with multiple people because the ATV racks and sand bags are very helpful and can be a safety issue.

Deliverables:
The calculated parameters of the deflection was calculated at the extreme and also at about 420lbs. At the extreme the rack would deflect at about 2.6” and at about 420lbs it would deflect at about 0.21”. The measurement for the 420lbs was about 0.756” of deflection. This could be because the tailgate movement wasn’t reduced and there may have been some movement for the original rack in the front of the truck bed. This may have been why the results were higher than the calculated results.

The strain that was calculated for the rack extension was for 420lbs as well at 407$\mu\varepsilon$. The amount of strain that was measured when the testing was done was about 320$\mu\varepsilon$.

For the original data and graphs to represent the data trends, please the appendix.

Conclusion:
In conclusion these are the two major testing methods that was used, deflection and strain. As discussed above these were measured by using sand bags to slowly apply weight to the rack to measure the deflection and the strain.

Report Appendix:

Gant Chart:

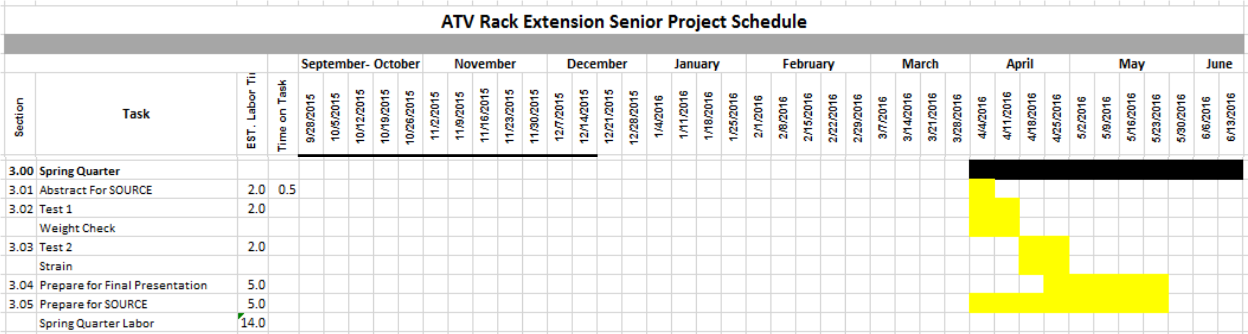


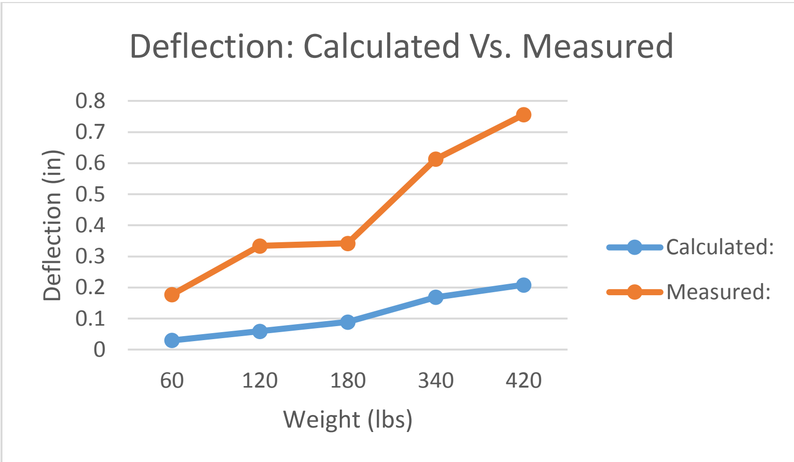
Table 1: Deflection

Deflection		
Weight (lbs):	Calculated:	Measured:
60	0.0297931	0.177
120	0.05958621	0.334
180	0.08937931	0.342
340	0.16882759	0.613
420	0.20855172	0.756

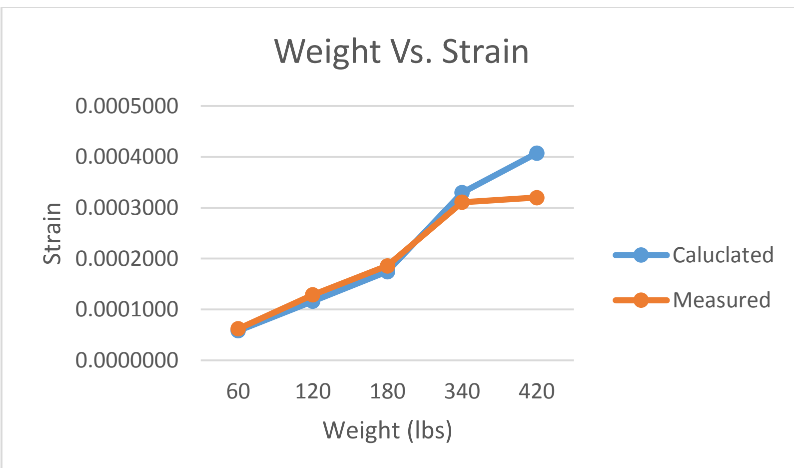
Table 2: Strain

Strain:	Calculated	Measured
Weight (lbs):	Strain	Strain
60	0.0000582	0.000062
120	0.0001164	0.000129
180	0.0001746	0.000186
340	0.0003297	0.000311
420	0.0004073	0.00032

Graph 1



Graph 2



Appendix J

In the following pages consist of a resume.

smithtri@cwu.edu
253-988-9616
19814 126th St Ct E
Bonney Lake WA, 98391

Trista Smith

OBJECTIVE:

To obtain a challenging and rewarding engineering internship that offers diverse job responsibilities with an engineering discipline, one that will fully utilize my technical knowledge and leadership abilities, but can help me gain more experience within the Mechanical Engineering field.

EDUCATION:

Central Washington University

Graduation Date: June 2016
Major: Bachelor of Science, Mechanical Engineering Technology
Minor: Business

Relevant Courses: Composites and Plastics, Thermal and Fluid Dynamics, Strengths of Materials, Metallurgy, Statics, Machining (Milling Machine, Lathe, Drill), Physics, Pre-Calculus, Calculus, Business Law, Accounting 1 & 2, and Chemistry.

Technical Skills: AutoCad, Industrial Engineering Technology (Basic Engineering), Information Technology (Microsoft Word, Excel, Access, and Power Point), Engineering Project Cost and Analysis, and Solid Works (3D Modeling).

Abaris Training

Course Taken: Advanced Composite Structures: Fabrication and Damage Repair-Phase 1.

Learned about the general history of Composites and developed the terminology needed to succeed in the work environment. Built multiple panel layups including prepreg and carbon uni-tape materials while learning about the symmetric and asymmetric laminates, and layup using dry glass cloth and liquid epoxy resin. Formed various ways to vacuum bag with different types of bleeder/breather sequences and resin flow characteristics. Utilized pleats to minimize bridging when vacuuming a part with a high angled core. Learned oven curing when using a vacuum bag and the cooling requirements and performed a repair that involved sanding the part in preparation for wet layup.

LEADERSHIP EXPERIENCE:

President- Society of Manufacturing Engineers Club. Central Washington University. (June 2014-Current)

Lead the student chapter at CWU creating activities for other members for participation, on and off campus. Communicate with a lead member at SME to help with activity ideas and gain contact with different companies for tours. Coordinate and work with the American Society of Mechanical Engineers (ASME) President for combined meeting plans and assist each other when needed.

Vice President- Society of Manufacturing Engineers Club. Central Washington University. (Sept. 2013 – June 2014)

Lead and establish group activities to engage and learn about the engineering field. Coordinate group field trips to local businesses.

WORK EXPERIENCE:

Hexcel **June 2015-Sept. 2015**
Kent, WA
Manufacturing Engineering Intern

Wrote and edited planning while supporting the shop floor. Analyzed part engineering and spec requirements.

Frankies Pizza **une 2013- Sept. 2013**
Bonney Lake, WA **June 2012- Sept. 2012**
March 2011- Sept. 2011

In Store Worker and Delivery Driver

Deliver and make pizza while bringing a positive and energetic attitude to the atmosphere while still working efficiently with my coworkers. Receive payments from customers and account for daily end of shift store balances.

St. Elizabeth Hospital **Jan. 2011 to Sept. 2011**
Enumclaw, WA
Volunteer

Emergency room receptionist. Monitored visitor access and directed patients to the correct destination while maintaining security awareness. Gained communication skills while receiving phone calls and relayed messages to emergency room nurses and doctors.

Boeing Employee Credit Union **Jan. 2010 to June 2010**
Bonney Lake High School BECU Center
Financial Consultant

Assisted members in creating their financial accounts and helped members accomplish their financial objective by assisting them in their financial needs.

Bonney Lake Sumner Little League **2009, 2010**
Bonney Lake, WA
Umpire

Ensured the rules of softball in games throughout the season. Worked with coaches and parents to help the game run smoothly.

Wild Waves Theme Park **June 2009 to Aug. 2009**
Federal Way, WA
Trained/Certified Lifeguard

Maintained constant surveillance of patrons in the facility; acted immediately and appropriately to secure the safety of patrons in the event of an emergency. Presented professional appearance and attitude at all times, and maintained a high standard of customer service.

COMMUNITY SERVICE:

FIRST Lego League Competition **January 17, 2015**
Volunteer Judge

Judged the Core Values Section of the competition. These values include teamwork, inspiration, and gracious professionalism. Listened to the students about how they applied these core values in their project and outside of this project and competition

.ACCOMPLISHMENTS:

30 Under 30 Nomination for Manufacturing Engineering Magazine
Nominated By Natalie Lowell

Nominated by Natalie Lowell, Manager of Membership Engagement at SME in Dearborn MI. This honors young leaders in manufacturing and the STEM fields that underpin this profession.

CLUBS:

Society of Manufacturing Engineers (SME), Central Washington University.
Member. 2012-Present.

REFERENCES:

Timothy Grangruth (206) 437-0066
Other References available Upon Request.