Wrapping Test System for CNH Round Balers

Phase 4 Final Report

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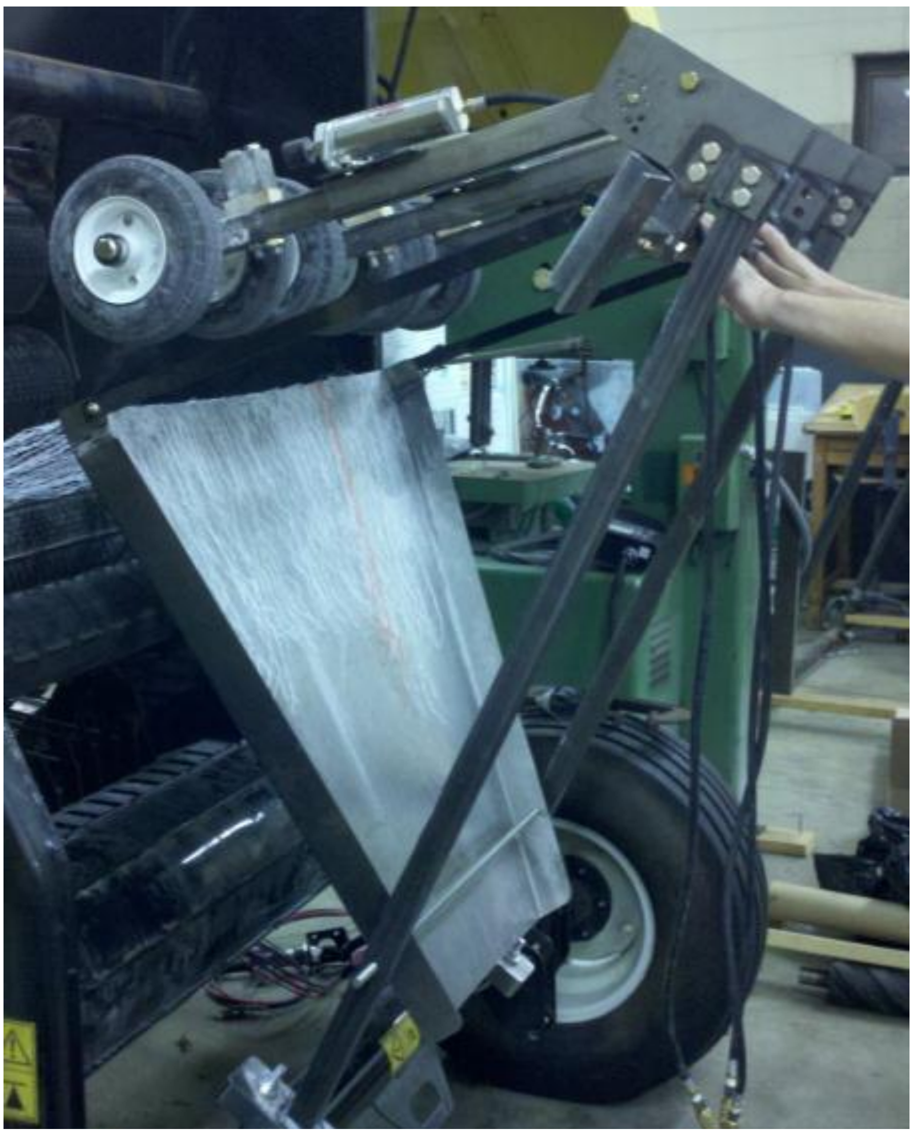

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Problem Statement and Project Scope

Current methods for pulling the netting during New Holland round baler net wrapping tests are inefficient, time consuming, and depend on availability of crop. Currently, CNH has two methods for performing these tests:

1. The first method can be performed inside of the CNH facility, and involves pulling the netting out of the baler by hand, wrapping the net around the lower roller within baler and securing it with tape. The operator then runs baler, and the roller which is securing the netting wraps up the netting, pulling it from the baler. Once testing is completed, the operator must unwrap the netting from the roller, and dispose of the netting.
2. An alternative current method simply involves attaching a baler to a tractor, and taking it into the field. Once in the field, an actual bale of hay is made, and crop is used to test the wrapping system.

CNH has tasked the University of Delaware Mechanical Engineering design team with the task of designing and testing an effective and feasible prototype which will act as an alternative to the two currently used methods of testing net wrapping performance. The mechanism must operate within a New Holland round baler chamber and will successfully pull netting from the baler. The design will be used as a lab stand for future round baler net wrapper functionality development.

Project requirements

There were no updates for the prototype requirements during phase IV of the design process. Refer to phase III for a table of the final prototype requirements. For reference, the table has been reprinted below.

Table 1: Ranked sponsor wants and corresponding metrics

Ranked Sponsor Wants		Metrics		
Rank	**Description**	**Metric**	**Range**	**Target Value**
1	Successfully pulls netting from baler	Pulling force	100 - 150 lb	150 lb
2	Speed is adjustable to match PTO speed	Speed of Pull	300 - 450 ft/min	424 ft/min
3	Weighs less than 100 lb	Weight	< 100 lb	80 lb
3	Safe to Use	Pinch points exposed to operator	No Range	0 Pinch Points
5	Fits within lower part of the baler frame	Width	fixed	4 ft
6	Detachable from baler frame	Number of permanent connections to baler	No Range	0 Permanent Connections
7	Uses minimal net length at start-up	Starting exposed net length	1-6 inches	1 inch
8	Lasts for 50000 cycles	Cycles to Failure	>= 50000 cycles	75000 cycles
9	Cost Effective	Cost	$0 - $5000	$3,000
10	Minimal time between trials	Time between trials	1 - 5 min	2 min

The team also determined during phase III that the following requirements had to be met in order to satisfy all of the requirements set by the sponsor. The metrics obtained were determined through preliminary tests performed during phase III of the design process.

Table 2

New Metrics from Testing Results			
Metric	**Range**	**Target Value**	**correlated sponsor want**
Normal force required to pinch and pull net	>=581 lb	600lb	successfully pulls the netting
Displacement of Tire	<8 mm	5 mm	successfully pulls the netting

The two new metrics directly correlate to the sponsor want for the baler to successfully pull the netting from the baler. In order for the prototype to successfully pull the netting from the baler, the prototype had to meet the new metrics determined during the phase III preliminary tests. Consequently, no additional validation tests were required for these two metrics as they are accounted for through the validation of the primary sponsor want that the net be pulled successfully from the baler.

Overview of Final Prototype

After successfully completing the drawing package, all completed drawings were delivered to the sponsor for fabrication. Additionally, all required purchased parts were tabulated and passed onto the sponsor to place the orders. The purchased parts were delivered and the team was able to inspect and order any parts that were seen to be missing while waiting on the fabrication of machined parts. CNH made a majority of the parts in their development facility for the team. Once all parts were fabricated, the ones which were part of a weld assembly were moved into a new work order for completion. The weld assemblies were the last to be completed. Once finished, the team was able to pick up all fabricated parts from the CNH technical center. Table 1 provides a complete bill of materials. The completed drawing package can be found in the appendix.

Table 3: A complete bill of materials for the finalized design

CNH Part Number	Description	Quantity
84560697	Foot Piece	2
84560698	Main Support Bar	2
84560699	Pneumatic Cylinder	3
84560700	Vertical Attachment	3
84560701	Gusset Plate	6
84560702	Vertical to Horizontal Bar Connector Sheet	6
84560703	Horizontal Bar	1
84560704	Bracket for Pneumatic Cylinder	3
84560705	Inner Clamp Piece	2
84560706	Pneumatic Cylinder Support Sheet	3
84560708	Inner Telescoping Tube	3

CNH Part Number	Description	Quantity
84560721	Vertical Attachment Spacer	6
84560722	Main Bar Spacer	6
84560723	Weld Assembly 1	2
84560724	Sub Assembly 1	1
84560725	Outer Telescoping Tube	3
84560726	Threaded Rubber Bumper	3
84560727	Adhesive Rubber Bumper	2
84560728	Pneumatic Regulator	1
84560729	Regulator Mounting Bracket	1
84567076	Air Hose	6
84567077	Air Toggle Valve	1

84560709	U-Bolt	2
84560710	L-Bracket Tray Support	2
84560711	Shaft	1
84560712	Tire	6
84560713	Steel Shaft Collar	18
84560714	1/4" Coupler Body	1
84560715	Tray Connector Piece	2
84560716	Tray	1
84560717	Outer Clamp Piece	2
84560720	Pushing Block	3

84567078	3-Way Air Splitter	1
84567079	1/4" Coupler Plug	4
84567080	Sub Assembly 2	1
84567081	Sub Assembly 3	1
84567082	Weld Assembly 2	3
84567083	Weld Assembly 3	3
84567084	Weld Assembly 4	1
84567085	Weld Assembly 5	3
84567087	Final Assembly	1

With all parts of the design obtained, assembly of the prototype was completed. The following is a detailed description of the final prototype assembly, split into sub-assemblies.

<u>Sub-Assembly 1</u> (Part No. 84560724)

1. Attach Weld Assembly 1 (84560723) between Weld Assembly 2 (84567082) and Weld Assembly 3 (84567081) using ½” bolts. This is done by connecting the Vertical Attachment part of Weld Assembly 1 to the corresponding holes in the gusset plate weld assemblies.
2. Connect Weld Assembly 4 (84567083) between Weld Assembly 2 and Weld Assembly 3 using ½” bolts. This step is completed by connecting the Main Support Bar to the locating holes in Weld Assembly 2 and 3.
3. Attach L-Bracket Tray Support (84560710) to the corresponding holes on the Horizontal Bar using ¼” bolts. Do this one on each side of Horizontal Bar.

<u>Sub-Assembly 2</u> (Part No. 84567080)

1. Slide Shaft (84560711) into the center Inner Telescoping Tube (84560708), being sure not to thread the shaft through the other two Inner Telescoping Tube. Secure the tube with Steel Shaft Collars (84560713) on both sides.
2. Slide a total of 4 Tires (84560712) onto the shaft. Place 2 tires on each side of the center Inner Telescoping Tube, securing each wheel with collars on each side. Place wheels at equal distances apart from each other.
3. Attach the two other Inner Telescoping Tubes onto the shaft, one on each side of the shaft and secure with collars on each side of both bars.
4. Slide the remaining two wheels onto the shaft, one on each side of the shaft. Secure these wheels with collars and create equal spacing between all shaft components.
5. Bolt Pneumatic Cylinder Bracket (84560729), with Pneumatic Cylinder (84560728) attached, to the welded plate found on the Outer Telescoping Tube (84560725) by using two 5/16” bolts. Do this for all three Outer Telescoping Bars.
6. Insert Inner Telescoping Bars into respective Outer Telescoping Bars.

Sub Assembly 3 (Part No. 84567081)

1. Attach Tray Connector Piece (84560715) to the outside wall of Tray (84560716) using ¼" bolts. One connector piece is attached per side of tray.

Final Assembly (Part No. 84567087)

1. Attach Sub-Assembly 2 (84567080) to Weld Assemblies 2 and 3 by inserting the Outer Telescoping Tube between the two weld assemblies and fixing the three pieces with two bolts. The main fastener is a ½" bolt and the other, used to locate the angle of the outer telescoping bar, is a ¼" bolts.
2. Connect Sub-Assembly 3 (84567081) to Sub-Assembly 1 (84560724) by attaching the Tray Connector Piece to the L-Bracket Tray Support by means of ¼" bolts.
3. Insert ½" bolts into locater holes in the lower portion of the Main Support Bar. Tighten the bolt to the Main Support Bar with a nut.
4. Rest Tray on bolts attaches to Main Support.
5. Secure prototype to baler by two means. Attach Foot Pieces to baler axle using U-Bolts (84560709). Clamp to baler walls using ½" bolts which connect Sub-Assembly 1 to Outer Clamp Piece (84560717).
6. Connect Air Hose (84567076) to the Pneumatic Cylinders (84560699) using the threaded ports on the back of the cylinder. Three hoses will now run out of the design (one from each cylinder)
7. Connect the three hoses to the 3-Way Air Splitter (84567076) and then fix another hose to the connected end. This hose runs to the Pneumatic Regulator (84560728). From the regulator, connect a hose to the Air Toggle Valve (84567077). Connect hose to the other end of the valve, and connect that to the air supply.
8. The prototype should be ready to operate.

Figures 1-6 provide several different views of the assembled prototype as well as pictures of the mechanism sitting within the baler.

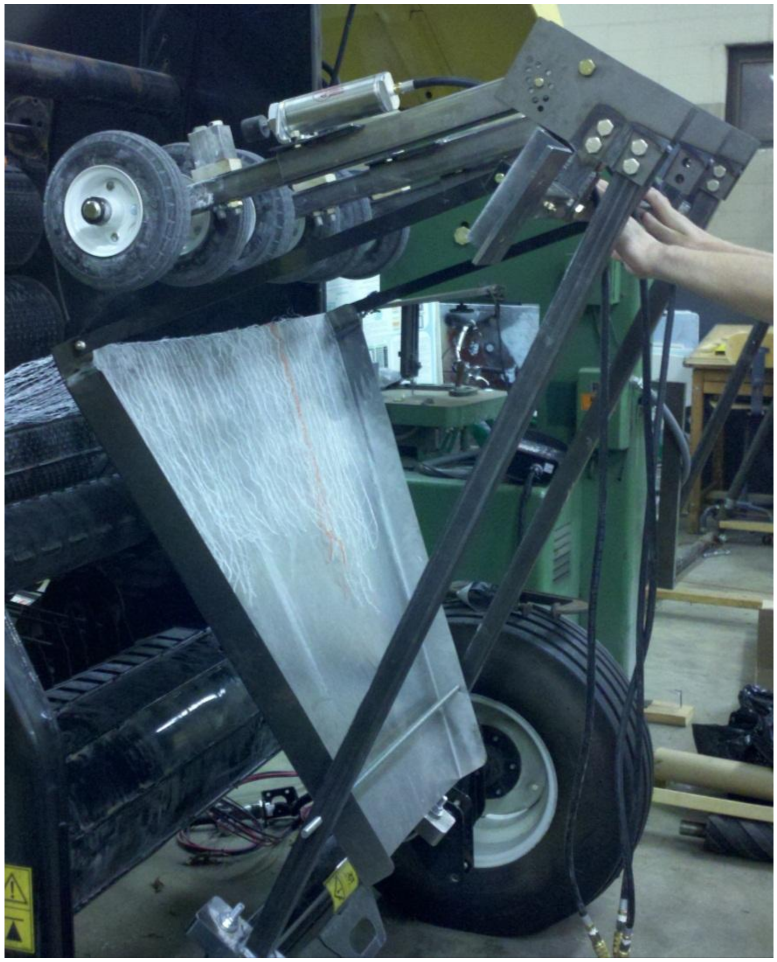


Figure 1: A view of the prototype being rotated into the baler

Figure 2: A side view of the prototype

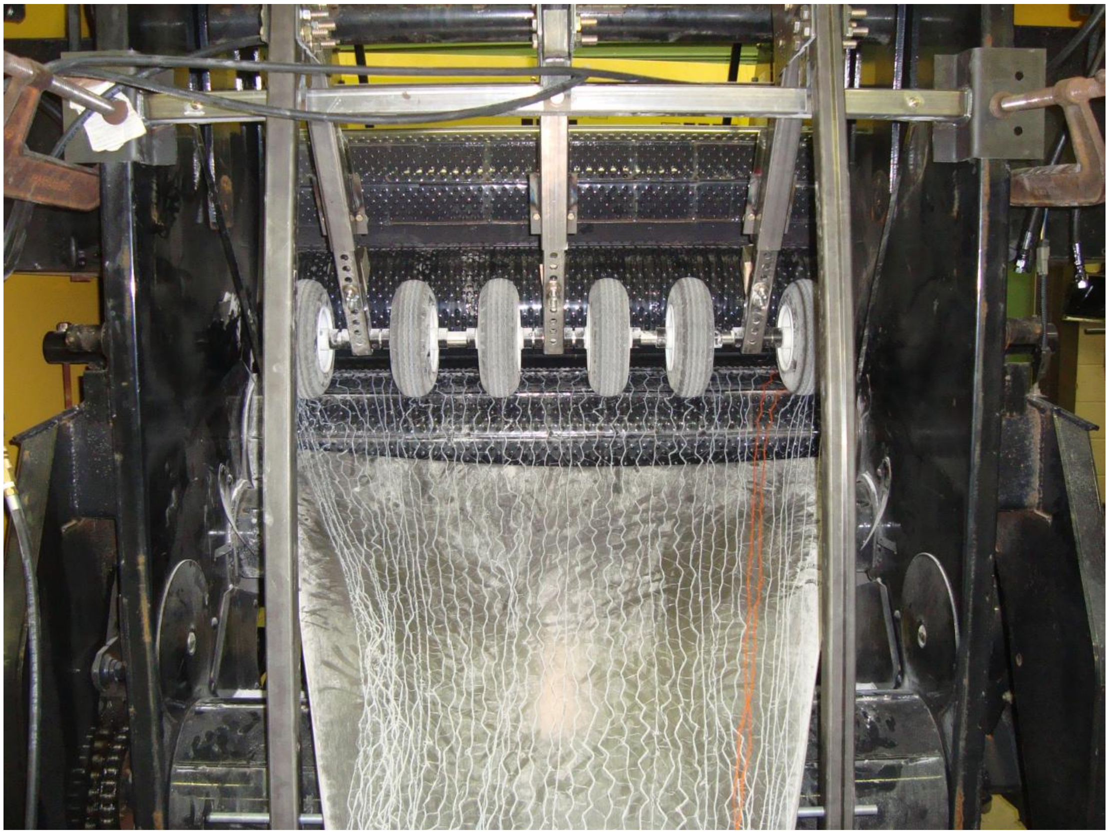


Figure 3: A view of the prototype secured in the baler

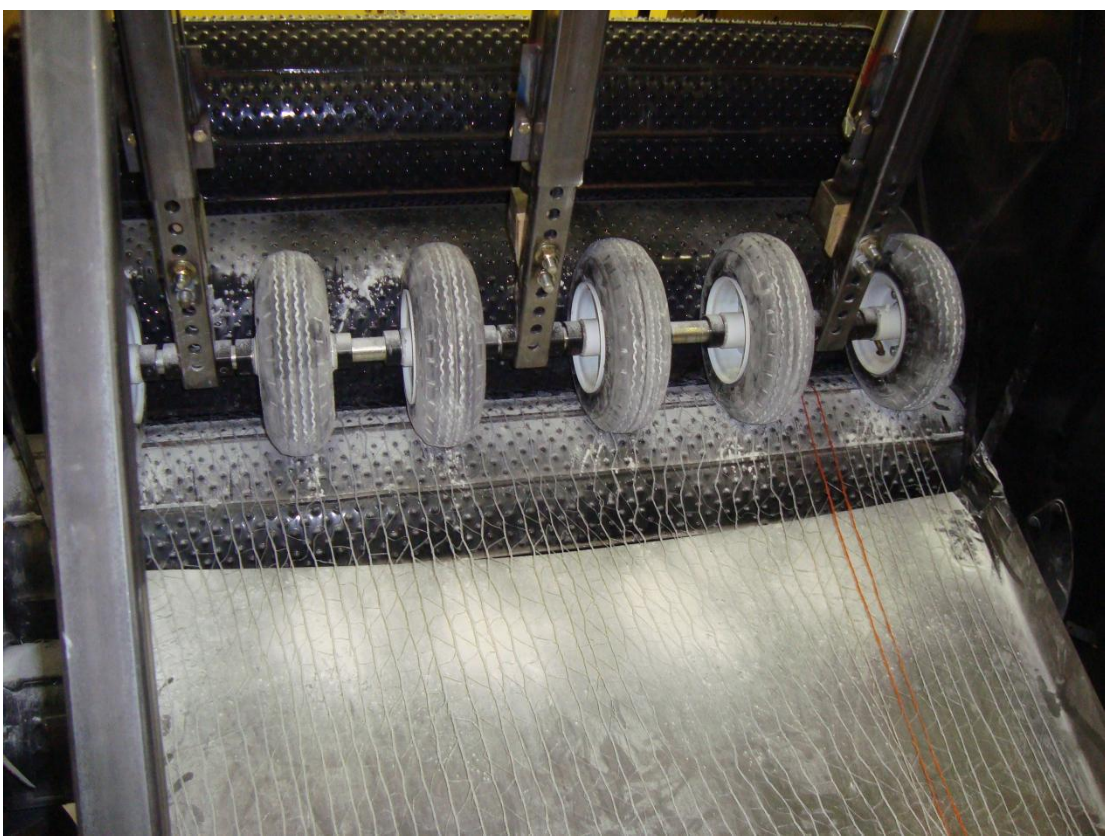


Figure 4: A close-up view of the tires within the baler

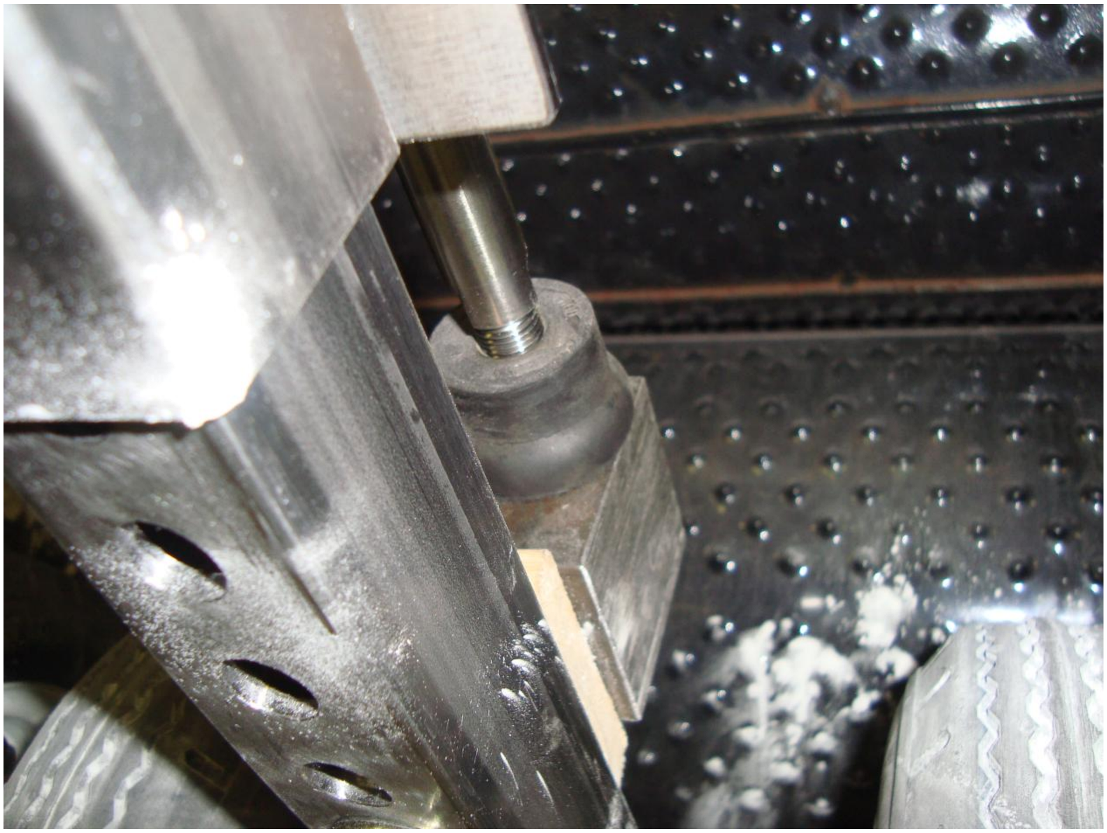


Figure 5: A close-up view of the pneumatic cylinder with rubber bumper actuated and pushing against block

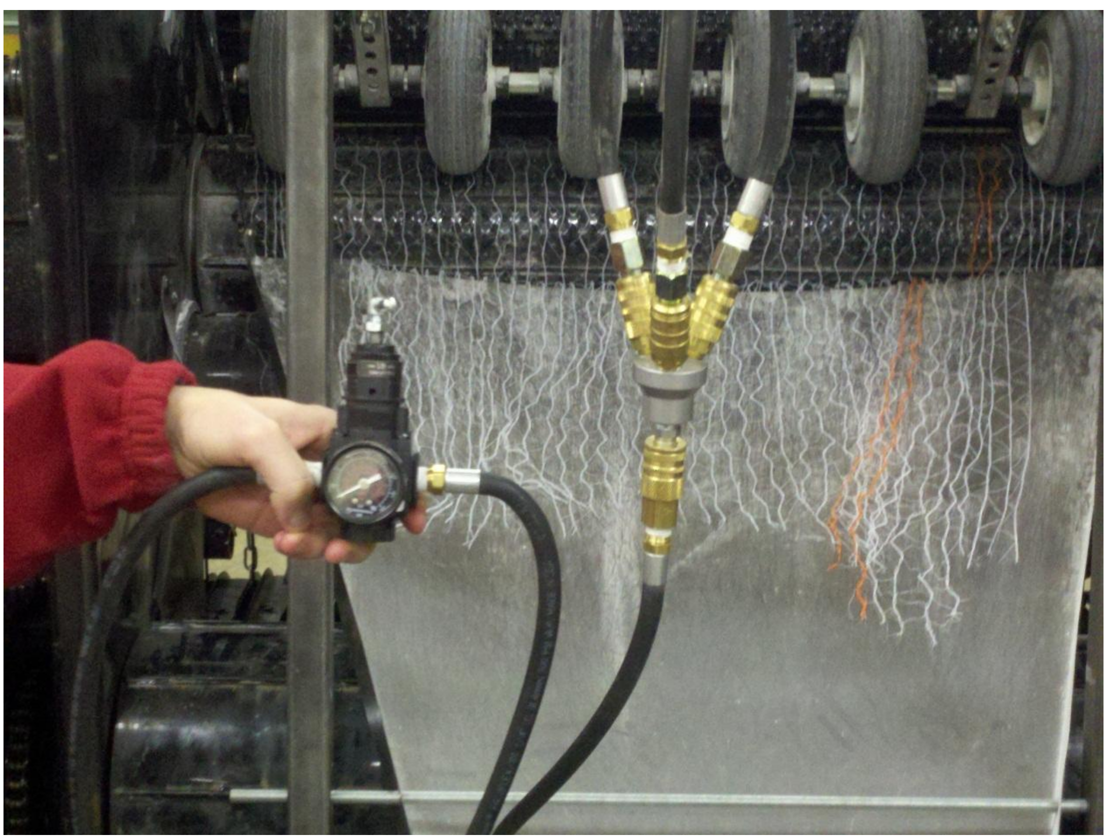


Figure 6: The pneumatic components of the design, leading to the air supply on left and 3 cylinders above

Metric Testing Plans

The following set of test plans outlines how the team attempted to validate all performance metrics within the design. The team made an effort to develop tests which would provide results which could be used to easily determine whether the sponsor's wants and constraints were met.

Customer Want: Can be operated by one technician
Metric: Prototype Weight
Target Value: 100lb

Objective of Testing

The objective of this test is to verify that weight of the prototype satisfies the constraint set by CNH. CNH desires a machine that can be operated by one technician. This means the operator must be able to lift, install, and run the mechanism without assistance from another person. The design team saw weight as the biggest factor in this constraint, and used weight as a metric to measure whether or not one person would be able to operate the machine by his or herself.

The team discussed with the sponsor and assigned this weight metric with a value of 100lb. Therefore, if the prototype of the assembly weighs less than 100lb, then the mechanism successfully meets the requirement of being operable by one person.

Description of the Test Rationale, and Procedures

The measurement device in this test will be a simple scale. The person performing the test will measure each component of the assembly when disassembled, and then add the individual component weights to obtain the weight of the entire prototype.

Experimental Plan

- *Variables to be measured*: Weight of individual prototype components
- *Variables to be changed*: Part being measured
- *Variables to be held constant*: Scale being used, initial weight reading on scale (should be zero)

Procedures to Prepare Test Samples

Before performing the test and measuring the weights of the prototype components, the person initiating the testing should follow the following procedure:

1. Take note of the part being measured to ensure it is not measured more than once
2. Be sure no excess pieces or debris are being measured with the part

Data Collection Plan

The test will be completed as follows:

1. Obtain individual part to be weighed

2. Zero the scale which will weigh the part
3. Measure the weight of the part
4. Record measurement
5. Repeat steps 2-4 five times for each component
6. Repeat steps 1-5 until all parts have been weighed
7. Add individual weights to obtain total weight of the prototype

Table 4

Trial	Part	Weight 1	Weight 2	Weight 3	Weight 4	Weight 5	Mean
1	Weld Assembly 1a (Leg 1) and Hardware						
2	Weld Assembly 1b (Leg 2) and Hardware						
3	Shaft						
4	Tire 1						
5	Tire 2						
6	Tire 3						
7	Tire 4						
8	Tire 5						
9	Tire 6						
10	18 Shaft Collars						
11	Inner Telescoping Tube a with Pushing Block a and Hardware						
12	Inner Telescoping Tube b with Pushing Block b and Hardware						
13	Inner Telescoping Tube c with Pushing Block c and Hardware						
14	Tray along with Struts and Hardware						
15	Assembled Horizontal Bar with Tray L-Brackets (a and b), Gusset Plates, Weld Assemblies (2-6), Pneumatic Cylinders (a, b, and c), Cylinder Brackets (a, b, and c), and Hardware						
Total							

Parts that were weighed but not added to the total system since they are put on to secure the structure once it is already inside the baler:

Table 5

Trial	Part	Weight 1	Weight 2	Weight 3	Weight 4	Weight 5	Mean
1	Outer Clamp Piece a						
2	Outer Clamp Piece b						
3	Both U-bolts with Hardware						
Total							

<u>Data Analysis Methods</u>

The total weight of the prototype will be determined by calculating the summation of the mean weights of each part. The formula for this calculation is as follows:

$$\sum_{i=1}^{43}(mean\ of\ trial\ i)$$

With this total weight, it can be determined if the target value was met.

<u>Risks and Contingencies</u>

There are no major risks or contingencies for this test. The test is simple and should only require the parts and a simple scale.

<u>Failure Analysis</u>

If the test fails, then the prototype is overweight and the design team must provide a solution to put the design within the sponsor's constraints.

<u>Resources</u>

For this test, the team will need the following equipment:

- All components of the design
- Scale to measure weight

Customer Want: Detachable from Baler
Metric: Number of Permanent Connections to Baler
Target Value: 0 Permanent Connections

Objective

The objective of this test is to determine if the designed prototype is completely detachable from the baler. The following test plan will be carried out to determine if the prototype meets the sponsor requirement that the design should be detachable from the baler. The test will involve a count of fixed connections between the baler and the prototype.

Procedure

- On the prototype, mark the connection points to the baler, say 1-10
- On the count sheet, describe the connections as either of the following
  - *Fixed (Permanently attaches to baler e.g. weld)*
  - *Not fixed (can be detached from baler)*
- Record the total number of "fixed" connections and "not fixed" connections in the table below

Table 6

Connection	Fixed or Not Fixed
Axle Connection 1	Not Fixed: Attached by U-Bolt
Axle Connection 2	Not Fixed: Attached by U-Bolt
Baler Frame Connection 1	Not Fixed: Attached by C-Clamp
Baler Frame Connection 2	Not Fixed: Attached by C-Clamp

Analysis

If fixed connections is >=1, the prototype is not detachable.

Otherwise, the prototype is detachable and meets the detachability requirement outlined in the sponsor needs and wants (Phase II)

Customer Want: Speed of Design matched PTO Speed
Metric: Speed of Prototype Roller
Target Value: Equal to the Baler Roller Speed

Objective

The objective of this validation test is to determine if the prototype speed matches a preset PTO (hence the baler) speed.

At a given PTO speed, the baler rollers and the prototype rollers should have the same surface velocity. To perform this test, the team will measure the angular velocity of the prototype and the baler roller using a tachometer. These results will be used to find the tangential surface velocity of both the tires and the baler roller. The speeds should match with 95% confidence.

Procedure

- Power the tractor and with the PTO set at zero, connect all the baler fittings to the tractor.
- Attach the prototype to the baler and actuate the pneumatics slightly.
- On exposed surface of the prototype tire mark up a "bright spot" for later use with the laser to measure rpm.
- Start the tractor and set its engine speed to 2000rpm.
- Turn on the PTO and allow the baler to begin rotating. The prototype wheels should roll with the baler roller.
- Using the tachometer, measure the angular velocity of the baler roller and each of the six tires on the prototype.
- Record ten measurement trials of the tire rpm in the following table:

Table 7

Tire	Tire Angular Velocity (rpm)	Baler Roller Angular Velocity (rpm)
1		
2		
3		
4		
5		
6		

- Repeat the above procedure with the tractor PTO set to 1500, 1000 and 500 PTO speeds.
- Measure the distance traveled on the baler roller by the tire through one complete tire revolution.

Analysis

Using the results from the test, calculate the ratio of the baler roller to tire angular velocities. This can be thought of as a gear ratio and will help determine if the tangential speeds of the tire and roller match.

Calculate the mean ratio and determine the standard deviation. Compare this mean and standard deviation to the ratio obtained through dividing the circumference of the baler roller by the distance traveled by the tire in one tire revolution.

Determine if the prototype speed matches that of the baler with 95% confidence (two standard deviations).

Risk and Contingencies

Avoid lose clothing that may be caught up in the rotating parts.

Resources

- Laser digital tachometer.
- Prototype
- Tractor with PTO drive shaft
- Data sheet

Customer Want: Fits within the lower part of the baler frame
Metric: Width and Height
Target Value: 4 feet

Objective

The objective of this test is to measure the maximum width and height of prototype to determine of the customer want of fitting within the lower part of the baler frame has been met.

Description of Test Rationale, and Procedures

This test will prove if the prototype will work within a four foot baler with the back hatch still attached.

Procedures to Prepare Test Samples or Materials

Once the parts are all assembled, while using a tape measure, measure by hand the width and height of the prototype. Measurements can be taken at various lengths apart from one another to ensure with confidence that previous measurements were correct or lie within the given constraint/target value.

Data Collection Plan

In a listing format, record the width and height measurements on paper:

Table 8

Sample	Width	Height
1		
2		
3		
4		
5		

Data Analysis Methods

Determine whether or not the measurements found lie within the given constraints. These constraints consist of a maximum width of four feet and maximum height of six feet. If so, to further confirm this, pick up the prototype and set it on the axel, rotate it into the back end of the baler, and see first-hand if it fits inside and under the rubber belts.

Failure Analysis

If it so happens that the width and height requirements are not met, immediate action has to be done, possibly extra machining, by the team to fix the problem.

Resources
-*Test Equipment*: Pen and paper, tape measure, assembled prototype

Customer Want: Minimal time between trials
Metric: Time between trials (set-up time)
Target Value: 2 minutes

<u>Objective</u>

Measure the time between X number of trials and compare these to the target values.

<u>Description of Test Rationale, and Procedures</u>

This test will determine if two people are able to set up and run the prototype safely and effectively in a timely manner between each cycle.

<u>Experimental Plan</u>

-*Measured or Response Variable*: Time it takes between each trial
-*Variables to Change*: Pressure that is being applied
-*Variables to Held Constant*: Steps to force netting through along with length in which duck bill is inserted

<u>Procedures to Prepare Test Samples or Materials</u>

Assemble the prototype with all of the required parts. Move prototype into the vicinity of the baler, set it on the axle, and rotate it into the bale chamber until the clamps fit snug against the outer wall casing of the baler. Begin to clamp one side to the baler frame with two large bolts and outer clamp piece. Then bolt both feet to the axel with the U-bolts. Clamp the other remaining side to the outer wall casing. After these steps are taken, you may proceed to test once the tractor and PTO are set up correctly.

<u>Data Collection Plan</u>

In a listing format, record the time it takes between running each trial on paper:

Table 9

Sample	Time Between Trials (seconds)
1	
2	
3	
4	
5	
Average	
Standard Deviation	

Data Analysis Methods

Determine whether or not the measurements found lie within the given target. This target was set to have a two minute max between each trial. After a considerable amount of trials, the verdict of whether the target will be met will be clear. It also depends on if the person running the equipment is familiar with the tractor, PTO, baler, and prototype.

Risks and Contingencies

The risks are cut down since the prototype is automated and the person running the equipment does not have to pull the netting at all in between cycles. Still the operator should be aware of the dangers that are present.

Resources

- *DAQ Hardware, Instruments*: Tractor, round baler, and PTO drive
- *Test Equipment and Hardware*: Prototype, pencil, and paper
- *People*: Facilitators of the test

Customer Want: Uses minimal net length at startup
Metric: Initial starting Exposed Net Length
Target Value: 1 inch

Objective of Testing

The purpose of this test is to determine the smallest amount of exposed netting that the mechanism can initially pinch and pull at the startup of a simulated net-wrapping cycle. During an actual bale cycle, once the net wrap cycle is initiated, the duckbill enters the bale chamber and exposed netting to the hay. An exposed net length of 1 inch is typically all the bale of crop needs to pinch and begin wrapping itself. Because the duckbill typically exposes 1 inch of netting, this is the target value for the length of netting the design is capable of pinching.

Description of Test Rationale, and Procedures

This test will be performed within a CNH-provided round baler. The team will measure lengths of exposed netting and vary these lengths between trials. The netting will then be retracted out of the baling chamber, the pulling mechanism will be properly installed, and the baling chamber will be powered via the PTO of a tractor. Once the net is reinserted into the baling chamber, these tests will continue to vary the net length until a minimum starting length is determined. Once the team has found the smallest amount of starting net length that the design can pull, it can be decided whether or not the design meets the sponsor's constraint.

Experimental Plan

- *Variables to be measured*: Whether or not the prototype can begin pulling the netting
- *Variables to be changed*: The starting exposed length of netting within the bale chamber
- *Variables to be held constant*: Pressure of tires, angle of applied force, PTO Speed, exerted force

Procedures to Prepare Test Samples

Before performing the test, the person initiating the testing should adhere to the following procedure:

1. Assemble the prototype and transfer to testing site
2. Properly install the pulling mechanism into the baling chamber
3. Secure the prototype to baler by:
    a. Clamp one side of the prototype to the frame of the baler
    b. Secure to baler axle using U-bolts
    c. Clamp remaining side to baler frame
4. Connect pneumatic system to prototype by attaching hoses to the pneumatic cylinders, leading to regulator, valve, and air supply. (Refer to schematic of the pneumatic system for detailed setup instructions)
5. Attach baler to tractor via PTO drive shaft

Data Collection Plan

The following procedure will be followed to determine the minimum starting net length required:

1. Prior to starting the tractor and PTO, actuate duckbill and pull out netting by hand, cutting the net to the desired starting length (as per Table 8)
2. Once this length has been set, retract the duckbill from the baling chamber
3. Apply pressure to pneumatic cylinders, forcing tires onto baler rollers
4. Turn on tractor and begin to run the PTO at maximum speed
5. Reinsert the duckbill into the baling chamber to allow the netting to lay over the baler roller
6. Record whether or not the netting is successfully pulled from baler
7. Repeat steps 1-6 until all starting net lengths are measured and a minimal starting length is determined

Table 10: Data table for test of minimum initial starting net length

Trial	Starting Net Length (in)	Net Pulled?					
		Yes(Y)/ No(N)	Yes(Y)/ No(N)	Yes(Y)/ No(N)	Yes(Y)/ No(N)	Yes(Y)/ No(N)	Yes(Y)/ No(N)

Data Analysis Methods

From the test, it should be clear what the design is capable of in terms of how little netting is needed to be exposed for a successful bale cycle simulation. With the value for this starting length, the team can determine whether or not the design meets the sponsor's want.

Risks and Contingencies

Due to the high forces being applied during this testing, there are safety precautions that the operator should adhere to. Safety goggles should be worn, and no loose clothing or jewelry should be exposed while the test is underway. Once the PTO is initiated and the test has begun, a safe distance should be kept. The pneumatic regulator is in a position such that the operator has no need to enter the bale chamber. If there is a problem during the testing, the tractor and PTO should be immediately shut off.

Failure Analysis

In the event that the starting net length required is too large (the duckbill has a maximum amount of length that can be inserted into the baler) then the team must perform a redesign and suggest a way to accomplish the sponsor constraint of minimal starting exposed net length.

<u>Resources</u>

Equipment required for the test includes:

- Tractor with PTO hookup
- Baler with PTO driveshaft
- Pneumatic air supply
- Assembled prototype
- Spool of netting within baler

The facilitators of this test are the four members of the CNH design team

Customer Want: Successfully Pulls Netting from Baler
Metric: Pulling Force
Target Value: 150lb

Objective of Testing

The objective of this test is to validate the key aspect of the design, its pulling force. The purpose of this prototype is to pull netting from a CNH baler. This test will show if the design can successfully serve its purpose. The overall objective of the test is to measure the pulling force of the prototype and determining whether the design meets the sponsor's want.

Description of Test Rationale, and Procedures

The metric of pulling force was assigned as the most significant aspect of the design and must be met to satisfy the sponsor's fundamental want. The team will perform an indirect measurement of the pulling force. The pulling force of the prototype will be determined by first measuring the amount of normal force the design can apply to the baler roller. Then, using these results and the coefficient of friction determined in the design phase of the project, the pulling force of the system can be calculated.

Experimental Plan

- *Variables to be measured*: Normal force exerted by prototype
- *Variables to be changed*: Pressure applied to the pneumatic cylinders
- *Variables to be held constant*: Pressure of tires, angle of applied force, PTO Speed

Procedures to Prepare Test Samples

Before performing the test and measuring the normal force of the prototype, the person initiating the testing should adhere to the following procedure:

6. Assemble the prototype and transfer to testing site
7. Secure the prototype to baler by:
    a. Clamp one side of the prototype to the frame of the baler
    b. Secure to baler axle using U-bolts
    c. Clamp remaining side to baler frame
8. Connect pneumatic system to prototype by attaching hoses to the pneumatic cylinders, leading to regulator, valve, and air supply. (Refer to schematic of the pneumatic system for detailed setup instructions)
9. Attach baler to tractor via PTO drive shaft

Data Collection Plan

The following procedure will be followed to measure the pulling force of the design:

1. Actuate duck bill to insert netting into the bale chamber

2. Manually pull extra netting out of duck bill into bale chamber to ensure tire is in complete contact with the netting once pressure is applied
3. Open valve within the pneumatic system to apply the initial test pressure to the main ribbed baler roller
4. Turn on tractor and set PTO speed (maximum speed) to run the baler and begin test
5. Record pressure and whether or not it successfully pulls the netting
6. Vary pressure in accordance to table 9 and record results
7. Once all pressures are tested, shutoff tractor and PTO and testing is complete

Table 11: Data table for test. Normal force calculated using F= (3 cylinders)*P*A where A = pi*r^2, r = 1in

Trial	Pressure (psi)	Calculated Normal Force (lb)	Netting Pulled? (Yes/No)
1	30	282.7	
2	40	377.0	
3	50	471.2	
4	60	565.5	
5	70	659.7	
6	80	754.0	
7	90	848.2	
8	100	942.5	
9	120	1131.0	

Data Analysis Methods

Using the lowest pressure needed to successfully pull the netting (determined using data collected) perform the following analysis to find the pulling force of the prototype.

$$\mu = 0.29 \ (calculated\ during\ friction\ testing)$$

$$F_{pulling} = \mu \times F_{normal}$$

From the friction testing, it was calculated that a normal force of 517lb was required to successfully pull the netting from the baler. The test performed here should show how close this calculation was to the actual pulling capabilities of the prototype. Using the equation provided above, the data table can be extended to include pulling force. Table 10 provides the space for the calculated data.

Table 12: Data table with space provided to include pulling capabilities of the design at different cylinder pressures

Trial	Pressure (psi)	Calculated Normal Force (lb)	Calculated Pulling Force (lb)
1	30	282.7	
2	40	377.0	
3	50	471.2	
4	60	565.5	
5	70	659.7	
6	80	754.0	
7	90	848.2	
8	100	942.5	
9	120	1131.0	

This analysis should provide the minimum applied normal force and cylinder pressure required to pull the netting while under tension.

Risk and Contingencies

Due to the high forces being applied during this testing, there are safety precautions that the operator should adhere to. Safety goggles should be worn, and no loose clothing or jewelry should be exposed while the test is underway. Once the PTO is initiated and the test has begun, a safe distance should be kept. The pneumatic regulator is in a position such that the operator has no need to enter the bale chamber. If there is a problem during the testing, the tractor and PTO should be immediately shutoff.

Failure Analysis

In the event that the netting is not successfully pulled from the baler at any of the tested cylinder pressures, then a redesign must be considered by the team in order to meet the sponsor's need of 150 pounds of pulling force.

Resources

Equipment required for the test includes:

- Tractor with PTO hookup
- Baler with PTO driveshaft
- Pneumatic air supply
- Assembled prototype

The facilitators of this test are the four members of the CNH design team.

Customer Want: Design is Safe to Use
Metric: Number of Pinch Points Exposed to Operator
Target Value: 0 Pinch Points

Objective of the Test

The objective of this test is to provide a way to verify there are no accessible pinch points to the user during assembly or automation of the mechanism.

Description of Test Rationale

The user has been provided a safe working distance from any pinch points to prevent injury. These pinch points are the six points of contact between the six pneumatic wheels and the baler roller as well as the three pinch points created between the pneumatic cylinders and their respective pushing blocks.

Experimental Plan

Validation of this metric was designed into the mechanism. The mechanism will be assembled and automated to verify that a safe working distance from pinch points has been incorporated in the design.

Procedures

During the setup of the automation process, the user would be using a pressure regulator, away from the baler, to provide the necessary pressure to the pneumatic cylinders. This creates the pinch points between the pneumatic cylinders and the pushing blocks and translates this pressure to create pinch points between the pneumatic tires and the baler roller. For this test plan, order the possible pinch points and determine if these locations are dangerous to the user during operation.

Table 13

Pinch Point within Design	Distance from Edge of Baler (in)	Pinch Point Exposed to User?
Pneumatic Cylinder 1		
Pneumatic Cylinder 2		
Pneumatic Cylinder 3		
Baler Roller and Tire 1		
Baler Roller and Tire 2		
Baler Roller and Tire 3		
Baler Roller and Tire 4		
Baler Roller and Tire 5		
Baler Roller and Tire 6		

Analysis

If the pinch points are more than 12 inches from the edge of the baler, then the pinch points are defined as ‘not exposed to operator’. This can be said because the operator should not enter the bale chamber during operation of the device, and 12 inches is a sufficient minimum distance to provide safety.

Risk and Contingencies

Injury or risk of injury can be avoided by educating the operator on the setup and automation of the mechanism. The user must know assembly procedures and automation procedures. The user must also be aware of possible swaying and that operation must be halted in order to gain access to the baling chamber.

Resources

Resources required are a CNH round baler, a tractor to provide power via its PTO, and the net pulling mechanism designed by the University of Delaware design team.

Customer Want: Cost Efficient Design
Metric: Cost of Prototype
Constrain: $5000

<u>Objective of the Test</u>

The objective of this test is to confirm that the mechanism costs less than the given constraint of $5000 provided by CNH.

<u>Description of Test Rationale</u>

This will verify that the cost of the mechanism is less than $5000, thus showing the mechanism is acceptable to CNH.

<u>Procedures</u>

Create a list of all materials and quantity used in the mechanism as well as their purchase costs, manufacturing costs, and if applicable, fabrication and capital costs. Then, total up the final costs and compare to the $5000 limit.

<u>Data Collection</u>

Table 14

Part No.	Description	Qty.	Price (ea.)	Notes	CNH Part No.	Cost
					Total Cost:	

Data Analysis

Compare to the $5000 limit. If the total cost is less, the design team has successfully designed the mechanism for the cost metric.

Resources

Resources needed are a master parts list, quantity of each part, and a calculator or access to Excel.

Metric Test Results

The following section outlines the results from the validation testing performed by the team.

Customer Want: Can be operated by one technician
Metric: Weight
Target Value: 100lb

<u>Overview of Test</u>

This test was performed to determine the total weight of the assembled design to verify if the weight constraint was met.

<u>Results</u>

Table 15

Trial	Part	Weight 1	Weight 2	Weight 3	Weight 4	Weight 5	Mean
1	Weld Assembly 1a (Leg 1) and Hardware	17.4 lbs.	17.4 lbs.	17.4 lbs.	17.4 lbs.	17.4 lbs.	17.4 lbs.
2	Weld Assembly 1b (Leg 2) and Hardware	17.4 lbs.	17.4 lbs.	17.4 lbs.	17.4 lbs.	17.4 lbs.	17.4 lbs.
3	Shaft	9.0 lbs.	9.0 lbs.	9.0 lbs.	9.0 lbs.	9.0 lbs.	9.0 lbs.
4	Tire 1	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.
5	Tire 2	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.
6	Tire 3	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.
7	Tire 4	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.
8	Tire 5	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.
9	Tire 6	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.	4.2 lbs.
10	18 Shaft Collars	3.0 lbs.	3.0 lbs.	3.0 lbs.	3.0 lbs.	3.0 lbs.	3.0 lbs.
11	Inner Telescoping Tube a with Pushing Block a and Hardware	5.2 lbs.	5.2 lbs.	5.2 lbs.	5.2 lbs.	5.2 lbs.	5.2 lbs.
12	Inner Telescoping Tube b with Pushing Block b and Hardware	5.2 lbs.	5.2 lbs.	5.2 lbs.	5.2 lbs.	5.2 lbs.	5.2 lbs.
13	Inner Telescoping Tube c with Pushing Block c and Hardware	5.2 lbs.	5.2 lbs.	5.2 lbs.	5.2 lbs.	5.2 lbs.	5.2 lbs.
14	Tray along with Struts and Hardware	11.2 lbs.	11.2 lbs.	11.2 lbs.	11.2 lbs.	11.2 lbs.	11.2 lbs.
15	Assembled Horizontal Bar with Tray L-Brackets (a and b), Gusset Plates, Weld Assemblies (2-6), Pneumatic Cylinders (a, b, and c), Cylinder Brackets (a, b, and c), and Hardware	47.4 lbs.	47.4 lbs.	47.4 lbs.	47.4 lbs.	47.4 lbs.	47.4 lbs.
Total							146.2 lbs.

Parts that were weighed but not added to the total system since they are put on to secure the structure once it is already inside the baler:

Table 16

Trial	Part	Weight 1	Weight 2	Weight 3	Weight 4	Weight 5	Mean
1	Outer Clamp Piece a	5.0 lbs.	5.0 lbs.	5.0 lbs.	5.0 lbs.	5.0 lbs.	5.0 lbs.
2	Outer Clamp Piece b	5.0 lbs.	5.0 lbs.	5.0 lbs.	5.0 lbs.	5.0 lbs.	5.0 lbs.
3	Both U-bolts with Hardware	2.0 lbs.	2.0 lbs.	2.0 lbs.	2.0 lbs.	2.0 lbs.	2.0 lbs.
Total							12.0 lbs.

Conclusion

Unfortunately, the team's prototype shows to be overweight after the data was complied. Fortunately, the prototype is not extremely over the weight limit so small things can be implemented to fall under the weight constraint. The tray, along with the struts and L-bracket that holds the tray could be made out of aluminum instead of steel. The heavy foot piece that is welded to the main support bar can be machined so that it less thick and is not as wide. Another option would be to take out the middle inner/outer telescoping tubes along with the gusset plates, weld assemblies, and pneumatic cylinder/bracket that are involved with this structure. If you take this route, two or more tires should be added onto the shaft to prevent bending. Doing this would take a considerable amount of weight off of the prototype.

As of now, two people have to lift the assembled prototype onto the axel of the baler. Once the prototype is rotated into the baler, only one operator has to take over to clamp the sides to the baler frame, U-bolt the feet to the axel, and set the pneumatic hoses and regulators up to the air tanks.

Customer Want: Detachable from Baler
Metric: Number of Permanent Connections to Baler
Target Value: 0 Permanent Connections

Overview of Test

The objective of this test was to determine the number of permanent connections the design has to the baler. This metric correlated to the customer want of the design being detachable from the baler. The team decided that by quantifying the number of permanent connections to the baler, it could be determined if the design is detachable or not. The test counted the number of permanent fixtures to the baler. A permanent attachment was defined as anything that could not be undone by simple means such as a weld or adhesion. A non-fixed attachment was defined as any attachment which was easily undone with standard tools, for instance a clamped or bolted connection. The figure below shows the results of the test.

Results

Table 17

Connection	Fixed or Not Fixed
Axle Connection 1	Not Fixed: Attached by U-Bolt
Axle Connection 2	Not Fixed: Attached by U-Bolt
Baler Frame Connection 1	Not Fixed: Attached by C-Clamp
Baler Frame Connection 2	Not Fixed: Attached by C-Clamp

Total Permanent Connections: 0

Conclusion

It was observed that with the completed design, zero permanent connections exist. Therefore, the target value was met and this particular customer want was fulfilled.

More fundamentally, this design is easily taken in and out of the round baler, leaving the baler unchanged. The sponsor desired a device which could be used in a baler without modifying the baler in anyway and allowing removal of the mechanism. This desire was met with the completed design.

Validation test passed and customer constraint met.

Customer Want: Speed of Design Matches PTO Speed
Metric: Speed of Prototype Roller
Target Value: Equal to the Baler Roller Speed

Overview of Test

This validation test was performed to determine if the design meets the customer want of matching the speed of the baler. The sponsor wanted to be sure that the device would be moving at the same speed as the baler, to ensure proper removal of netting. If the team had chosen to use an external power source, this constraint may have proven to be a difficult one to achieve. However, the selected design utilizes the baler roller as a power source and therefore should move at the same speed. Although it appeared to be an easy constraint to meet, the test was run to verify that the prototype does indeed move at the same speed as the roller. If the design passed the test, it could be said with certainty that the netting will be pulled at the correct speeds.

Results

The following tables outline the results from the five samples taken during the test. Each sample was done at a different PTO speed. The roller and tire speeds were measured using a tachometer. The roller speed was then divided by the tire speed to obtain a ratio which will be used to verify if the tangential velocities are equal.

Engine Speed = 750rpm; Baler Roller Speed = 47.9rpm		
Tire #	Tire Speed (rpm)	Angular Velocity Ratio
1	57.6	0.83
2	58.8	0.81
3	57.3	0.84
4	57.5	0.83
5	56.2	0.85
6	57.8	0.83
Average	57.5	0.83
Standard Dev.	0.8	0.01

Engine Speed = 1000rpm; Baler Roller Speed = 66.2rpm		
Tire #	Tire Speed (rpm)	Angular Velocity Ratio
1	77.8	0.85
2	77.5	0.85
3	77.8	0.85
4	78.2	0.85
5	79.0	0.84
6	78.1	0.85
Average	78.1	0.85
Standard Dev.	0.5	0.01

Engine Speed =1500rpm; Baler Roller Speed = 98.4rpm		
Tire #	Tire Speed (rpm)	Angular Velocity Ratio
1	116.7	0.84
2	118.4	0.83
3	116.4	0.85
4	116.4	0.85
5	115.6	0.85
6	116.5	0.84
Average	116.7	0.84
Standard Dev.	0.8	0.01

Engine Speed =2100rpm; Baler Roller Speed = 132.8rpm		
Tire #	Tire Speed (rpm)	Angular Velocity Ratio
1	158.8	0.84
2	156.6	0.85
3	156.7	0.85
4	157.7	0.84
5	154.3	0.86
6	158.2	0.84
Average	157.1	0.85
Standard Dev.	1.5	0.01

Engine Speed =2400rpm; Baler Roller Speed = 160.6rpm		
Tire #	Tire Speed (rpm)	Angular Velocity Ratio
1	191.7	0.84
2	188.4	0.85
3	191.6	0.84
4	191.6	0.84
5	195.9	0.82
6	191.9	0.84
Average	191.9	0.84
Standard Dev.	2.2	0.01

Sample	Engine Speed (rpm)	Average Angular Velocity Ratio
1	750	0.83
2	1000	0.85
3	1500	0.84
4	2100	0.85
5	2400	0.84

Total Mean of Average Angular Velocity Ratios = 0.84

Standard deviation of the data = 0.010

For 95%confidence = 2σ = 0.020,

Measured speed ratio = 0.84 +/- 0.020 with 95% CI

The measured roller ratio was seen to be 0.83 +/- 0.05. This was determined by measuring the circumference of the baler roller and the distance the on the roller a tire traveled during one tire rotation. The distance traveled by the tire was then divided by the circumference of the roller to obtain the ratio. This ratio was measured while the tire was under load to account for the deflection of the tire. This allowable range of 0.83 +/- 0.05 was met by the design with 95% confidence since the measured speed ratio using the tachometer was found to be 0.84 +/- 0.02 with a 95% confidence interval.

<u>Calculation of Reliability</u>

$$R = 1 - \left(\frac{True\ Deviation}{Measured\ Deviation}\right)^2$$

$$R = 1 - \left(\frac{0.01}{0.05}\right)^2 = 0.96 = \mathbf{96}\%\ \boldsymbol{Reliability}$$

<u>Conclusion</u>

The roller to tire ratio can be used to find the tangential velocities of the tire and the roller. Since the ratios match, it can be determined that the prototype tire tangential velocity match the baler roller tangential velocity at every operational speed with 95% confidence.

Validation test passed and customer constraint met.

Customer Want: Fits within the lower part of the baler frame
Metric: Width and Height
Target Value: Width: 48inches; Height: 50inches

Overview of Test

This test was performed to verify that the device fits within the lower part of the baler frame. This customer want was quantified with a metric of width and height of the design. Measurements were made with a tape measure and at various points across the prototype.

Results

Table 18

Sample	Width (inches)	Height (inches)
1	45.5	56.5
2	45.4	56.0
3	45.5	56.3
4	45.4	56.2
5	45.5	56.4
Average	45.6	56.3
Standard Deviation	0.055	0.19

From the above results, it can be seen that the width constraint is met with 99.9% confidence. This can be seen because the mean width (45.6in) plus 3 standard deviations (0.055in) is still less than the constraint of 48 inches.

Conclusion

The team validated and passed the height and width requirements for the baler provided to the design team by the sponsor, but other minor adjustments must be made to fit the prototype into the lower portion of most balers at the CNH facility. The height requirement was not imposed by the sponsor until after the design was completed and submitted for fabrication.

The balers at the CNH facility have a back hatch and belts that would be cause for concern. Our prototype would have to be lowered to 50 inches, to fit under the belts, which could be done by cutting off a portion of the main support bars and drilling two new ½ inch holes in each of them. The angle of the arms can be adjusted with the gusset plate within the design and therefore can be changed to fit a variety of different-sized balers.

Customer Want: Minimal time between trials
Metric: Time between trials (set-up time)
Target Value: 2 minutes

Overview of Test

This test was designed to test the metric of time between trials. The team had designed the device with the thought that in between wrap cycles the user may need to remove the mechanism from the baler. It was determined that 2 minutes was the target value for this time in between trials. The test was run using a stop watch to measure how long two people could install the device within the baler. The prototype was not removed from the axle as it is unnecessary to do so in order to set up the next trial.

Results

Table 19

Sample	Time in Between Trials (seconds)
1	45.52
2	26.11
3	35.20
4	24.41
5	27.67
Average	31.78
Standard Deviation	7.8

Now to allow for 95% confidence, we will multiply the standard deviation by 2:

$$2\sigma = 2(7.8) = 15.6$$

The answer found above can now be used to determine if the metric, time in between trials, falls under two minutes and meets our target value.

$$\text{Mean} \pm 15.6 = 31.78 \pm 15.6$$

$$\Longrightarrow 31.78 + 15.6 = 47.38 \text{ seconds}$$

$$\Longrightarrow 31.78 - 15.6 = 16.18 \text{ seconds}$$

Conclusion

Both of these answers clearly show that they fall well with under the two minute target value and even are under one minute. The test is validated and passes.

Validation test passed and customer constraint met.

Customer Want: Uses minimal net length at startup
Metric: Initial Starting exposed net length
Target Value: 1 inch

Overview of Test

In a true testing environment, this design would be used by having it in the baler, and inserting the duckbill to provide the system with netting. The netting would be grabbed while under zero tension, and the duckbill would then retract, applying tension to the netting. When the simulated bale cycle was complete, the duckbill would retract further, initiating the cutting cycle, and the net would be cut.

This particular test was performed to test the first step of the bale wrap cycle explained above, the initial grabbing of netting. The test helped to determine the minimum length of initially exposed netting which could successfully be pulled from the baler by the design.

Data Collection

Below is a data table containing the results of the minimum starting net length test:

Table 20

Trial	Starting Net Length (in)	Net Pulled?					
		Yes(Y)/ No(N)	Yes(Y)/ No(N)	Yes(Y)/ No(N)	Yes(Y)/ No(N)	Yes(Y)/ No(N)	Yes(Y)/ No(N)
1	10	Y	Y	Y	Y	Y	Y
2	9	Y	Y	Y	Y	Y	Y
3	8	Y	Y	Y	Y	Y	Y
4	7	Y	Y	Y	Y	Y	Y
5	6	Y	Y	Y	Y	Y	Y
6	5	Y	Y	Y	Y	Y	Y
7	4	Y	Y	Y	Y	Y	Y
8	3	Y	Y	Y	Y	Y	Y
9	2	N	Y	N	Y	Y	Y
10	1	N	N	N	N	N	N

Analysis

Observing the above data, it can be seen the netting is consistently pulled between the initial starting lengths of 3-10 inches and is not pulled at an initial starting length of 1 inch. Though, at an initial net starting length of 2 inches, the testing yielded inconsistencies pulling the netting. To determine how consistent the netting is pulled, a reliability test was completed and revealed that the netting would be pulled 66.67% of the time with an initial starting net length of 2 inches. The reliability tests also revealed the netting is consistently pulled a minimum initial starting length of 3 inches while the netting is not pulled at a minimum initial starting length of 1 inch.

$$Reliability = (\#\ successful\ trials / \#\ trials\ conducted)\ \times 100$$

$$Reliability = (4\ successful\ trials / 6\ trials\ conducted)\ \times 100$$

$$\boldsymbol{Reliability = 66.67\%}$$

Conclusion

Based upon these results, it can be concluded the shortest initial net length that can be consistently pulled is 3 inches. A minimum initial starting length of 2 inches does not yield a high enough reliability to confirm it can be consistently pulled through the system. As a path forward, more tests need to be completed to confirm these results. These conclusions suggest the target value of a minimal initial net length of 1 inch has not been satisfied. Though, because the mechanism is able to pull a minimum initial net length of 3 inches, the constraint has been met, ultimately validating the mechanism has fulfilled this metric requirement.

Customer Want: Successfully Pulls Netting from Baler
Metric: Pulling Force
Target Value: 150lb

Overview of Test

This test was created to determine if the device could successfully pull the netting from the baler. This was quantified by pulling force. This would be measured by determining the pressure at which the mechanism could successfully pull netting from the baler. This yes/no result could then be used to determine the critical cylinder pressure at which operation should occur, and if the design meets the customer want of successfully pulling netting from the baler.

Results

When using the white roll of netting with two orange stripes:

Table 21

Trial	Pressure (psi)	Calculated Normal Force (lb)	Netting Pulled at Engine Speed of 2400rpm? (Yes/No)	Netting Pulled at Engine speed of 2100rpm? (Yes/No)	Netting Pulled at Engine speed of 1000rpm? (Yes/No)
1	30	282.7	No	No	No
2	40	377.0	No	No	No
3	50	471.2	No	No	No
4	60	565.5	No	No	No
5	70	659.7	No	No	No
6	80	754.0	No	No	Yes
7	90	848.2	No	No	Yes
8	100	942.5	No	No	Yes
9	120	1131.0	No	No	Yes

Conclusion

From these results, our team cannot conclude that our metric is validated. The net was successfully pulled at 1000rpm engine speed, but it is required to pull the netting at PTO speeds of 540rpm (2000-2100rpm engine speed) and above.

Although, these test were performed by laying the netting over top of the main roller by hand and starting the PTO. In this case, the tires are already pressed onto the netting before the PTO is started which may create a sudden shock/jolt on the strands of netting that are being pinched between the tire and the roller. This may be the cause for the ripping.

The first roll of netting that was used contained blue and white strands and revealed that it could be pulled at the PTO rated speed of 540rpm in the same situation as laying the netting over the roller by hand. Unfortunately, the supply of this roll was limited and ran out before testing could be performed.

Also, when the team performed tests on the minimal length of net, it was found that the netting was pulled at 540rpm PTO speed with three inches of netting exposed. The tests at CNH will be performed under these circumstances; meaning the net will be fed in through the rollers by a duckbill and pulled out by hand.

After completion of the tests and keeping these other key factors in mind, the team feels the tests could be redone to hold more variables constant. These tests could also be redone to cater to CNH's plans so that use of the prototype is more relevant to them.

Table 22

Trial	Pressure (psi)	Calculated Normal Force (lb)	Calculated Pulling Force (lb)
1	30	282.7	81.98
2	40	377.0	109.33
3	50	471.2	136.648
4	60	565.5	163.99
5	70	659.7	191.31
6	80	754.0	218.66
7	90	848.2	245.98
8	100	942.5	273.33
9	120	1131.0	327.99

From the result table above, it is seen that the netting will be pulled with 150 pounds of force at a little less than a pressure of 60 psi that is applied to each pneumatic cylinder. It was seen that when tests were run at 1000rpm engine speed (half PTO-rated speed), the netting could be pulled at max pressure (120psi). The slack was then completely out of the netting system and tests were run to find the critical pressure. The pressure was decreased by 5psi between tests, and the duckbill was not moved to assure that tension was not lost within the system and no slack was present. It is critical that no slack is present in the netting line because the ripping was found to occur when loose netting was pulled and the tension was applied as a shock to the system.

It was found that the design successfully pulled netting under these ideal conditions at as low of cylinder pressures as 45psi. This actually exceeds the predictions of between 50 and 60psi. This discrepancy can be accredited to the coefficient of friction used in the calculations. The actual coefficient of friction must have been higher than that which was measured in phase 3. This result is good, as it allowed the team to design with a conservative friction coefficient.

Customer Want: Safe to Use
Metric: Number of Exposed Pinch Points to Operator
Target Value: 0 Exposed Pinch Points

Overview of Test

The objective of this test was to verify that the design is safe for the operator to use. This was quantified by creating a metric of number of pinch points exposed to the operator. It was decided that a safe design would have no pinch points that the operator could hurt themselves in.

Since pinching action is a key component to the design, pinch points could not be completely omitted from the design. Instead, protocols were created which the technician must adhere to when using the machine. As stated by the operator's manual, the technician should keep all limbs and parts of body out of the bale chamber during operation of the device.

Since the user must remain outside of the baler during operation of the device, it was determined that an exposed pinch point is defined as one that is less than 12inches from edge of the baler. The following table shows the distance from the edge of the bale chamber to the pinch point.

Results

Table 23

Pinch Point within Design	Distance from Edge of Baler (in)	Pinch Point Exposed to User?
Pneumatic Cylinder 1	17.2	No
Pneumatic Cylinder 2	17.2	No
Pneumatic Cylinder 3	17.2	No
Baler Roller and Tire 1	23.8	No
Baler Roller and Tire 2	23.8	No
Baler Roller and Tire 3	23.8	No
Baler Roller and Tire 4	23.8	No
Baler Roller and Tire 5	23.8	No
Baler Roller and Tire 6	23.8	No

Conclusion

It was observed that the pinch points closest to the operator at any time were those between the pneumatic cylinders and pushing blocks. This pinch point was measured to be 17.2 inches from the edge of the baler. Since none of the pinch points were less than 12 inches from the edge of the baler, the user is not in danger of injury as long as they adhere to the user's manual and remain outside of the bale chamber during operation.

Validation test passed and customer constraint met.

Customer Want: Design is Cost Effective
Metric: Cost of Prototype
Constraint: $5000
Target Value: $3000

<u>Overview of Test</u>

This test was simply a calculation of the total cost to create an assembled prototype. Costs included purchased parts, raw material costs for fabricated parts, machining costs per hour, welding costs per hour, and administrative costs per part.

<u>Data Collection</u>

Displayed below is the list of all purchase parts costs, fabrication costs, welding costs, administrative part number costs, and steel product costs by weight.

Table 24

Part No.	Description	Qty.	Price (ea.)	Notes	CNH Part No.	Cost
4997T73	Pneumatic Wheel with Two-Piece Rim, 8.9" X 2.8", Center Hub, 1" Axle, Roller Bearing, 295# Capacity	6	$39.57		84506712	$237.42
3043T51	Zinc-Plated Steel U-Bolt 1/2"-13 X 1-1/2" Thrd Length, for 4-1/2" OD, 2020# Wll	2	$4.15		84506709	$8.30
6498K252	Stainless Steel Air Cylinder Nose-Mount, Spring Return, 2" Bore, 2" Stroke	3	$69.79		84506699	$209.37
6498K575	Foot Bracket for 2" Bore Stainless Steel Air Cylinder	3	$10.00		84506704	$30.00
9414T19	Black-Oxide Steel Set Screw Shaft Collar 1" Bore, 1-1/2" Outside Diameter, 5/8" Width	18	$1.47		84506713	$6.46
9546K12	Threaded Rubber Bumper with Metal Core, Neoprene, 1-1/4" Diameter, 1/2"-20 Threaded Hole	3	$8.76		84560726	$26.28
95495k68	Adhesive-Backed Polyurethane Bumper Dome Top, 3/4" Dia, 5/64" H, Clear	1	$5.53		84560727	$5.53
4931T142	Steel, 1-1/2" Square, Solid Tubing for Heavy Duty Telescoping-Tube Framing	1	$43.48	Length to order: 12ft	84560708	$43.48
4931T143	Steel, 1-3/4" Square, Solid Tubing for Heavy Duty Telescoping-Tube Framing	1	$50.32	Length to order: 12ft	84560725	$50.32
4959K21	Air Regulator with Pressure Gauge 1/4" Pipe Size, 94 Max SCFM, 5 to 150 PSI Range	1	$30.90		84560728	$30.90
4957K61	Mounting Bracket for 1/4" & 3/8" Pipe Size Air Filter/Regulator/Lubricator	1	$5.31		84560729	$5.31
5304K82	Air and Water Hose W/Brass Male Both Ends, 1/4" ID, 200 PSI	6	$11.74	Length to order: 5ft	84567076	$70.44

3662T24	Panel-Mount Brass Toggle Valve Inline, 1/4" NPTF Female	1	$32.69		84567077	$32.69
3122-15X	Brass flat hex manifold w/ 3 coupler bodies & 1 coupler plug	1	$25.80		84567078	$25.80
1502	1/4" FPT connector plug similar to Milton 728	4	$1.05		84567079	$4.20
150	1/4" FPT coupler body similar to Milton 715	1	$3.80		84560714	$3.80
-	Administrative Parts Number Cost	-	$50/part #	18 Part #'s	-	$900.00
-	Total Weight of Steel Products	-	$0.50/ lb	105.6 lbs.	-	$52.80
-	Welding Hour Cost	-	$78.81/hr	8 hours welding	-	$630.48
-	Machining Hours Cost	-	$78.81/hr	8 hours machining	-	$630.48
					Total Cost:	**$ 3,024.06**

Data Analysis

The total cost of the prototype comes to be $3,024.06 and does not meet the target value of $3,000 by a mere $24.06. Though, the cost constraint for the prototype is $5,000 and the prototype cost is well under this cost constraint. Based upon this constraint value, it can be confirmed the prototype successfully falls within the budget allocated to the design team and design team has fulfilled the cost effective metric.

Validation test passed and customer constraint met.

Failure Modes Effects Analysis (FMEA)

From the FMEA analysis, it was found that the greatest risk of associated with the prototype was the tire leak. This is due to the fact that tire leaks are difficult to detect and has a great detrimental effect on performance of the prototype

The lowest risk associated with the prototype was breaking of the axle and leaking of the hoses due to excessive exposure to UV light. In as much as breaking of the axle is catastrophic, it is easily detected since the axle has to bend before breaking.

The leak of the hoses due to UV light exposure is also unlikely since the prototype will be mainly used in shaded environment away from UV light.

The figure on the following page provides the FMEA matrix which was completed to determine what is likely to fail first within the design.

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)									
COMPONENT		FAILURE MODE	CAUSE OF FAILURE	POSSIBLE EFFECT	POTENTIAL SEVERITY	PROBABILITY OF OCCURRENCE	PROBABILITY OF NOT BEING DETECTED	RISK PRIORITY NUMBER (RPN)	PREVENTIVE ACTION
1	**Axle**	Break	Excessive loading from the pneumatics	loss of operation	10	2	1	**20**	Regulator installed along the pneumatic line to provide a real time reading of the pressure
		Bending	Excessive loading from the pneumatics	Uneven pulling of the netting across the width of the baler	8	5	7	**280**	Regulator installed along the pneumatic line to provide a real time reading of the pressure
2	**Tires**	Burst	Exececssive pressure due to overloading by the pneumatics	loss of functionality of the prototype. Sudden failure of the prototype to pull the netting	10	5	1	**50**	Regulator installed along the pneumatic line to provide a real time reading of the pressure. Also avoid overpressurization of the tire.
		leak	Pricking due to sharp objects on the roller surface	uneven pulling of the netting across the baler	8	6	10	**480**	Always put the tire valve caps on during operation of the prototype
			Faulty nose valve in the tires						Operator reqired to inspect the roller surface for sharp points prior to using the prototype
3	**Pneumatic Cylinder**	burst	Excessive pressure application	loss operation of the prototype	10	1	10	**100**	Regulator installed along the pneumatic line to provide a real time reading of the pressure
		Leak	Loose fittings with the hoses or weak valve within the pneumatic cylinder	Total failure of the prototype to pull the netting	7	2	8	**112**	Use the teflon taping during assembly of the pneumatic connectors
4	**Pneumatic Hoses**	Burst	excessive pressure	loss of operation of the prototype	10	3	10	**300**	installation of a pressure gage with a relief valve
		leak	weathering	loss of air pressure	4	1	5	**20**	Avoid excessive exposure of the pneumatic hoses to UV light
			Pinching	loss of air pressure	4	5	5	**100**	Re-routing and securing pneumatic hoses around pinch points

Figure 7: FMEA Matrix

Path Forward and Transition Plan for Sponsor

Though the prototype has satisfied the majority of the constraints, there are a few aspects of the prototype that propose concerns for future use. These concerns require modifications to be made to allow the prototype to function more efficiently. Updated CAD drawings containing corrections will be provided to the sponsor. The concerns and necessary revisions are discussed below:

Height

Concern:

The prototype has been designed to the specifications of the round baler presented to the design team for testing. This round baler's tailgate is detached and the prototype has been designed without the height constraint of the tailgate's rubber belts. Installing the prototype into a round baler at the CNH Research and Development Facility may present problems due to the height constraint presented by the tailgate rubber belts.

Revision:

The prototype should be installed into the baling chamber to determine if the rubber belts interfere with the prototype's functionality or installation process. If the rubber belts do not interfere with the prototype's functionality or installation process, the height does not need to be adjusted. If the rubber belts do have an effect on the prototype's functionality or installation process, the length of Part Number 84560698 (Main Support bar) is required to be reduced to the height that is necessary to create a clearance between the rubber belts and the prototype.

Clamping System

Concern:

The clamps are designed for the round baler presented to the design team for testing. As the clamps were bolted to induce the necessary clamping force, it was observed the clamps lost contact with the baler wall and began to pivot round the baler wall's edge. This prevented the prototype from securing to the baler frame.

Revision:

C-clamps should be implemented to secure the prototype to the round baler frame. Installing c-clamps will ensure the prototype will not fail under the forces created through the pneumatic system. C-clamps also allow for quicker and simpler installation and detachment process.

Pushing Block

Concern:

The pushing block lacks the essential height required to allow pneumatic cylinder rubber stoppers to maintain complete contact with the pushing block. This causes the rubber stoppers to fold over the top of the pushing block, creating the possibility of slipping or creating a stress concentration on the pushing block.

Revision:

Increasing the height of the pushing block will enable the pneumatic cylinder rubber stoppers to consistently maintain contact with the pushing block and will prevent the rubber stoppers from folding or slipping.

Tire Setup

Concern:

The prototype currently consists of six 8.9" diameter pneumatic tires that have a zigzag tire tread pattern. These tires are evenly spaced and create the contact area between the baler roller and the prototype. The tread of the tire limits the surface contact area and permits gaps rather than creating an area of complete contact. This decrease in surface area enables the possibility of creating a stress concentration where the pneumatic tires tear the netting instead of pulling the netting. The tires also contain hair like features on its surface from the molding process.

Revision:

The area of contact between the pneumatic tires and the baler roller can be increased with the addition of two more tires. The prototype has been designed to allow for two additional tires and will allow the pressure from the pneumatic system to be translated through eight tires rather than six tires. The tread of the tire should be lathed off in order to create a flat, uniform surface on the tire as well as discard of the hair like features.

Tray

Concern:

The current tray width does not extend from one side of the baling chamber wall to the other. The gap between the edges of the tray and the baling chamber wall enables the netting to flow through these gaps as well as bunch at the beginning of the tray rather than funnel the netting down the tray. The tray also tends to sag in the middle. This sagging causes the tray to make contact with the baler rollers and induces bouncing during testing. The gap between the tray and the baler roller is large enough where the netting could possibly funnel down into this gap.

Revision:

The tray width needs to be extended to leave a minimal gap between the baling chamber wall and the tray. This will prevent the netting from possibly funneling into the gaps between the baler wall and tray. Drilling holes into the lower walls of the tray will allow for a bolt to securely attach the tray to the prototype and minimize the gap between the baller roller and the tray. A metal bar should also be welded or adhesively attached to the underside of the tray to prevent the middle from sagging.

Netting

Concern:

Different types of netting were used while testing of the prototype. These different types of netting led to some differences in test results. Much of the testing was performed using orange striped netting and it was observed that this netting tended to fail more easily at higher PTO speeds whereas when a blue stripped netting was used, tearing did not occur.

Revision:

This issue should not concern the type of netting utilized during testing, but rather emphasize the mechanical differences between different types of netting and how different results should be expected. This concern should also stress the importance of the contact surface area created between the tires and baler roller. Different types of netting may require larger contact surface area due to net strand orientations. Because of these different net strand orientations, more vertical strands may be consistently pinched for one than compared to another. The amount of netting left on the netting roll should also be a possible cause of concern due to the fact that rolls of netting with larger diameters require a larger inertia to overcome.

Weight

Concern:

The weight of the prototype exceeds the weight constraint by 47 pounds. This excess weight does not allow the facilitator to easily maneuver or install the prototype into the baling chamber.

Revision:

Weight could be reduced with different material selection methods. An example of this is by fabricating the tray out of aluminum rather than steel. Steel was used because of convenience but further investigation into materials selection could reveal that lighter materials could be used to construct structures and reduce weight. Some of these structures that should be investigated include: CNH Part Number 84560697, 84560698, 84560701, 84560702, 84560716. An overall investigation is required to determine other methods to decrease the weight of the prototype.

Figure 8 below shows a 3D model of the updated design. Changes include a wider tray, 2 more tires, more adjustability for the tray on the main bars, and a support beam for the tray.

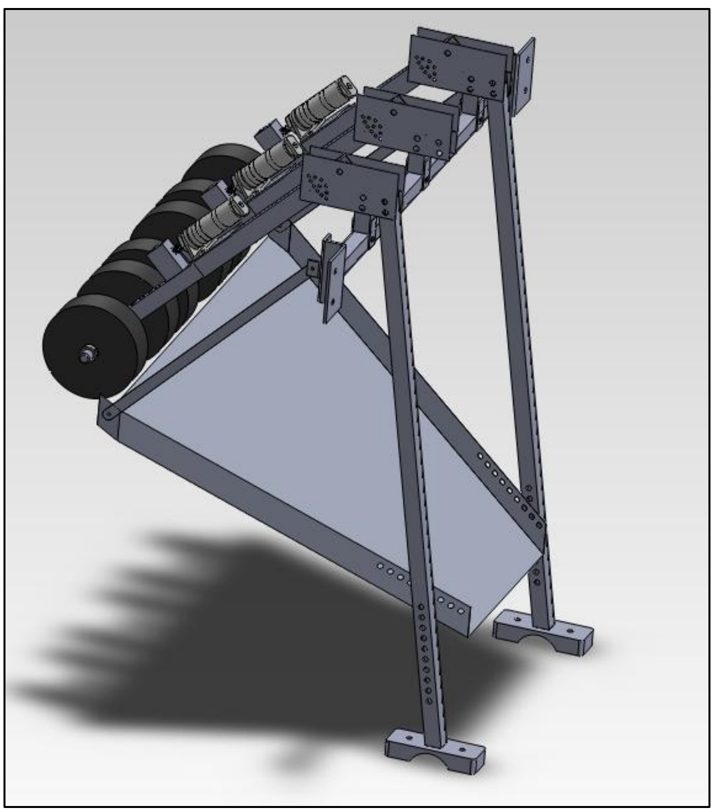


Figure 8

User’s Manual

<u>Assembling the Machine</u>

Assembly 1:

Start with the horizontal bar. Easily bolt on the two small L-bracket tray support pieces near the ends of the horizontal bar. Then begin to force all three vertical attachments (weld assembly 6’s) into place and secure them with bolts and flanged nuts. The next step would be to secure all six gusset plates (weld assembly 2 and 3) to the vertical attachments. Next, set the main support bars and foot pieces (weld assembly 1) in between the outside pairs of gusset plates and secure them when the feet are sitting flush with the ground. With washers, bolt the outer telescoping tubes inside the gusset plates while giving a little bit of slack to later find the desired angle.

Assembly 2:

Slide the shaft through one of the inner telescoping tubes. Slide necessary collars and two tires on before sliding the shaft through another inner telescoping tube. Repeat the previous step and slide the last steel collars and tires onto both ends of the shaft. **Do not secure any steel collars to the shaft at this time.** Begin to line up all three inner telescoping tubes with the three outer telescoping tubes. Slide the inner tubes into the outer tubing at the same time until one of the tubes can be pinned from the side. Proceed to pin the other two tubes to secure the bars from sliding when the device is being transported. **Now begin** to secure the collars, starting with the outsides of the inner tubing. Every other collar is tightened by certain judgment of uniformity between the tires. Leave minimal space between the collars and the tires so the tires may rotate freely.

Once everything on the shaft is secure, move these assembled parts to the baler. Rest the feet on the axel and rotate the device into the baler until the clamps hit the outer baler frame. Rotate the shaft upwards and take out the three pins to allow the bars to slide. Once the tires are sitting on top of the main roller, at the desired angle, use locking pins to secure the outer telescoping tubes to the gusset plates. Also, finish tightening all three flanged nuts at the top of the outer telescoping tubes to the gusset plates to insure that the tubes will not rotate. The next step would be to re-pin the inner and outer telescoping tubes together, as the tires are pressing against the roller in the baler, to maintain that precise spacing.

Assembly 3:

Hook up hoses to the air supply. Connect the regulator to the main hose and the other three hoses to the three prong valve system. Secure the cylinder brackets to the pneumatic cylinders and screw on all three rubber tips to the pneumatic cylinders. Proceed to connect the hoses to the back end of the pneumatic cylinders.

Separately bolt the tray connector pieces to the far end (larger end) of the tray with simple hardware.

Combining Assemblies:

As the main assembled device is sitting inside the baler, secure the foot pieces to the axel with two U-bolts. Now rotate the device out of the baler so that the main support bar rests on the floor. Secure the three pneumatic cylinder brackets to the outer telescoping tube (weld assembly 5) with remaining hardware. Rotate the device back into the baler. Fit and bolt the steel blocks into place so that the pneumatic tips are able to actuate and press against the blocks within at least two inches. Clamp both sides of the horizontal bar (weld assembly 4) to the outer frame of the baler with C-clamps. Next, the tray should be brought into the back of the baler. After being bolted at the top to the L-bracket, the bottom can be situated and bolted into place. You have now assembled the machine and can begin testing once air is applied to the pneumatic cylinder and tires.

<u>Setting up the Machine</u>

Two operators will be needed to lift the machine off of the ground and onto the axel. From there, one person can easily rotate the machine into the baler until the ends of the horizontal bar press firm against the outer walls of the back end of the baler. The operator can then begin to secure the foot pieces to the axel with U-bolts, and clamp the top ends to the frame with C-clamps. Next, all three pins, preventing the telescoping tubes from sliding, would have to be pulled out. The operator would then connect the hoses to the back end of the pneumatic cylinders and open the valve to let air through. The operator would regulate how much pressure is needed. Once the operator is satisfied with all the connections and pressure being applied to the tires, he/she can begin testing.

Projected Viability

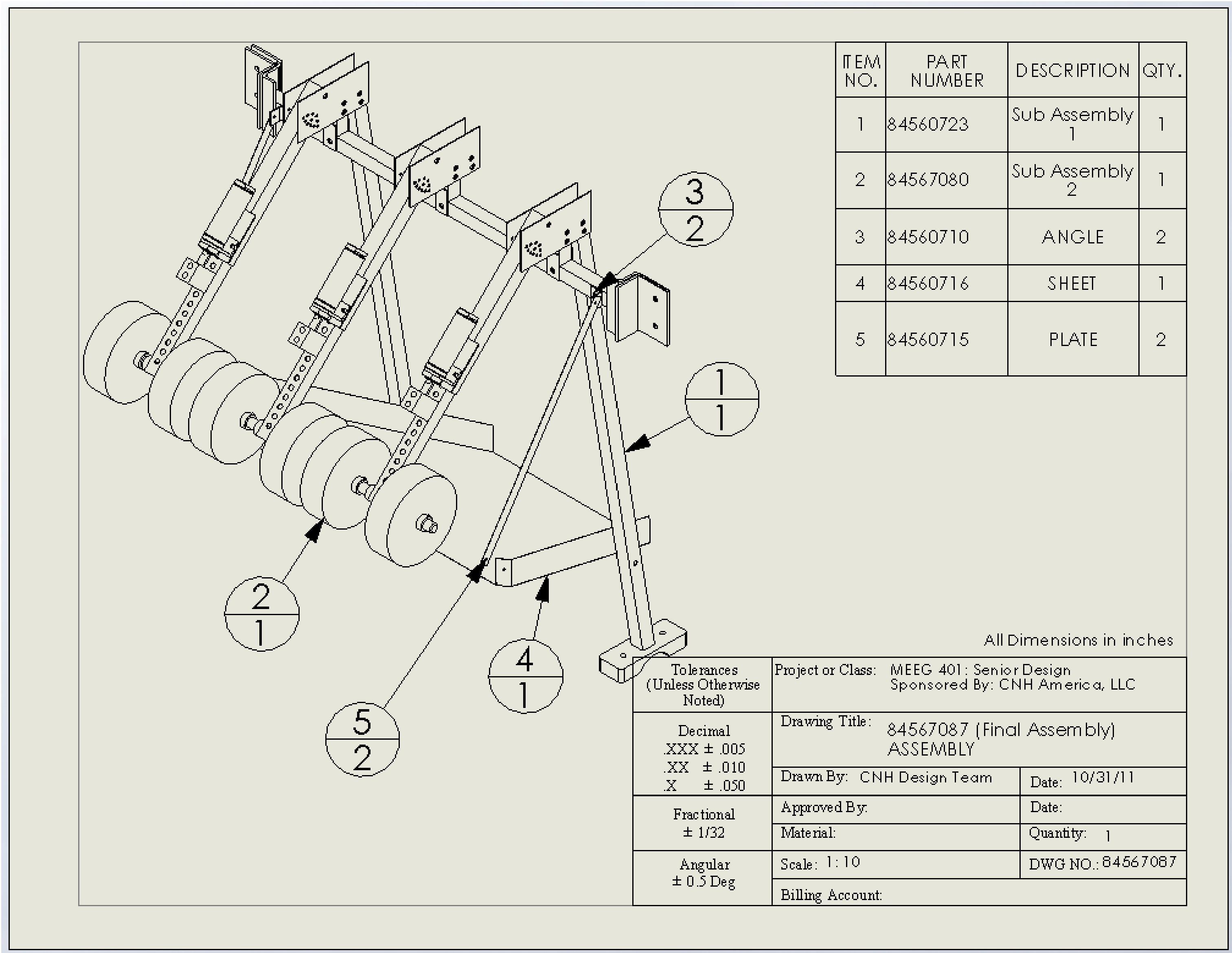
There is no true commercial viability to this design because it is not intended to be a commercial project. However, it is a viable design as a lab stand overall. The mechanism did not meet all constraints and was not able to ultimately complete a full automatic bale cycle, but it was close. The design showed that pneumatic cylinders were a viable way to apply pressure to a fixed shaft with moving tires. The pneumatic tires were observed to be an excellent solution to the ribbed roller vibrations induced within the system.

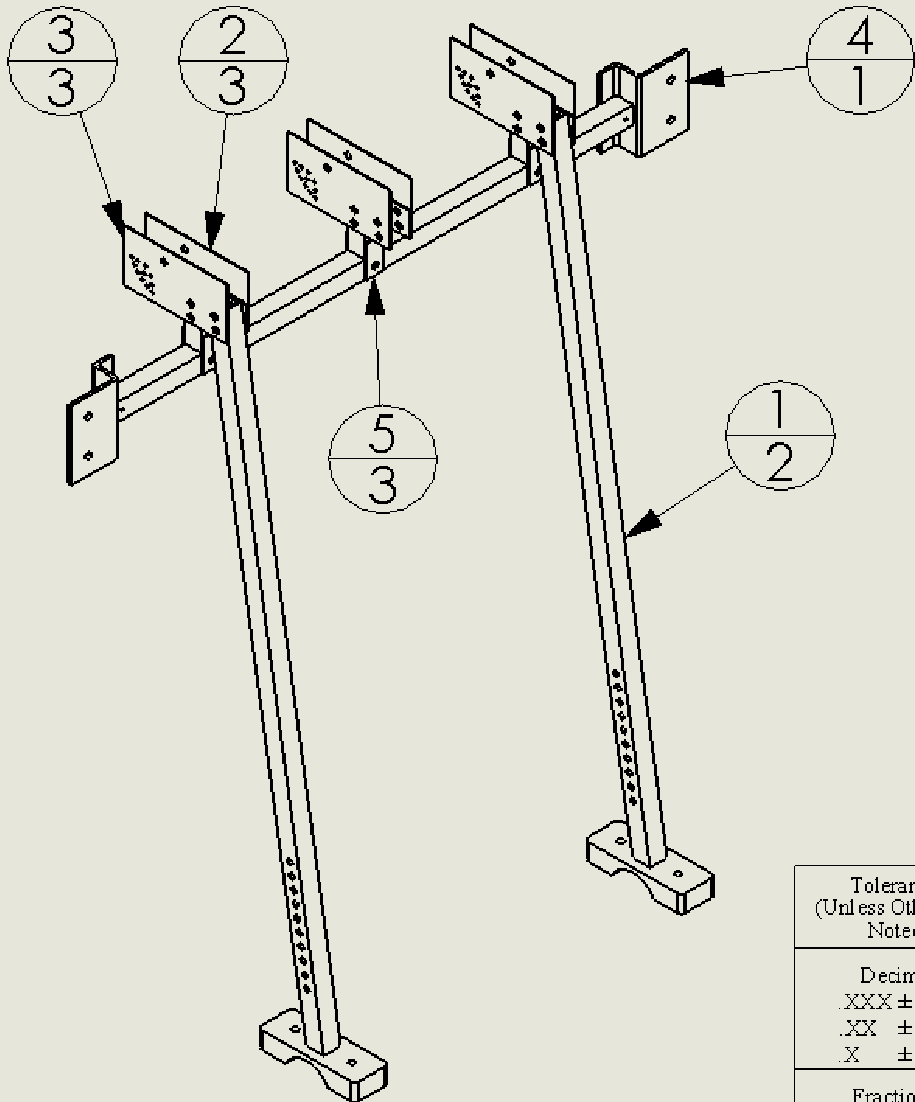
Many expected problems actually turned out to be non-issues. An original concern was that the axle would tend to sway while tests were being run and the device might bump into the walls of the baler. It was actually observed to be a very rigid mechanism which became very solid under testing conditions. The tires performed better than expected, grabbing tail net lengths as low as 2 inches. The U-bolt system also proved to be a good way to secure the device to the baler axle.

Overall this concept was a viable solution to the problem provided by the sponsor. Solutions to the concerns seen within the transition plan (found earlier in this report) will only make the design perform better and be an even more viable solution to the initial problem.

Appendix

The following is an updated drawing package for the revised design





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	84560723	Weld Assembly 1	2
2	84567082	Weld Assembly 2	3
3	84567083	Weld Assembly 3	3
4	84567084	Weld Assembly 4	1
5	84567088	Weld Assembly 6	3

All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560724 (SUB ASSEMBLY 1) FRAME A	
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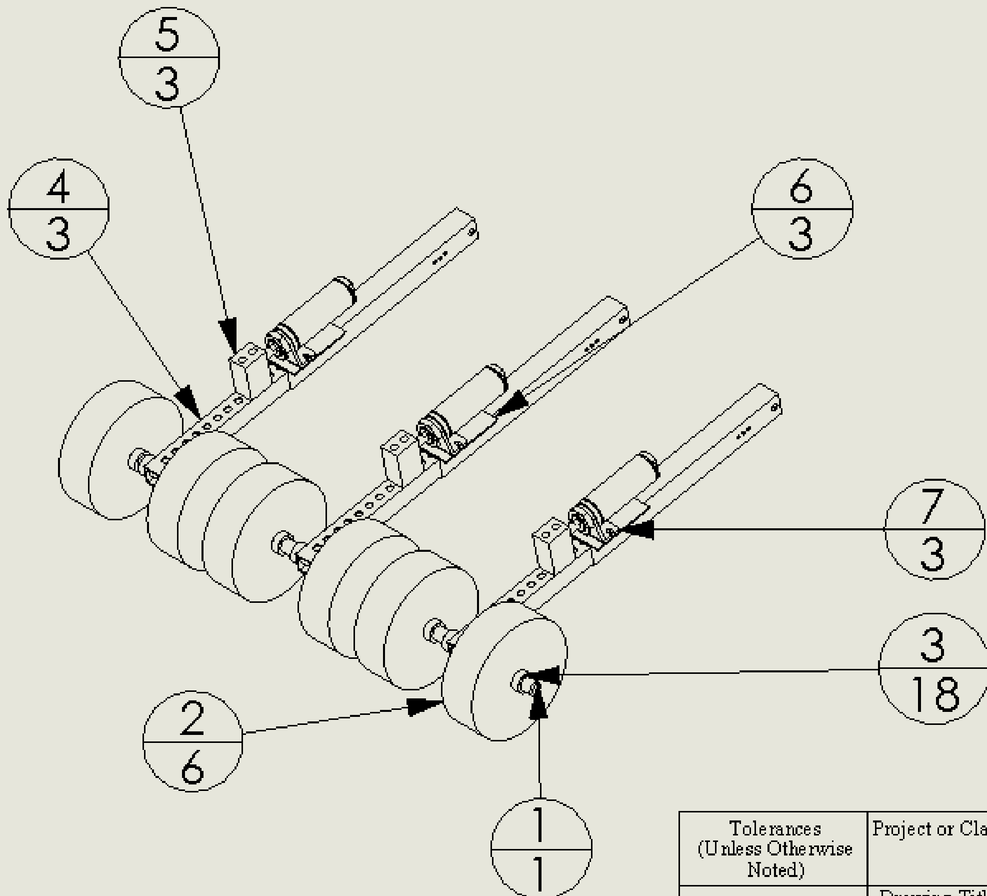

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1	84560711	Shaft	1
2	84560712	Tire	6
3	84560713	Steel Shaft Collar	18
4	84560708	Inner Telescoping Tube	3
5	84560720	Pushing Block	3
6	84567085	Weld Assembly 5	3
7	84560704	Bracket for Pneumatic Cylinder	3

All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84567080 (SUB ASSEMBLY 2) TIRE A	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
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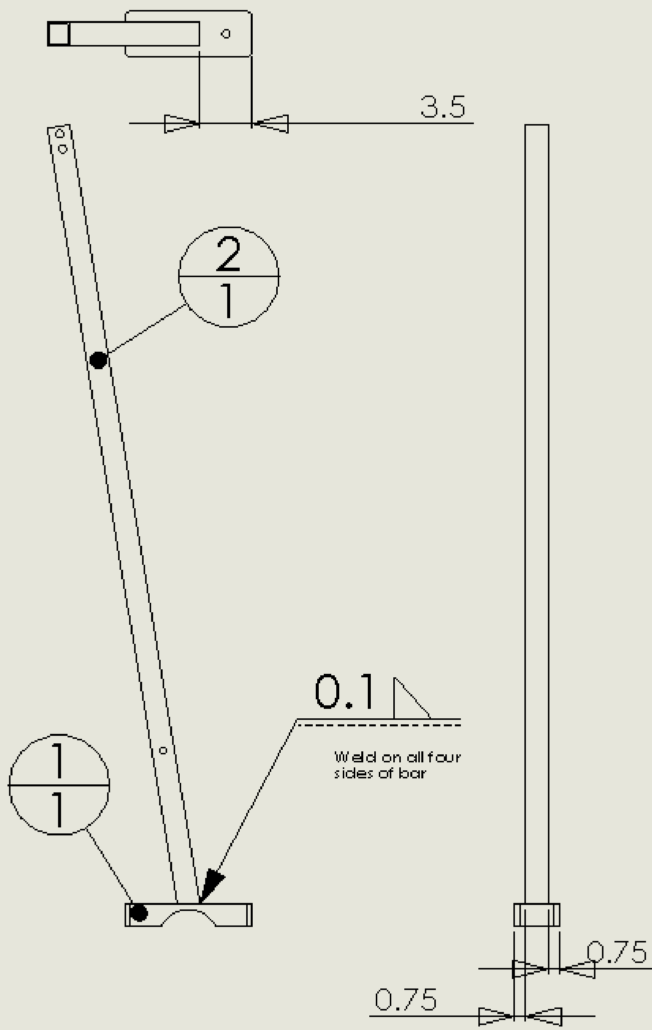
2	84560698	Main Support Bar	1



All Dimensions in inches

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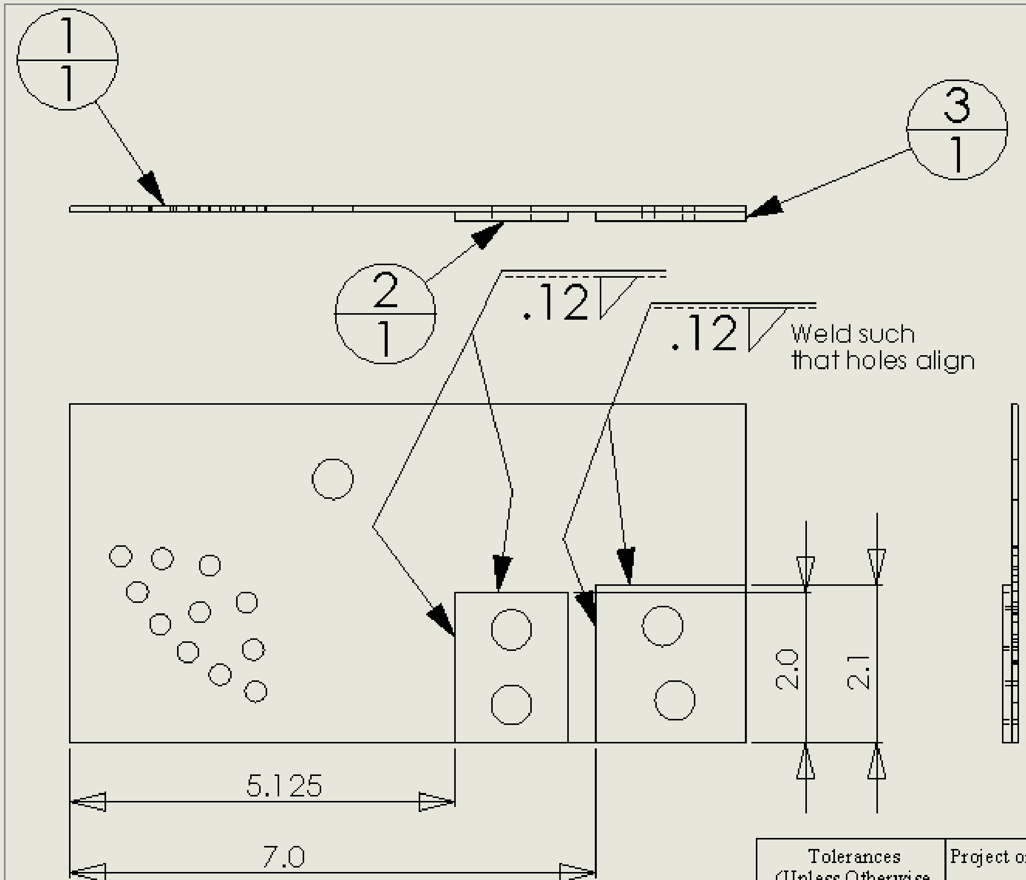

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	84560701	PLATE	1
2	84560721	PLATE Vertical Bar Attachment Spacer	1
3	84560722	PLATE Main Bar Spacer	1

All Dimensions in inches

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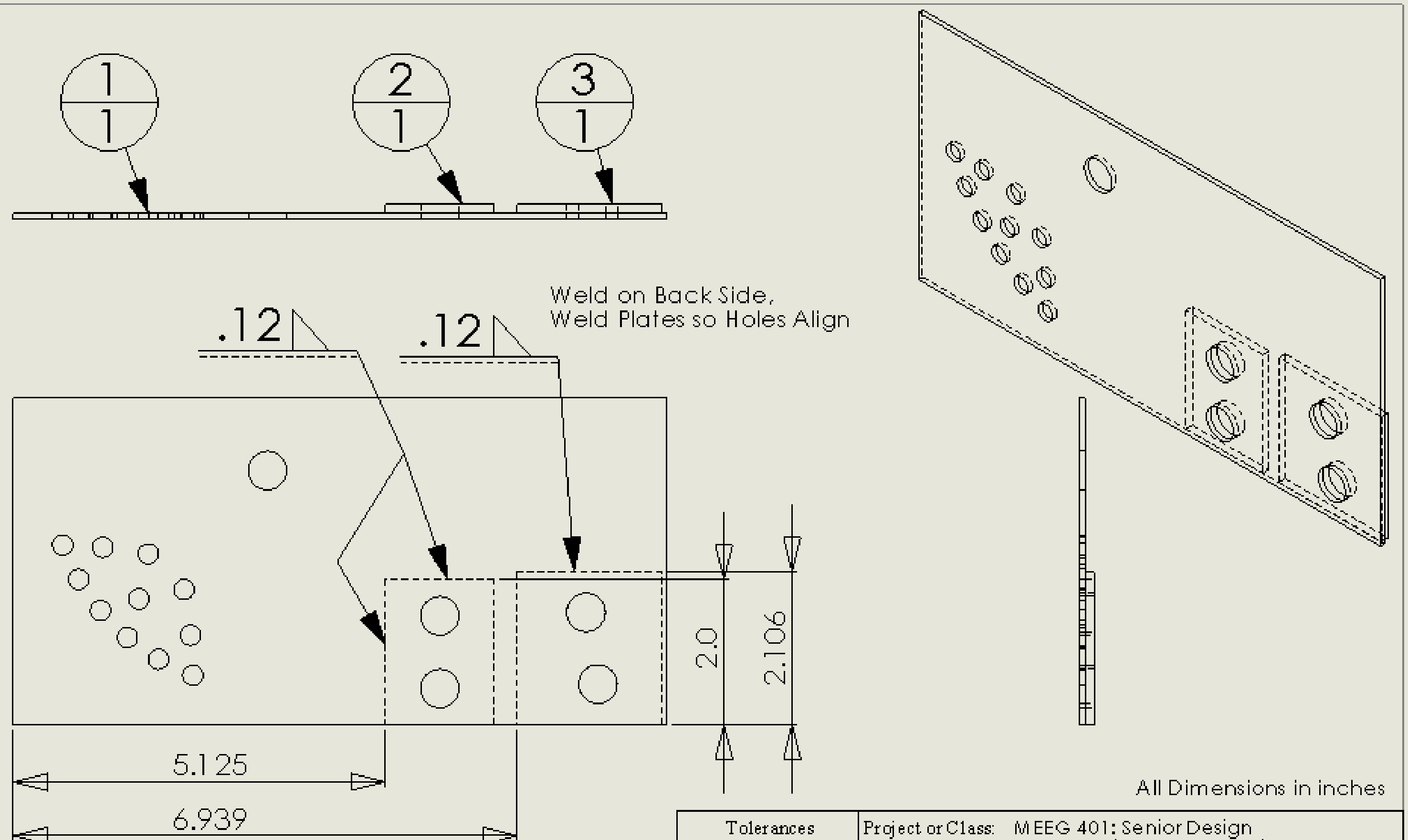

All Dimensions in inches

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
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2	84560721	Vertical AttachmentPL ATE	1
3	84560722	Main Bar PLATE	1

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84567083 (ASSEMBLY 3) PLATE LH WA	
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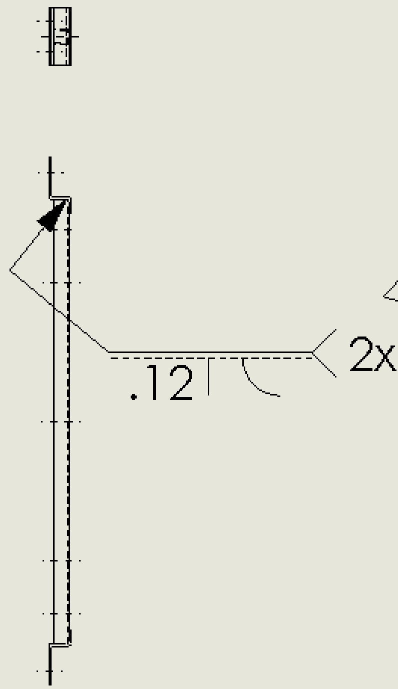
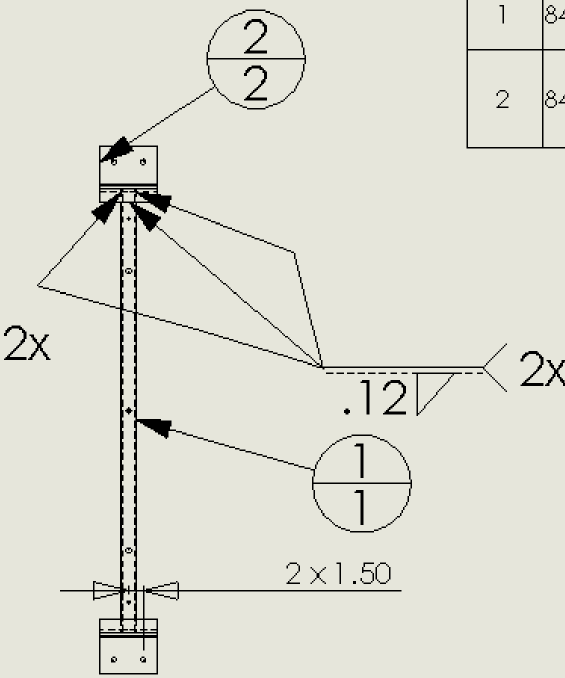
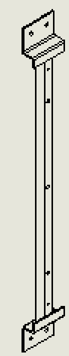
Fractional ± 1/32	Approved By:	Date:
	Material:	Quantity: 3
Angular ± 0.5 Deg	Scale: 1:2	DWG NO.: 84567083
	Billing Account:	

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	84560703	TUBE	1
2	84560705	SUPPORT	2







All Dimensions in inches

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	Material:	Quantity: 1
Angular ± 0.5 Deg	Scale: 1: 15	DWG NO.: 84567084
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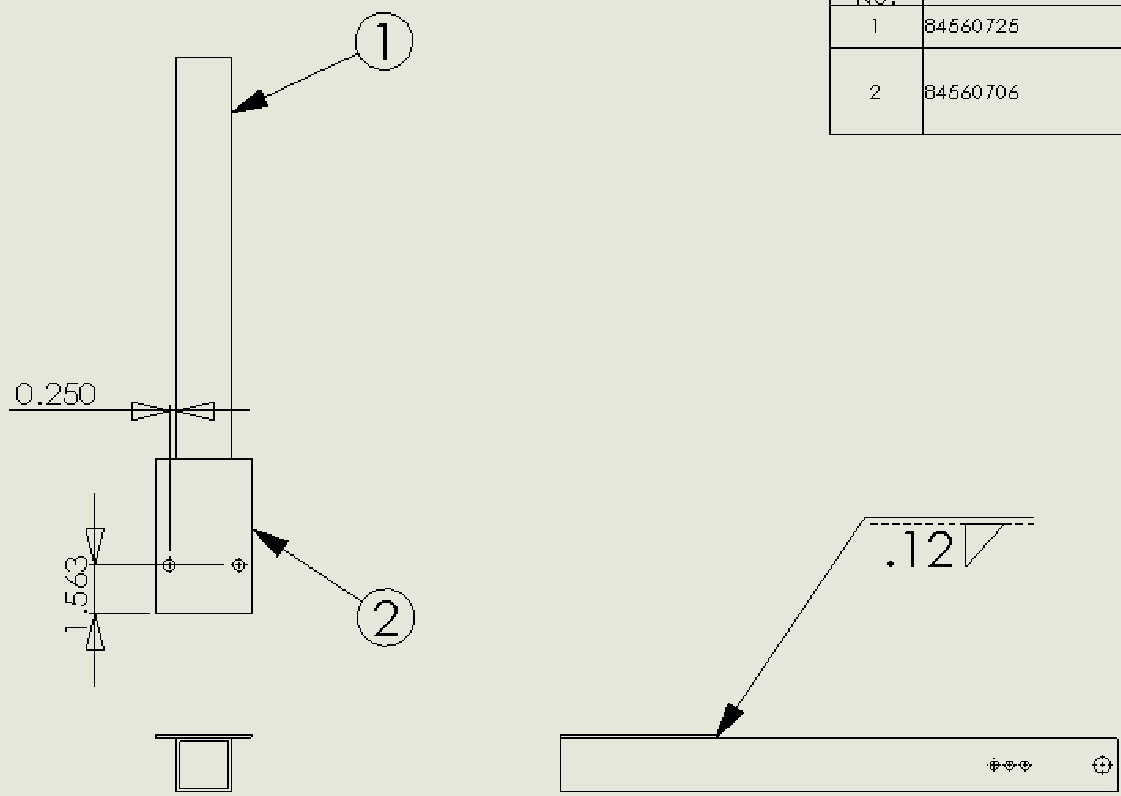
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	84560725	Outer Telescoping Tube	1
2	84560706	Pneumatic Cylinder Support Sheet	1



All Dimensions in inches

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Fractional ± 1/32	Approved By:	Date:	
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Angular ± 0.5 Deg	Scale: 1:2	DWG NO.: 84567085	
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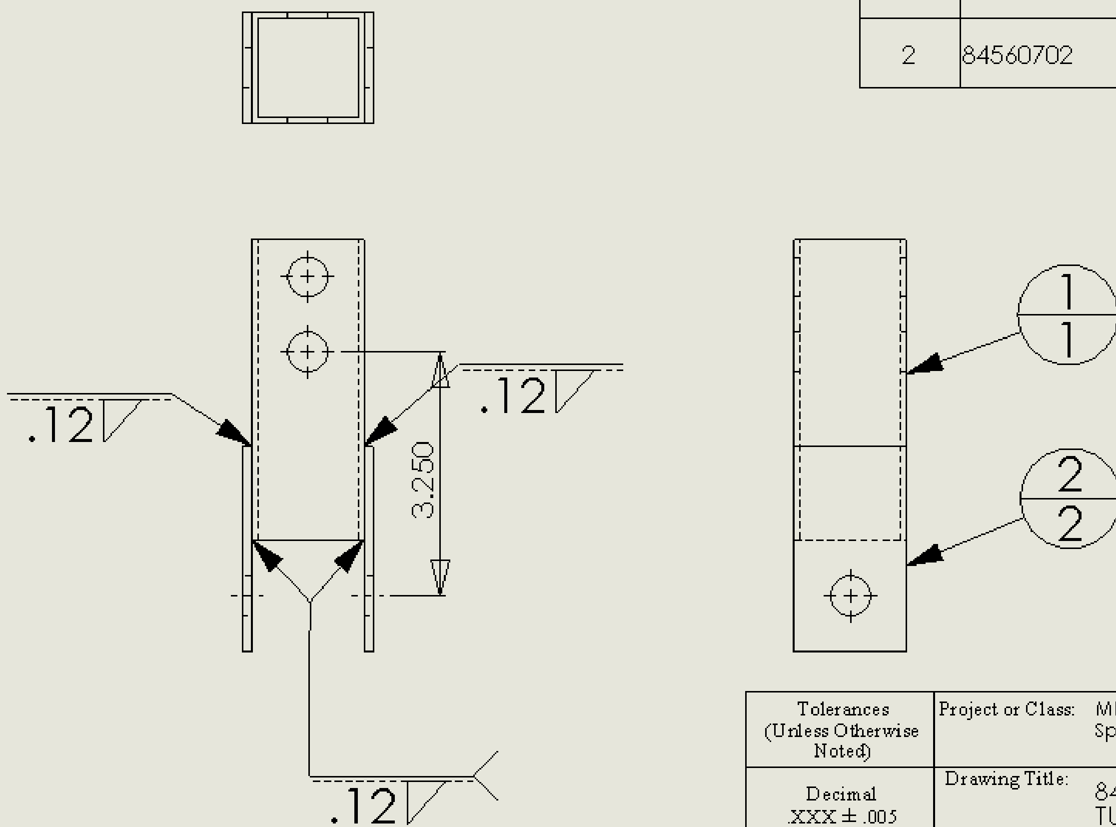

All Dimensions in inches

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Fractional ± 1/32	Approved By:	Date:	
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Angular ±0.5 Deg	Scale: 1:2	DWG NO.: 84567088	
	Billing Account:		

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
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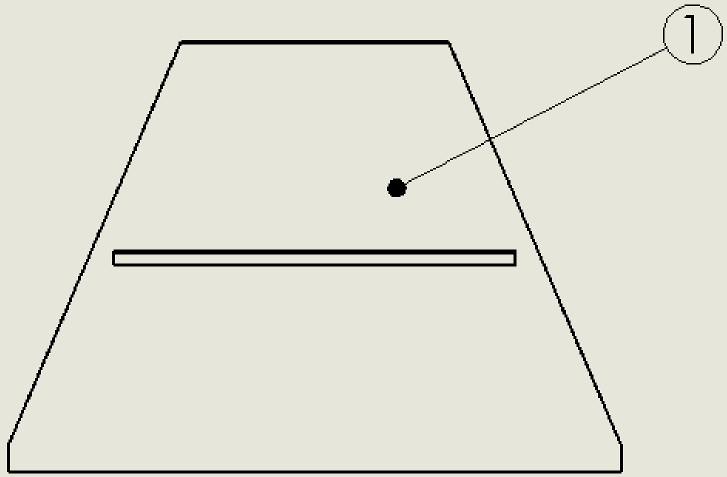
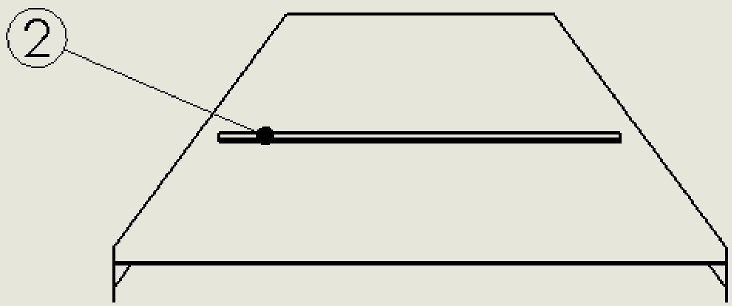
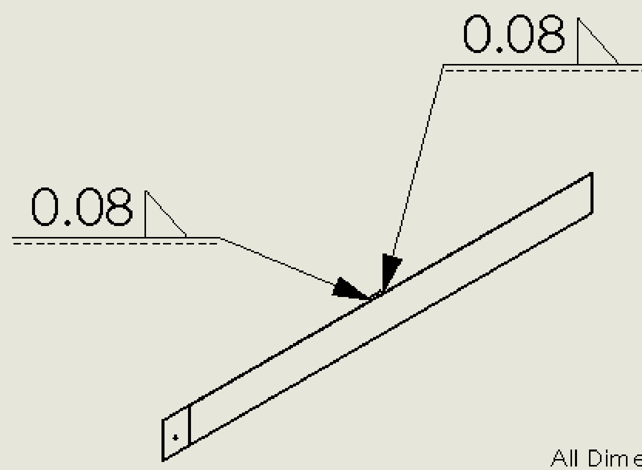
2	84567089	Tray Support Rod	1







All Dimensions in inches

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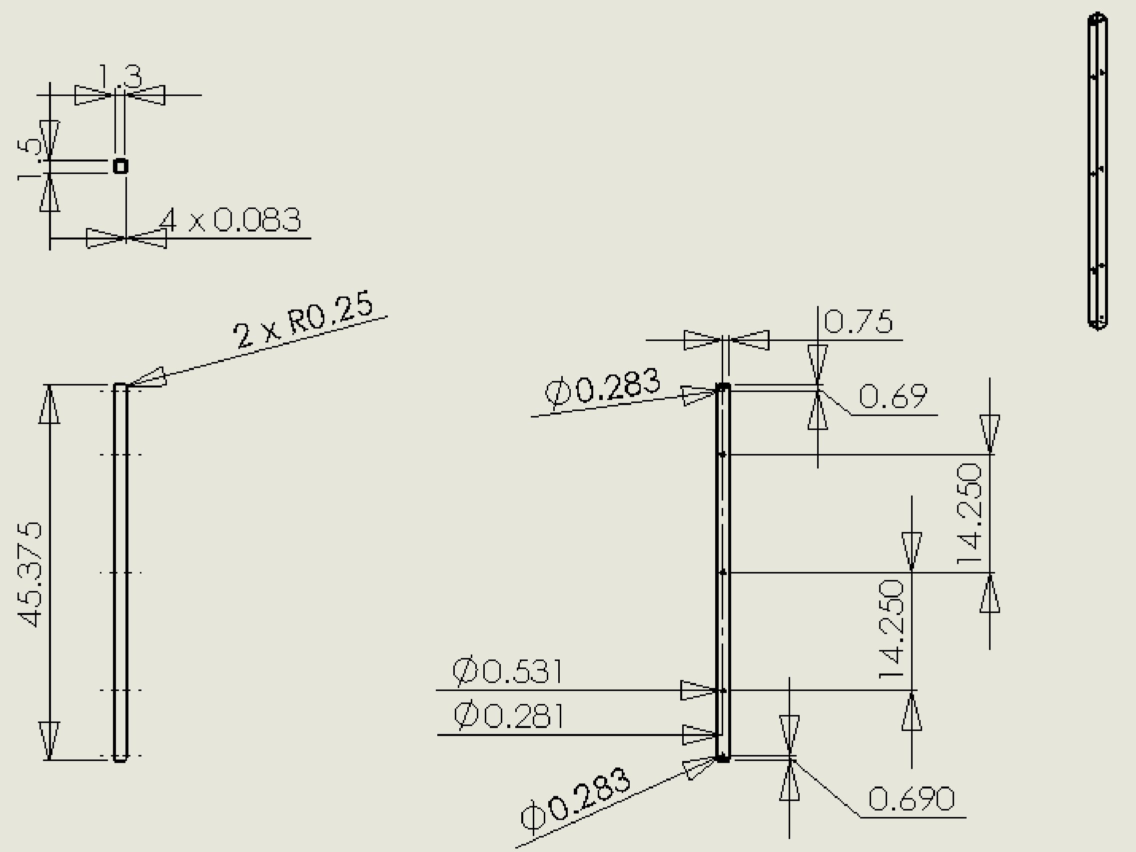

All Dimensions in inches

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Fractional ± 1/32	Approved By:	Date:
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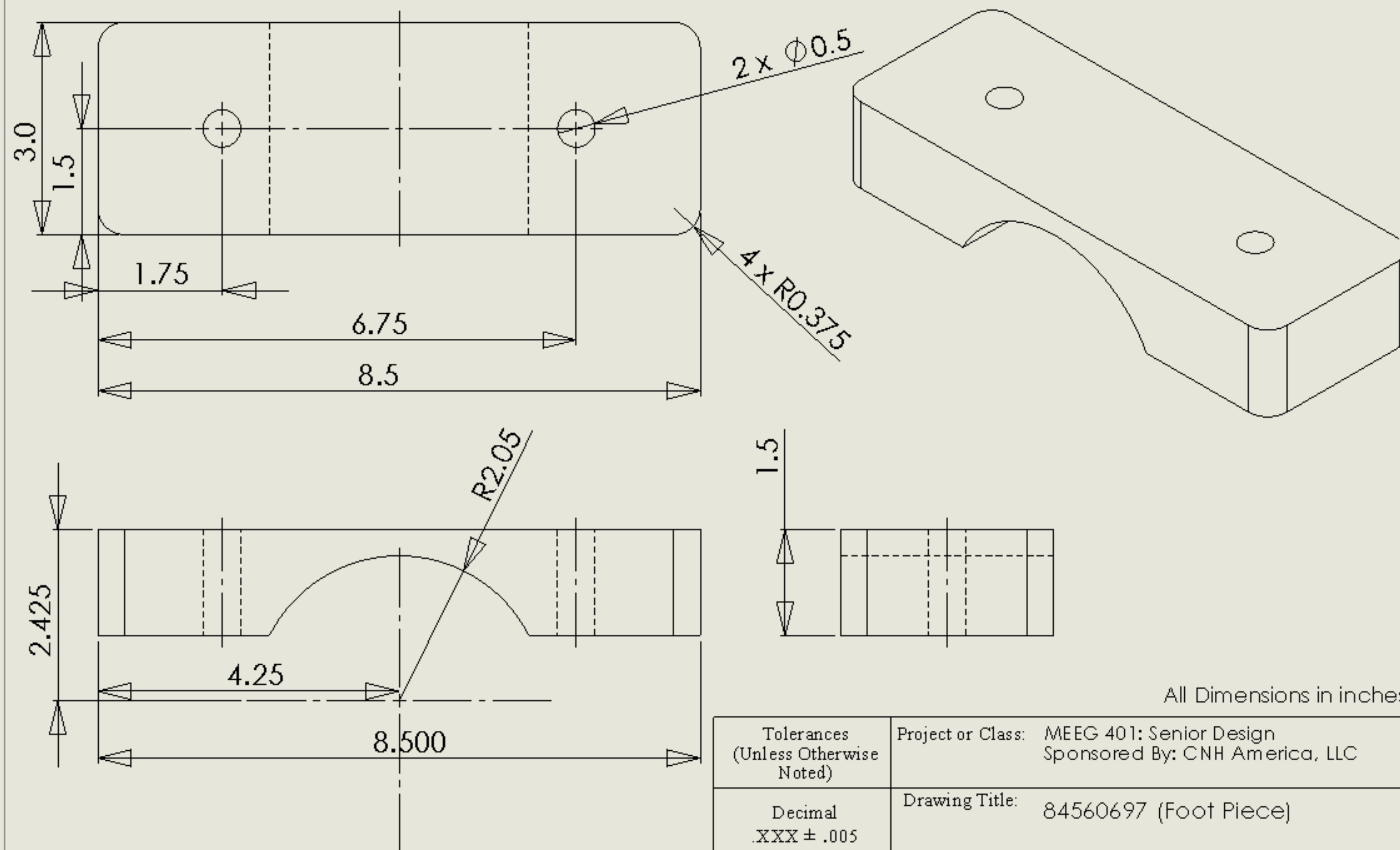
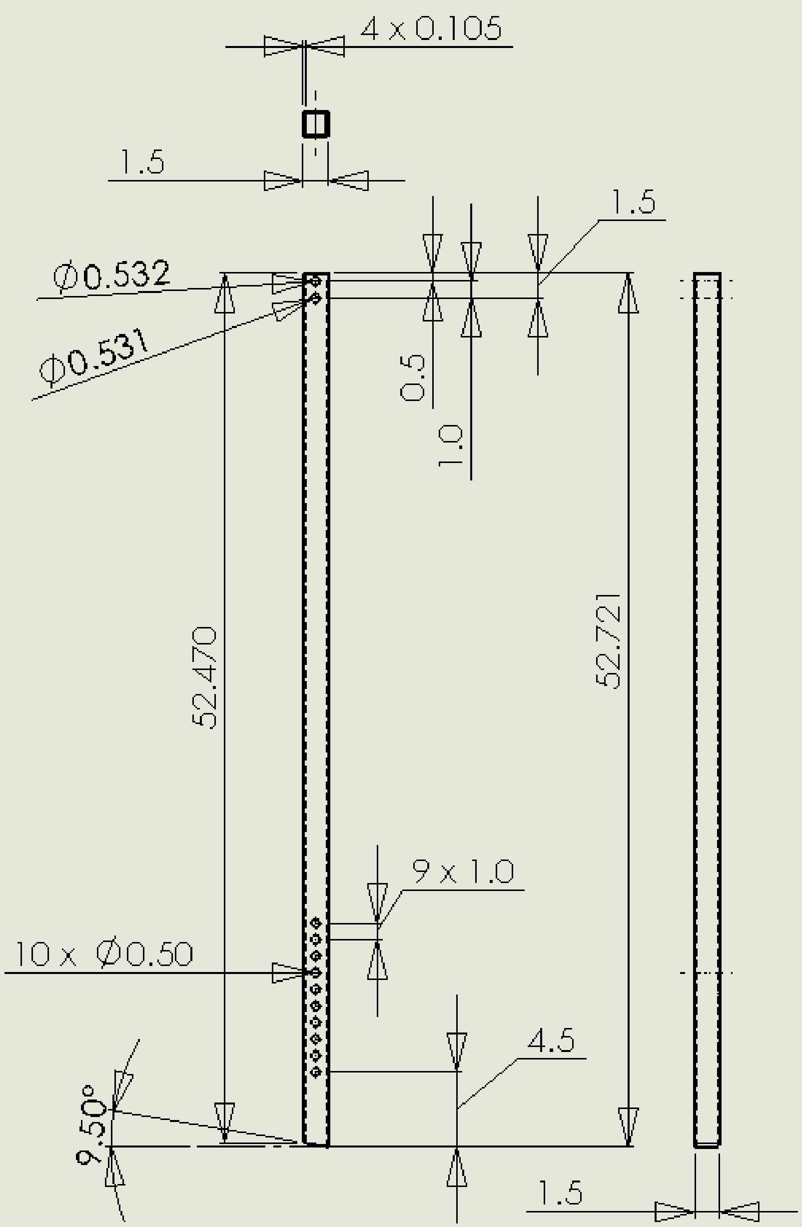
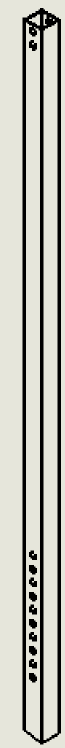
Angular ± 0.5 Deg	Scale: 1: 20	DWG NO.: 84560703
	Billing Account:	



All Dimensions in inches

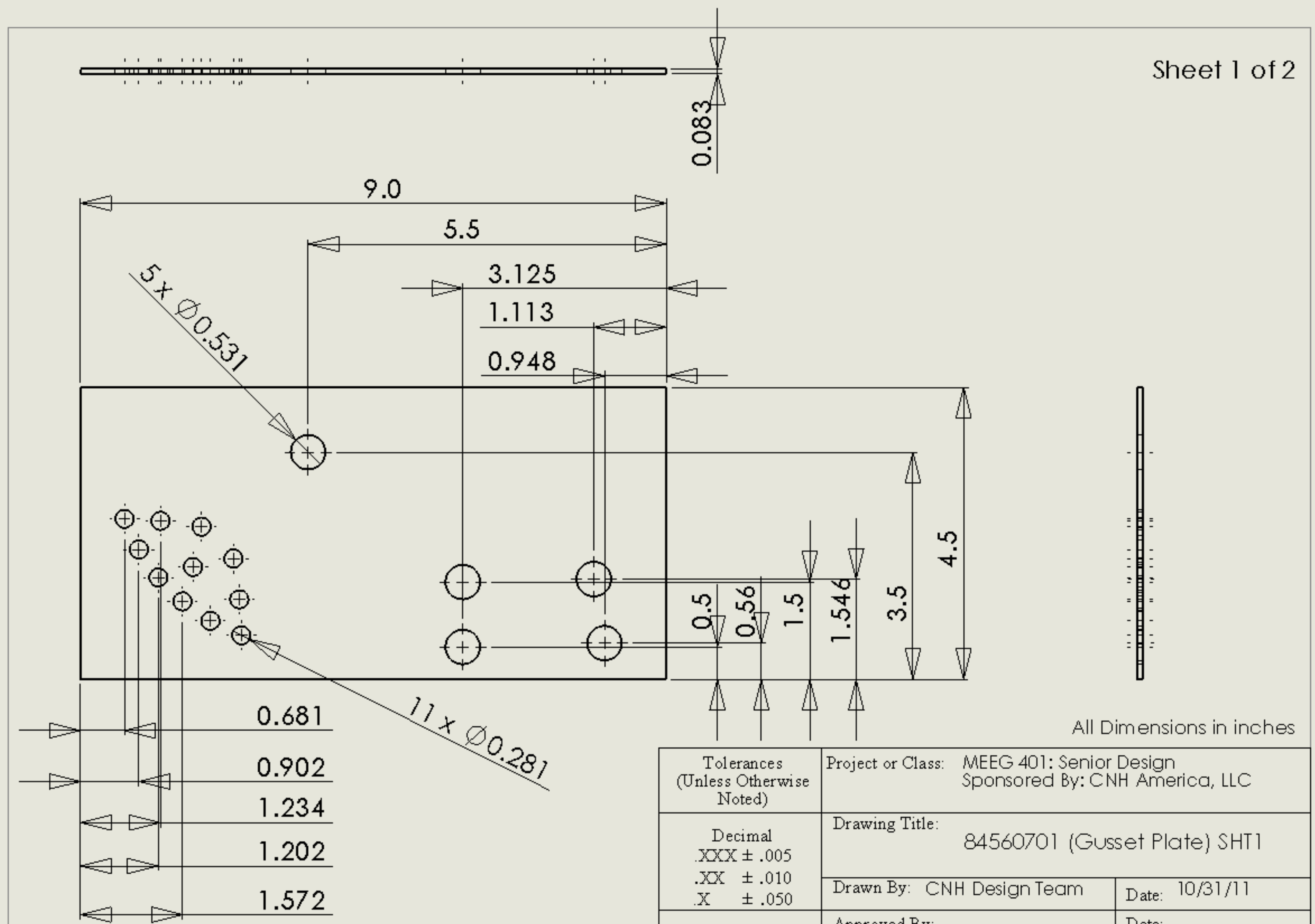
Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC		
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560697 (Foot Piece)		
	Drawn By: CNH Design Team	Date: 10/31/11	
Fractional ± 1/32	Approved By:	Date:	
	Material: CD Flat, ASTM A108, 1018	Quantity: 2	
Angular ± 0.5 Deg	Scale: 1:2	DWG NO.: 84560697	
	Billing Account:		





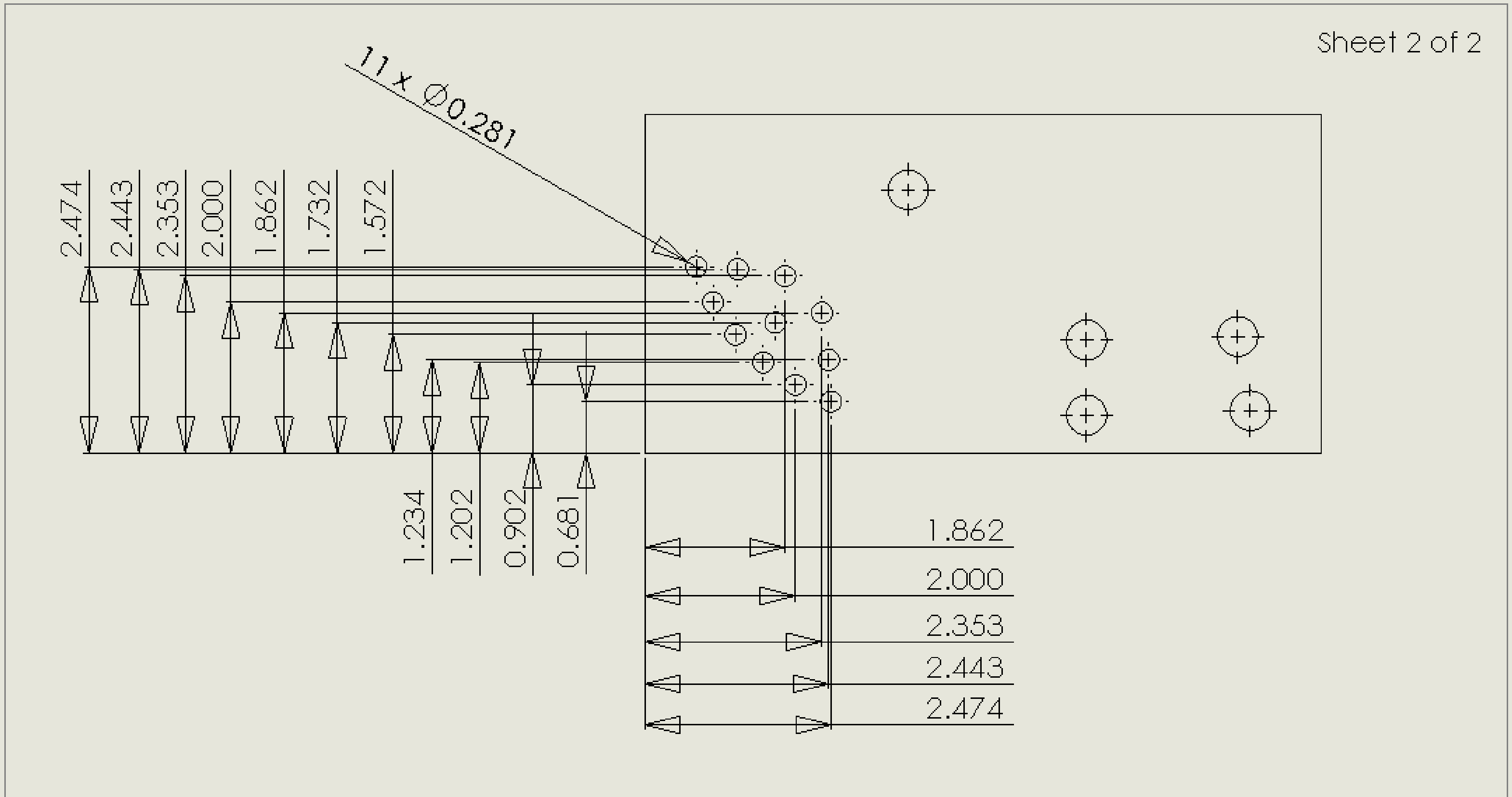
All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560698 (MAIN SUPPORT BAR) TUBE	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: SQR Tube ASTM A500, Grade C	Quantity: 2
Angular ± 0.5 Deg	Scale: 1: 10	DWG NO.: 84560698
	Billing Account:	

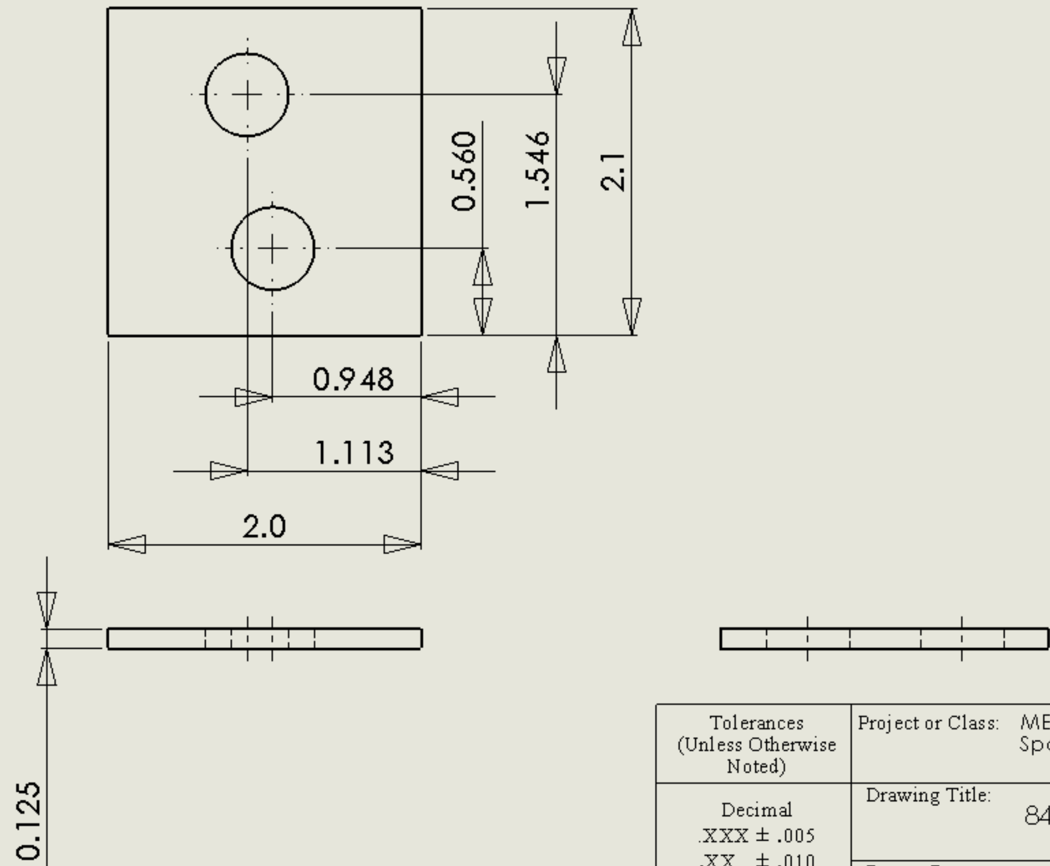


All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560701 (Gusset Plate) SHT1	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: CR STRIP,ASTM A1011, CS TYPEB	Quantity: 6
Angular ± 0.5 Deg	Scale: 1:2	DWG NO.: 84560701
	Billing Account:	

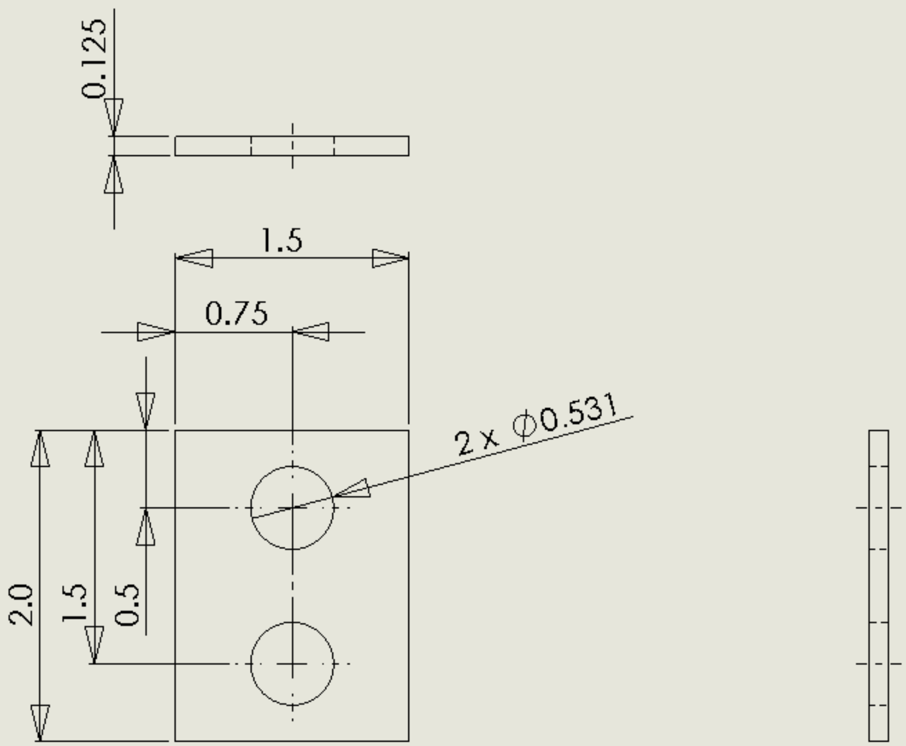


Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560701 (Gusset Plate) SHT2	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: CR STRIP,ASTM A1011, CS TYPEB	Quantity:
Angular ± 0.5 Deg	Scale: 1: 2	DWG NO.: 84560701
	Billing Account:	



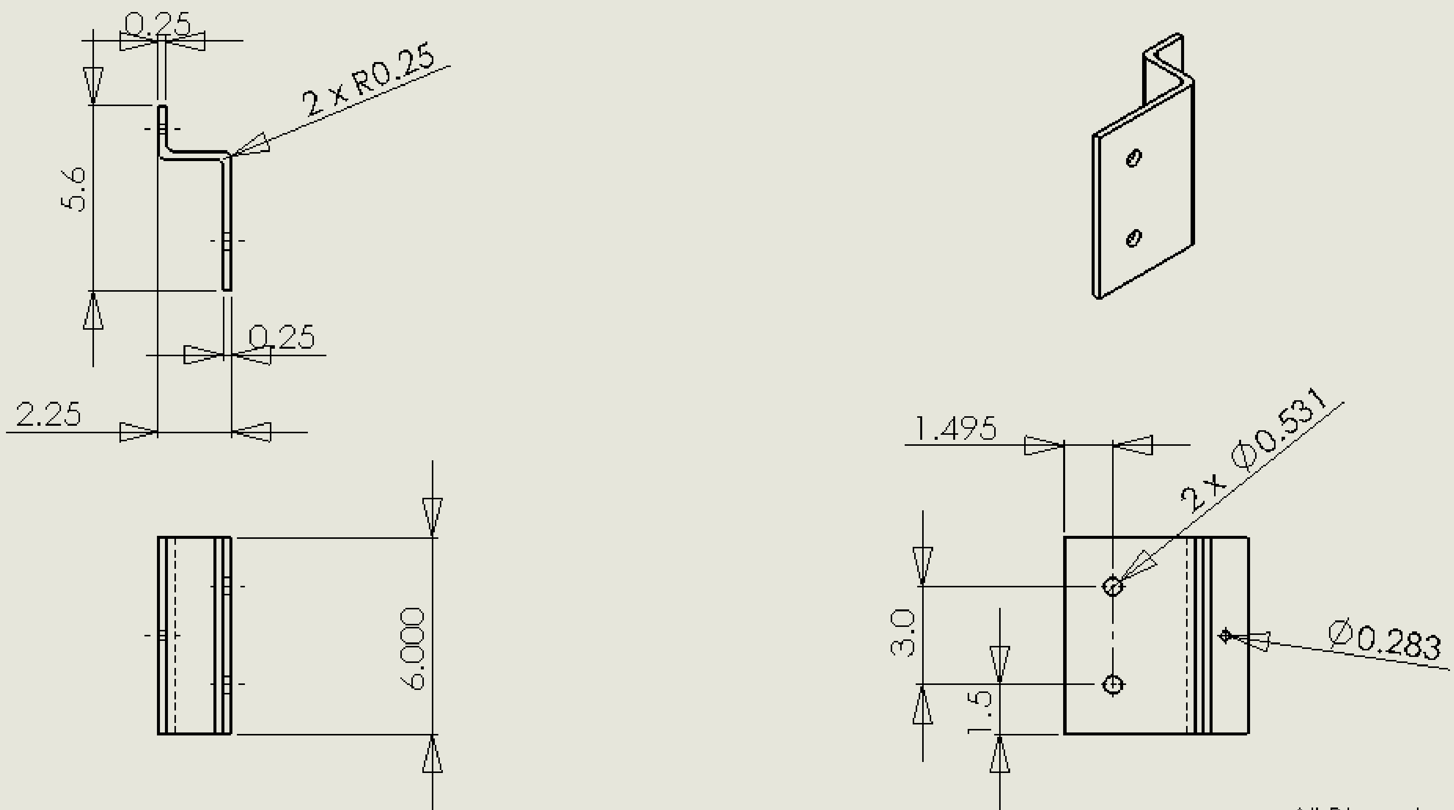
All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560722 (Main Bar Spacer)	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: HR STRIP,ASTM A1011,CS TYPE B	Quantity: 6
Angular ± 0.5 Deg	Scale: 1:1	DWG NO.: 84560722
	Billing Account:	



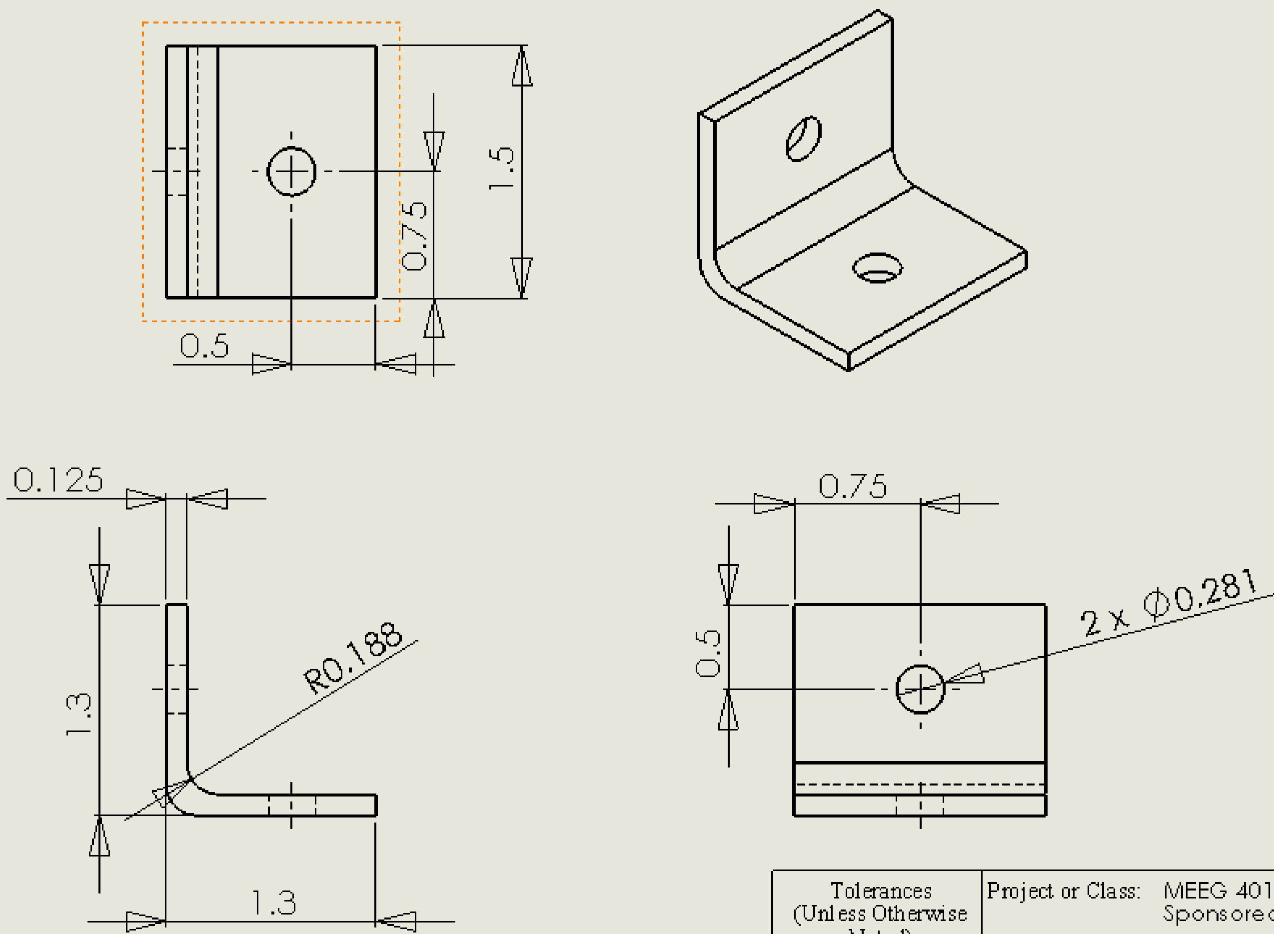
All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560721 (Vertical Attachment Spacer)	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: HR STRIP, ASTM A1011, CS TYPE B	Quantity: 6
Angular ± 0.5 Deg	Scale: 1:1	DWG NO.: 84560721
	Billing Account:	



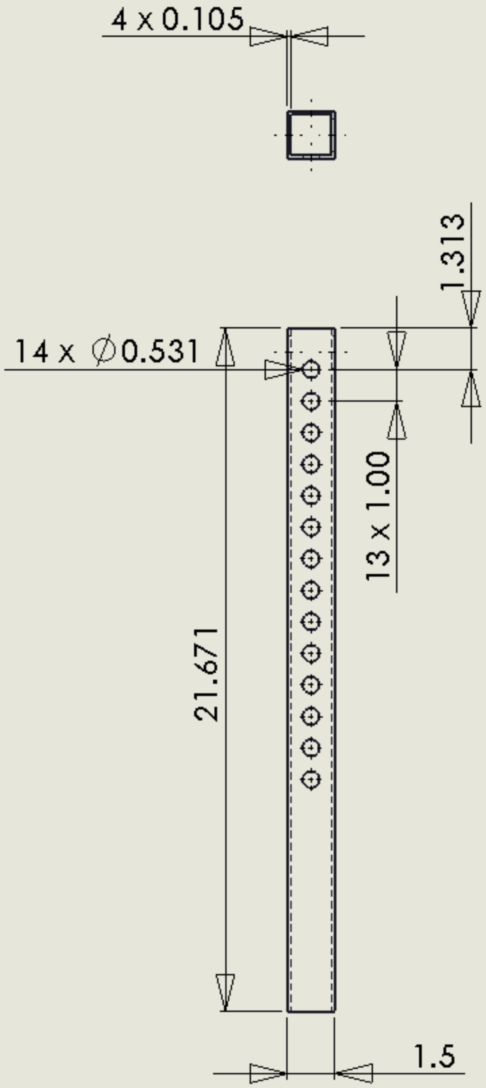
All Dimensions in inches

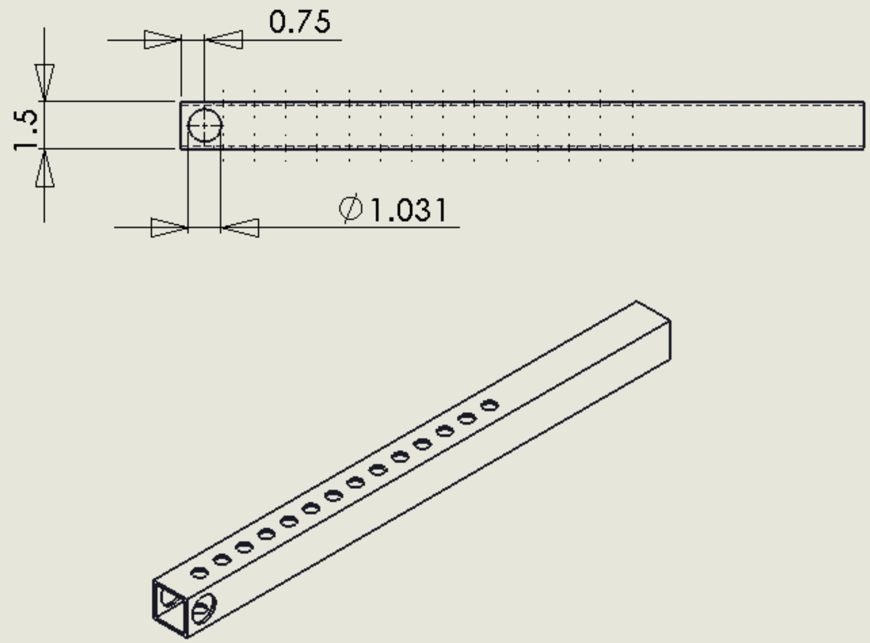
Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560705 (Inner Clamp Piece) SUPPORT	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: CD Flat, ASTM A108, 1018	Quantity: 2
Angular ± 0.5 Deg	Scale: 1:2	DWG NO.: 84560705
	Billing Account:	



All Dimensions in inches

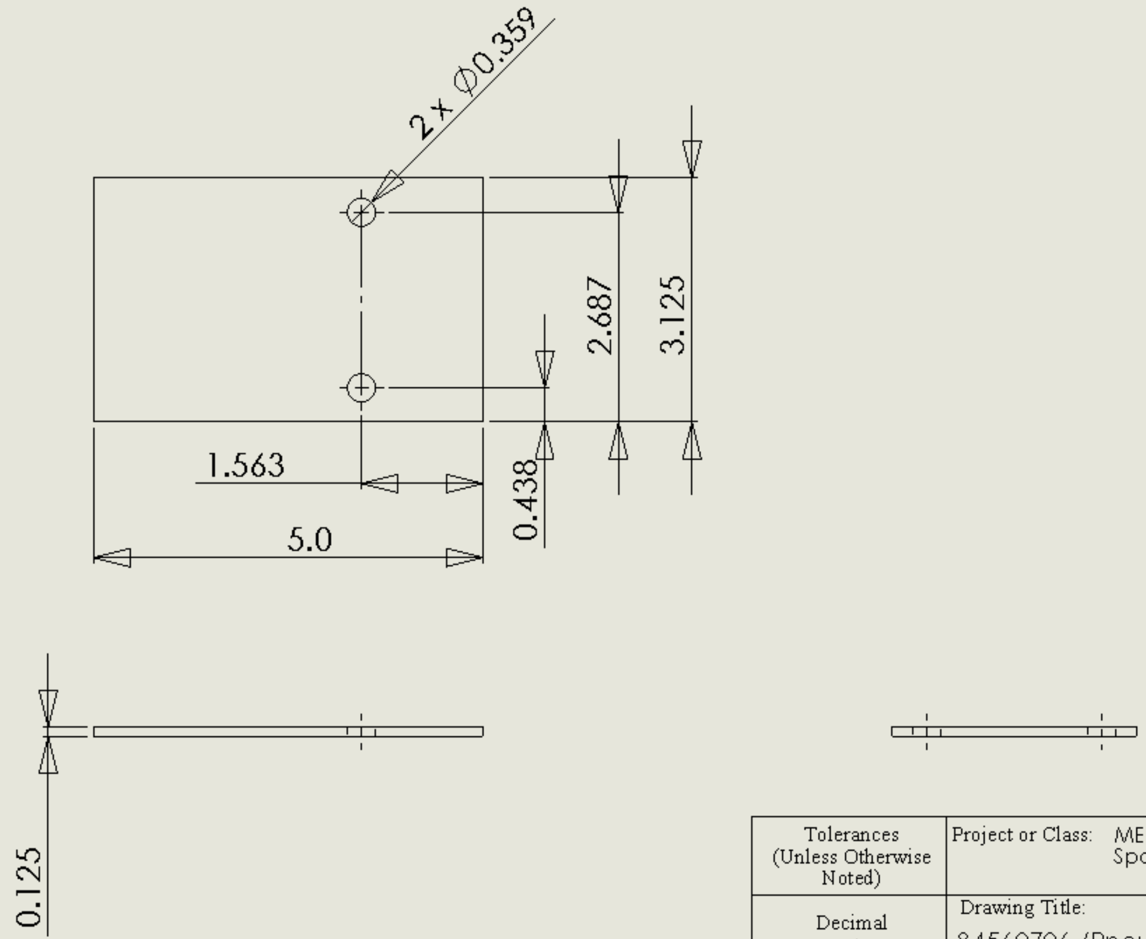
Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560710 (L-Bracket Tray Support) ANGLE	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: HR SHEET METAL, A STM A1008, CS TYPE B	Quantity: 2
Angular ± 0.5 Deg	Scale: 1:2	DWG NO.:84560710
	Billing Account:	





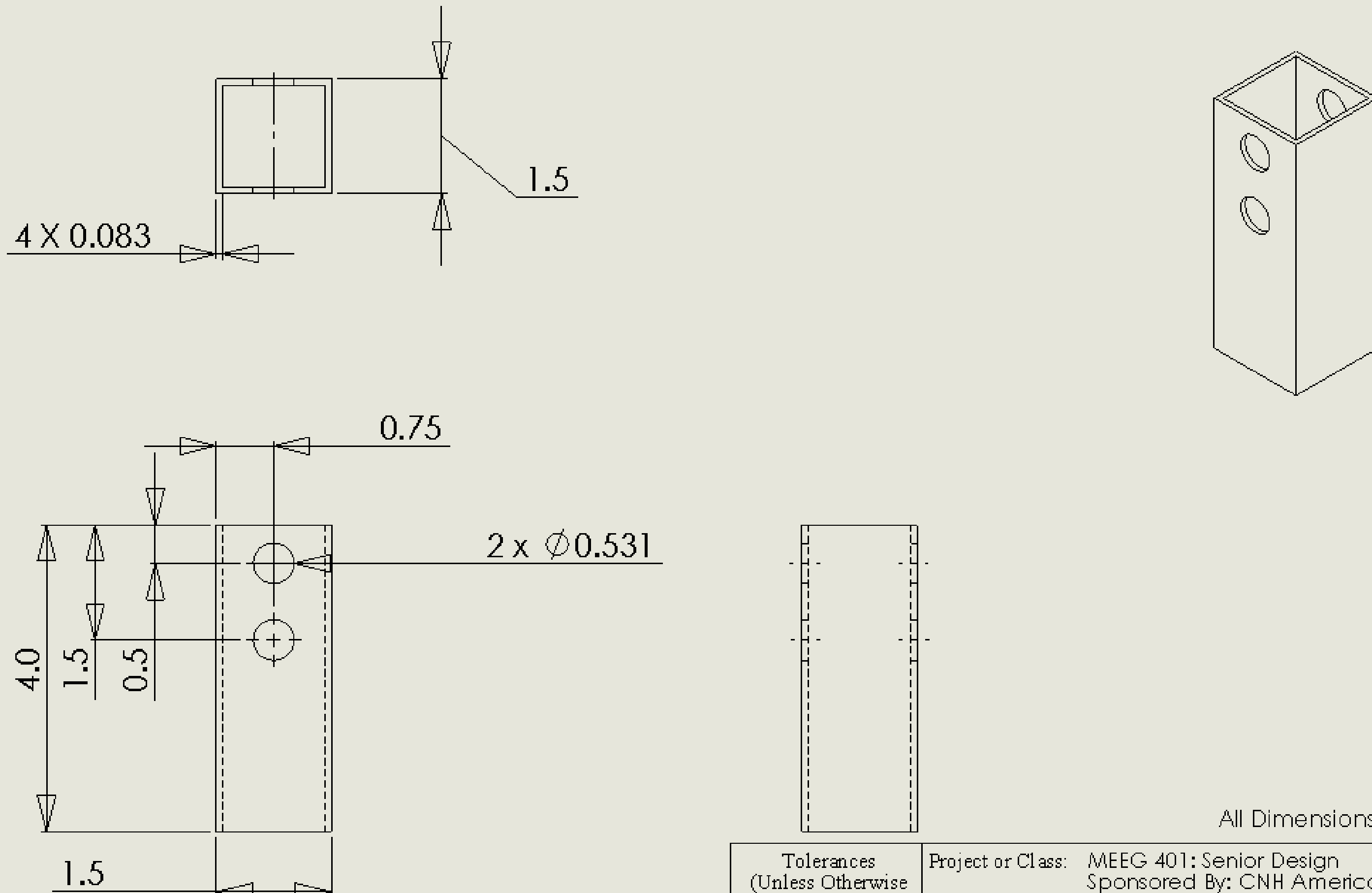
All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560708 (Inner Telescoping Tube)	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: PURCHASED PART TO BE MODIFIED	Quantity: 3
Angular ± 0.5 Deg	Scale: 1:5	DWG NO.: 84560708
	Billing Account:	



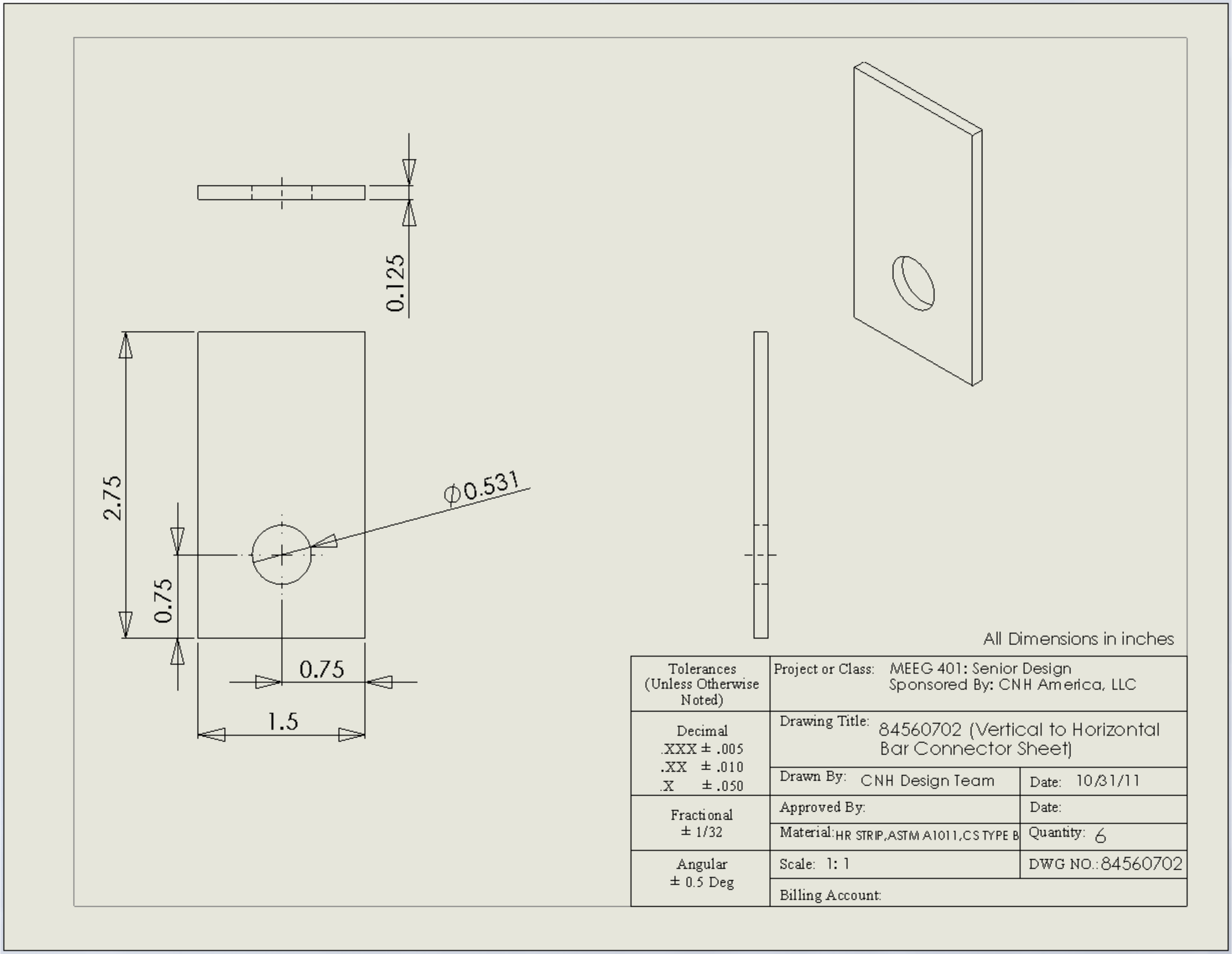
All Dimensions in inches

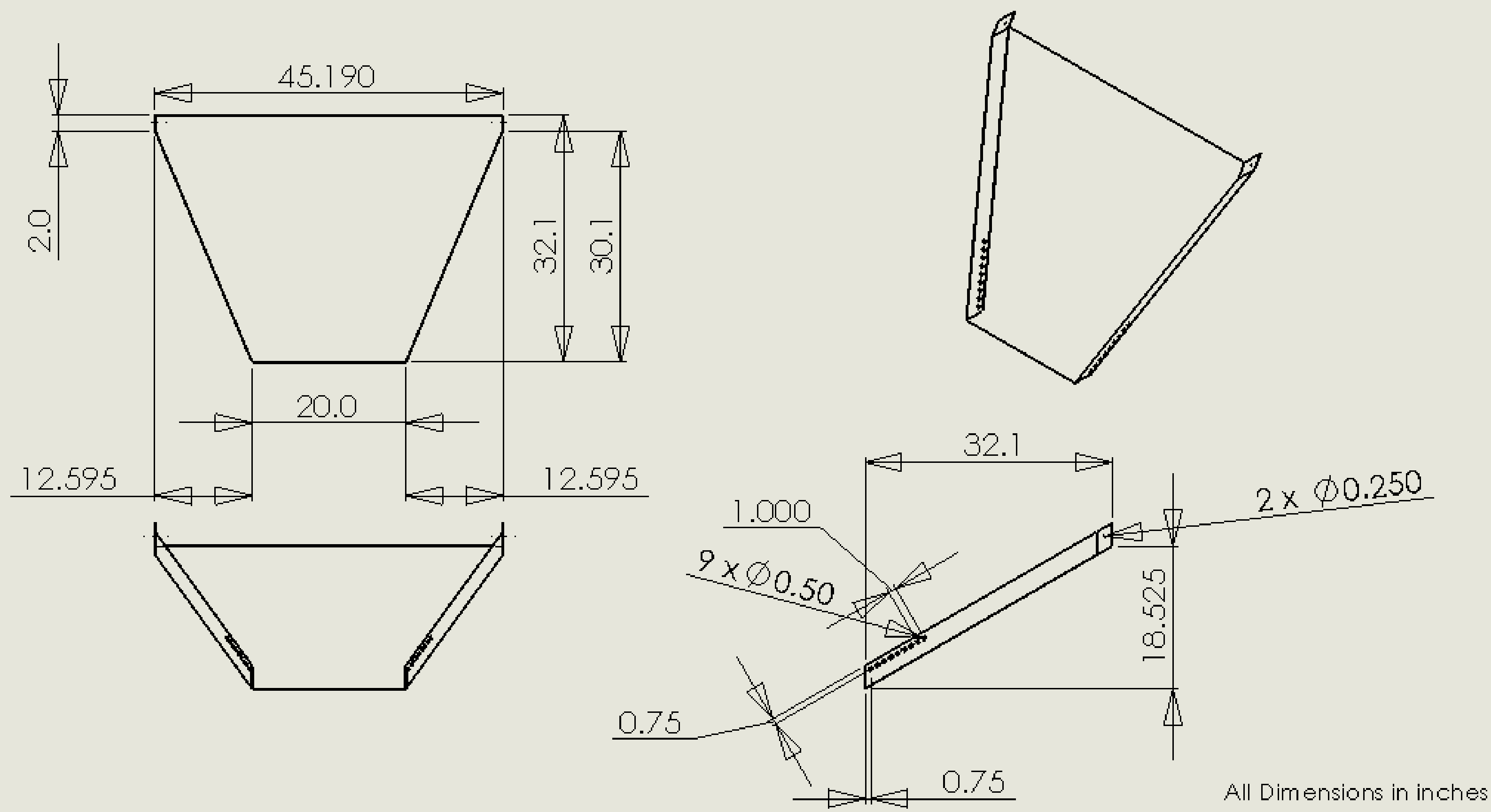
Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560706 (Pneumatic Cylinder Support Sheet)	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: HR STRIP,ASTM A1011,CS TYPE B	Quantity: 3
Angular ± 0.5 Deg	Scale: 1:2	DWG NO.: 84560706
	Billing Account:	



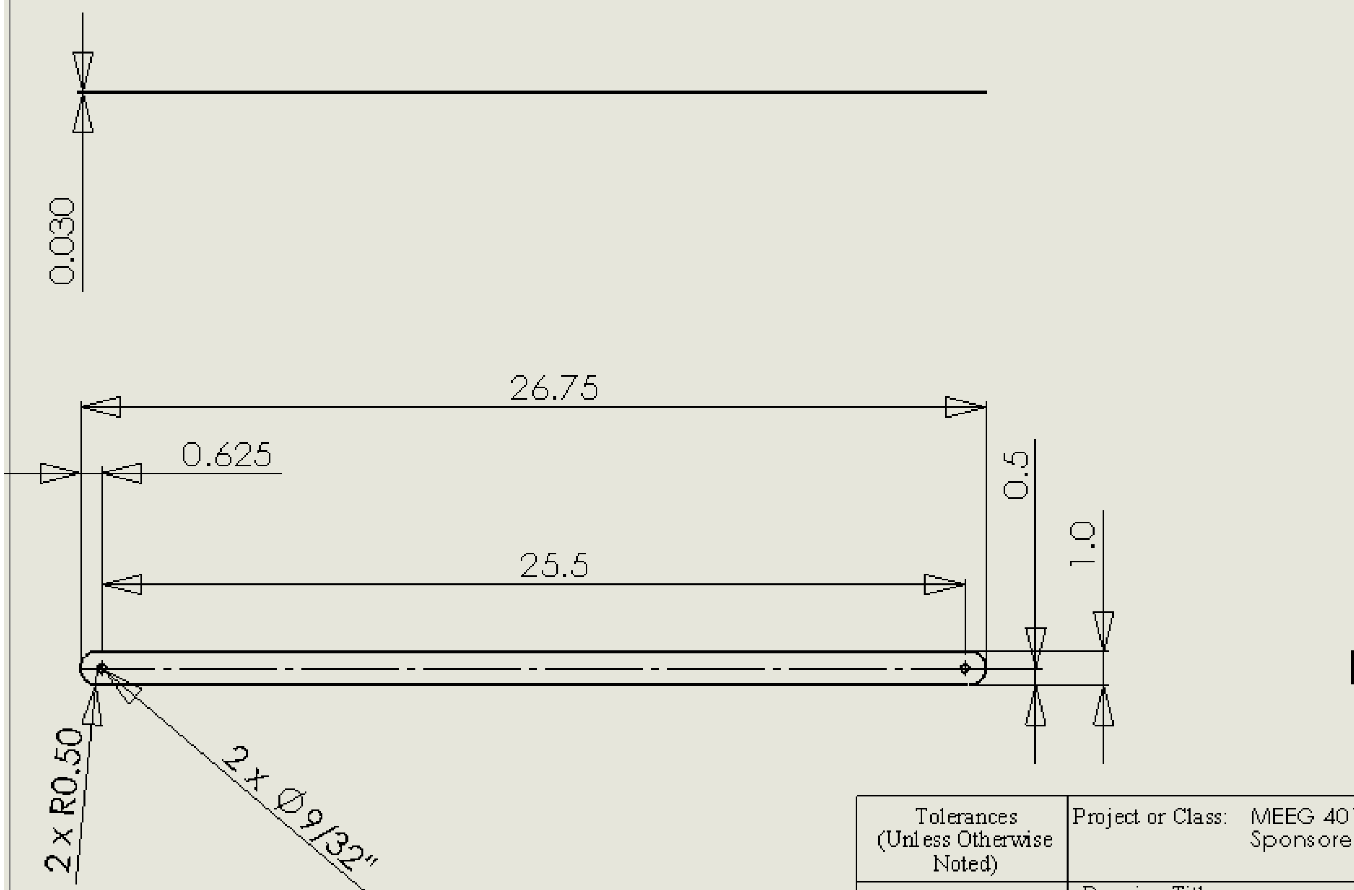
All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560700 (Vertical Bar Attachment)	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: SQR Tube ASTM A500, Grade C	Quantity: 3
Angular ± 0.5 Deg	Scale: 1:2	DWG NO.: 84560700
	Billing Account:	


0.125
2.75
0.75
ϕ0.531
0.75
1.5
All Dimensions in inches
Tolerances (Unless Otherwise Noted)
Decimal
.XXX ± .005
.XX ± .010
.X ± .050
Fractional
± 1/32
Angular
± 0.5 Deg
Project or Class: MEEG 401: Senior Design
Sponsored By: CNH America, LLC
Drawing Title: 84560702 (Vertical to Horizontal Bar Connector Sheet)
Drawn By: CNH Design Team
Date: 10/31/11
Approved By:
Date:
Material: HR STRIP,ASTM A1011,CS TYPE B
Quantity: 6
Scale: 1: 1
DWG NO.: 84560702
Billing Account:

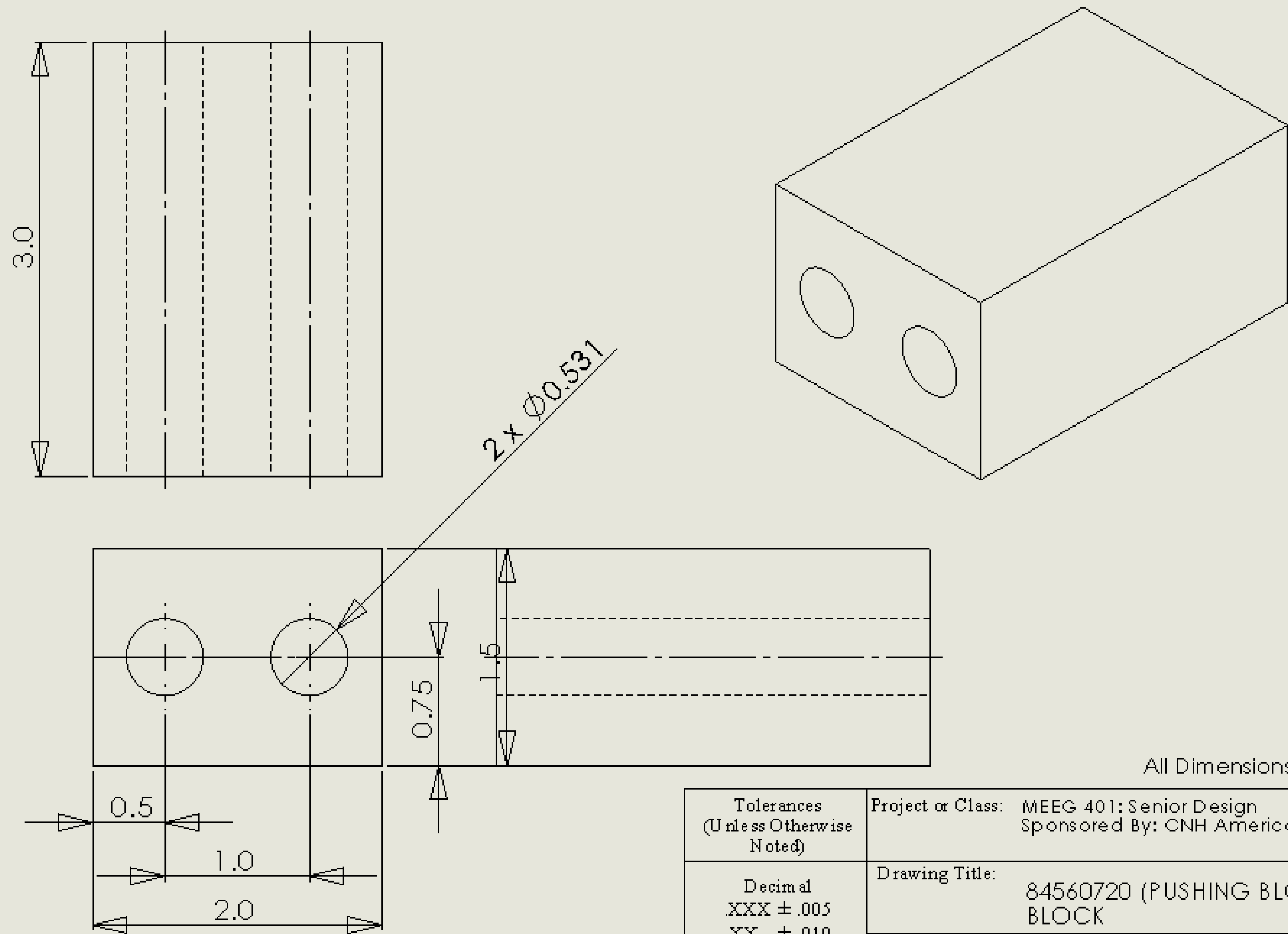


Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560716 (Tray)	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: CR SHEET,ASTM A1008 CS TYPE B	Quantity: 1
Angular ± 0.5 Deg	Scale: 1:20	DWG NO.: 84560716
	Billing Account:	



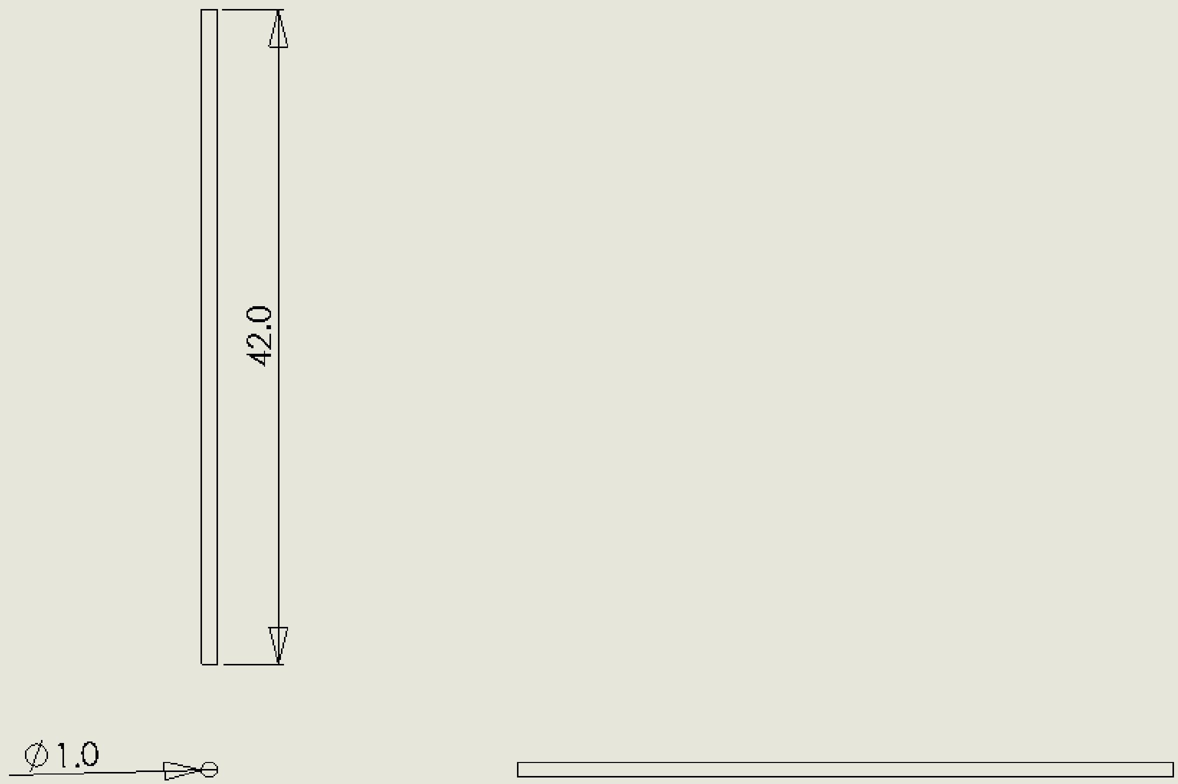
All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560715 (Tray Connector Piece)	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: CR SHEET,ASTM A1008, CS TYPE B	Quantity: 2
Angular ± 0.5 Deg	Scale: 1: 5	DWG NO.: 84560715
	Billing Account:	



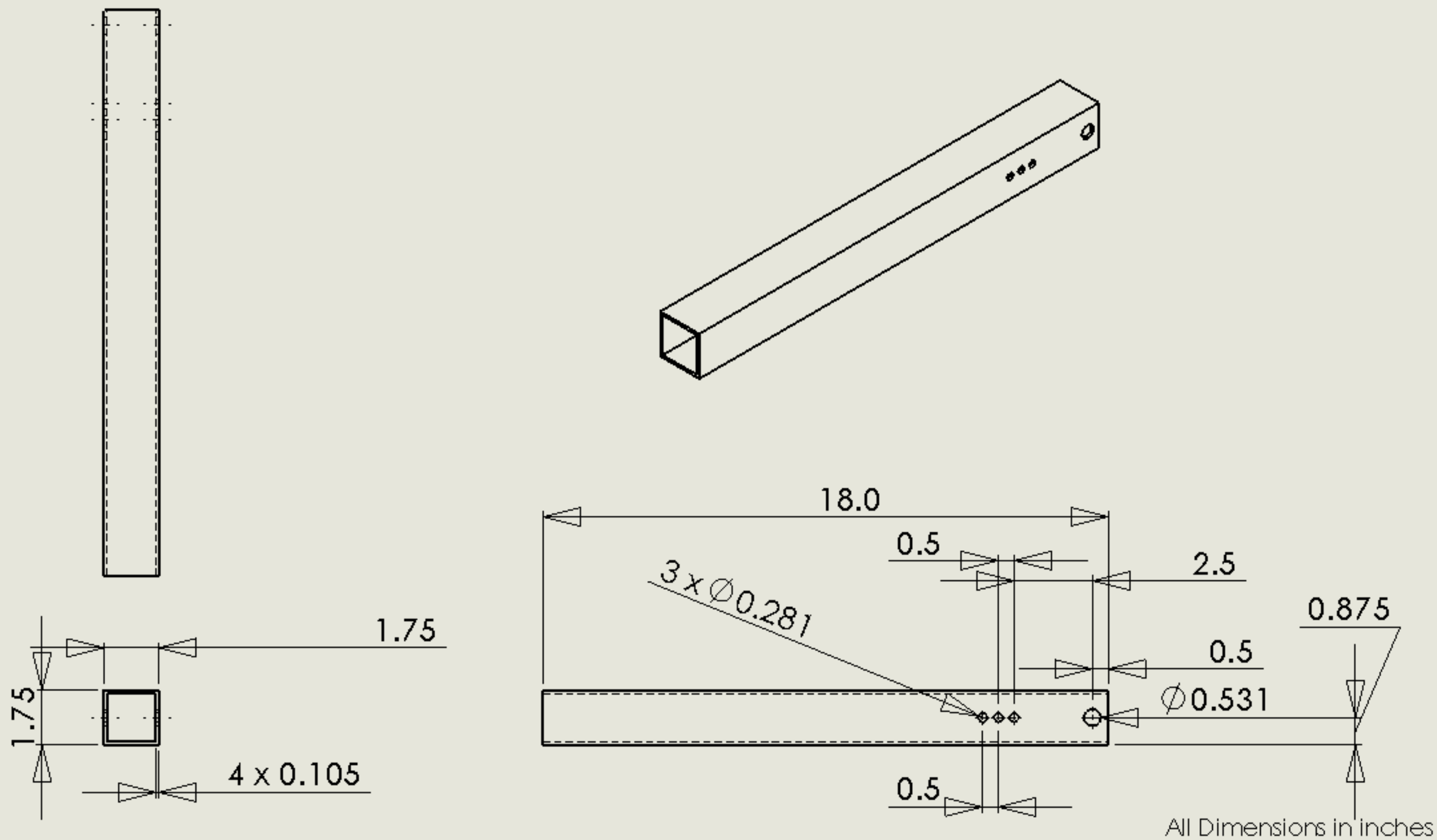
All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560720 (PUSHING BLOCK) BLOCK	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: CD FLAT,ASTM A108,1018	Quantity: 3
Angular ± 0.5 Deg	Scale: 1:1	DWG NO.: 84560720
	Billing Account:	

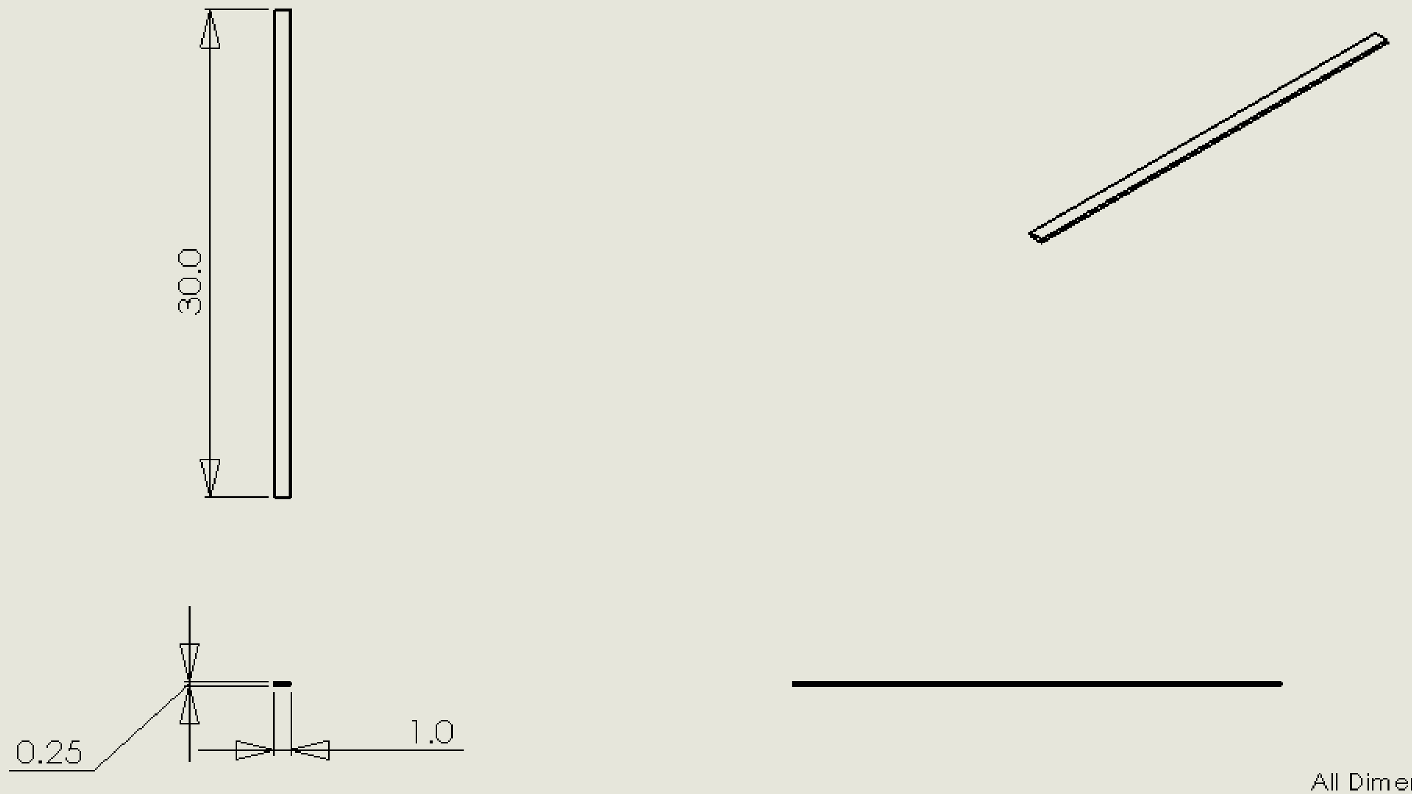


All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560711 (Shaft)	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: CD ROUND STOCK, ASTM A108,1018	Quantity: 1
Angular ± 0.5 Deg	Scale: 1: 10	DWG NO.: 84560711
	Billing Account:	

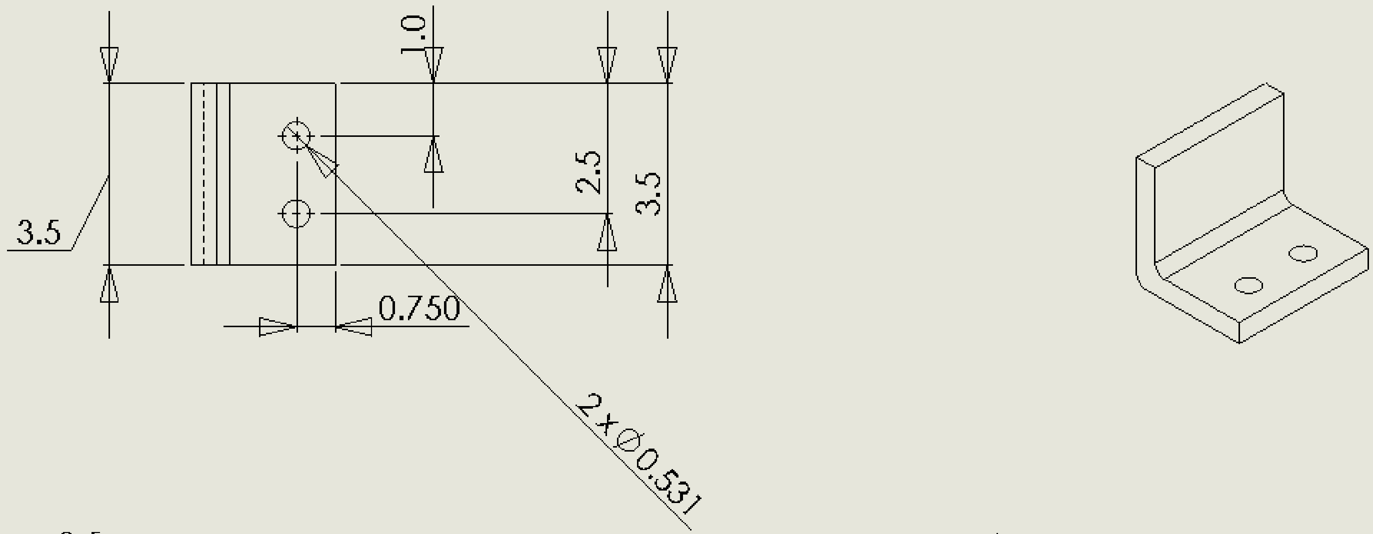


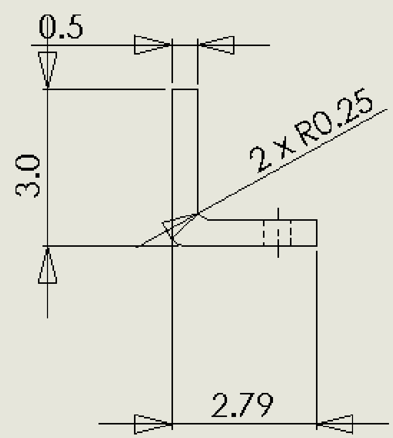
Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560725 (OUTER TELESCOPING TUBE) TUBE	
	Drawn By: CNH Design Team	Date: 10/31/11
Fractional ± 1/32	Approved By:	Date:
	Material: PURCHASED PART TO BE MODIFIED	Quantity: 3
Angular ± 0.5 Deg	Scale: 1:5	DWG NO.: 84560725
	Billing Account:	

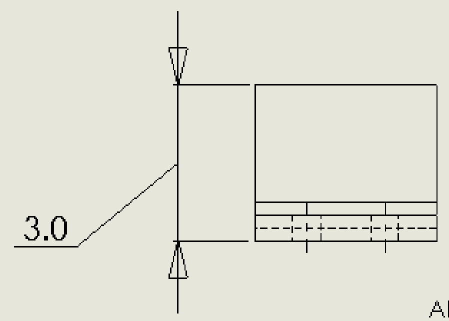


All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC	
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84567089 (Tray Support Rod) Sheet	
	Drawn By: CNH Design Team	Date: 12/10/11
Fractional ± 1/32	Approved By:	Date:
	Material: Sheet Metal	Quantity: 1
Angular ± 0.5 Deg	Scale: 1: 10	DWG NO.: 84567089
	Billing Account:	







All Dimensions in inches

Tolerances (Unless Otherwise Noted)	Project or Class: MEEG 401: Senior Design Sponsored By: CNH America, LLC		
Decimal .XXX ± .005 .XX ± .010 .X ± .050	Drawing Title: 84560717 (Outer Clamp Piece)		
	Drawn By: CNH Design Team	Date: 10/31/11	
Fractional ± 1/32	Approved By:	Date:	
	Material: CD Flat, ASTM A108, 1018	Quantity: 2	
Angular ± 0.5 Deg	Scale: 1:3	DWG NO.: 84560717	
	Billing Account:		