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JME 4110 Final Report -Trunk Lift Assist

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This document presents the design for device to assist with loading and unloading of items into the trunk compartment of an automobile. Enclosed in this report is the rationale behind the design decisions based on consumer interviews, relevant regulating codes and standards, and necessary design constraints. Initial concept drawings and the selection process leading to the initial embodiment design are contained in this report. All initial and final CAD drawings and assembly instructions are incorporated into this summary statement as well as photographs and video links.

JME 4110 Design Report

Trunk Lift Assist

Kyle Copeland
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1 INTRODUCTION

1.1 VALUE PROPOSITION

For the elderly and physically challenged who are dissatisfied with having to bend over and remove items from the storage areas of their vehicles, our product is a aftermarket load managing system that will both rotate and telescope out of automobile storage areas. This provides a less body & strength intensive method for removing ones belongings from automobile storage areas unlike the current method of bending over into the vehicle and lifting loads far from the bodies' center of gravity risking injury.

1.2 TEAM MEMBERS

Kyle Copeland
Ben Hogan
Jon Krems
Tom Schuh

2 BACKGROUND INFORMATION STUDY

2.1 DESIGN BRIEF

Proposed design for a motorized load management system for aftermarket installation in automobile trunk compartments. This system is designed for elderly and the physically challenged to assist in the loading and unloading of items in the trunk compartment of vehicles. The design encompasses a platform that will both raise and lower and will additionally provide movement inward and outward of the trunk compartment which current designs lack. The motorized system will operate off of the existing 12 volt electrical system standard on most production automobiles. The design will be tailored for universal application in most vehicles while not interfering with § 571.401 Standard No. 401; Interior trunk release. It is also important to allow access to tire changing equipment; i.e. spare tire, jack, & tire iron. The design will allow for a less physically demanding method for placement and retrieval of items from automobile trunk compartments unlike the current unergonomic practice of bending over at the waist and retrieving items at a distance from ones body.

2.2 BACKGROUND SUMMARY

A search for existing designs that were similar to our chosen topic lead to two patents that are shown in the figures below.

United States Patent [19]

Pawl

[11] **Patent Number: 4,969,793**

[45] **Date of Patent: Nov. 13, 1990**

[54] **POWER TRUNK LIFT**

[76] Inventor: **E. Timothy Pawl**, P.O. Box 5425, 4960 Arrowhead Rd., West Bloomfield, Mich. 48033

[21] Appl. No.: **156,246**

[22] Filed: **Feb. 16, 1988**

[51] **Int. Cl.**[5] **B65G 67/00**

[52] **U.S. Cl.** **414/462**; 414/540; 414/495; 414/641; 414/522; 254/122; 187/18

[58] **Field of Search** ..... 414/462, 495, 522, 641; 254/9 R, 9 B, 9 C, 122, 126; 187/8.71, 8.72, 18; 248/421; 74/520, 521; 296/37.1

[56] **References Cited**

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FOREIGN PATENT DOCUMENTS

1756778	4/1970	Fed. Rep. of Germany	414/495

Primary Examiner—Frank E. Werner

Attorney, Agent, or Firm—Charles W. Chandler

[57] **ABSTRACT**

A power-operated lift, adapted to be mounted in a vehicle trunk has linkage means for raising a load-supporting platform in a vertical direction. The platform can be manually moved in a horizontal direction to remove the load from the trunk. The platform can be pivoted about the frame to provide access to a wheel well beneath the lift. A reversible motor is connected to the linkage for either raising or lowering the platform with respect to the trunk floor.

7 Claims, 5 Drawing Sheets

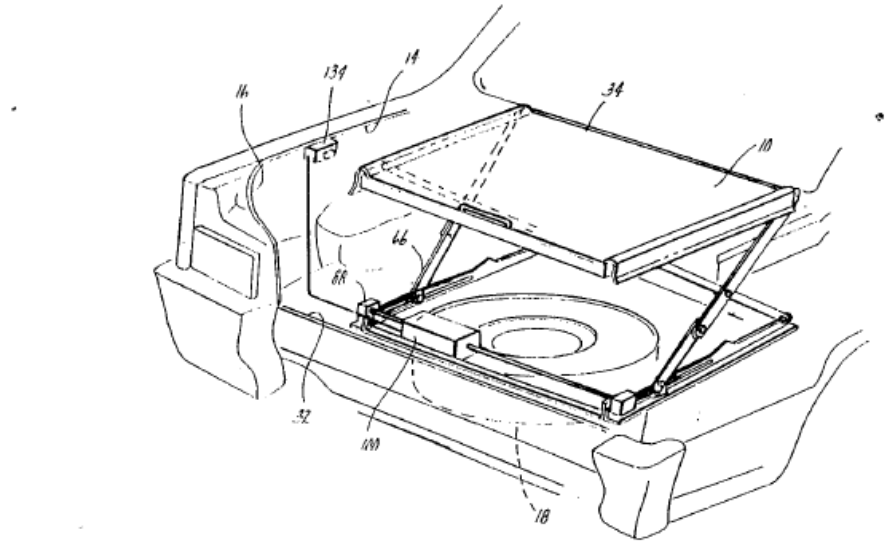

Figure 1 - Patent Example 1

US005765987A

United States Patent [19]

Zimmermann

[11] Patent Number: 5,765,987

[45] Date of Patent: Jun. 16, 1998

[54] **AUTOMOBILE TRUNK LOAD AND UNLOAD ASSIST DEVICE AND METHOD**

[76] Inventor: **Jacqueline E. Zimmermann**, 60243 Trailwood, Washington, Mich. 48094

[21] Appl. No.: **728,442**

[22] Filed: **Oct. 10, 1996**

[51] **Int. Cl.**[6] **B65G 67/00**

[52] **U.S. Cl.** **414/786**; 414/462

[58] **Field of Search** 414/462; 187/273, 187/274, 275; 108/44, 147; 224/499, 497, 550; 211/187; 248/157, 419, 172

[56] **References Cited**

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4,969,793	11/1990	Pawl	414/462
5,054,578	10/1991	Smillie, III et al.	414/462

FOREIGN PATENT DOCUMENTS

2157258	10/1985	United Kingdom	414/462

Primary Examiner—Karen M. Young
Assistant Examiner—Douglas Hess
Attorney, Agent, or Firm—Vanophem Meehan & Vanophem, P.C.

[57] **ABSTRACT**

A device to assist in loading and unloading objects into and from the trunk compartment of an automotive vehicle, the device having a lower platform supported on the floor of the trunk compartment, an upper platform positioned above the lower platform, a plurality of vertically extensible pneumatic operators for supporting the upper platform on the lower platform, an accumulator containing pressurized air, and a piping system for connecting the accumulator to each of the pneumatic operators to simultaneously extend each of the pneumatic operators and thereby lift the level of the upper platform with respect to the lower platform to a level at which objects can be transferred to and from the trunk compartment by a sliding action. An electric air pump is also provided to introduce pressurized air into the accumulator, and a safety switch is provided to prevent lifting the upper platform while the trunk is closed. The upper platform is provided with a multitude of horizontally extensible slides, to permit the surface area of the upper platform to be increased, and a pair of openings to permit the compact device to be placed into, and removed from, the trunk compartment of a vehicle.

2 Claims, 1 Drawing Sheet

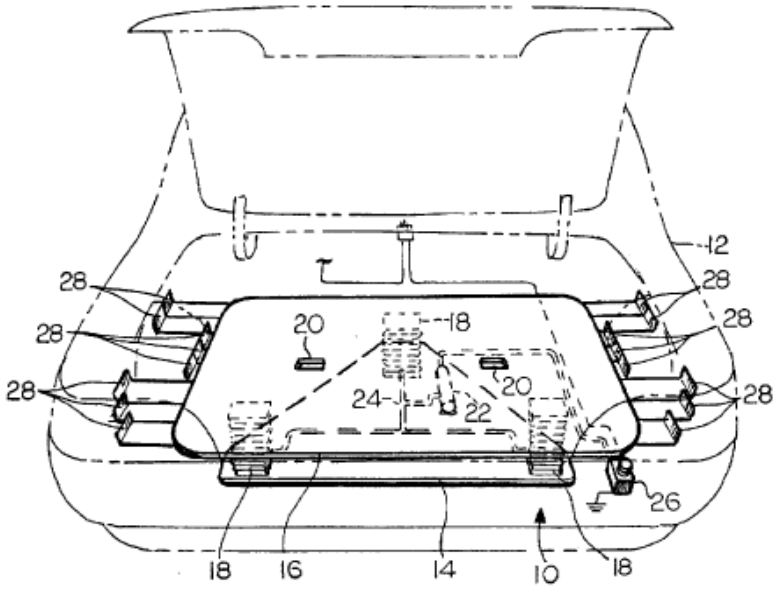


Figure 2 - Patent Example 2

3 CONCEPT DESIGN AND SPECIFICATION

3.1 USER NEEDS, METRICS, AND QUANTIFIED NEEDS EQUATIONS.

3.1.1 User Needs Interview

Table 1 - User Needs Interview

Project/Product Name: Trunk Lift Assist (TLA) Customer: Dr. Mark Jakiela Address: Washington University Willing to do follow up? Yes Type of user: Elderly & Physically Challenged		Interviewer(s): Kyle Copeland, Ben Hogan, Jon Krems, & Tom Schuh Date: 06/12/16 Currently uses: Non-ergonomic Physical Ability	
Question	Customer Statement	Interpreted Need	Importance
How much weight do you need this to lift?	A full weeks worth of groceries, which includes several gallon jugs of stuff. I would guess that 60-70 lbs is a good number.	Can lift a full week's worth of groceries	5
What height would you prefer the unloading deck to reach?	So I can take stuff off of if without bending. No less than countertop (36") and probably no need for higher than 60"	Can raise loads above user's waist	5
What kinds of items do you need assistance with?	I want it to safely contain and hoist a typical grocery haul. So, some heavier and more awkward stuff but a large number items. Another use is large bags of pet supplies (e.g. guinea pig bedding, etc.) This would be smaller number of larger heavier items.	Can hold a large number of smaller items Can hold a small number of large items	4
How often do you	Every trip to the	Can operate many	5

intend to use this?	grocery store at least, in addition to other uses. 3-4 times / week.	times per week	
Will access to the spare tire & associated tools be imperative?	No, flats are rare enough that I think we can run that risk.	Can access spare tire/tool compartment	1
What kind of vehicle do you vision using this item on?	SUV's for sure, as well as the trunks of sedans. Coupes (hatchbacks) not necessary.	Can install in any type of vehicle	4
How fast do you prefer the lift to operate?	All stuff, in one load, into or out of trunk in 5-10 seconds. Can be slower if need be. Fast not critical.	Can cycle quickly	2
Do you intend this to be a permanent installation?	Semi permanent. When installed, likely to leave it there. Maybe remove for making a trip with lots of luggage. Definitely an aftermarket product.	Can be removed quickly and easily if/when needed	2
Where do you intend to purchase this device?	Online. Possibly at wheelchair distributors, etc. Maybe eventually big box places (WalMart, AutoZone)	Can be purchased online	2
How far do you expect this item to protrude from the trunk compartment?	I see it as a platform with the footprint of a shopping cart. That footprint (2'X 3') should not overlap the car's footprint. Should be able to walk around three sides of platform.	Can extend out of the trunk	3
How large should the	2' X 3' minimum. See	Has adequate lifting	5

lift area be?	above.	area	

3.1.2 Identified Metrics

Table 2 - Identified Metrics

Metric Number	Associated Needs (1-??)	Metric	Units	Min Value	Max Value
1	1	Lifting Load	lbs	20	100
2	2	Vertical Travel	in	5	18
3	1, 3, 4, 12	Platform Length	in	12	48
4	1, 3, 4, 12	Platform Width	in	12	36
5	5	Duty Cycle	Cycles/week	2	60
6	6, 9	Removal Time	minutes	5	30
7	7, 10	Overall Unit Length	in	18	40
8	7, 10	Overall Unit Width	in	12	36
9	8	Cycle Time	seconds	5	60
10	6, 9	Removable	Binary	0	1
11	11	Horizontal Travel	in	0	24
12	6, 9, 10	Overall Unit Weight	lbs	20	50
13	7, 10	Overall Unit Height	in	2	12

3.1.3 Quantified Needs Equations

Table 3 - Quantified Needs Matrix

Trunk Lift Assist		Metric															
		Lifting Load	Vertical Travel	Platform Length	Platform Width	Duty Cycle	Removal Time	Overall Unit Length	Overall Unit Width	Cycle Time	Removable	Horizontal Travel	Overall Unit Weight	Overall Unit Height	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	TLA can lift a full week's worth of groceries	0.333		0.333	0.333										1.000	0.119	0.119
2	TLA can raise loads above user's waist		1.000												1.000	0.119	0.119
3	TLA can hold a large number of smaller items			0.500	0.500										1.000	0.095	0.095
4	TLA can hold a small number of large items			0.500	0.500										1.000	0.095	0.095
5	TLA can operate many times per week					1.000									1.000	0.119	0.119
6	TLA can provide access to spare tire/tool compartment						0.250				0.500		0.250		1.000	0.024	0.024
7	TLA can be installed in any type of vehicle							0.333	0.333					0.333	1.000	0.095	0.095
8	TLA can fully cycle quickly									1.000					1.000	0.048	0.048
9	TLA can be removed quickly and easily if/when needed						0.250				0.500		0.250		1.000	0.048	0.048
10	TLA can be purchased online							0.250	0.250				0.250	0.250	1.000	0.048	0.048
11	TLA can extend out of the trunk											1.000			1.000	0.071	0.071
12	TLA has adequate lifting area			0.500	0.500										1.000	0.119	0.119
	Units	lbs	in	in	in	Cycles/week	minutes	in	in	seconds	binary	in	lbs	lbs	Total Happiness		1
	Best Value	100	18	48	36	60	5	18	12	5	1	24	20	2			
	Worst Value	20	5	12	12	2	30	40	36	60	0	0	50	12			
	Actual Value	100	18	48	36	60	5	18	12	5	1	24	20	2			
	Normalized Metric Happiness	1	1	1	1	1	1	1	1	1	1	1	1	1			

3.2 CONCEPT DRAWINGS

CONCEPT 1

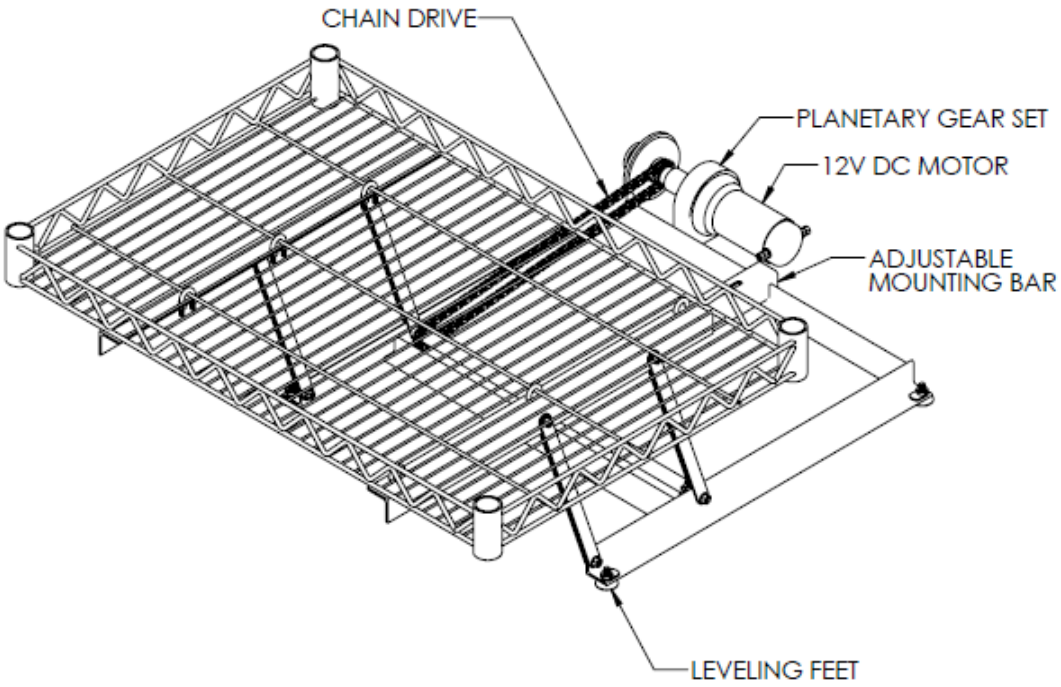


Figure 3 - Concept 1 Drawing

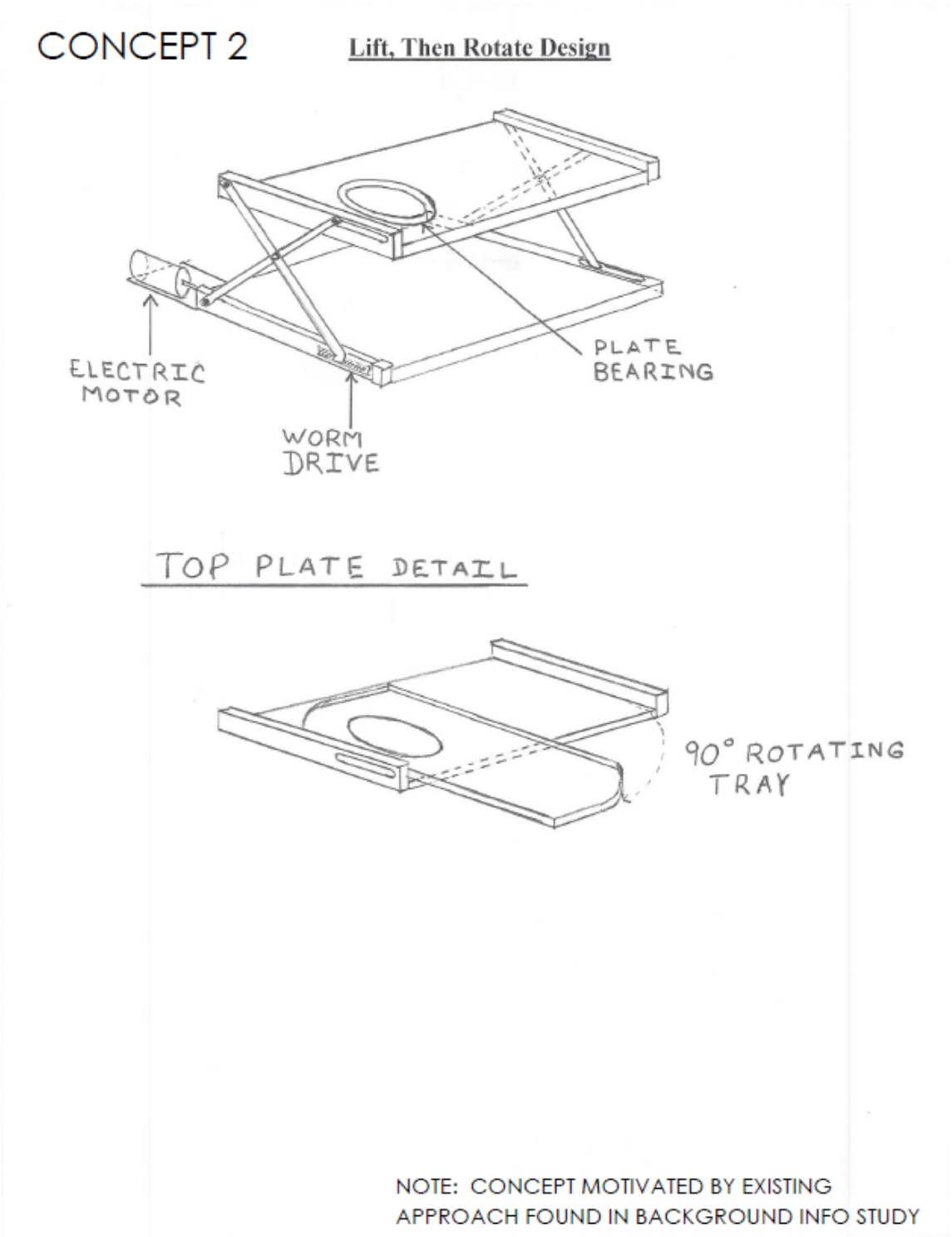
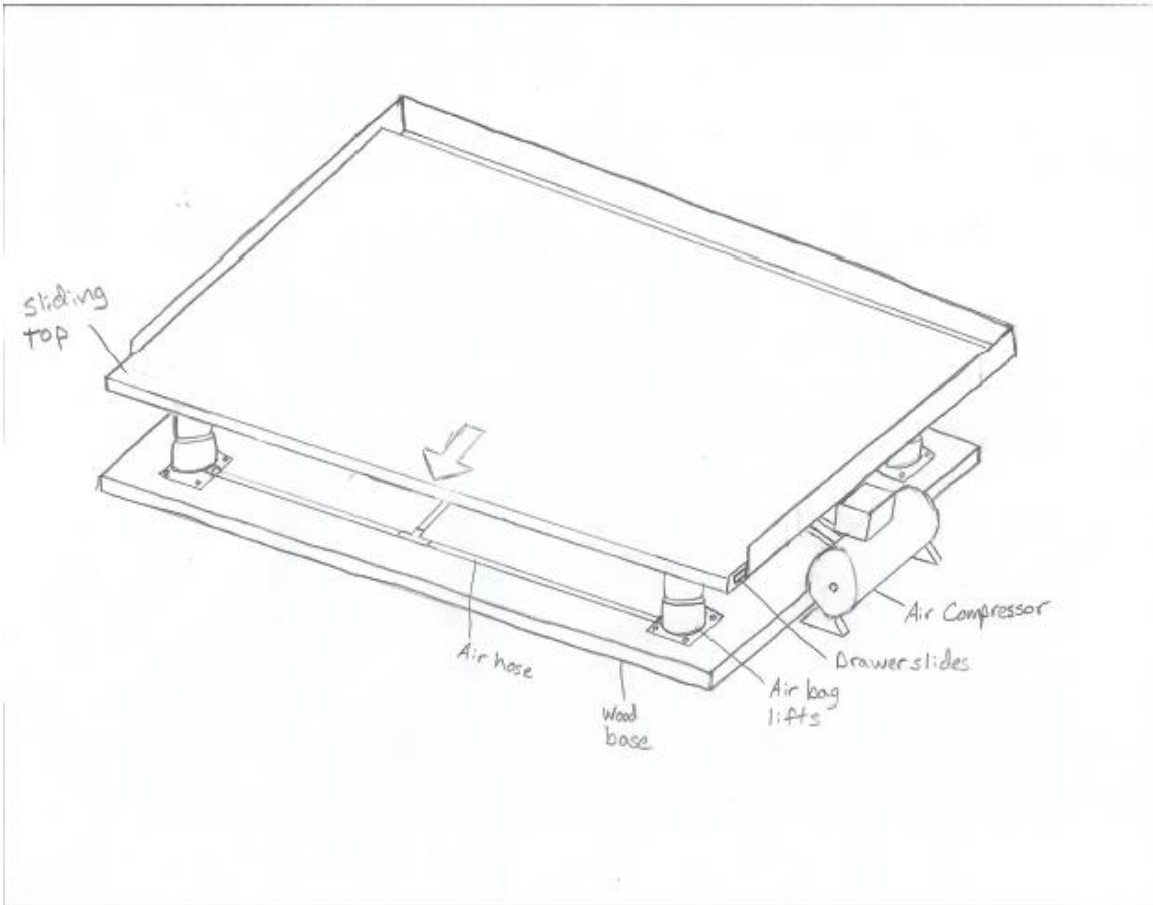


Figure 4 - Concept 2 Drawing

CONCEPT 3



NOTE: CONCEPT MOTIVATED BY EXISTING APPROACH FOUND IN BACKGROUND INFO STUDY

Figure 5 - Concept 3 Drawing

CONCEPT 4

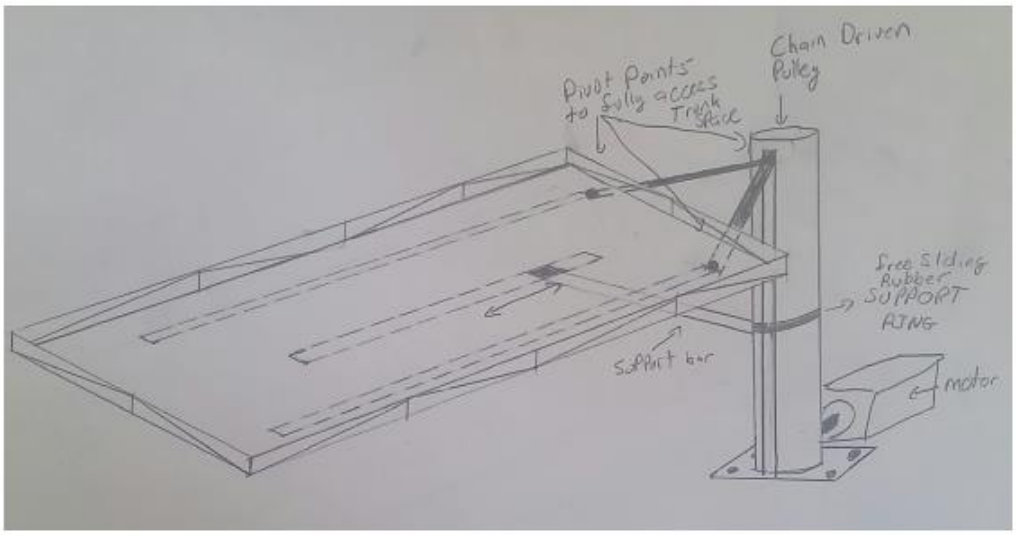


Figure 6 - Concept 4 Drawing

3.3 CONCEPT SELECTION PROCESS.

3.3.1 Concept Scoring

Concept #1 Scoring

Table 4 - Concept 1 Quantified Needs Matrix

Trunk Lift Assist	Metric															
	Lifting Load	Vertical Travel	Platform Length	Platform Width	Duty Cycle	Removal Time	Overall Unit Length	Overall Unit Width	Cycle Time	Removable	Horizontal Travel	Overall Unit Weight	Overall Unit Height	Need Happiness	Importance Weight (all entries should add up to 1	Total Happiness Value
Need	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**			
TLA can lift a full week's worth of groceries	0.333		0.333	0.333										0.618	0.119	0.074
TLA can raise loads above user's waist		1.000												0.385	0.119	0.046
TLA can hold a large number of smaller items			0.500	0.500										0.583	0.095	0.056
TLA can hold a small number of large items			0.500	0.500										0.583	0.095	0.056
TLA can operate many times per week					1.000									1.000	0.119	0.119
TLA can provide access to spare tire/tool compartment						0.250				0.500		0.250		0.867	0.024	0.021
TLA can be installed in any type of vehicle							0.333	0.333					0.333	0.372	0.095	0.035
TLA can fully cycle quickly									1.000					1.000	0.048	0.048
TLA can be removed quickly and easily if/when needed						0.250				0.500		0.250		0.867	0.048	0.041
TLA can be purchased online							0.250	0.250				0.250	0.250	0.395	0.048	0.019
TLA can extend out of the trunk											1.000			0.417	0.071	0.030
TLA has adequate lifting area			0.500	0.500										0.583	0.119	0.069
Units	**lbs**	**in**	**in**	**in**	**Cycles/week**	**minutes**	**in**	**in**	**seconds**	**binary**	**in**	**lbs**	**lbs**	**Total Happiness**		**0.61249**
Best Value	100	18	48	36	60	5	18	12	5	1	24	20	2			
Worst Value	20	5	12	12	2	30	40	36	60	0	0	50	12			
Actual Value	75	10	36	24	60	5	36	28	5	1	10	36	6			
Normalized Metric Happiness	0.688	0.385	0.667	0.500	1.000	1.000	0.182	0.333	1.000	1.000	0.417	0.467	0.600			

Concept #2 Scoring

Table 5 - Concept 2 Quantified Needs Matrix

Trunk Lift Assist	Metric															
	Lifting Load	Vertical Travel	Platform Length	Platform Width	Duty Cycle	Removal Time	Overall Unit Length	Overall Unit Width	Cycle Time	Removable	Horizontal Travel	Overall Unit Weight	Overall Unit Height	Need Happiness	Importance Weight (all entries should add up to 1	Total Happiness Value
Need	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**			
TLA can lift a full week's worth of groceries	0.333		0.333	0.333										0.514	0.119	0.061
TLA can raise loads above user's waist		1.000												0.231	0.119	0.027
TLA can hold a large number of smaller items			0.500	0.500										0.583	0.095	0.056
TLA can hold a small number of large items			0.500	0.500										0.583	0.095	0.056
TLA can operate many times per week					1.000									1.000	0.119	0.119
TLA can provide access to spare tire/tool compartment						0.250				0.500		0.250		0.133	0.024	0.003
TLA can be installed in any type of vehicle							0.333	0.333					0.333	0.261	0.095	0.025
TLA can fully cycle quickly									1.000					0.364	0.048	0.017
TLA can be removed quickly and easily if/when needed						0.250				0.500		0.250		0.133	0.048	0.006
TLA can be purchased online							0.250	0.250				0.250	0.250	0.279	0.048	0.013
TLA can extend out of the trunk											1.000			0.250	0.071	0.018
TLA has adequate lifting area			0.500	0.500										0.583	0.119	0.069
Units	**lbs**	**in**	**in**	**in**	**Cycles/week**	**minutes**	**in**	**in**	**seconds**	**binary**	**in**	**lbs**	**lbs**	**Total Happiness**		**0.47105**
Best Value	100	18	48	36	60	5	18	12	5	1	24	20	2			
Worst Value	20	5	12	12	2	30	40	36	60	0	0	50	12			
Actual Value	50	8	36	24	60	25	36	36	40	0	6	40	6			
Normalized Metric Happiness	0.375	0.231	0.667	0.500	1.000	0.200	0.182	0.000	0.364	0.000	0.250	0.333	0.600			

Concept #3 Scoring

Table 6 - Concept 3 Quantified Needs Matrix

Trunk Lift Assist	Metric															
	Lifting Load	Vertical Travel	Platform Length	Platform Width	Duty Cycle	Removal Time	Overall Unit Length	Overall Unit Width	Cycle Time	Removable	Horizontal Travel	Overall Unit Weight	Overall Unit Height	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**			
TLA can lift a full week's worth of groceries	0.333		0.333	0.333										0.722	0.119	0.086
TLA can raise loads above user's waist		1.000												0.077	0.119	0.009
TLA can hold a large number of smaller items			0.500	0.500										0.583	0.095	0.056
TLA can hold a small number of large items			0.500	0.500										0.583	0.095	0.056
TLA can operate many times per week					1.000									1.000	0.119	0.119
TLA can provide access to spare tire/tool compartment						0.250				0.500		0.250		0.000	0.024	0.000
TLA can be installed in any type of vehicle							0.333	0.333					0.333	0.233	0.095	0.022
TLA can fully cycle quickly									1.000					0.182	0.048	0.009
TLA can be removed quickly and easily if/when needed						0.250				0.500		0.250		0.000	0.048	0.000
TLA can be purchased online							0.250	0.250				0.250	0.250	0.175	0.048	0.008
TLA can extend out of the trunk											1.000			0.500	0.071	0.036
TLA has adequate lifting area			0.500	0.500										0.583	0.119	0.069
Units	lbs	in	in	in	Cycles/week	minutes	in	in	seconds	binary	in	lbs	lbs	Total Happiness		0.46967
Best Value	100	18	48	36	60	5	18	12	5	1	24	20	2			
Worst Value	20	5	12	12	2	30	40	36	60	0	0	50	12			
Actual Value	100	6	36	24	60	30	40	24	50	0	12	50	10			
Normalized Metric Happiness	1.000	0.077	0.667	0.500	1.000	0.000	0.000	0.500	0.182	0.000	0.500	0.000	0.200			

Concept #4 Scoring

Table 7 - Concept 4 Quantified Needs Matrix

Trunk Lift Assist	Metric															
	Lifting Load	Vertical Travel	Platform Length	Platform Width	Duty Cycle	Removal Time	Overall Unit Length	Overall Unit Width	Cycle Time	Removable	Horizontal Travel	Overall Unit Weight	Overall Unit Height	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**			
TLA can lift a full week's worth of groceries	0.333		0.333	0.333										0.514	0.119	0.061
TLA can raise loads above user's waist		1.000												0.538	0.119	0.064
TLA can hold a large number of smaller items			0.500	0.500										0.583	0.095	0.056
TLA can hold a small number of large items			0.500	0.500										0.583	0.095	0.056
TLA can operate many times per week					1.000									1.000	0.119	0.119
TLA can provide access to spare tire/tool compartment						0.250				0.500		0.250		0.042	0.024	0.001
TLA can be installed in any type of vehicle							0.333	0.333					0.333	0.167	0.095	0.016
TLA can fully cycle quickly									1.000					0.727	0.048	0.035
TLA can be removed quickly and easily if/when needed						0.250				0.500		0.250		0.042	0.048	0.002
TLA can be purchased online							0.250	0.250				0.250	0.250	0.167	0.048	0.008
TLA can extend out of the trunk											1.000			0.417	0.071	0.030
TLA has adequate lifting area			0.500	0.500										0.583	0.119	0.069
Units	lbs	in	in	in	Cycles/week	minutes	in	in	seconds	binary	in	lbs	lbs	Total Happiness		0.51606
Best Value	100	18	48	36	60	5	18	12	5	1	24	20	2			
Worst Value	20	5	12	12	2	30	40	36	60	0	0	50	12			
Actual Value	50	12	36	24	60	30	40	24	20	0	10	45	12			
Normalized Metric Happiness	0.375	0.538	0.667	0.500	1.000	0.000	0.000	0.500	0.727	0.000	0.417	0.167	0.000			

3.3.2 Physical Feasibility Analysis

Concept #1

This concept is probably the most feasible of the four. The electric winch will be the only costly material used in the building of concept 1. We decided that the top platform can be made from inexpensive wire shelving and the rest would be made from steel. The availability of differing sizes of wire shelving platforms allows a myriad of different sized applications for differing vehicles. This means we would be able to bring an affordable and adaptable item to market. We will require a relatively strong winch to overcome the initial lift of the platform when loaded, but there are plenty of options that are in our budget. The rest of the hardware and materials are easily purchased and fabricated for assembly of this concept

Concept #2

This concept uses an electric motor and a worm drive to lift the top platform. A worm/screw drive can be difficult to fabricate or may be difficult to find. He precision required for the worm/screw drive could lead to challenges that may hinder the overall design. These can be heavy and require a strong electric motor. This design also relies on a large turn-top bearing and platform for added accessibility. While a large platform bearing is available to handle a potential loading on the shelf, the force required to rotate the shelf may be beyond the capability of the user. Another challenge involved with this design is the straight vertical lift will both limit the size of the platform and the application range of vehicles.

Concept #3

Concept 3 requires an air compressor and tank to fill airbags that lift the top platform. This system can be expensive and it is difficult to control the air flow to lift the bags slowly and evenly. This design might also have stability problems once the bags are inflated. As with concept #2, the straight vertical operation of the unit will not be accommodated by many vehicles leading to very limited applications.

Concept #4

Concept 4 requires drilling holes and bolting the device to the floor of the trunk. This means it will be more of a permanent installation. The tower/pulley design limits the height that the platform can be raised in the trunk. The actual pivoting of the unit to the exterior from the storage space also presented challenges that interfered with the lifting mechanism. This concept required very specific parameters that were only available on a limited number of vehicles.

3.3.3 Final Summary Statement

When considering the user needs scoring, feasibility of building, and project budget, concept #1 stands out as the winner of the concept selection. This concept had the highest user needs score of the four with the score of 61.2. We are relying on an electric winch and chain drive which is a relatively easy and reliable method for transferring torque. The remaining materials for the build are easily obtainable and do not require any difficult machining. We should be able to fabricate, assemble, and test the design with plenty of time for adjustments and multiple iterations. This design gives us the opportunity to build something that is actually affordable and could be a real consumer product.

The remaining 3 concepts were obviously workable but did not meet the needs of our user. The limited applications provided by the other concepts left this group with a potentially vehicle specific apparatus with limited application.

3.4 PROPOSED PERFORMANCE MEASURES

The overall performance measure that requires the unit to be able to lift and accommodate a week's worth of groceries uncovered some deficiencies in our design. Following selection of concept #1 as our final design, certain specifications had to be addressed. The requirement to be able to both lift and protrude from the interior cargo area and the constraints provided by vehicles immediately presented design challenges. The need for a large platform, which could also be adaptable to a variety of vehicles, led to the desire to use interchangeable shelving for the platform. The force required to actuate the device had to be addressed due to the initial torque required to begin the lifting motion. The challenges presented by the constraints of the trunk opening, the load lifting requirements, and the overall motion both up and out of the storage compartment had to be addressed. The desired concept is adaptable which allows the accommodation of the overall performance measure, load size and weight, while providing for many of the needs discovered in the needs and concept generation.

3.5 REVISED SPECIFICATIONS

Table 8 - Metrics Table for Trunk Lift Assist (TLA) Revised

Metric Number	Associated Need	Metric	Units	Min Value	Max Value
1	1	Lifting Load	lbs	50	75
2	2	Vertical Travel	in	5	18
3	1,3,4,12,13	Platform Length	in	20	36
4	1,3,4,12,13	Platform Width	in	12	24
5	5	Duty Cycle	Cycles/week	2	60
6	6,9	Removal Time	Minutes	5	30
7	7,10	Overall Unit Length	in	18	40
8	7,10	Overall Unit Width	in	12	36
9	8	Cycle Time	Seconds	5	60
10	6,9	Removable	Binary	0	1
11	11	Horizontal Travel	in	0	24
12	6,9,10	Overall Unit Weight	lbs	20	50
13	7,10	Overall Unit Height	in	6	12
14	14	Cart Holder	Binary	0	1

Table 9 - Needs Table for Trunk Lift Assist (TLA) Revised

Need Number	Need	Importance
1	TLA can lift a full week's worth of groceries	5
2	TLA can raise loads above user's waist	5
3	TLA can hold a large number of smaller items	4
4	TLA can hold a small number of large items	4
5	TLA can operate many times per week	5
6	TLA can provide access to spare tire/ tool compartment	1
7	TLA can be installed in any type of vehicle	4
8	TLA can fully cycle quickly	2
9	TLA can be removed quickly and easily if/when needed	2
10	TLA can be purchased online	2
11	TLA can extend out of the trunk	3
12	TLA has adequate lifting area	5
13	TLA has interchangeable lifting platforms	4
14	TLA is able to hold shopping cart securely	3

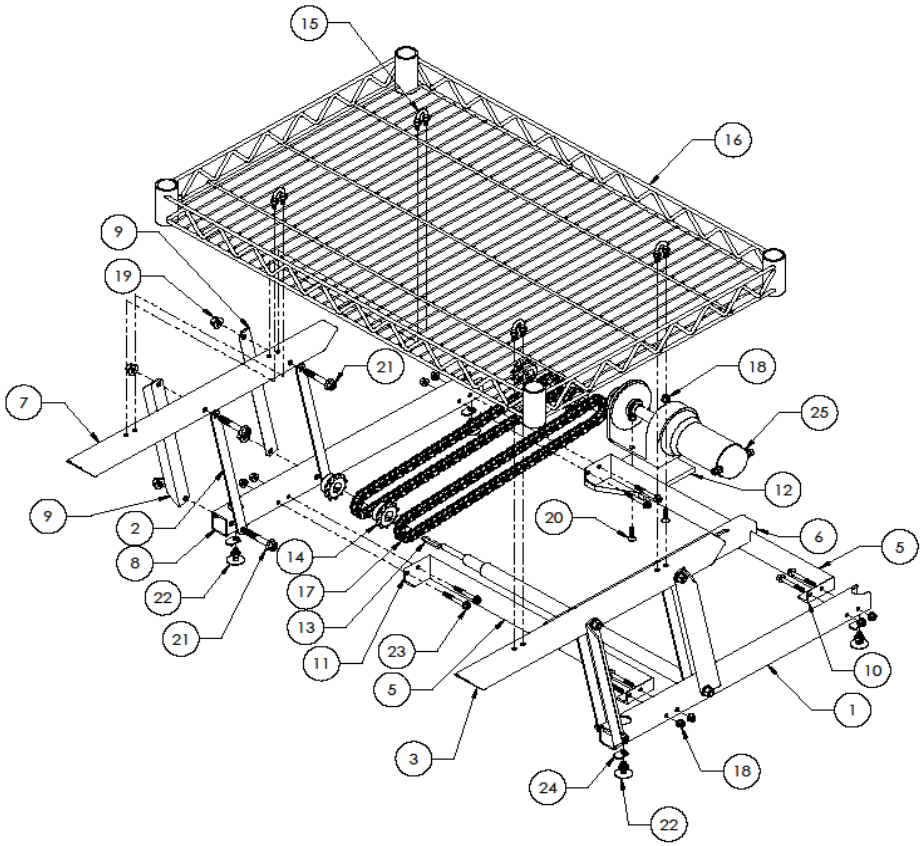
Concept #1 Revised Scoring

Table 10 - Concept 1 Revised Quantified Needs Matrix

Trunk Lift Assist		Metric																
		Lifting Load	Vertical Travel	Platform Length	Platform Width	Duty Cycle	Removal Time	Overall Unit Length	Overall Unit Width	Cycle Time	Removable	Horizontal Travel	Overall Unit Weight	Overall Unit Height	Cart Holder	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
1	TLA can lift a full week's worth of groceries	0.333		0.333	0.333											1.000	0.102	0.102
2	TLA can raise loads above user's waist		1.000													0.385	0.102	0.039
3	TLA can hold a large number of smaller items			0.500	0.500											1.000	0.082	0.082
4	TLA can hold a small number of large items			0.500	0.500											1.000	0.082	0.082
5	TLA can operate many times per week					1.000										1.000	0.102	0.102
6	TLA can provide access to spare tire/tool compartment						0.250				0.500		0.250			0.867	0.020	0.018
7	TLA can be installed in any type of vehicle							0.333	0.333					0.333		0.505	0.082	0.041
8	TLA can fully cycle quickly									1.000						1.000	0.041	0.041
9	TLA can be removed quickly and easily if/when needed						0.250				0.500		0.250			0.867	0.041	0.035
10	TLA can be purchased online							0.250	0.250				0.250	0.250		0.495	0.041	0.020
11	TLA can extend out of the trunk											1.000				0.417	0.061	0.026
12	TLA has adequate lifting area			0.500	0.500											1.000	0.102	0.102
13	TLA has interchangeable lifting platforms			0.500	0.500											1.000	0.082	0.082
14	TLA is able to hold shopping cart securely														1.000	1.000	0.000	0.000
Units		lbs	in	in	in	Cycles/week	minutes	in	in	seconds	binary	in	lbs	in	binary	Total Happiness		0.771106
Best Value		75	18	36	24	60	5	18	12	5	1	24	20	6	1			
Worst Value		50	5	12	12	2	30	40	36	60	0	0	50	12	0			
Actual Value		75	10	36	24	60	5	36	28	5	1	10	36	6	1			
Normalized Metric Happiness		1.000	0.385	1.000	1.000	1.000	1.000	0.182	0.333	1.000	1.000	0.417	0.467	1.000	1.000			

4 EMBODIMENT AND FABRICATION PLAN

4.1 EMBODIMENT/ASSEMBLY DRAWING



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	00001-001	RIGHT BASE TUBE	1
2	00001-002	INNER PARALLEL LINK	4
3	00001-004	RIGHT PLATFORM TUBE	1
4	00001-007	LINK DRIVE SHAFT	1
5	00001-008	FRONT/REAR BASE ANGLE	2
6	00001-009	MOUNTING TUBE	1
7	00001-010	LEFT PLATFORM TUBE	1
8	00001-011	LEFT BASE TUBE	1
9	00001-012	OUTER PARALLEL LINK	4
10	00001-013	RIGHT BASE MOUNT ANGLE	2
11	00001-014	LEFT BASE MOUNT ANGLE	2
12	00001-015	MOTOR MOUNT PLATE	1
13	00001-016	DRIVESHAFT KEY	1
14	2500T433	ANSI #40 11T ROLLER SPROCKET	4
15	3043T611	1/4-20 UBOLT FOR 9/16 OD	4
16	5101T447	24"X36" HEAVY DUTY WIRE SHELF	1
17	7265K304	ANSI #40H ROLLER CHAIN	2
18	90949A016	1/4-20 LOCKNUT	10
19	90949A031	3/8-16 LOCKNUT	8
20	91263A562	1/4-20X1 FLAT HEAD CAP SCREW	2
21	92316A633	3/8-16X2-1/4 FLANGE HEAD CAP	6
22	92670A783	5/16-18X1 ELEVATOR BOLT	4
23	92979A138	1/4-20X2 FLANGE HEAD CAP SCREW	8
24	94579A500	5/16-18 WELD NUT	4
25	400195A	12V 2500LB WINCH	1

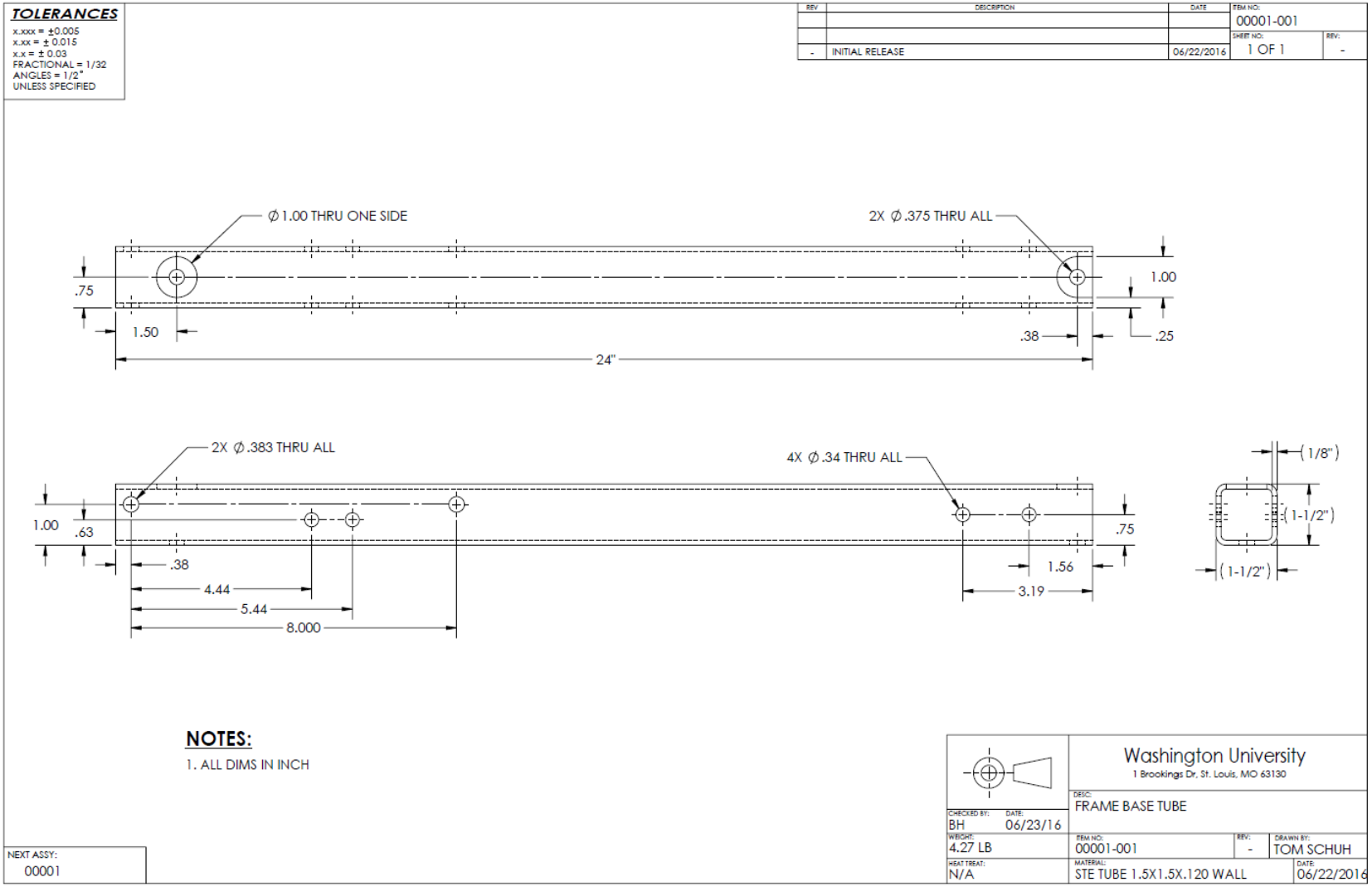
Figure 7 - Embodiment/Assembly Drawing

4.2 PARTS LIST

Table 11 - Initial Parts List

ITEM NO.	PART NO.	DESCRIPTION	QTY.	QTY/UNIT	VENDOR	VENDOR NO	PRICE	EXTENDED PRICE	MIN QTY PRICE
1	00001-001	RIGHT BASE TUBE	1	24	SPEEDYMETALS.COM	ts1.5x.120	$0.38	$9.12	$9.12
2	00001-002	INNER PARALLEL LINK	4	12	SPEEDYMETALS.COM	18f.125x.75	$0.12	$5.76	$5.76
3	00001-004	RIGHT PLATFORM TUBE	1	24	SPEEDYMETALS.COM	ts1.5x.120	$0.38	$9.12	$9.12
4	00001-007	LINK DRIVE SHAFT	1	26	SPEEDYMETALS.COM	18r1	$0.53	$13.78	$13.78
5	00001-008	FRONT/REAR BASE ANGLE	2	21	SPEEDYMETALS.COM	ha.125x1	$0.17	$7.14	$7.14
6	00001-009	MOUNTING TUBE	1	19	SPEEDYMETALS.COM	ts1.5x.120	$0.38	$7.22	$7.22
7	00001-010	LEFT PLATFORM TUBE	1	24	SPEEDYMETALS.COM	ts1.5x.120	$0.38	$9.12	$9.12
8	00001-011	LEFT BASE TUBE	1	24	SPEEDYMETALS.COM	ts1.5x.120	$0.38	$9.12	$9.12
9	00001-012	OUTER PARALLEL LINK	4	12	SPEEDYMETALS.COM	ha.125x1	$0.17	$8.16	$8.16
10	00001-013	RIGHT BASE MOUNT ANGLE	2	3	SPEEDYMETALS.COM	ha.125x1	$0.17	$1.02	$1.02
11	00001-014	LEFT BASE MOUNT ANGLE	2	3	SPEEDYMETALS.COM	ha.125x1	$0.17	$1.02	$1.02
12	00001-015	MOTOR MOUNT PLATE	1	5	SPEEDYMETALS.COM	18f.375x4	$1.17	$5.85	$5.85
						RAW MTL TOTAL =		$86.43	$86.43
13	00001-016	DRIVESHAFT KEY	1		MCMASTER.COM	98535A140	$1.84	$1.84	$1.84
14	2500T433	ANSI #40 11T ROLLER SPROCKET	4		MCMASTER.COM	2500T433	$16.12	$64.48	$64.48
15	3043T611	1/4-20 UBOLT FOR 9/16 OD	4		MCMASTER.COM	3043T611	$0.47	$1.88	$1.88
16	5101T447	24"X36" HEAVY DUTY WIRE SHELF	1		MCMASTER.COM	5101T447	$47.15	$47.15	$47.15
17	7265K304	ANSI #40H ROLLER CHAIN	2		MCMASTER.COM	7265K304	$49.72	$99.44	$99.44
18	90949A016	1/4-20 LOCKNUT	10		MCMASTER.COM	90949A016	$0.06	$0.56	$5.63
19	90949A031	3/8-16 LOCKNUT	8		MCMASTER.COM	90949A031	$0.16	$1.26	$7.87
20	91263A562	1/4-20X1 FLAT HEAD CAP SCREW	2		MCMASTER.COM	91263A562	$0.34	$0.69	$8.59
21	92316A633	3/8-16X2-1/4 FLANGE HEAD CAP	6		MCMASTER.COM	92316A633	$0.55	$3.30	$13.77
22	92670A783	5/16-18X1 ELEVATOR BOLT	4		MCMASTER.COM	92670A783	$0.36	$1.43	$8.95
23	92979A138	1/4-20X2 FLANGE HEAD CAP SCREW	8		MCMASTER.COM	92979A138	$0.26	$2.06	$6.43
24	94579A500	5/16-18 WELD NUT	4		MCMASTER.COM	94579A500	$0.29	$1.16	$7.24
25	400195A	12V 2500LB WINCH	1		HARBORFREIGHT.COM	400195A	$89.99	$89.99	$89.99
						HARDWARE TOTAL =		$315.24	$363.26
							TOTAL =	$401.67	$449.69

4.3 DRAFT DETAIL DRAWINGS



TOLERANCES
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x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

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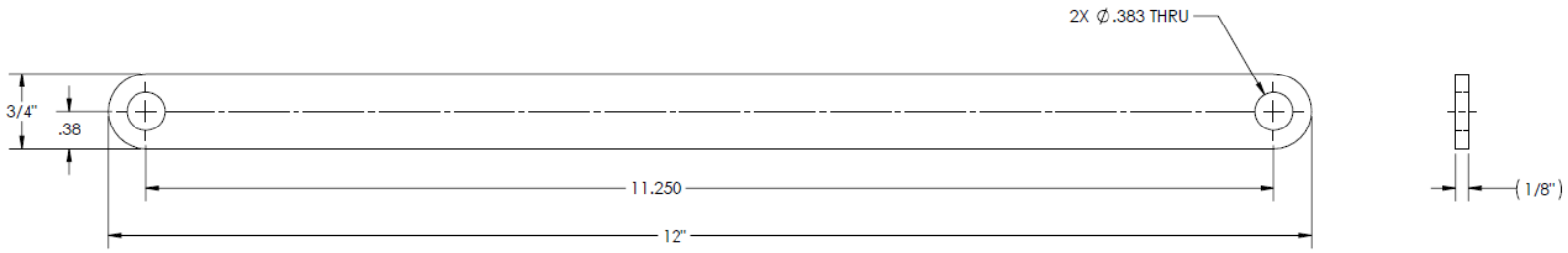
			SHEET NO: 1 OF 1 / REV: -
-	INITIAL RELEASE	06/22/2016	



NOTES:
1. ALL DIMS IN INCH

NEXT ASSY: VARIOUS

Washington University
1 Brookings Dr, St. Louis, MO 63130

CHECKED BY: BH	DATE: 06/23/16	DESC: INNER PARALLEL LINK BAR	
WEIGHT: 0.30 LB		ITEM NO: 00001-002	REV: - / DRAWN BY: TOM SCHUH
HEAT TREAT: N/A		MATERIAL: STE PLT 1/8 HR A36	DATE: 06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

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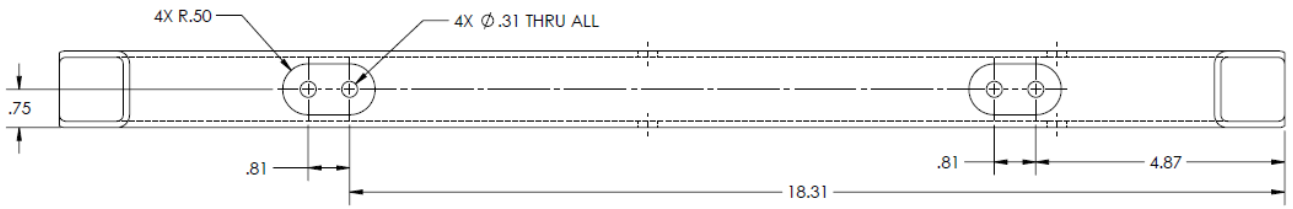
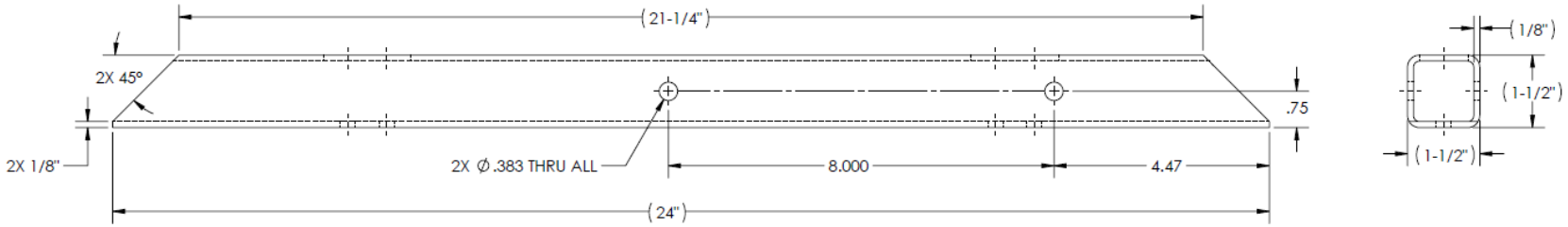
			SHEET NO: 1 OF 1 / REV: -
-	INITIAL RELEASE	06/22/2016	





NOTES:

1. ALL DIMS IN INCH

NEXT ASSY: 00001

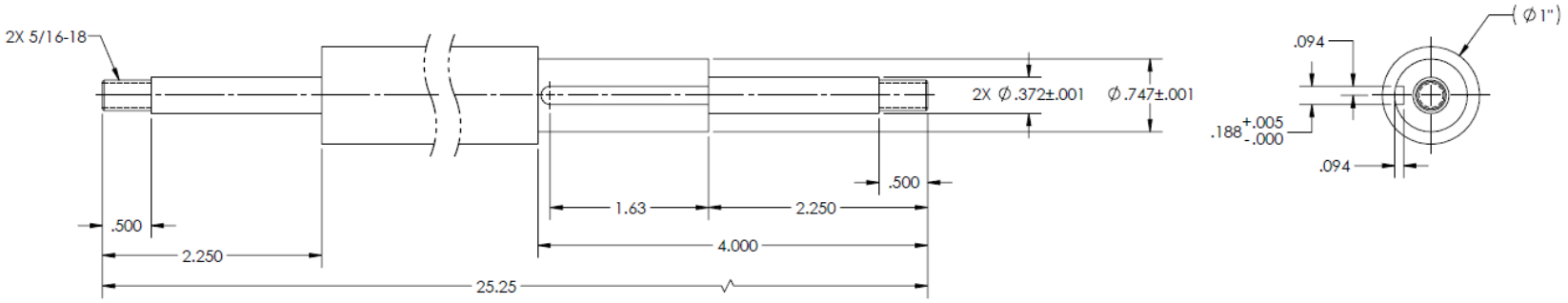
17.00 x 11.00 in

Washington University
1 Brookings Dr, St. Louis, MO 63130

CHECKED BY: BH	DATE: 06/23/16	DESC: PLATFORM FRAME TUBE	
WEIGHT: 4.00 LB		ITEM NO: 00001-004	REV: - / DRAWN BY: TOM SCHUH
HEAT TREAT: N/A		MATERIAL: STE TUBE 1.5X1.5X.120 WALL	DATE: 06/22/2016

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00001-007
			SHEET NO: 1 OF 1 / REV: -
-	INITIAL RELEASE	06/22/2016	



NOTES:
1. ALL DIMS IN INCH

NEXT ASSY: 00001
17.00 x 11.00 in

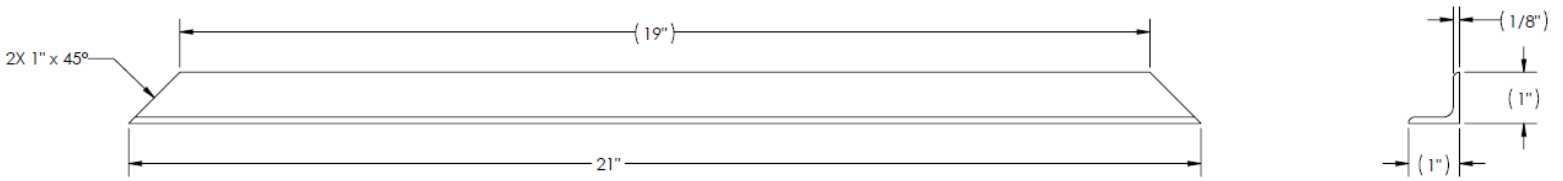
Washington University
1 Brookings Dr, St. Louis, MO 63130

CHECKED BY: BH	DATE: 06/23/16	DESC: LINK DRIVE SHAFT	
WEIGHT: 4.54 LB		ITEM NO: 00001-007	REV: - / DRAWN BY: TOM SCHUH
HEAT TREAT: N/A		MATERIAL: STE ROUND 1" 4140/4142 DG&P	DATE: 06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00001-008	
			SHEET NO: 1 OF 1	REV: -
-	INITIAL RELEASE	06/22/2016		



NOTES:

1. ALL DIMS IN INCH

NEXT ASSY: VARIOUS

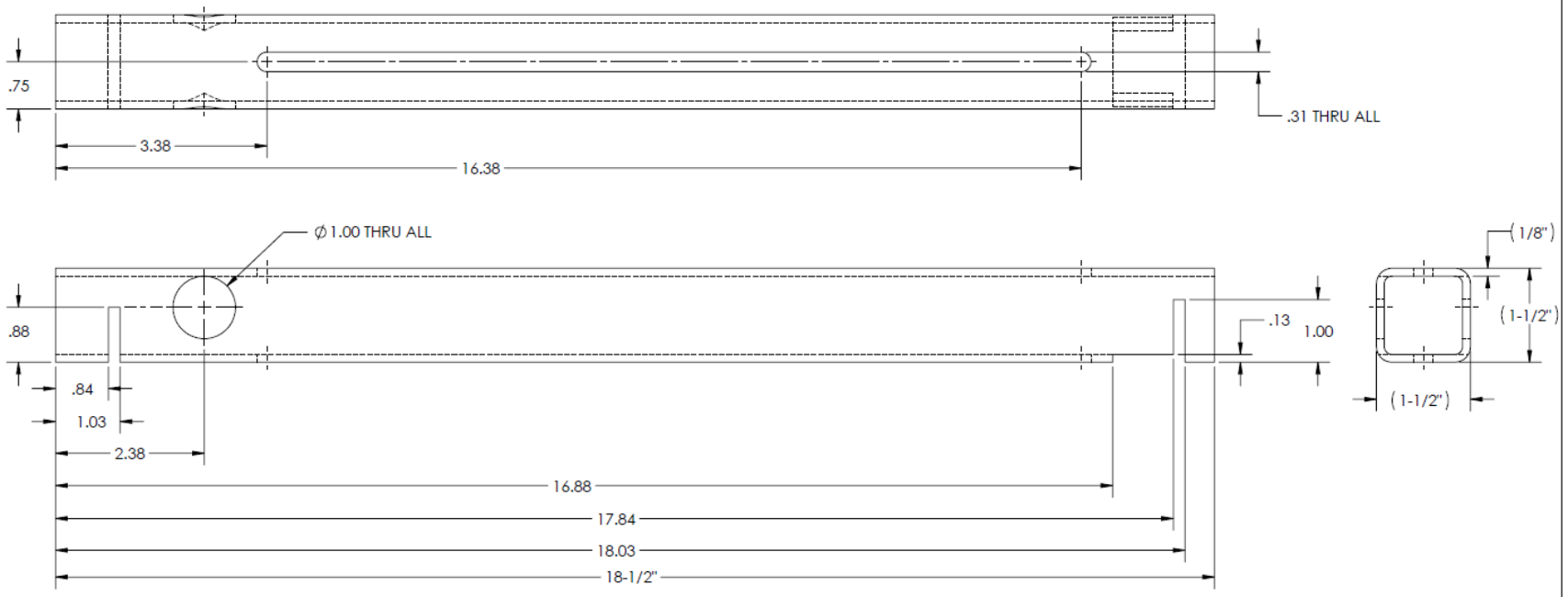
Washington University
1 Brookings Dr, St. Louis, MO 63130

DESC: FRONT/REAR BASE ANGLE

CHECKED BY: BH	DATE: 06/23/16		
WEIGHT: 1.35 LB	ITEM NO: 00001-008	REV: -	DRAWN BY: TOM SCHUH
HEAT TREAT: N/A	MATERIAL: STE ANGLE 1/8X1X1		DATE: 06/22/2016

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00001-009
			SHEET NO: 1 OF 1 / REV: -
-	INITIAL RELEASE	06/22/2016	



NOTES:

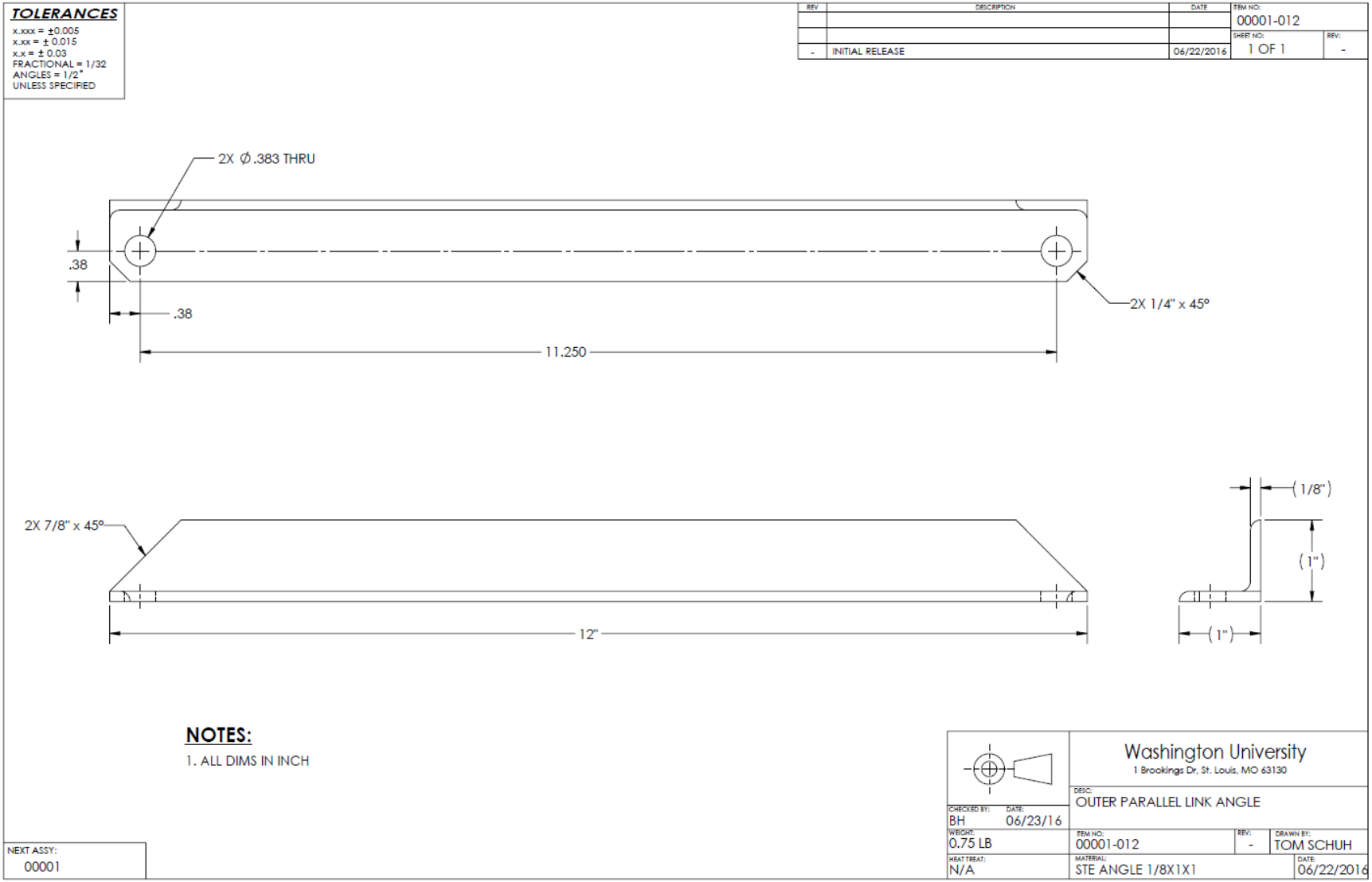
1. ALL DIMS IN INCH

NEXT ASSY: 00001

Washington University
1 Brookings Dr, St. Louis, MO 63130

DESC: MOUNTING TUBE

CHECKED BY: BH	DATE: 06/23/16		
WEIGHT: 2.94 LB	ITEM NO: 00001-009	REV: -	DRAWN BY: TOM SCHUH
HEAT TREAT: N/A	MATERIAL: STE TUBE 1.5X1.5X.120 WALL		DATE: 06/22/2016


TOLERANCES
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x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO:
00001-012
SHEET NO:
1 OF 1
REV:
-
INITIAL RELEASE
06/22/2016
2X Ø.383 THRU
.38
.38
11.250
2X 1/4" x 45°
2X 7/8" x 45°
12"
1/8"
1"
1"
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00001
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
0.75 LB
HEAT TREAT:
N/A
Washington University
1 Brookings Dr, St. Louis, MO 63130
DESC:
OUTER PARALLEL LINK ANGLE
ITEM NO:
00001-012
REV:
-
DRAWN BY:
TOM SCHUH
MATERIAL:
STE ANGLE 1/8X1X1
DATE:
06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00001-016	
			SHEET NO: 1 OF 1	REV: -
-	INITIAL RELEASE	06/22/2016		

NOTES:

1. ALL DIMS IN INCH

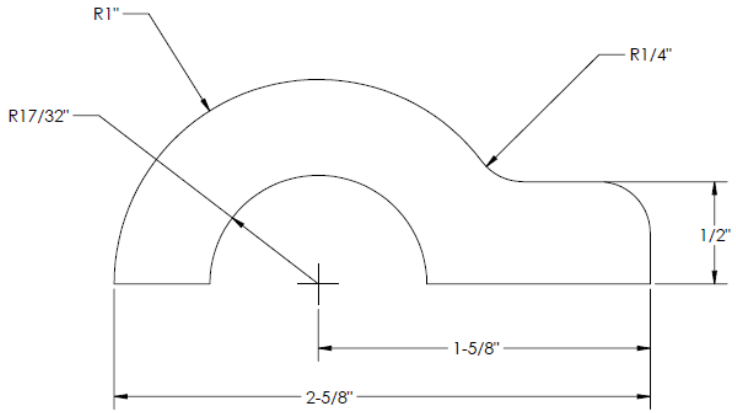
NEXT ASSY: 00001

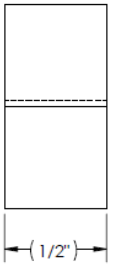
Washington University
1 Brookings Dr, St. Louis, MO 63130

CHECKED BY: BH	DATE: 06/23/16	DESC: DRIVESHAFT KEY	
WEIGHT: 0.86 LB	ITEM NO: 00001-016	REV: -	DRAWN BY: TOM SCHUH
HEAT TREAT: N/A	MATERIAL: STE 3/16X3/16 KEYSTOCK		DATE: 06/22/2016

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00001-017
			SHEET NO: 1 OF 1 / REV: -
-	INITIAL RELEASE	06/22/2016	





NOTES:
1. ALL DIMS IN INCH

NEXT ASSY: 00001

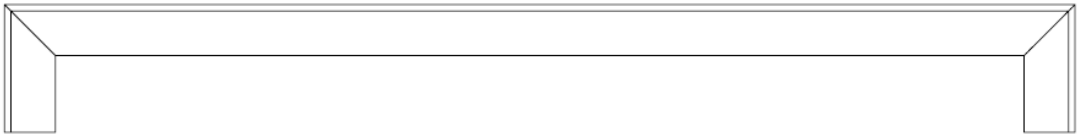
Washington University
1 Brookings Dr, St. Louis, MO 63130

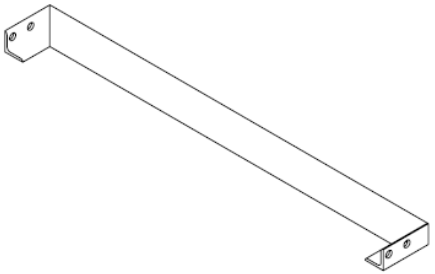
CHECKED BY: BH / DATE: 06/23/16	DESC: STOP BLOCK		
WEIGHT: 11.89 LB	ITEM NO: 00001-017	REV: -	DRAWN BY: TOM SCHUH
HEAT TREAT: N/A	MATERIAL: STE PLT 1/2" HR A36		DATE: 06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00002	
			SHEET NO: 1 OF 1	REV: -
-	INITIAL RELEASE	06/22/2016		





NOTES:

1. ALL DIMS IN INCH

ITEM NO.	PART NO.	DESCRIPTION	QTY.
3	00002-002	FR MOUNT ANGLE	1
2	00002-001	FL MOUNT ANGLE	1
1	00001-008	FRONT/REAR BASE ANGLE	1

Washington University
1 Brookings Dr, St. Louis, MO 63130

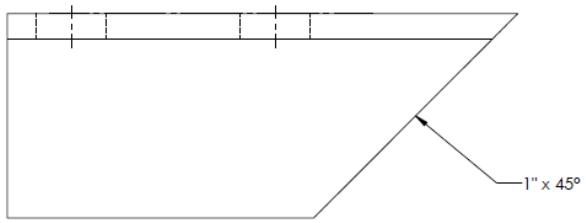
DESC: FRONT BASE MOUNT

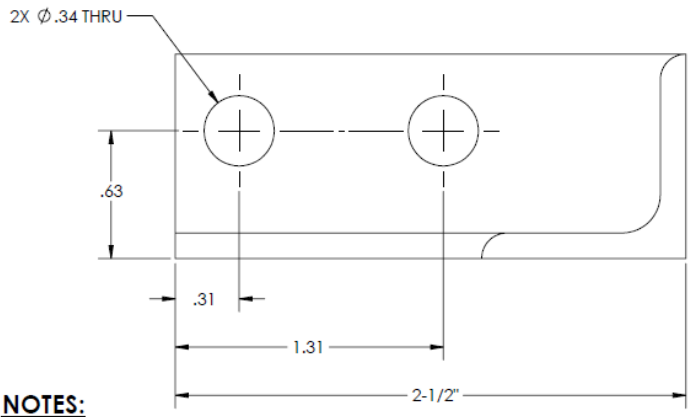
CHECKED BY: BH DATE: 06/23/16
WEIGHT: 1.63 LB
ITEM NO: 00002
REV: -
DRAWN BY: TOM SCHUH
HEAT TREAT: N/A
MATERIAL: SEE BOM
DATE: 06/22/2016

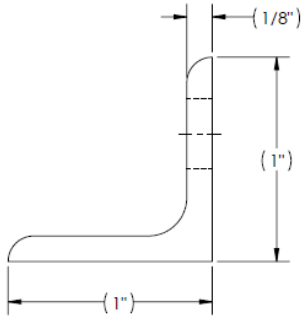
NEXT ASSY: 00001

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00002-001
			SHEET NO: 1 OF 1
-	INITIAL RELEASE	06/22/2016	REV: -







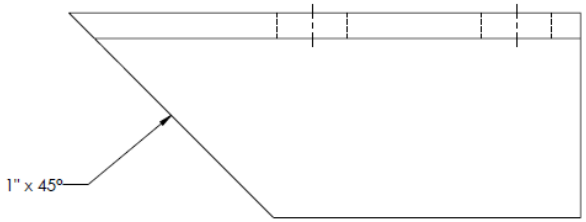
NOTES:
1. ALL DIMS IN INCH

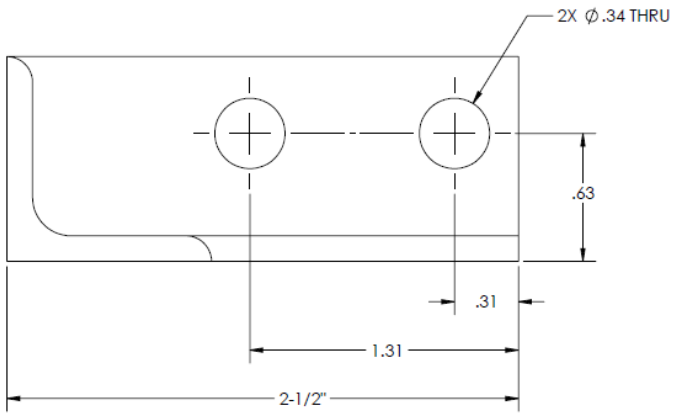
NEXT ASSY: 00002

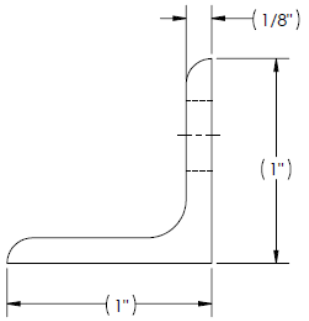
CHECKED BY: BH	DATE: 06/23/16	Washington University, 1 Brookings Dr, St. Louis, MO 63130	
		DESC: FL MOUNT ANGLE	
WEIGHT: 0.14 LB		ITEM NO: 00002-001	REV: -
HEAT TREAT: N/A		MATERIAL: STE ANGLE 1/8X1X1	DRAWN BY: TOM SCHUH
			DATE: 06/22/2016

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00002-002
			SHEET NO: 1 OF 1 / REV: -
-	INITIAL RELEASE	06/22/2016	







NOTES:
1. ALL DIMS IN INCH

Washington University
1 Brookings Dr, St. Louis, MO 63130

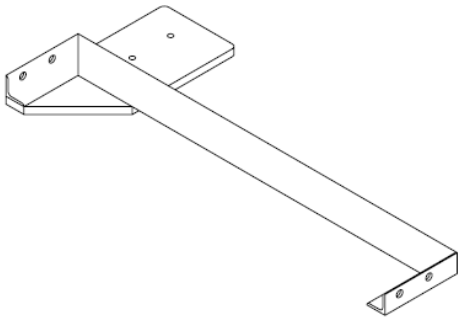
DESC: FR MOUNT ANGLE
CHECKED BY: BH DATE: 06/23/16
WEIGHT: 0.14 LB
ITEM NO: 00002-002
REV: -
DRAWN BY: TOM SCHUH
HEAT TREAT: N/A
MATERIAL: STE ANGLE 1/8X1X1
DATE: 06/22/2016

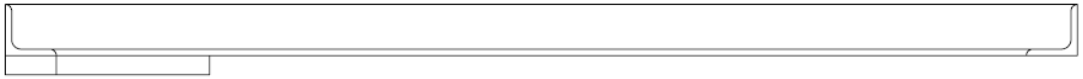
NEXT ASSY: 00002
17.00 x 11.00 in

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00003
			SHEET NO: 1 OF 1
-	INITIAL RELEASE	06/22/2016	REV: -





NOTES:

1. ALL DIMS IN INCH

ITEM NO.	PART NO.	DESCRIPTION	QTY.
4	00003-003	MOTOR MOUNT PLATE	1
3	00003-002	RR MOUNT ANGLE	1
2	00003-001	LR MOUNT ANGLE	1
1	00001-008	FRONT/REAR BASE ANGLE	1

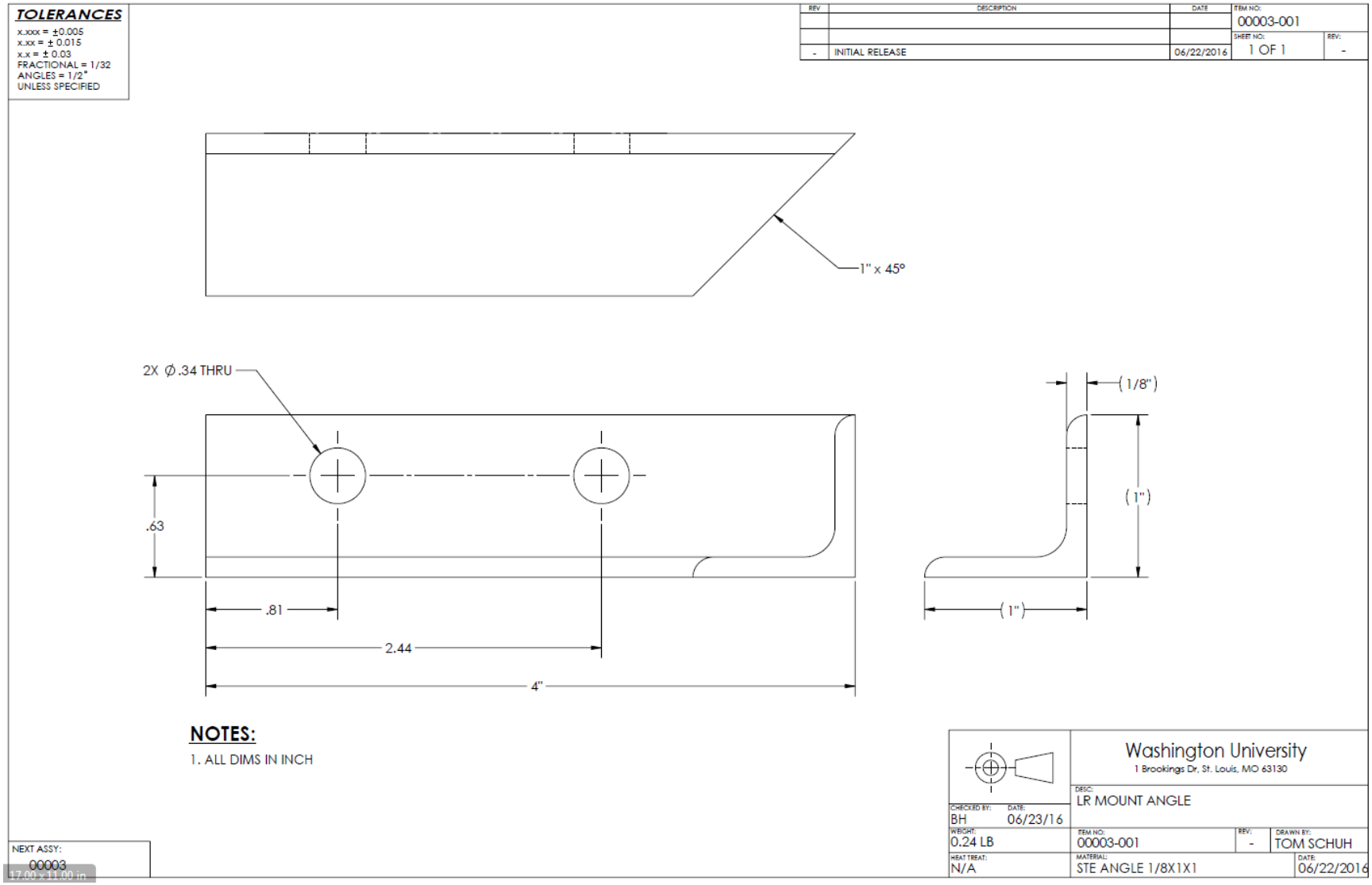
Washington University
1 Brookings Dr, St. Louis, MO 63130

DESC: REAR BASE MOUNT

CHECKED BY: BH
DATE: 06/23/16
WEIGHT: 5.06 LB
ITEM NO: 00003
REV: -
DRAWN BY: TOM SCHUH
HEAT TREAT: N/A
MATERIAL: SEE BOM
DATE: 06/22/2016

NEXT ASSY: 00001

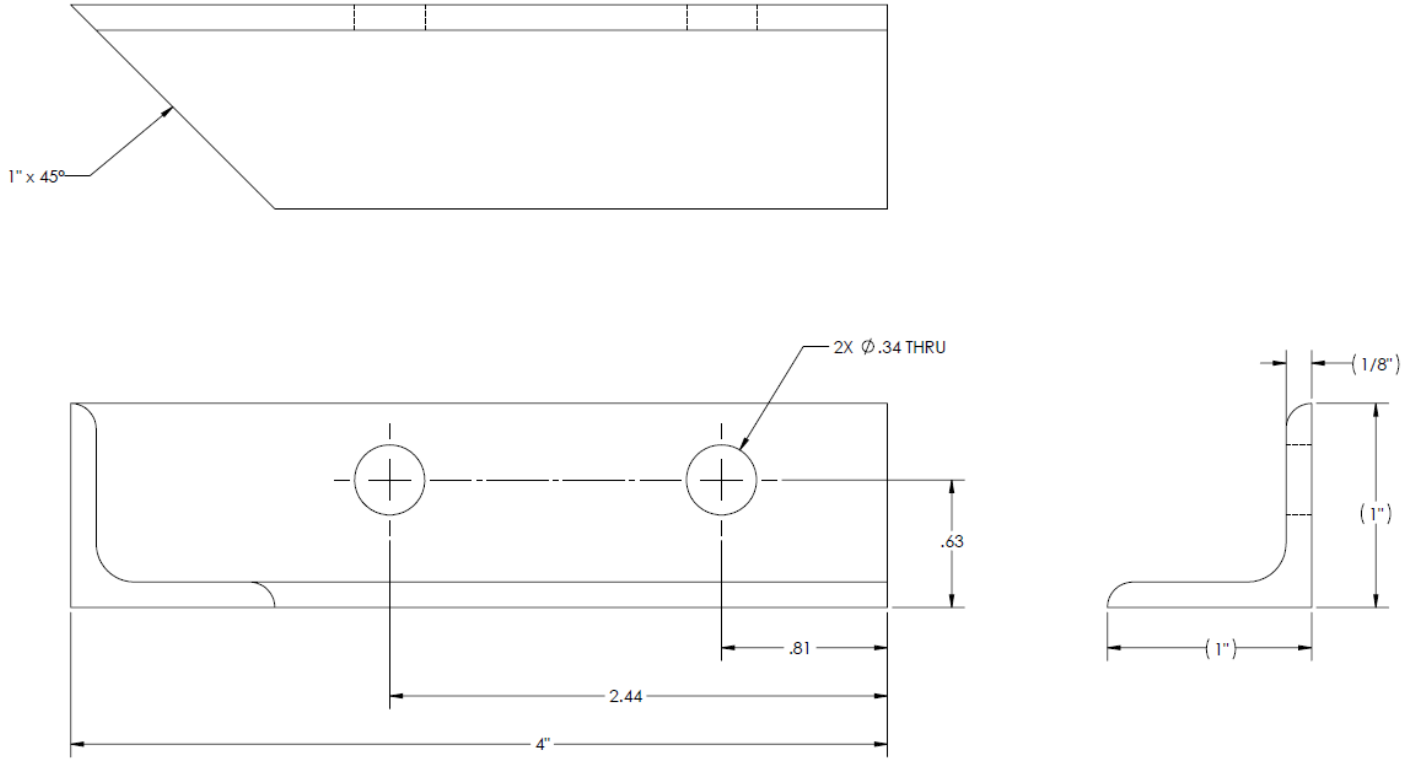
17.00 x 11.00 in


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO:
00003-001
SHEET NO:
1 OF 1
REV:
-
INITIAL RELEASE
06/22/2016
1" x 45°
2X Ø.34 THRU
.63
.81
2.44
4"
(1/8")
(1")
(1")
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00003
17.00 x 11.00 in
Washington University
1 Brookings Dr, St. Louis, MO 63130
DESC:
LR MOUNT ANGLE
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
0.24 LB
ITEM NO:
00003-001
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE ANGLE 1/8X1X1
DATE:
06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00003-002
			SHEET NO: 1 OF 1 / REV: -
-	INITIAL RELEASE	06/22/2016	



NOTES:

1. ALL DIMS IN INCH

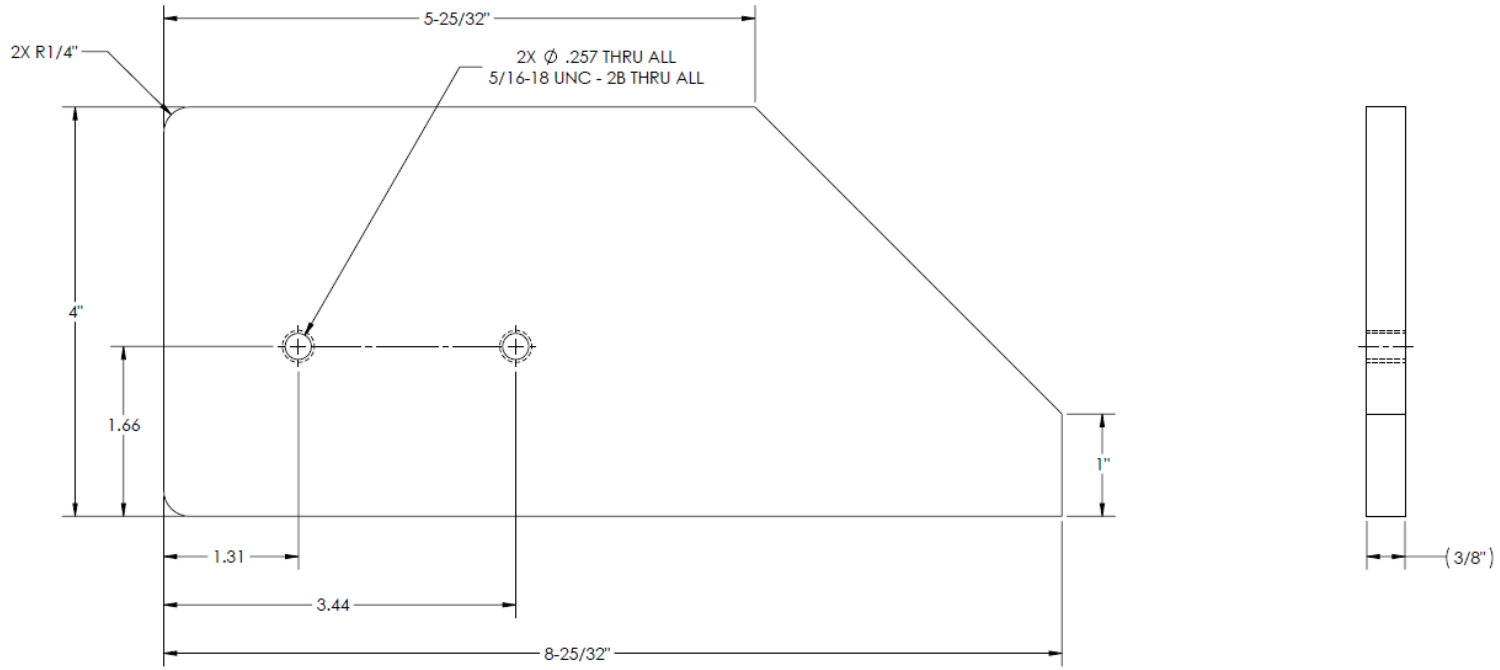
NEXT ASSY: 00003

Washington University
1 Brookings Dr, St. Louis, MO 63130

CHECKED BY: BH	DATE: 06/23/16	DESC: RR MOUNT ANGLE	
WEIGHT: 0.24 LB		ITEM NO: 00003-002	REV: - / DRAWN BY: TOM SCHUH
HEAT TREAT: N/A		MATERIAL: STE ANGLE 1/8X1X1	DATE: 06/22/2016

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO:
			00003-003
			SHEET NO: 1 OF 1 / REV: -
-	INITIAL RELEASE	06/22/2016	



NOTES:
1. ALL DIMS IN INCH

NEXT ASSY: 00003

Washington University
1 Brookings Dr, St. Louis, MO 63130

DESC: MOTOR MOUNT PLATE

CHECKED BY:	DATE:	ITEM NO:	REV:	DRAWN BY:
BH	06/23/16	00003-003	-	TOM SCHUH
WEIGHT: 1461.33 LB		MATERIAL: STE PLT 3/8" HR A36		DATE: 06/22/2016
HEAT TREAT: N/A				

4.4 DESIGN RATIONALE

1. Frame Base Tube: This component was initially designed using 1/8”x1-1/2”x1-1/2” steel angle. Because of any possible side loading, it was thought that this would not add enough rigidity to the assembly, so it was recommended to weld bosses into the upright of the angle where the links connected. Instead of this, 1-1/2”x1-1/2”x11 GA steel tubing was chosen to reduce the complexity of the part (no welding required) and achieve the same effect.
2. Inner Parallel Link Bar: 1/8” A36 steel plate was chosen for the inner link bars. A36 was chosen because of its good weldability, which is needed because 1 set of the inner links will be welded to the drive shaft that will actuate the lift up and down.
3. Platform Frame Tube: Same rational as 1. Frame Base Tube:
4. Link Drive Shaft: 1” 4140/4142 steel round stock was chosen for the drive shaft. The size was determined by the size of the sprockets used, giving enough material to add shoulders for locating. The material itself was chosen because it was in stock and “donated”. The added strength is also a plus over low carbon steel as this will see quite a bit of bending force from the chain drive.
5. Mounting Tube: 1-1/2”x1-1/2”x11 GA steel tubing was chosen for the mount tube for two main reasons: 1 – it needed to be rigid enough to span the depth of the frame and support the force that would be applied to the center of it for mounting and 2 – it was the same as the frame and platform tubes, which reduced cost by not having to pay a premium for a small piece of material.
6. Outer Parallel Link angle: 1/8”x1”x1” steel angle was used for the outer parallel link bars. Angle was chosen over plate on the outer links to add strength in the transverse direction to counter any possible side loading the unit may see.
7. Drive Shaft Key: 3/16”x3/16” key stock was chosen to fit the standard keyway size in the chosen sprockets.
8. Stop Block: 3/8” AR36 steel plate was chosen for the stop blocks for its weldability.
9. Front Base Mount: 1/8”x1”x1” steel angle was used for the front base mount to add rigidity and save weight and cost over tubing.
10. Rear Base Mount: Save rational as the front base mount.
11. ANSI #40 Roller Sprocket: A single #35 sprocket was shown in the initial design. After some analysis, it was found that a single #35 sprocket/chain would not be strong enough, so 2x #40 sprockets were chosen, using the largest diameter we could find to fit into our design envelope.
12. ¼-20 U-Bolt: Chosen for its correct size to hold down our wire platform.
13. 24”x36” Heavy Duty Wire Shelf: Chosen for its strength, low cost and size flexibility.
14. ANSI #40H Roller Chain: Our design required that we would be able to lift a load of 75lbs. Under maximum loading conditions, we could see a required torque of 834in-lbs, which translates to and tensile force of 940lbs that the chain would have exerted on it. A single strand #40H roller chain has a “working load” of 1030 lbs. We wanted to add in a factor of safety of roughly 2, so we doubled up the number of chains. This is quite redundant,

considering the “working load” of the chain has a factor of safety of about 4:1 built into it already, but we wanted to make sure that the drive chains would not be a point of failure.

15. ANSI #40H Connecting Link: Sized to match chain.
16. 12V DC 2500lb Winch: Sized to meet the lift requirement with roughly a factor of safety of 2:1.
17. 5/16”-18 Flanged Locknut: Smooth flanges were chosen to help distribute any transverse loading. Locknuts were chosen to resist vibrating loose which could be a concern in the trunk of a vehicle.
18. 5-16”-18x2-1/4” Shoulder Bolt: 3/8”x1-3/4” shoulder to take the bearing loads of the pivoting links.
19. through 22: Various other 5/16”-18 hardware, sized for standardization across all hardware to help reduce the number of unique hardware part numbers.

5 ENGINEERING ANALYSIS

5.1 ENGINEERING ANALYSIS PROPOSAL

5.1.1 Engineering Analysis Contract

MEMS 411 / JME 4110
MECHANICAL ENGINEERING DESIGN PROJECT

ASSIGNMENT 5: Engineering analysis task agreement (2%)

ANALYSIS TASKS AGREEMENT

PROJECT: Trunk Lift Assist NAMES: Jonathan Krems INSTRUCTOR: Dr. Jakiela
Tom Schuh
Ben Hogan
Kyle Copeland

The following engineering analysis tasks will be performed:

Analysis before prototype:

1. Power requirements for lifting of loaded platform
   - Calculated by hand using maximum loading conditions

2. Chain and sprocket sizing
   - Calculated by hand using manufacturer supplied equations/tables.

3. Shaft stress calculations
   - Calculated by hand using maximum loading conditions (shear and bending).
   - Corroborated using finite element analysis

Analysis after prototype:

1. Testing stability of loading platform while loaded and fully extended
   - Physically push/pull in multiple axes of the extended, loaded platform

2. Testing stability of base while platform is loaded and fully extended
   - Physically push/pull in multiple axes of the extended, loaded platform

The work will be divided among the group members in the following way:

- Hand calculations : Jon Krems & Ben Hogan

- FEA : Tom Schuh

Instructor signature: Mark J. Jakiela Print instructor name: JAKIELA

(Group members should initial near their name above.)

5.2 ENGINEERING ANALYSIS RESULTS

5.2.1 Motivation

In order to ensure that our prototype worked without as desired, several analysis tasks were chosen and carried out both before the prototype was built, and after an initial version was built. Before any manufacturing was done, power requirements for lifting the loaded platform was calculated. This was important to the success of the design due to the 75lb lifting requirement that was set by the user needs analysis. With the power requirements known, next it was important to size the drive chain and sprockets, as well as the shafting sizes, to ensure they could handle the supplied power without failure. After the initial prototype was manufactured, several stability and rigidity tests were carried out to ensure that the design was strong enough for everyday use.

5.2.2 Analysis Summary

For calculating the power requirements, basic static equilibrium equations were used at maximum load and worst case positioning, $\Sigma F = 0$. The resulting torque was then used in a standard moment equation, $T = F \cdot r$, to determine the maximum force exerted on the drive chain. The initial torque calculated from the static equilibrium equation was also used in the basic stress equation, $\sigma = (T \cdot r)/J$

After the initial prototype was built and installed, the stability and rigidity tests were carried out by observation during use.

5.2.3 Methodology

For the analysis done prior to building the prototype, all calculations were carried out by hand. FEA using Solidworks Simulation was carried out to corroborate the hand calculations.

After the prototype was built and installed. It was actuated up and down to check performance, both loaded and unloaded. In its fully extended position, we did push/pull tests on the platform by loading it from the sides with our body weight.

5.2.4 Results

From our calculation, using our required load of 75lbs, we determined that a torque of 844 in·lb was required to actuate our fully loaded platform.

Using the largest sprocket possible for our package size resulted in a moment arm of 0.887 in. From this and the applied torque, we calculated a force of 997lb of force that would be exerted on our drive chain.

Using the stress equation with our designed shaft size of 0.75 in, we calculated a max stress of 10,189PSI.

The FEA results agreed with the above calculations, as well as pointing out some other possible areas of concern, such as higher stresses in the shaft keyways as well as higher stress concentrations in the lifting arms.

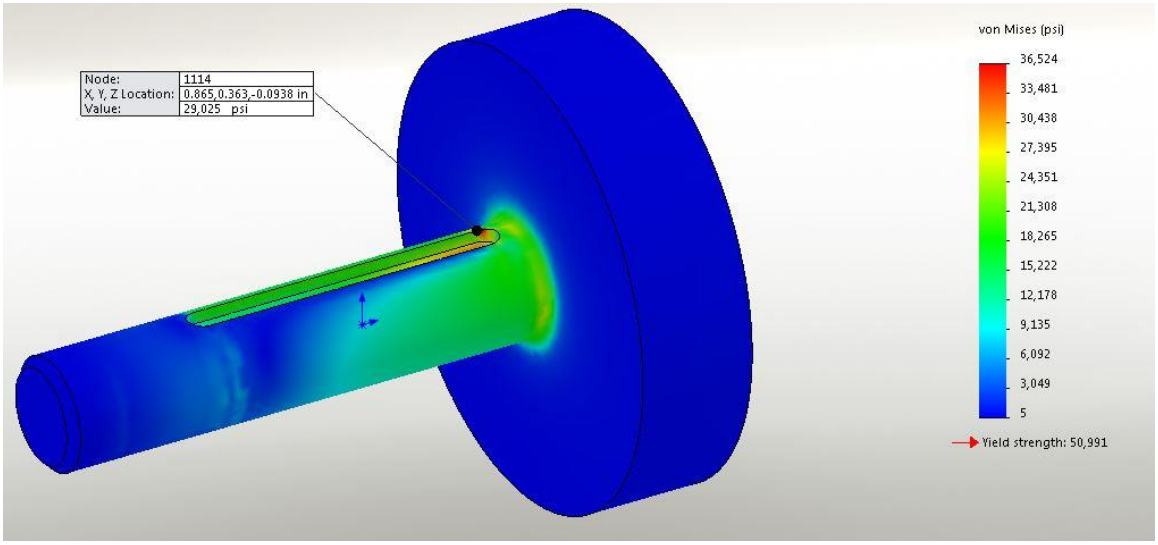


Figure 8 - Winch Shaft FEA Results

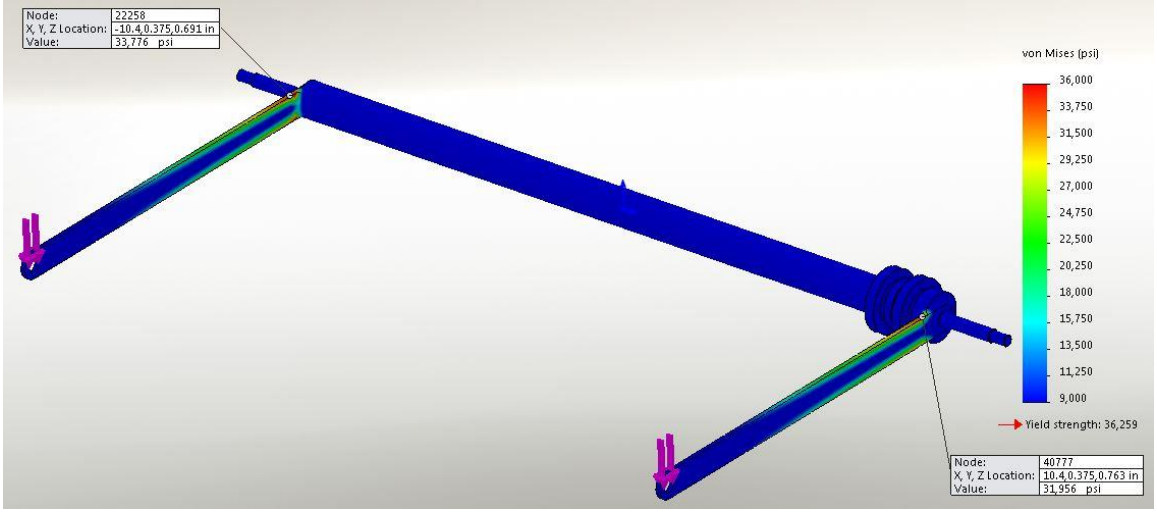


Figure 9 - Drive Arm and Shaft FEA Results

After the initial prototype was built, actuating the device to its limits and allowing it to stall on its hard stops revealed some weakness in its bolted connections, which allowed the frame to twist and torque out of square.

In the fully extended position, the platform was extremely rigid and showed very little deflection when applying large side loads.

5.2.5 Significance

After calculating the max load that would be exerted on the drive chain, we decided to increase the chain size that was selected in the initial concept. Because this particular calculation was done early in the design process the embodiment drawing does show our final sized double #40 chain and sprocket setup, however the original #20 single strand roller chain can be seen in or initial concept drawing.

Because the shafts were already sized appropriately, no changes were needed here.

To remedy the weak bolted frame, the size of part number 12 in the embodiment drawing was increased to span the entire width of the frame, and then welded to the lower frame tubes. A similar plate was added to the front frame angle. These can be seen in the final drawings, labeled with balloon numbers 9 and 10.

As it was unnecessary for the frame to be fully loaded like this in its fully extended and fully retracted positions, electronic limit switches were also added to stop the DC motor when the platform reached each extent, and this can be seen in the final drawings labeled with balloon number 24.

6 RISK ASSESSMENT

6.1 RISK IDENTIFICATION

In the arena of product design for the Motorized Load Management System, areas of concern have been identified. These factors enumerated below encompass the currently foreseen hindrances to a safe and effective production of a final distributable product. It is to be noted that this initial list is in no particular order. While this list does not necessarily account for all outliers that could affect the project, it does contain items that would cause a complete failure in the ability to bring the project to fruition.

- Supply Chain
- Funding
- Fabrication
- Manufacturing Facilities
- Product Liability

6.2 RISK ASSESSMENT

6.2.1 Supply Chain

Risk associated with an interruption in the supply chain. This can be interpreted as complete inability to attain the required parts by means of vendor inconsistency or actual logistic delivery of required materials.

Probability: High

Impact: High

6.2.2 Funding

Risk associated with an interruption of proper funding for the program.

Probability: Medium

Impact: High

6.2.3 Fabrication

Risk associated with the inability to manufacture the product based on lack of job skill-set or availability of fabrication equipment.

Probability: Medium

Impact: Medium

6.2.4 Manufacturing Facilities

Risk associated with the loss of production based on a loss of a manufacturing facility.

Probability: High

Impact: High

6.2.5 Product Liability

Risk associated with injury incurred by the end user of the product.

Probability: Low

Impact: High

6.3 RISK MITIGATION

6.3.1 Supply Chain

It is impossible to mitigate all problems that could occur in a supply chain. Due to the many variables associated with a supply change interruption, it is important to source materials from several vendors to minimize the risk to the overall production process. We found that it was important to source standard parts to allow the ability to order from a multitude of vendors. Elimination of specialized parts allows the flexibility to source required materials from different vendors in the event of a service interruption by any particular supplier.

6.3.2 Funding

It is impossible to mitigate all problems that could occur in a revenue source stream. It is important to retain investors that have additional available capital that are committed to the success of the project. Obtaining and maintaining an available line of credit in the event a distributor is unable to fulfill their financial commitments would allow the company to bridge an unanticipated shortfall in the regular revenue stream.

6.3.3 Fabrication

Potential for machining capacity breakdown and loss of personnel is inherent vulnerability in the production process. By cross craft training it would allow flexibility in the event of employee absence to adjust the production capability. Machine breakdowns as well as required maintenance can be a hindrance to the production process. Parallel manufacturing facilities would minimize the impact of required an unexpected loss of manufacturing capability. Maintaining additional production capacity at parallel manufacturing facilities would allow a dynamic response to unanticipated interruptions of the manufacturing flow.

6.3.4 Manufacturing Facilities

Unanticipated failures experienced by manufacturing facilities may be impossible mitigate due to the nature of the failure, i.e. natural disaster, loss of utilities, etc. Based on the potential for these failures, maintaining parallel manufacturing facilities at multiple locations provides the protection against a complete failure in the manufacturing process. By maintaining an updated list of alternative vacant facilities located in reasonably close proximity to the manufacturing facility, production could be shifted in the event that the current location becomes untenable.

6.3.5 Product Liability

The possibility of injury and even death must be avoided at all costs. Safety assessments by regulating bodies must be made at regular intervals to minimize the potential risk and identify new risks. End-user education in the form of print, digital, and on-line material must be maintained and provided to provide the consumer with all necessary information to safely operate the product. Liability insurance should be maintained to protect the company from potential litigation related to the unanticipated injury by the product. It is also important to maintain a customer database to allow for the recall or modification of the products upon identification of unforeseen safety hazard.

7 CODES AND STANDARDS

7.1 IDENTIFICATION

§ 571.401 Standard No. 401; Interior trunk release.

S1. *Purpose and scope.* This standard establishes the requirement for providing a trunk release mechanism that makes it possible for a person trapped inside the trunk compartment of a passenger car to escape from the compartment.

S2. *Application.* This standard applies to passenger cars that have a trunk compartment. This standard does not apply to passenger cars with a back door.

S3. *Definitions.*

Back door means a door or door system on the back end of a passenger car through which cargo can be loaded or unloaded. The term includes the hinged back door on a hatchback or a station wagon.

Trunk compartment. (a) Means a space that:

(1) Is intended to be used for carrying luggage or cargo,

(2) Is wholly separated from the occupant compartment of a passenger car by a permanently attached partition or by a fixed or fold-down seat back and/or partition,

(3) Has a trunk lid, and

(4) Is large enough so that the three-year-old child dummy described in subpart C of part 572 can be placed inside the trunk compartment, and the trunk lid can be closed and latched with all removable equipment furnished by the passenger car manufacturer stowed in accordance with label(s) on the passenger car or information in the passenger car owner's manual, or, if no information is provided, as located when the passenger car is delivered. (Note: For purposes of this standard, the part 572subpart C test dummy need not be equipped with the accelerometers specified in § 572.21.)

(b) Does not include a sub-compartment within the trunk compartment.

Trunk lid means a moveable body panel that is not designed or intended as a passenger car entry point for passengers and that provides access from outside a passenger car to a trunk compartment. The term does not include a back door or the lid of a storage compartment located inside the passenger compartment of a passenger car.

S4. *Requirements.*

S4.1 Each passenger car with a trunk compartment must have an automatic or manual release mechanism inside the trunk compartment that unlatches the trunk lid. Each trunk release shall conform, at the manufacturer's option, to either S4.2(a) and S4.3, or S4.2(b) and S4.3. The

manufacturer shall select the option by the time it certifies the vehicle and may not thereafter select a different option for the vehicle.

S4.2(a) Each manual release mechanism installed pursuant to S4.1 of this standard must include a feature, like lighting or phosphorescence, that allows the release mechanism to be easily seen inside the closed trunk compartment.

(b) Each automatic release mechanism installed pursuant to S4.1 of this section must unlatch the trunk lid within 5 minutes of when the trunk lid is closed with a person inside the trunk compartment.

S4.3(a) Except as provided in paragraph S4.3(b), actuation of the release mechanism required by S4.1 of this standard must completely release the trunk lid from all latching positions of the trunk lid latch.

(b)

(1) For passenger cars with a front trunk compartment that has a front opening trunk lid required to have a secondary latching position or latch system, actuation of the release mechanism required by paragraph S4.1 of this standard must result in the following:

(i) When the passenger car is stationary, the release mechanism must release the trunk lid from all latching positions or latch systems;

(ii) When the passenger car is moving forward at a speed less than 5 km/h, the release mechanism must release the trunk lid from the primary latching position or latch system, and may release the trunk lid from all latching positions or latch systems;

(iii) When the passenger car is moving forward at a speed of 5 km/h or greater, the release mechanism must release the trunk lid from the primary latching position or latch system, but must not release the trunk lid from the secondary latching position or latch system.

(2) The passenger cars described in paragraph S4.3(b)(1) are excluded from the requirements of this standard until September 1, 2002.

[66 FR 43121, Aug. 17, 2001, as amended at 67 FR 19523, Apr. 22, 2002]

OSHA regulations:

Regulation 1910.219 Section C

1910.219(c)(1)(i)

Each continuous line of shafting shall be secured in position against excessive endwise movement.

1910.219(c)(4)

Projecting shaft ends.

1910.219(c)(4)(i)

Projecting shaft ends shall present a smooth edge and end and shall not project more than one-half the diameter of the shaft unless guarded by non-rotating caps or safety sleeves.

1910.219(c)(4)(ii)

Unused keyways shall be filled up or covered.

Regulation 1910.219 Section F

1910.219(f)

Gears, sprockets, and chains –

1910.219(f)(1)

Gears. Gears shall be guarded in accordance with one of the following methods:

1910.219(f)(1)(i)

By a complete enclosure; or

1910.219(f)(1)(ii)

By a standard guard as described in paragraph (o) of this section, at least seven (7) feet high extending six (6) inches above the mesh point of the gears; or

1910.219(f)(1)(iii)

By a band guard covering the face of gear and having flanges extended inward beyond the root of the teeth on the exposed side or sides. Where any portion of the train of gears guarded by a band guard is less than six (6) feet from the floor a disk guard or a complete enclosure to the height of six (6) feet shall be required.

1910.219(f)(3)

Sprockets and chains. All sprocket wheels and chains shall be enclosed unless they are more than seven (7) feet above the floor or platform. Where the drive extends over other machine or working areas, protection against falling shall be provided. This subparagraph does not apply to manually operated sprockets.

7.2 JUSTIFICATION

Justification for Standard 571.401

This standard was designed for the safety of a person that becomes trapped in an automobile trunk compartment. These vehicles are equipped with a release handle that would release the trunk latching mechanism to allow an egress from the trunk compartment. Due to the fact that the Motorized Load Management System would be installed in automobile trunk compartments, it was imperative that the design does not interfere with a government mandated safety apparatus.

Justification for OSHA Regulation 1910.219 Section (c)

This regulation is to restrict the usage of exposed rotating shaft ends. The purpose of this regulation is to prohibit endwise movement and exposed ends of powered shafts. The purpose of this regulation is the protection of users from exposed shafts that could cause bodily harm. This regulation also requires that unused keyways be filled up or covered. This restriction also protects users from being harmed by the rotating shaft.

Justification for OSHA Regulation 1910.219 Section (f)

This regulation is to protect users from exposed gears and chain drives in power transfer systems. The crux of this regulation is to enclose exposed sprockets and chains that are less than seven feet from the floor surface. Enclosures will provide protection to the users from becoming entangled in the power transmission system and being injured or killed.

7.3 DESIGN CONSTRAINTS

Constraints for Standard 571.401

This standard was paramount in addressing the restrictions that would be placed on our design. The requirement to not hinder the operation of a government mandated safety apparatus required careful consideration into our proposed design.

Constraints for OSHA Regulation 1910.219 Section (c)

As stated in the preface of this document, the OSHA regulations would not apply to a consumer end use item, but some of the restrictions were viewed as a safety measure that should be implemented in our design. The fact that our power transmission shaft has exposed ends and a keyway, certain constraints would need to be addressed.

Constraints for OSHA Regulation 1910.219 Section (f)

As stated in the preface of this document, the OSHA regulations would not apply to a consumer end use item, but some of the restrictions were viewed as a safety measure that should be

implemented in our design. The fact that our power transmission system uses sprockets and chain drives, certain constraints would need to be addressed.

7.4 SIGNIFICANCE

Significance for Standard 571.401

Following a study of the location and operation of automobile trunk safety releases, it has been found that our design would not interfere with the function of this government mandated safety apparatus. Additional modification would not be required, however safety stickers regarding placement not interfering with trunk release mechanism may be necessary if the design moves to the production stage.

Significance for OSHA Regulation 1910.219 Section (c)

Careful study of our design shows that most of the specifics stated in the OSHA regulation were already met in the initial design. The requirement to not allow for endwise movement of the rotating shaft was addressed by the length and design of the original shaft. The additional requirement that any projecting ends of the shaft be less than one half the diameter of the shaft is addressed by the design parameters. One restriction regarding a sleeve to encase the rotating shaft was not addressed. While we did not find this restriction to be irrelevant, we found that the shaft is sufficiently protected by the operation of the device. It was discussed that while the device is in the fully lowered position, during operation, or the fully extended position, the rotating shaft would be inaccessible. The discussion also centered on the remote operation of the device that would allow the shaft to cease movement by release of the controller. It is again noted that safety precaution stickers regarding the rotating shaft would be necessary if the design moves past the prototype stage.

Significance for OSHA Regulation 1910.219 Section (f)

This regulation provided restrictions that could be overcome with our design and due to the safety provided by a chain guard assembly, seen in the final drawings labeled with balloon number 11, we deemed it necessary for the benefit of the consumer. The nature of our sprocket and chain design would not be hampered by any guard protection assembly. It was discussed at length as to what modifications could be made to protect against injury caused by the rotating chain. Although we found that while the device is in the fully lowered position, during operation, or the fully extended position, the sprockets and chains would be nearly inaccessible, we chose to err on the side of caution and protect against the unknown. It is again noted that safety precaution stickers regarding the sprockets and gears would be necessary if the design moves past the prototype stage.

8 WORKING PROTOTYPE

8.1 PROTOTYPE

Figure 10 - Retracted TLA

The Trunk Lift Assist system in the fully retracted position in the trunk of an automobile.

Figure 11 - Extended TLA

The Trunk Lift Assist system in the fully extended position in the trunk of an automobile.

8.2 PROTOTYPE VIDEO

A video showing our final working prototype can be seen at:

https://youtu.be/k38Ms2d3C44

8.3 SPECIFIC PROTOTYPE COMPONENTS

Figure 12 - TLA Retracted Profile

This photograph shows the side view of the Trunk Lift Assist in the fully retracted position in the trunk of an automobile.

Figure 13 - TLA Drive Motor

This photograph shows the Trunk Lift Assist drive motor while in the fully retracted position in the trunk of an automobile

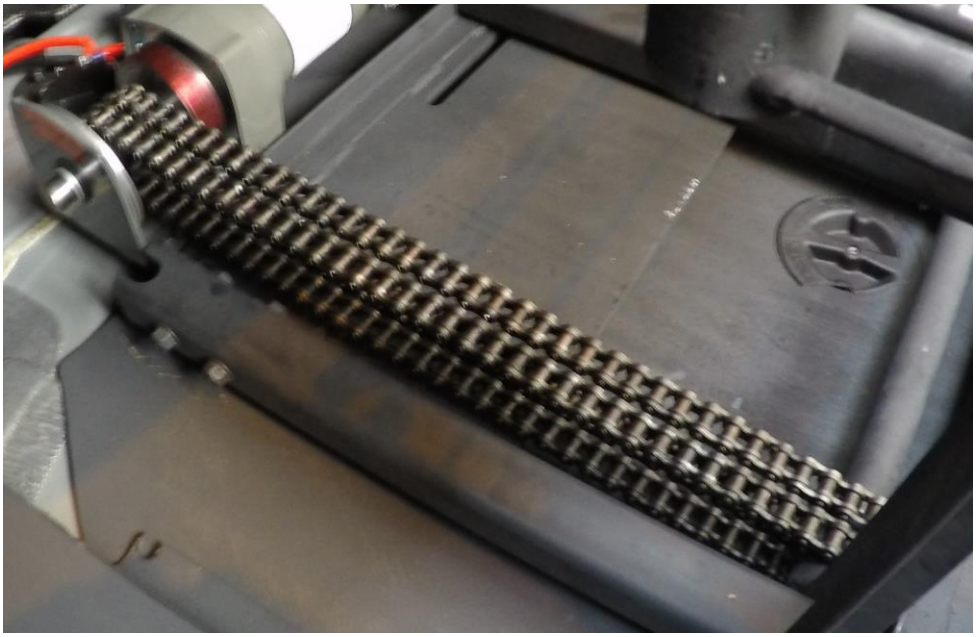


Figure 14 - TLA Dual Drive Chain

This photograph displays the dual sprocket and chain drive on the Trunk Lift Assist system.

Figure 15 - TLA Limit Switches

This photograph shows the two limit switches that shut off the drive system when the Trunk Lift Assist reaches either the fully retracted or fully extended position.

9 DESIGN DOCUMENTATION

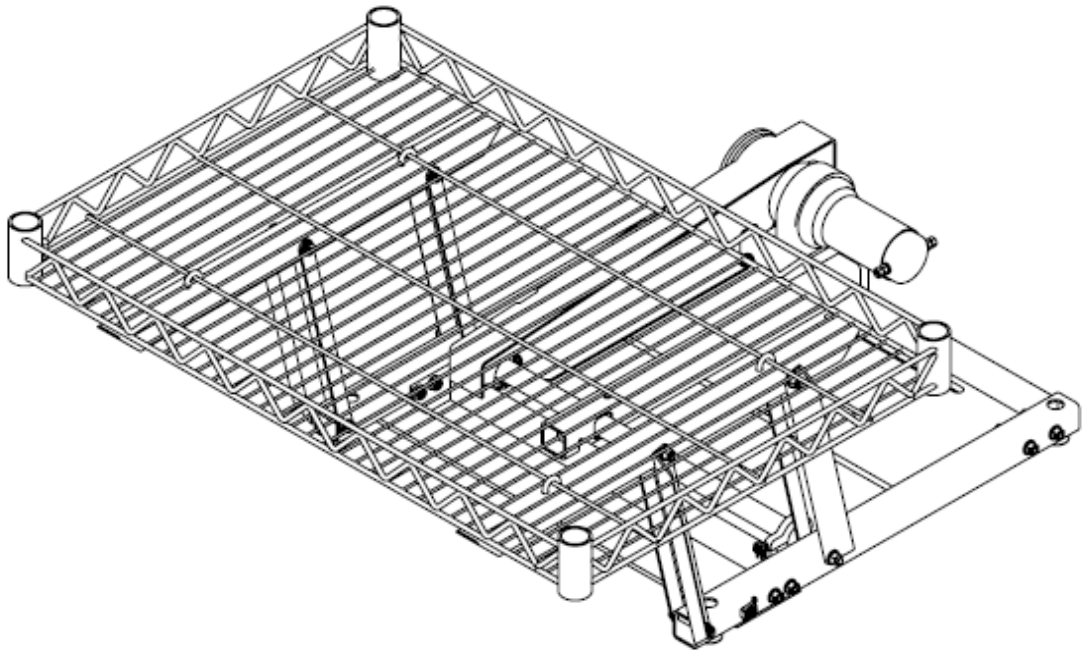
9.1 FINAL DRAWINGS AND DOCUMENTATION

9.1.1 Final Engineering Drawings

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV.	DESCRIPTION	DATE	ITEM NO.
			00001
			SHEET NO. 1 OF 6
-	INITIAL RELEASE	06/22/2016	REV. -



ITEM NO.	PART NO.	DESCRIPTION	QTY
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24	2750017	SPDT LIMIT SWITCH	2
23	94579A500	5/16-18 WELD NUT	4
22	94239A105	5/16-18X1/2 FLNG HD CAP SCREW	3
21	92670A783	5/16-18X1 ELEVATOR BOLT	4
20	92316A591	5/16-18X2 FLNGE HD CAP SCREW	8
19	91259A630	5/16-18X2-1/4 SHOULDER BOLT	6
18	90949A025	5/16-18 FLANGED LOCKNUT	16
17	7265K324	ANSI #40H CONNECTING LINK	2
16	7265K304	ANSI #40H ROLLER CHAIN	2
15	5101T447	24"X36" HEAVY DUTY WIRE SHELF	1
14	3043T611	1/4-20 UBOLT FOR 9/16 OD	4
13	2500T433	ANSI #40 11T ROLLER SPROCKET	4
12	00005	WINCH ASSEMBLY	1
11	00004	CHAIN GUARD	1
10	00003	REAR BASE MOUNT	1
9	00002	FRONT BASE MOUNT	1
8	00001-017	STOP BLOCK	1
7	00001-016	DRIVESHAFT KEY	1
6	00001-012	OUTER PARALLEL LINK ANGLE	4
5	00001-009	MOUNTING TUBE	1
4	00001-007	LINK DRIVE SHAFT	1
3	00001-004	PLATFORM FRAME TUBE	2
2	00001-002	INNER PARALLEL LINK BAR	4
1	00001-001	FRAME BASE TUBE	2

NOTES:

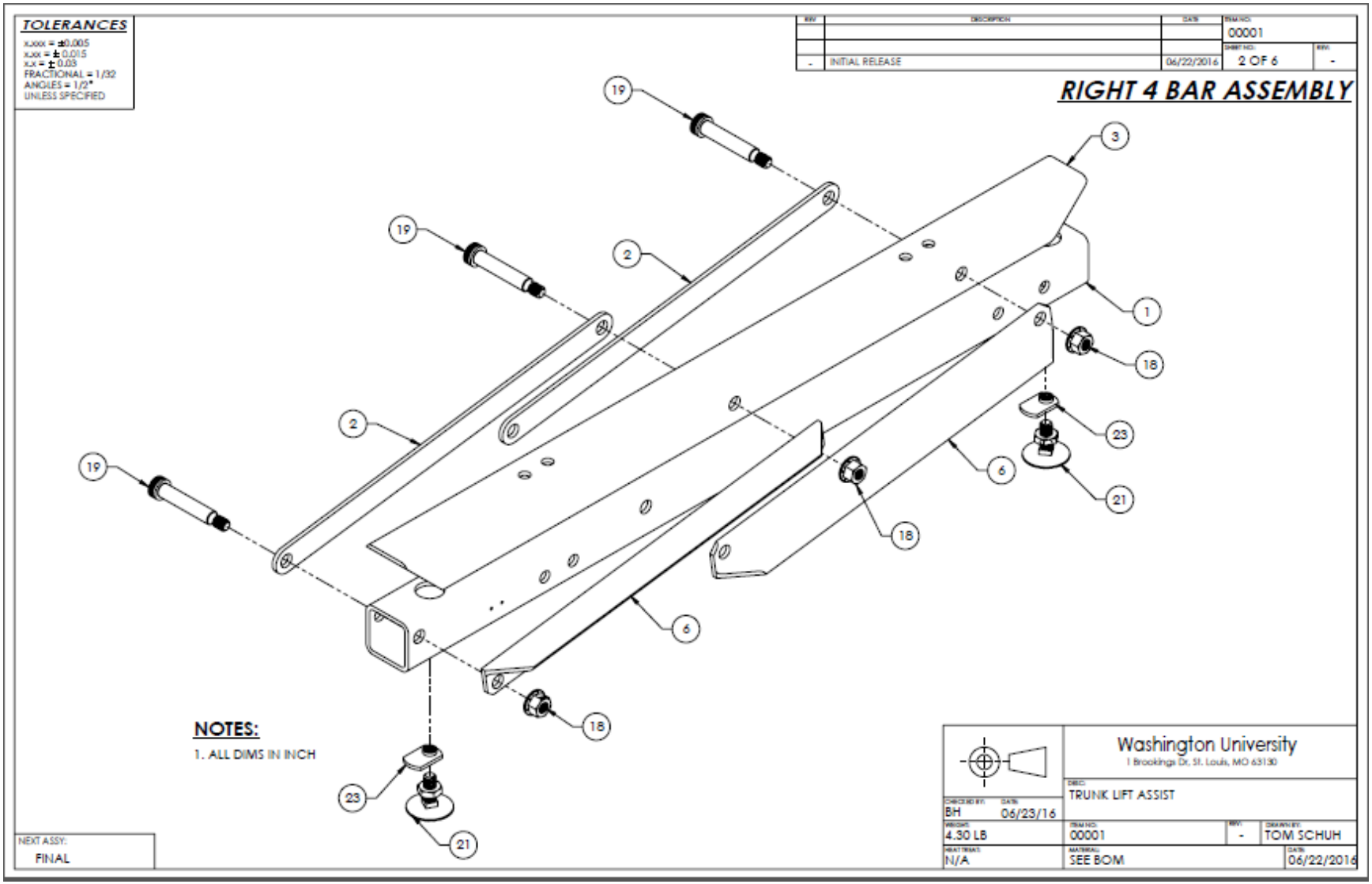
1. ALL DIMS IN INCH

NEXT ASSY: FINAL

Washington University
1 Brookings Dr. St. Louis, MO 63130

DESC: TRUNK LIFT ASSIST

CHECKED BY: BH | DATE: 06/23/16
WEIGHT: 4.30 LB | ITEM NO.: 00001 | REV.: - | DRAWN BY: TOM SCHUH
HEAT TREAT: N/A | MATERIAL: SEE BOM | DATE: 06/22/2016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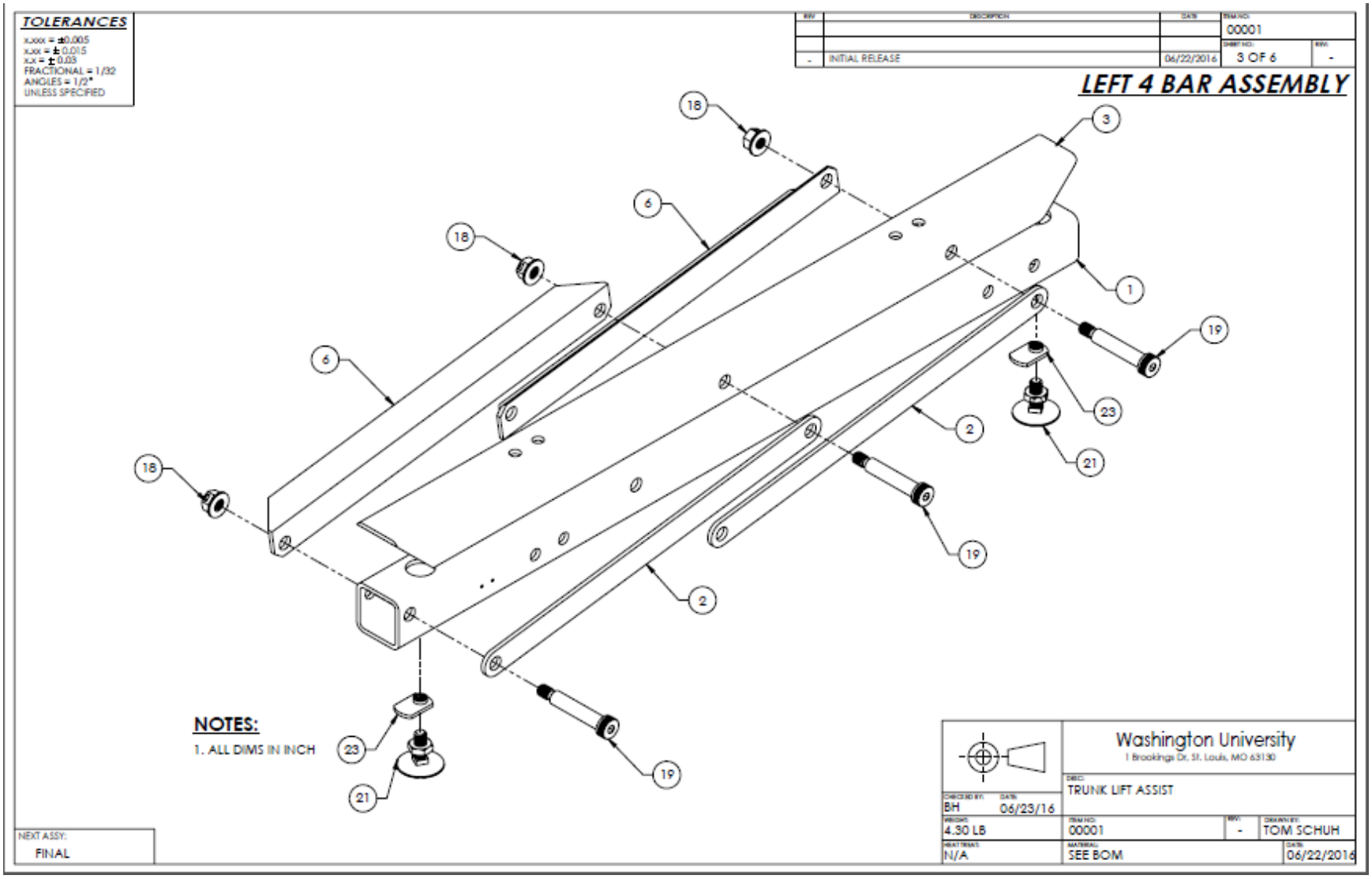
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO.
00001
SHEET NO.
2 OF 6
REV.
-
INITIAL RELEASE
06/22/2016
RIGHT 4 BAR ASSEMBLY
19
3
2
1
18
23
6
21
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
FINAL
Washington University
1 Brookings Dr. St. Louis, MO 63130
DESC:
TRUNK LIFT ASSIST
CHECKED BY:
BH
DATE
06/23/16
WEIGHT:
4.30 LB
ITEM NO.
00001
REV.
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
SEE BOM
DATE
06/22/2016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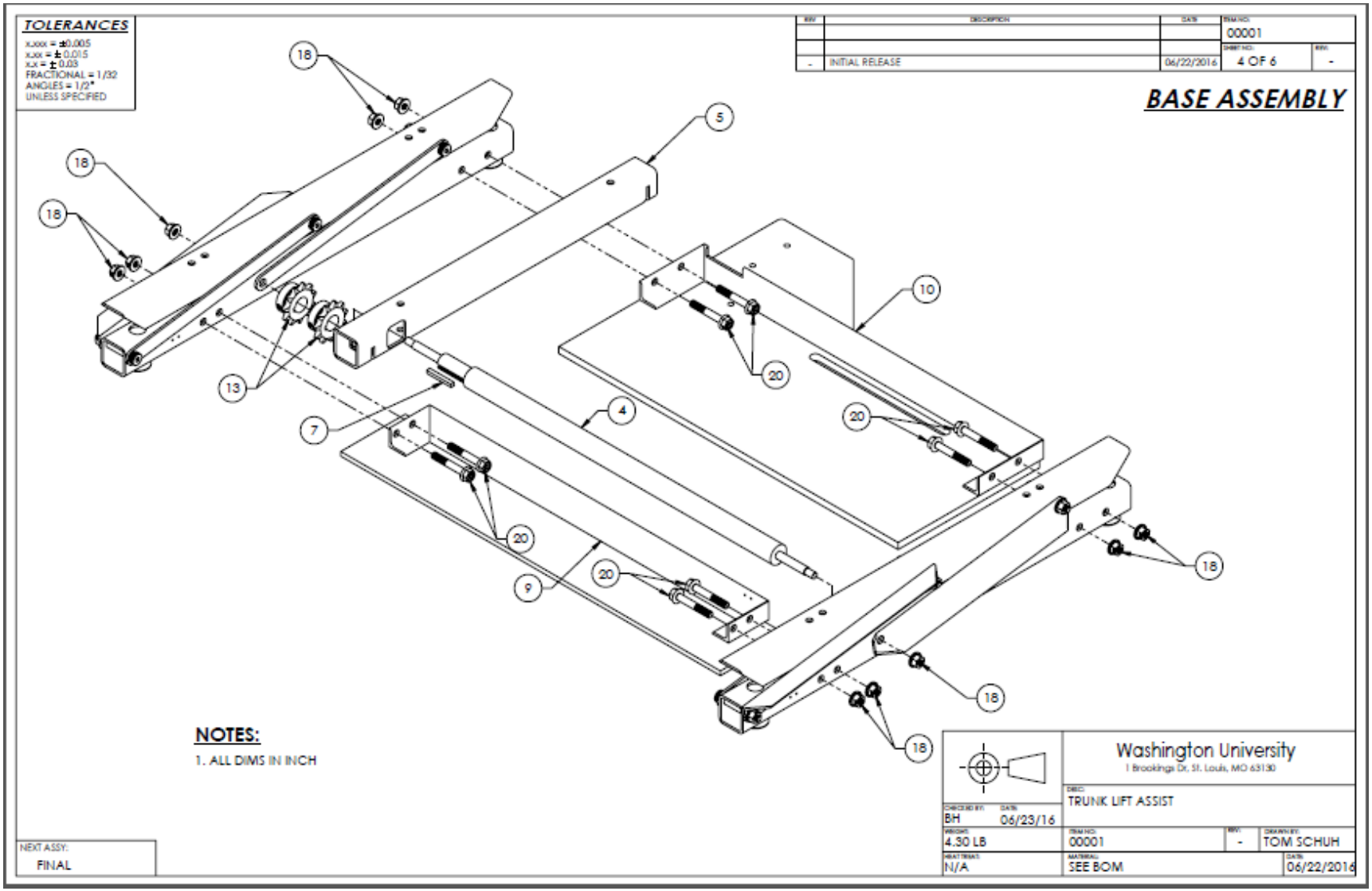
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
DWG NO.
00001
INITIAL RELEASE
06/22/2016
SHEET NO.
3 OF 6
REV
-
LEFT 4 BAR ASSEMBLY
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
FINAL
Washington University
1 Brookings Dr, St. Louis, MO 63130
DES:
TRUNK LIFT ASSIST
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
4.30 LB
DWG NO.
00001
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
SEE BOM
DATE:
06/22/2016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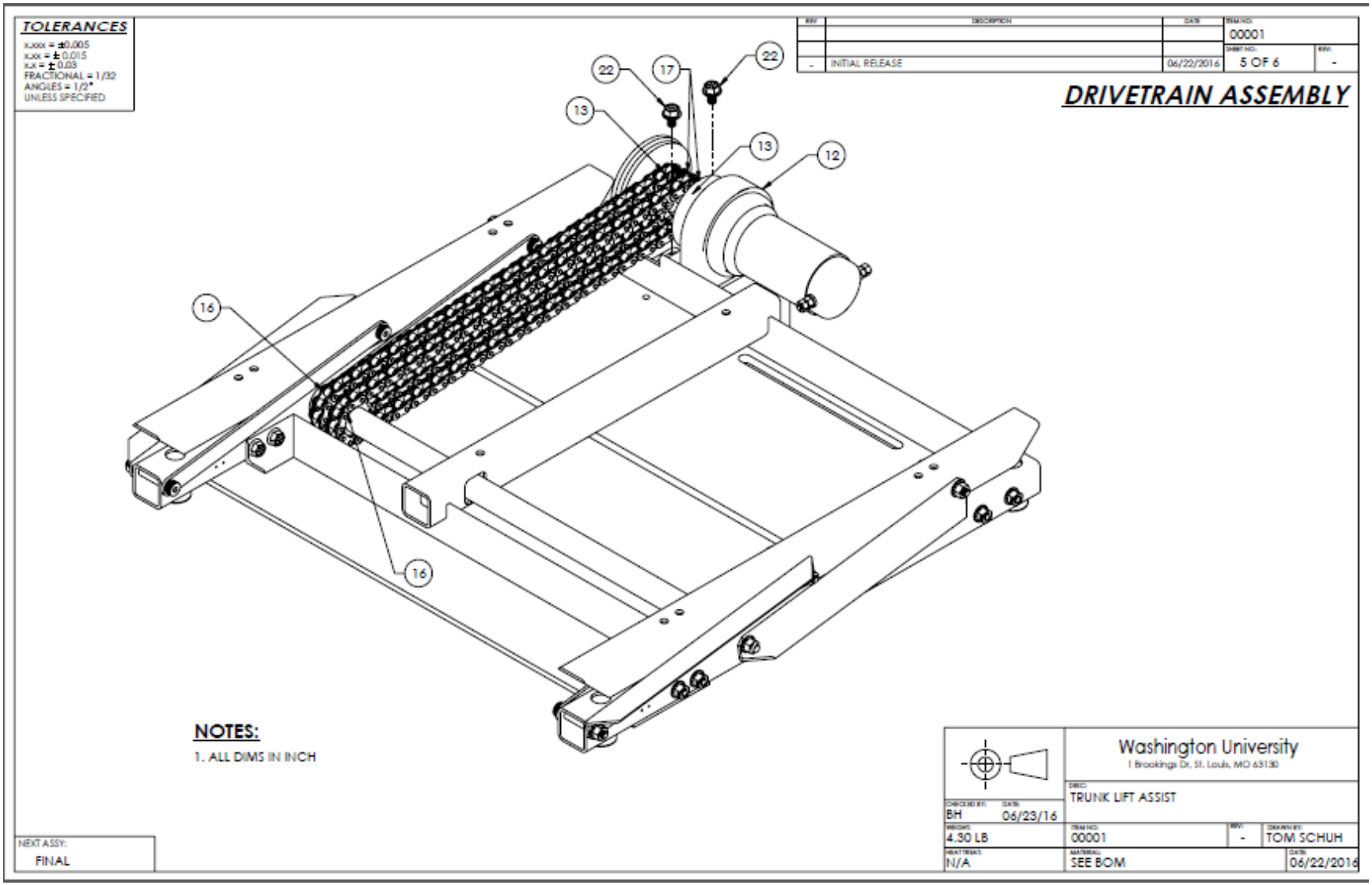
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
DWG NO
00001
SHEET NO
4 OF 6
REV
-
INITIAL RELEASE
06/22/2016
BASE ASSEMBLY
18
5
10
20
13
4
7
9
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
FINAL
Washington University
1 Brookings Dr. St. Louis, MO 63130
DESC
TRUNK LIFT ASSIST
CHECKED BY
BH
DATE
06/23/16
WEIGHT
4.30 LB
DWG NO
00001
REV
-
DRAWN BY
TOM SCHUH
HEAT TREAT
N/A
MATERIAL
SEE BOM
DATE
06/22/2016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x.x = ± 0.03
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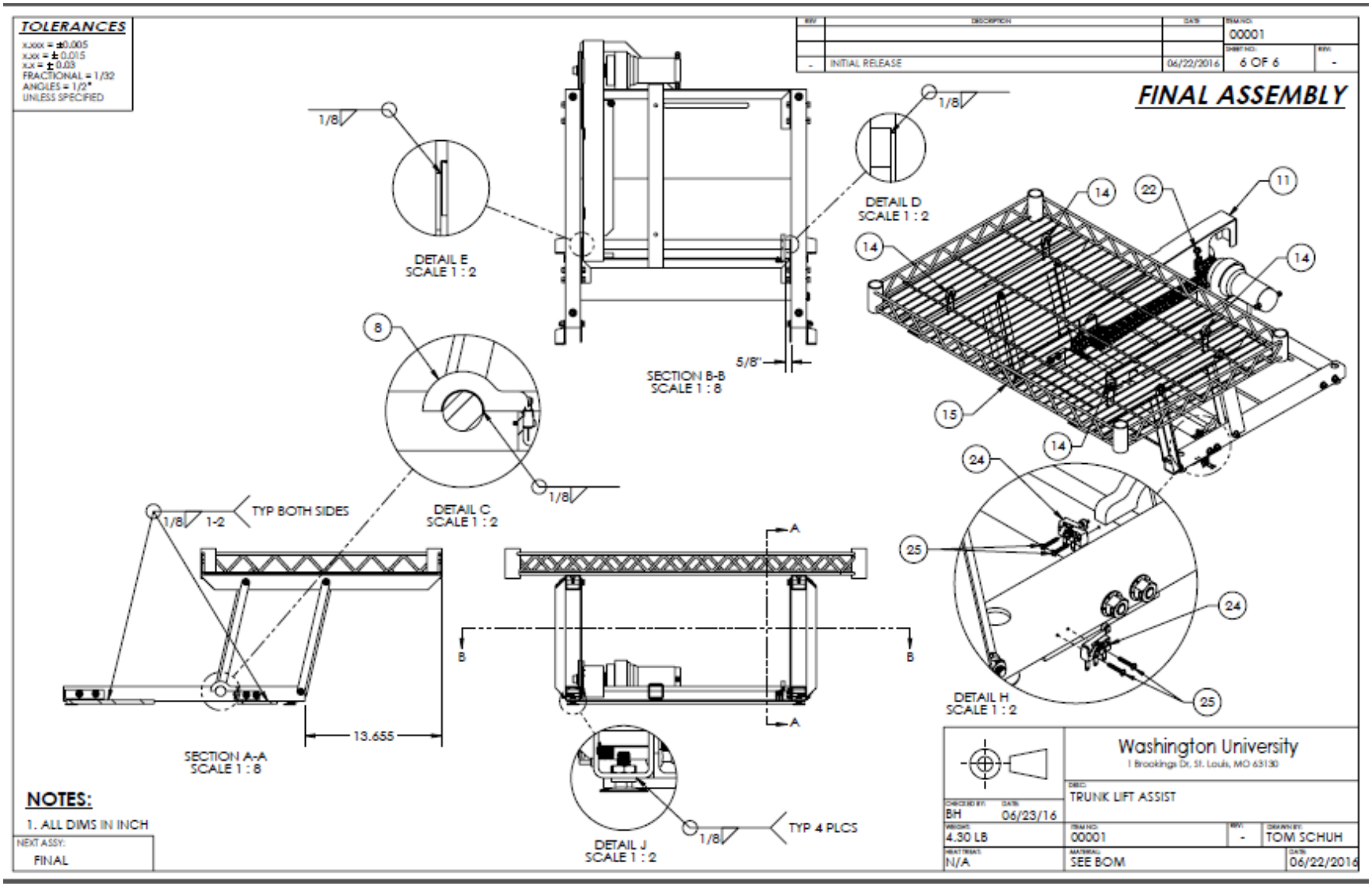
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
DWG NO
00001
SHEET NO
5 OF 6
REV
-
INITIAL RELEASE
06/22/2016
DRIVETRAIN ASSEMBLY
22
17
22
13
13
12
16
16
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
FINAL
Washington University
1 Brookings Dr. St. Louis, MO 63130
DESC:
TRUNK LIFT ASSIST
CHECKED BY:
BH
DATE
06/23/16
WEIGHT:
4.50 LB
DWG NO
00001
REV
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
SEE BOM
DATE
06/22/2016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x.xx = ± 0.015
x.x = ± 0.03
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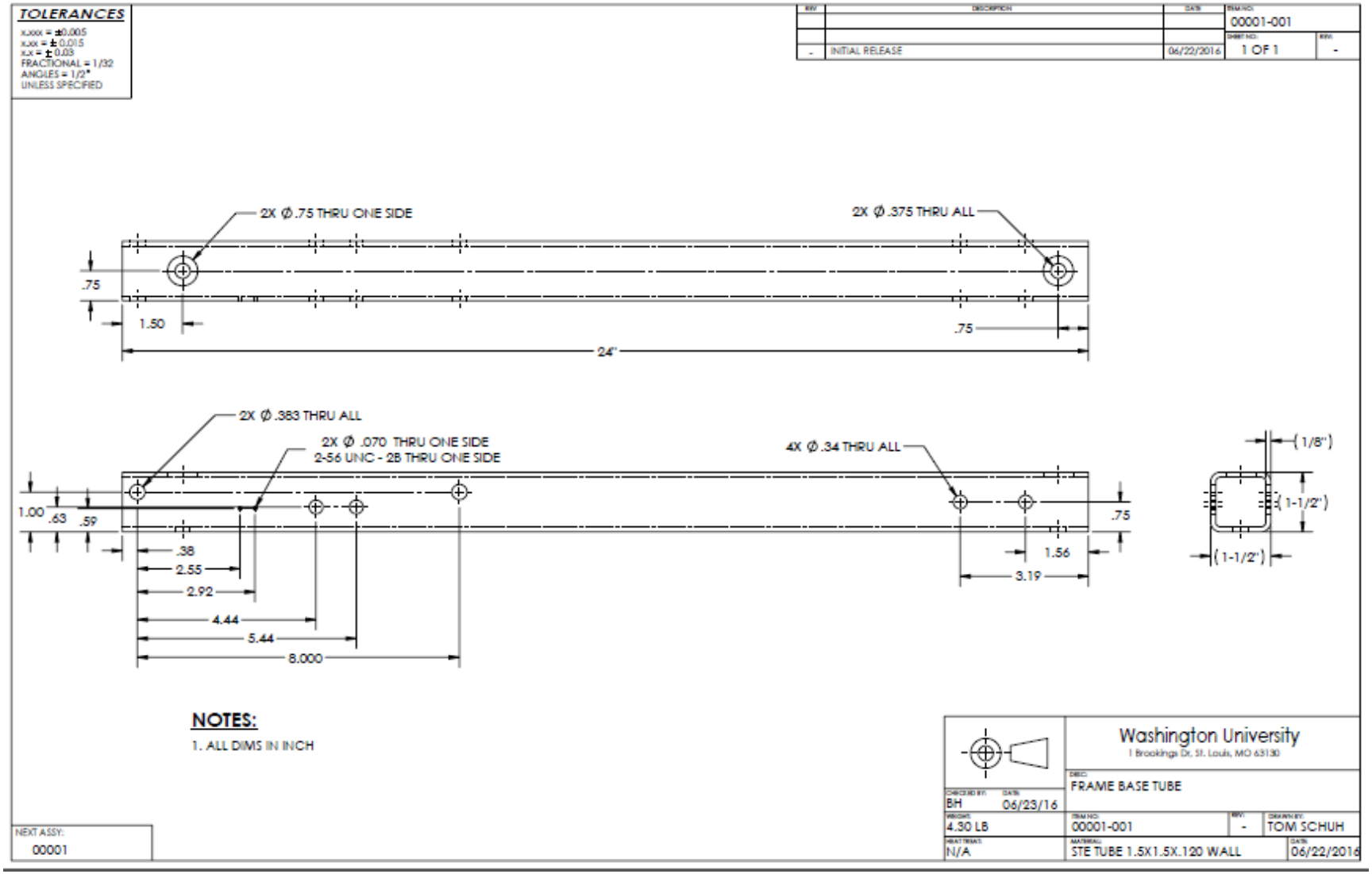
ANGLES = 1/2°
UNLESS SPECIFIED
INITIAL RELEASE
06/22/2016
00001
6 OF 6
FINAL ASSEMBLY
DETAIL E
SCALE 1 : 2
DETAIL D
SCALE 1 : 2
SECTION B-B
SCALE 1 : 8
5/8"
DETAIL C
SCALE 1 : 2
TYP BOTH SIDES
SECTION A-A
SCALE 1 : 8
13.655
DETAIL J
SCALE 1 : 2
TYP 4 PLCS
DETAIL H
SCALE 1 : 2
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
FINAL
Washington University
1 Brookings Dr, St. Louis, MO 63130
TRUNK LIFT ASSIST
BH
06/23/16
4.30 LB
00001
TOM SCHUH
N/A
SEE BOM
06/22/2016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x.xx = ± 0.015
x.x = ± 0.03
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ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO:
00001-001
SHEET NO:
1 OF 1
REV:
-
-
INITIAL RELEASE
06/22/2016
2X Ø .75 THRU ONE SIDE
2X Ø .375 THRU ALL
.75
1.50
.75
24"
2X Ø .383 THRU ALL
2X Ø .070 THRU ONE SIDE
2-56 UNC - 2B THRU ONE SIDE
4X Ø .34 THRU ALL
1.00
.63
.59
.38
2.55
2.92
4.44
5.44
8.000
.75
1.56
3.19
(1/8")
(1-1/2")
(1-1/2")
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00001
Washington University
1 Brookings Dr, St. Louis, MO 63130
DESC:
FRAME BASE TUBE
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
4.30 LB
ITEM NO:
00001-001
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE TUBE 1.5X1.5X.120 WALL
DATE:
06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO.
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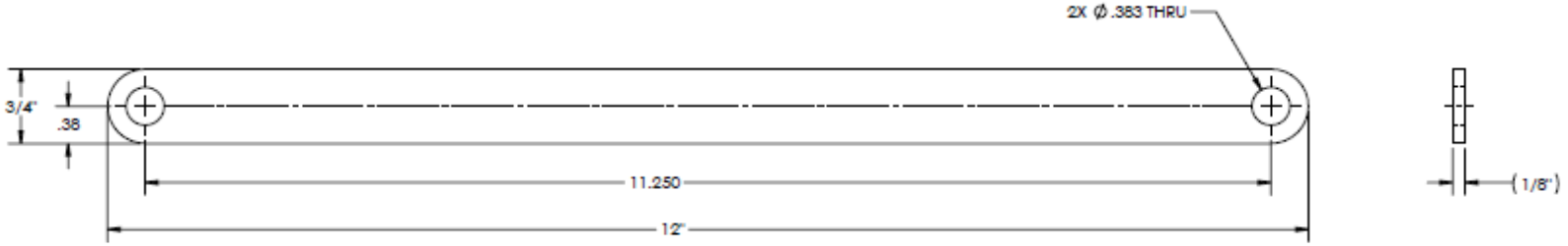
			SHEET NO.: 1 OF 1
-	INITIAL RELEASE	06/22/2016	REV: -



NOTES:

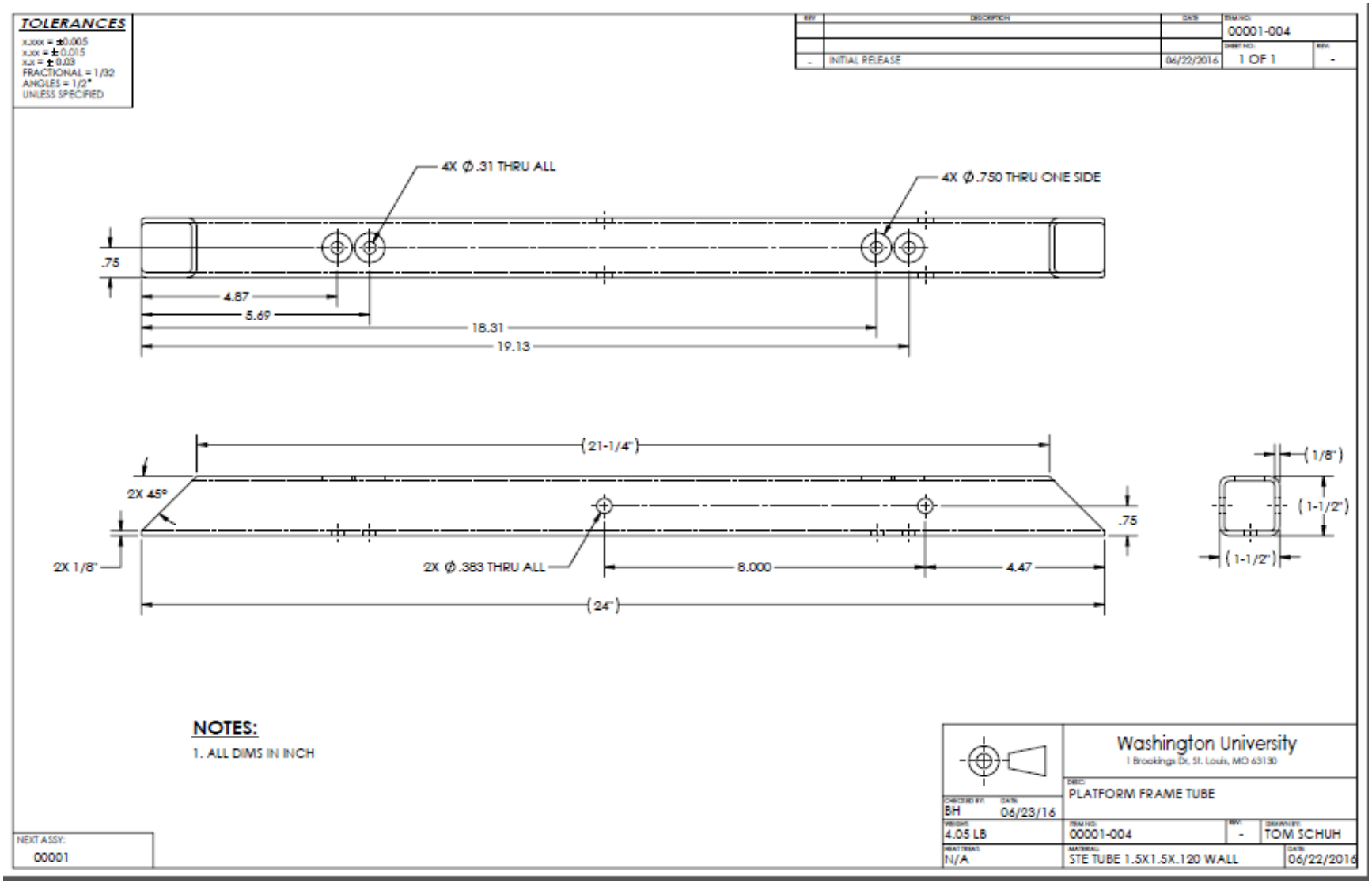
1. ALL DIMS IN INCH

NEXT ASSY:
VARIOUS

Washington University
1 Brookings Dr, St. Louis, MO 63130

DESC: INNER PARALLEL LINK BAR

CHECKED BY:	DATE:	ITEM NO.	REV:	DRAWN BY:
BH	06/23/16	00001-002	-	TOM SCHUH
WEIGHT: 0.30 LB				
HEAT TREAT: N/A		MATERIAL: STE PLT 1/8 HR A36		DATE: 06/22/2016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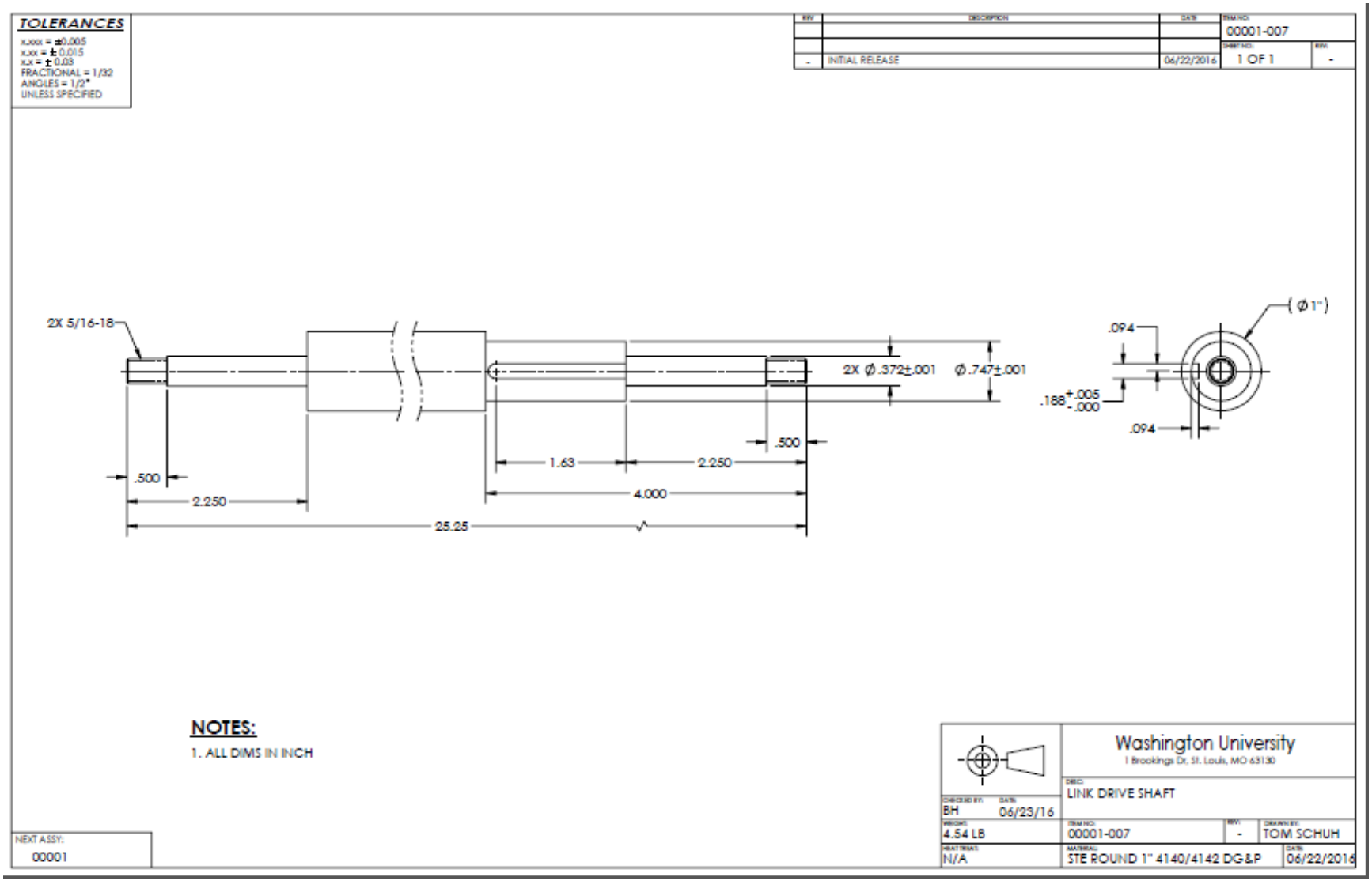
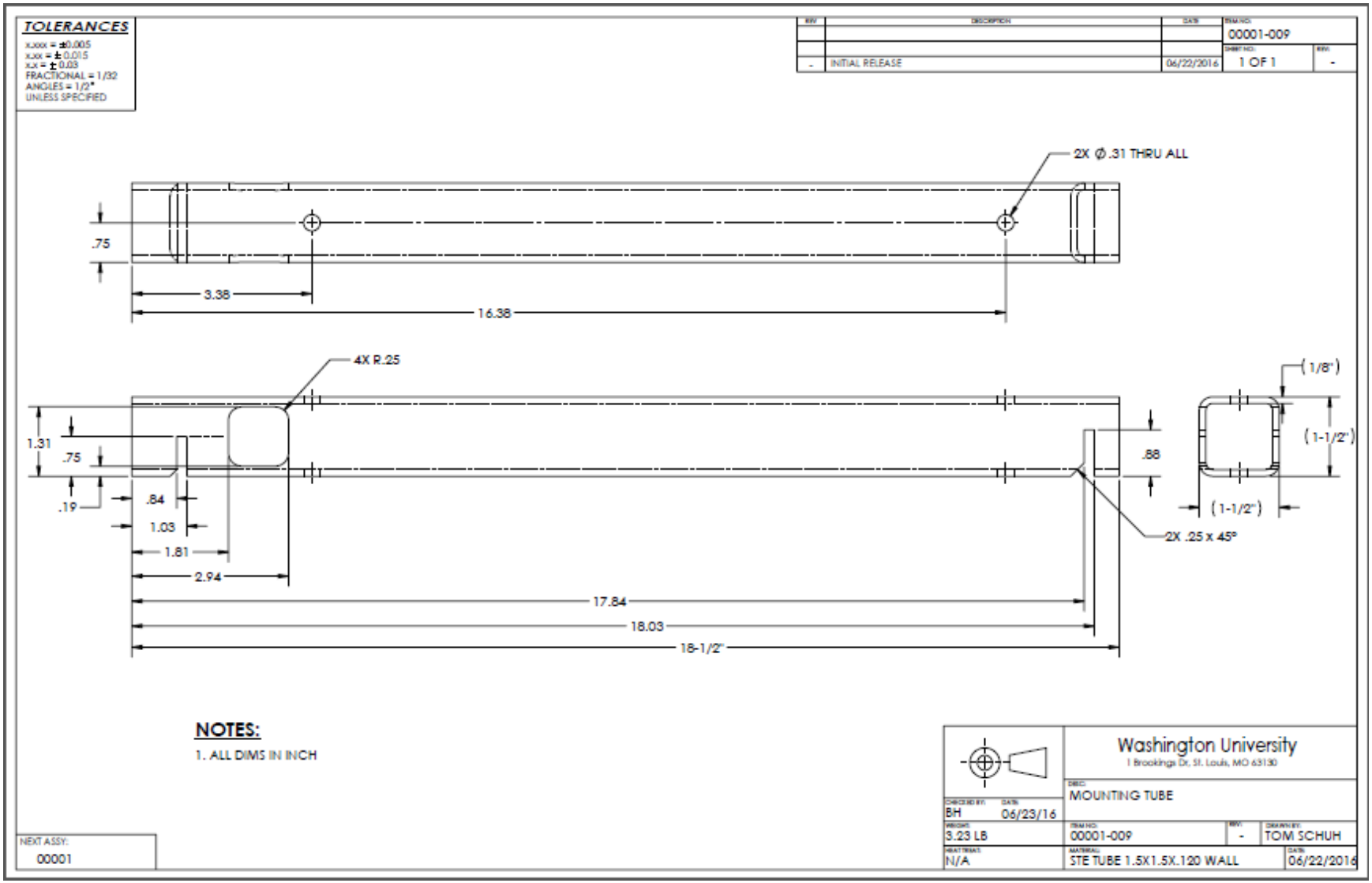
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
DWG NO.
00001-004
SHEET NO.
1 OF 1
REV
-
-
INITIAL RELEASE
06/22/2016
4X Ø .31 THRU ALL
4X Ø .750 THRU ONE SIDE
.75
4.87
5.69
18.31
19.13
(21-1/4")
2X 45°
2X 1/8"
2X Ø .383 THRU ALL
8.000
4.47
.75
(24")
(1/8")
(1-1/2")
(1-1/2")
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00001
Washington University
1 Brookings Dr, St. Louis, MO 63130
DWG:
PLATFORM FRAME TUBE
CHECKED BY:
BH
DATE
06/23/16
WEIGHT:
4.05 LB
DWG NO.
00001-004
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE TUBE 1.5X1.5X.120 WALL
DATE:
06/22/2016


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
PRINT NO:
00001-007
SHEET NO:
1 OF 1
REV:
-
-
INITIAL RELEASE
06/22/2016
2X 5/16-18
2X Ø .372±.001
Ø .747±.001
.500
1.63
2.250
4.000
25.25
.500
2.250
Ø 1"
.094
.188 +.005 -.000
.094
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00001
Washington University
1 Brookings Dr, St. Louis, MO 63130
LINK DRIVE SHAFT
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
4.54 LB
PART NO:
00001-007
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE ROUND 1" 4140/4142 DG&P
DATE:
06/22/2016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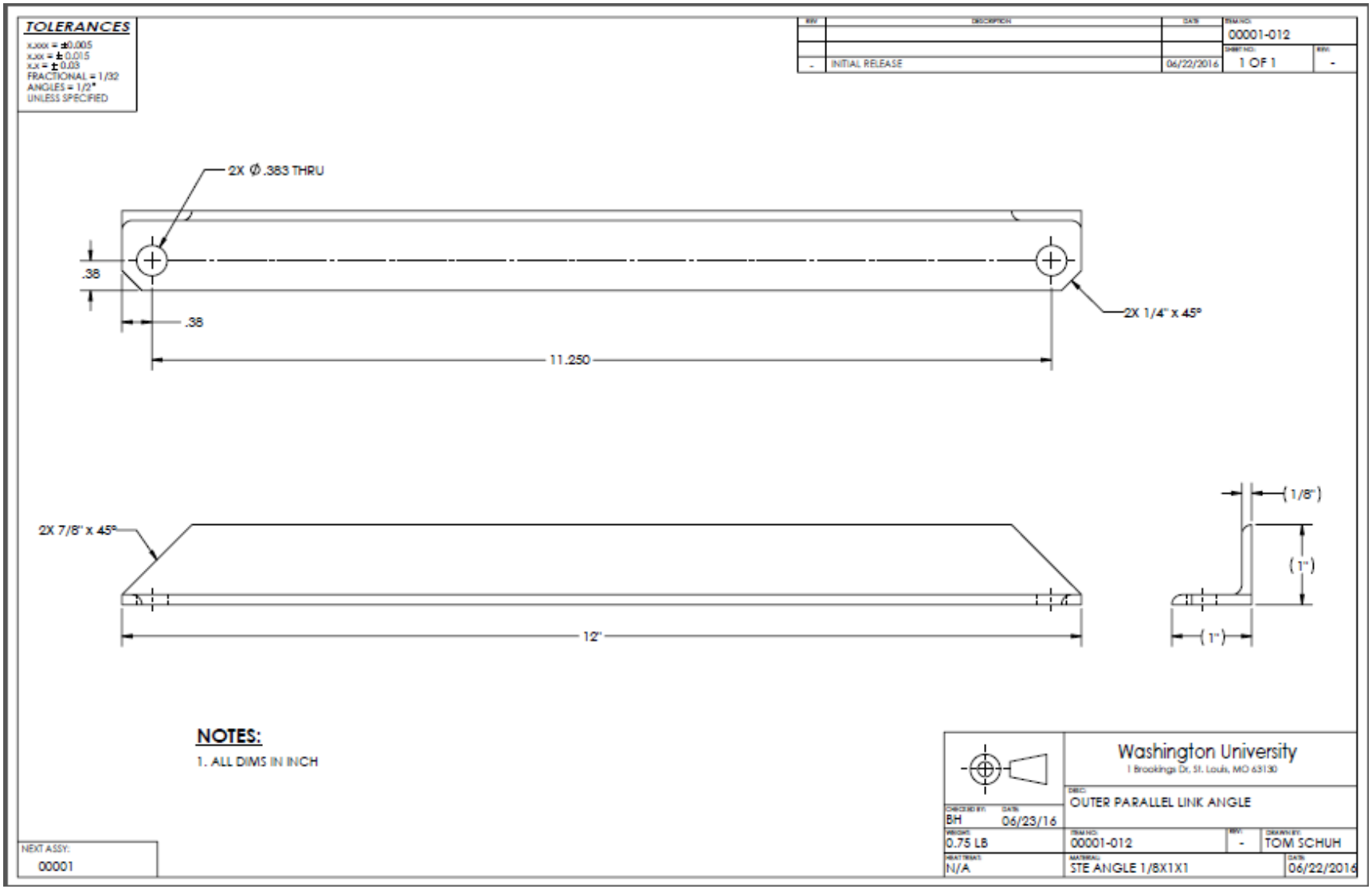
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
DWG NO.
00001-009
- INITIAL RELEASE 06/22/2016
SHEET NO.
1 OF 1
REV
-
2X Ø .31 THRU ALL
.75
3.38
16.38
4X R.25
1.31
.75
.19
.84
1.03
1.81
2.94
17.84
18.03
18-1/2"
.88
(1/8")
(1-1/2")
(1-1/2")
2X .25 x 45°
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00001
Washington University
1 Brookings Dr, St. Louis, MO 63130
DESC:
MOUNTING TUBE
CHECKED BY: BH
DATE: 06/23/16
WEIGHT: 3.23 LB
DWG NO.: 00001-009
REV: -
DRAWN BY: TOM SCHUH
HEAT TREAT: N/A
MATERIAL: STE TUBE 1.5X1.5X.120 WALL
DATE: 06/22/2016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x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
DWG NO.
00001-012
-
INITIAL RELEASE
06/22/2016
SHEET NO.
1 OF 1
REV
-
2X Ø.383 THRU
.38
.38
11.250
2X 1/4" x 45°
2X 7/8" x 45°
12"
1/8"
1"
1"
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00001
Washington University
1 Brookings Dr, St. Louis, MO 63130
DESC:
OUTER PARALLEL LINK ANGLE
CHECKED BY:
BH
DATE
06/23/16
WEIGHT:
0.75 LB
DWG NO.
00001-012
REV
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE ANGLE 1/8X1X1
DATE
06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	DRAWING NO.
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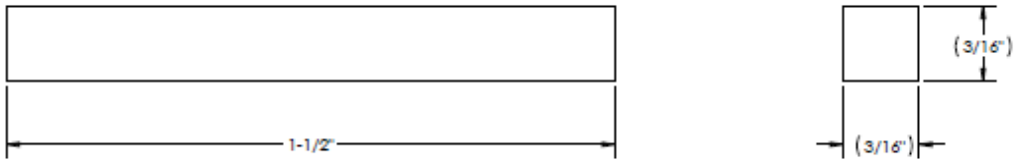
			SHEET NO. 1 OF 1
-	INITIAL RELEASE	06/22/2016	REV. -



NOTES:

1. ALL DIMS IN INCH

NEXT ASSY:
00001

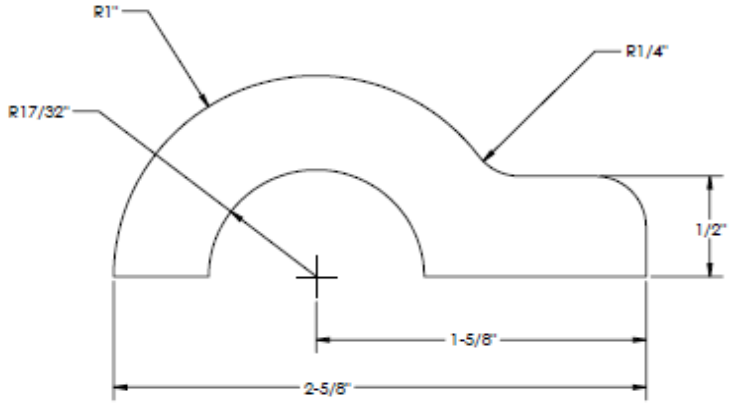
Washington University
1 Brookings Dr, St. Louis, MO 63130

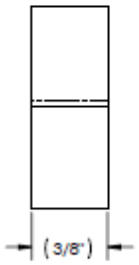
CHECKED BY: BH	DATE: 06/23/16	DESC: DRIVESHAFT KEY	
WEIGHT: 0.86 LB	DRAWING NO: 00001-016	REV: -	DRAWN BY: TOM SCHUH
HEAT TREAT: N/A	MATERIAL: STE 3/16X3/16 KEYSTOCK		DATE: 06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO.
			00001-017
-	INITIAL RELEASE	06/22/2016	SHEET NO. 1 OF 1 — REV: -





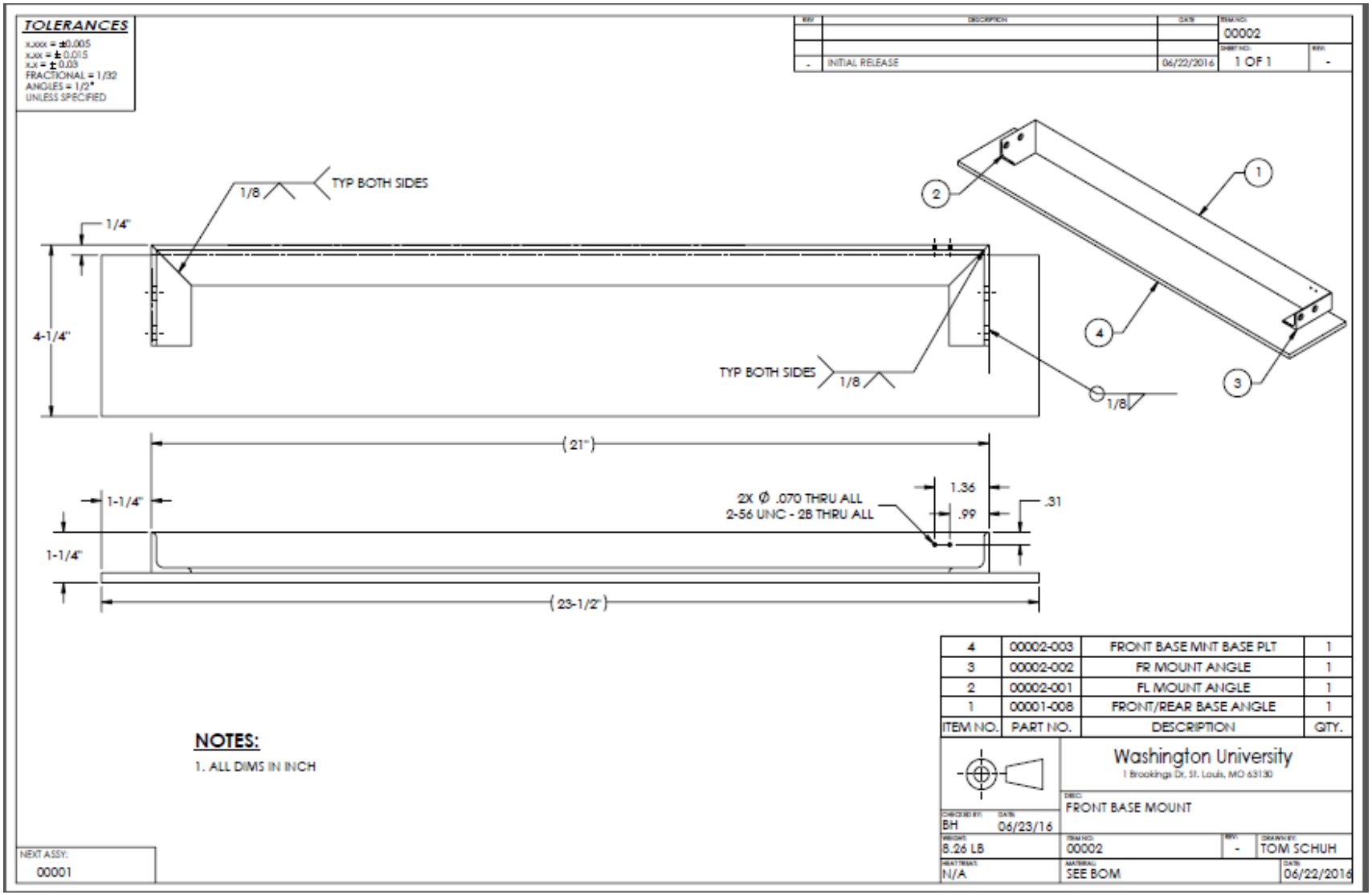
NOTES:

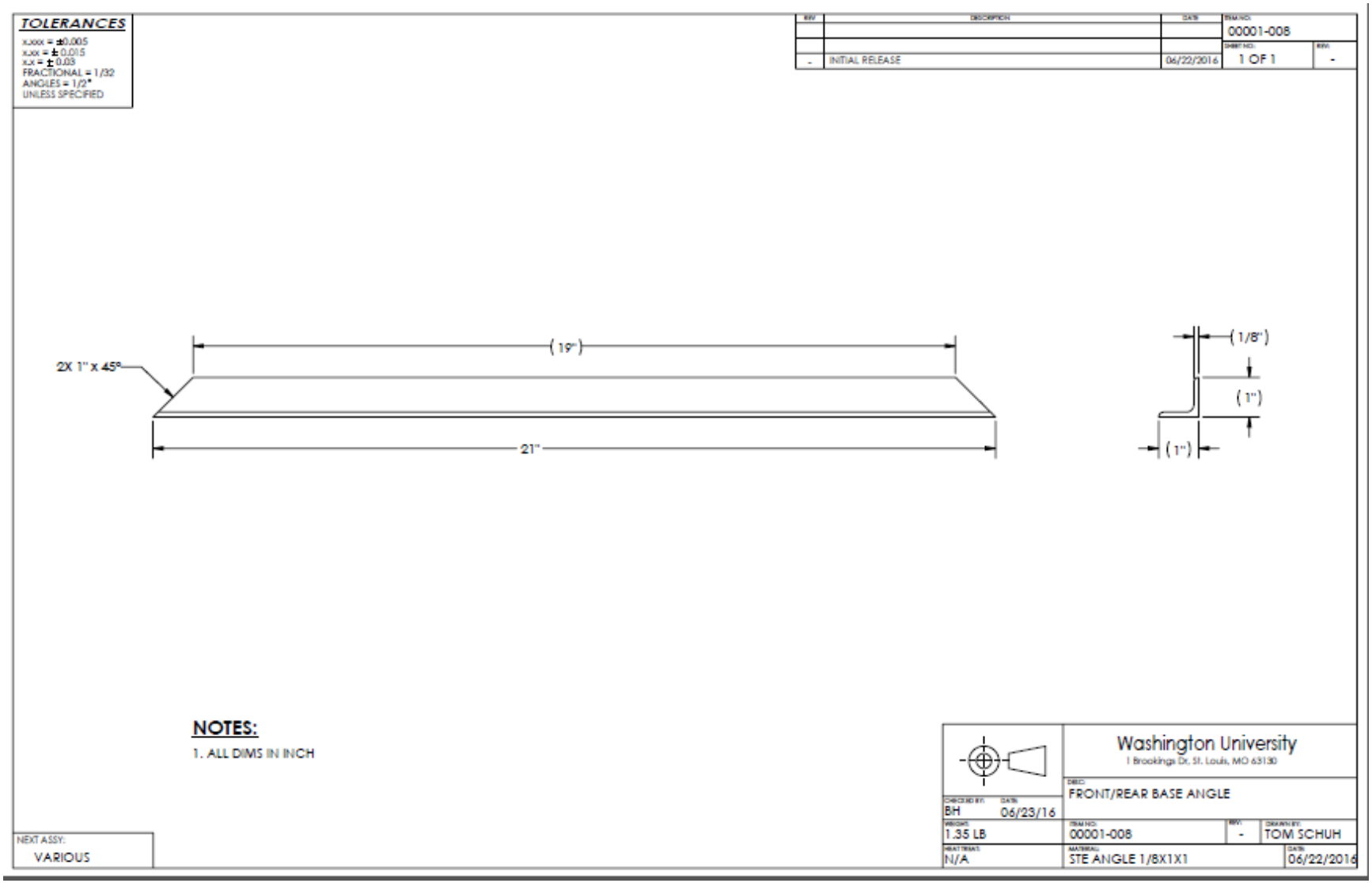
1. ALL DIMS IN INCH

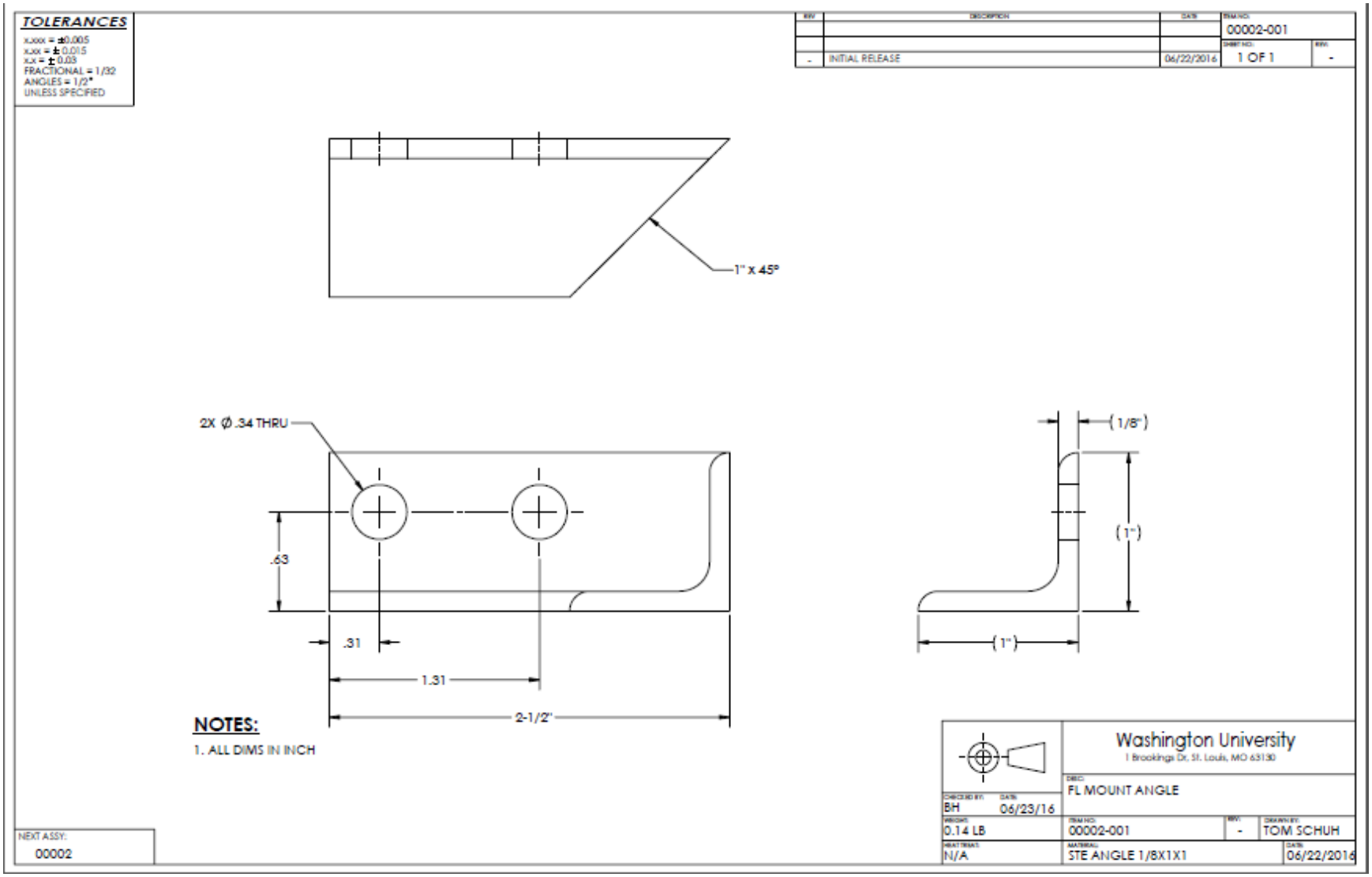
NEXT ASSY: 00001

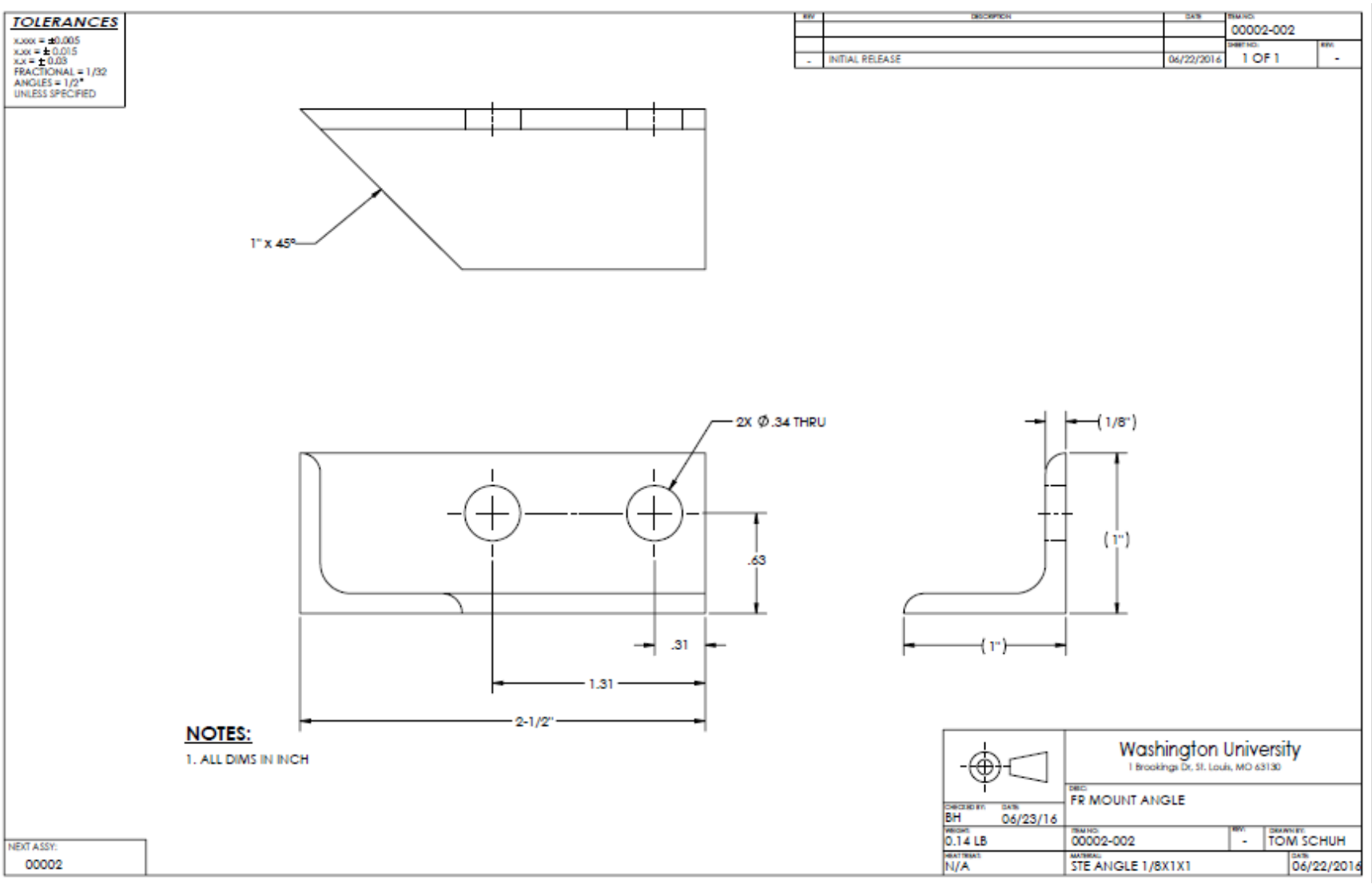
Washington University
1 Brookings Dr. St. Louis, MO 63130

CHECKED BY: BH — DATE: 06/23/16	DESC: STOP BLOCK		
WEIGHT: 8.92 LB	ITEM NO: 00001-017	REV: -	DRAWN BY: TOM SCHUH
HEAT TREAT: N/A	MATERIAL: STE PLT 3/8" HR A36		DATE: 06/22/2016


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO.
00002
SHEET NO.
1 OF 1
REV
-
INITIAL RELEASE
06/22/2016
TYP BOTH SIDES
1/8
1/4"
4-1/4"
TYP BOTH SIDES
1/8
1/8
1
2
3
4
21"
1-1/4"
1-1/4"
2X Ø .070 THRU ALL
2-56 UNC - 2B THRU ALL
1.36
.99
.31
23-1/2"
4 00002-003 FRONT BASE MNT BASE PLT 1
3 00002-002 FR MOUNT ANGLE 1
2 00002-001 FL MOUNT ANGLE 1
1 00001-008 FRONT/REAR BASE ANGLE 1
ITEM NO. PART NO. DESCRIPTION QTY.
NOTES:
1. ALL DIMS IN INCH
Washington University
1 Brookings Dr. St. Louis, MO 63130
DESC:
FRONT BASE MOUNT
CHECKED BY:
BH
DATE
06/23/16
WEIGHT:
8.26 LB
ITEM NO.
00002
REV
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
SEE BOM
DATE
06/22/2016
NEXT ASSY:
00001


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
PART NO.
00001-008
SHEET NO.
1 OF 1
REV
-
-
INITIAL RELEASE
06/22/2016
2X 1" x 45°
19"
21"
1/8"
1"
1"
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
VARIOUS
Washington University
1 Brookings Dr, St. Louis, MO 63130
DESC:
FRONT/REAR BASE ANGLE
CHECKED BY:
BH
DATE
06/23/16
WEIGHT:
1.35 LB
PART NO.
00001-008
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE ANGLE 1/8X1X1
DATE:
06/22/2016

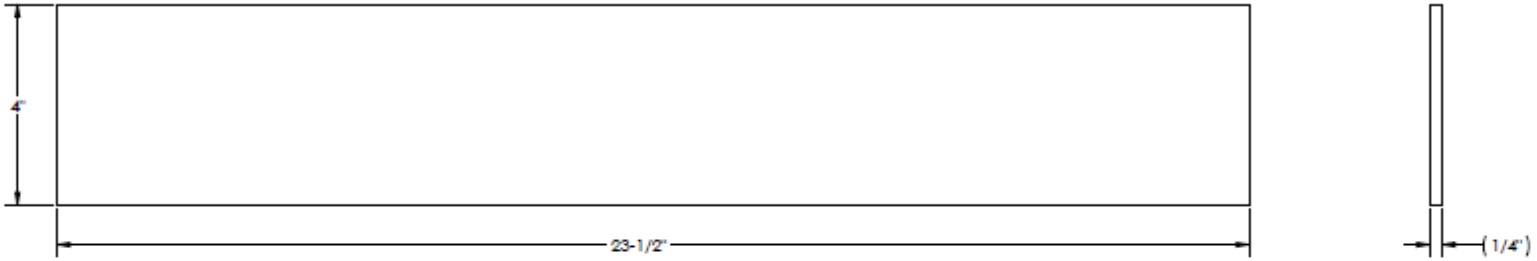

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO.
00002-001
SHEET NO.
1 OF 1
REV
-
INITIAL RELEASE
06/22/2016
1" x 45°
2X Ø .34 THRU
.63
.31
1.31
2-1/2"
1/8"
1"
1"
NOTES:
1. ALL DIMS IN INCH
Washington University
1 Brookings Dr. St. Louis, MO 63130
DESC:
FL MOUNT ANGLE
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
0.14 LB
ITEM NO.
00002-001
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE ANGLE 1/8X1X1
DATE:
06/22/2016
NEXT ASSY:
00002


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
PART NO:
00002-002
SHEET NO:
1 OF 1
REV:
-
INITIAL RELEASE
06/22/2016
1" x 45°
2X Ø .34 THRU
.63
.31
1.31
2-1/2"
(1/8")
(1")
(1")
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00002
Washington University
1 Brookings Dr, St. Louis, MO 63130
DESC:
FR MOUNT ANGLE
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
0.14 LB
PART NO:
00002-002
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE ANGLE 1/8X1X1
DATE:
06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO.
			00002-003
			SHEET NO.: 1 OF 1
-	INITIAL RELEASE	06/22/2016	REV. -



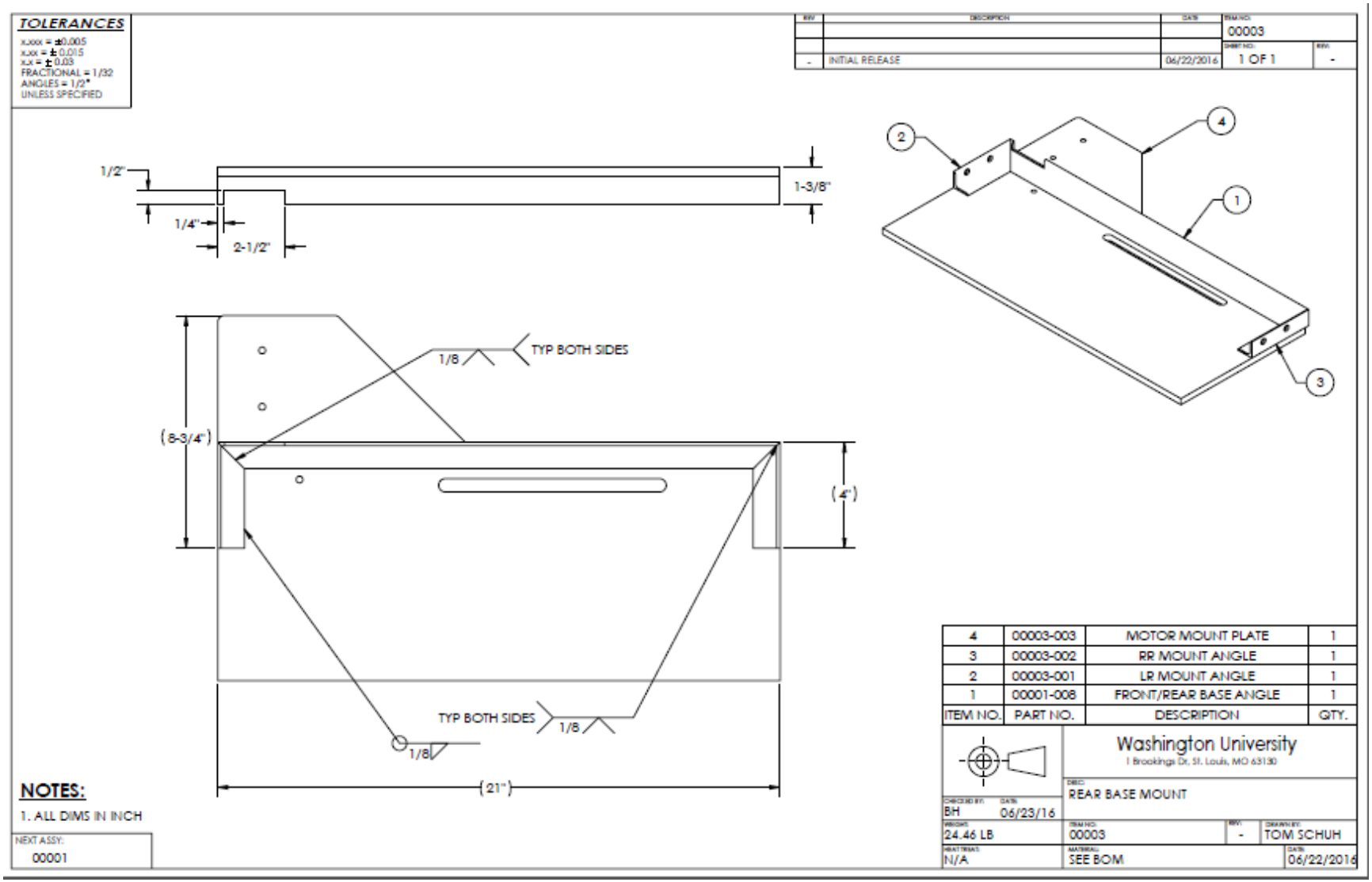
NOTES:

1. ALL DIMS IN INCH

NEXT ASSY:
00002

Washington University
1 Brookings Dr, St. Louis, MO 63130

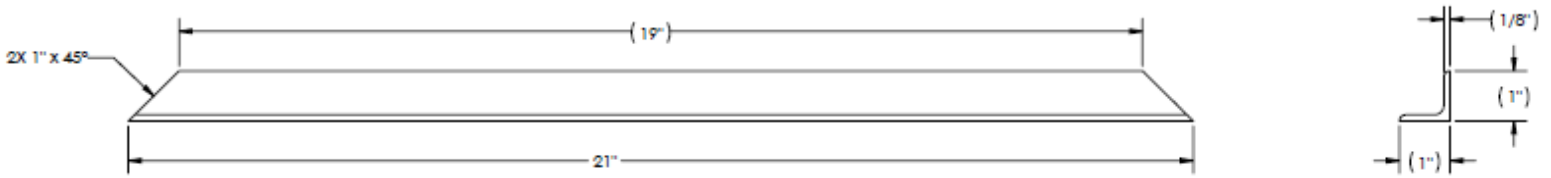
CHECKED BY: BH	DATE: 06/23/16	DESC: FRONT BASE MNT BASE PLT	
WEIGHT: 6.622 LB		ITEM NO.: 00002-003	REV: - DRAWN BY: TOM SCHUH
HEAT TREAT: N/A		MATERIAL: STE PLT 1/4 HR A36	DATE: 06/22/2016


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
PRINT NO.
00003
SHEET NO.
1 OF 1
REV.
-
INITIAL RELEASE
06/22/2016
1/2"
1/4"
2-1/2"
1-3/8"
1/8
TYP BOTH SIDES
(8-3/4")
(4")
TYP BOTH SIDES
1/8
1/8
(21")
2
4
1
3
4 00003-003 MOTOR MOUNT PLATE 1
3 00003-002 RR MOUNT ANGLE 1
2 00003-001 LR MOUNT ANGLE 1
1 00001-008 FRONT/REAR BASE ANGLE 1
ITEM NO. PART NO. DESCRIPTION QTY.
Washington University
1 Brookings Dr, St. Louis, MO 63130
DWG.
REAR BASE MOUNT
CHECKED BY: BH
DATE: 06/23/16
WEIGHT: 24.46 LB
ITEM NO. 00003
REV. -
DRAWN BY: TOM SCHUH
HEAT TREAT: N/A
MATERIAL: SEE BOM
DATE: 06/22/2016
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00001

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV.	DESCRIPTION	DATE	ITEM NO.
			00001-008
			SHEET NO. 1 OF 1
-	INITIAL RELEASE	06/22/2016	REV. -



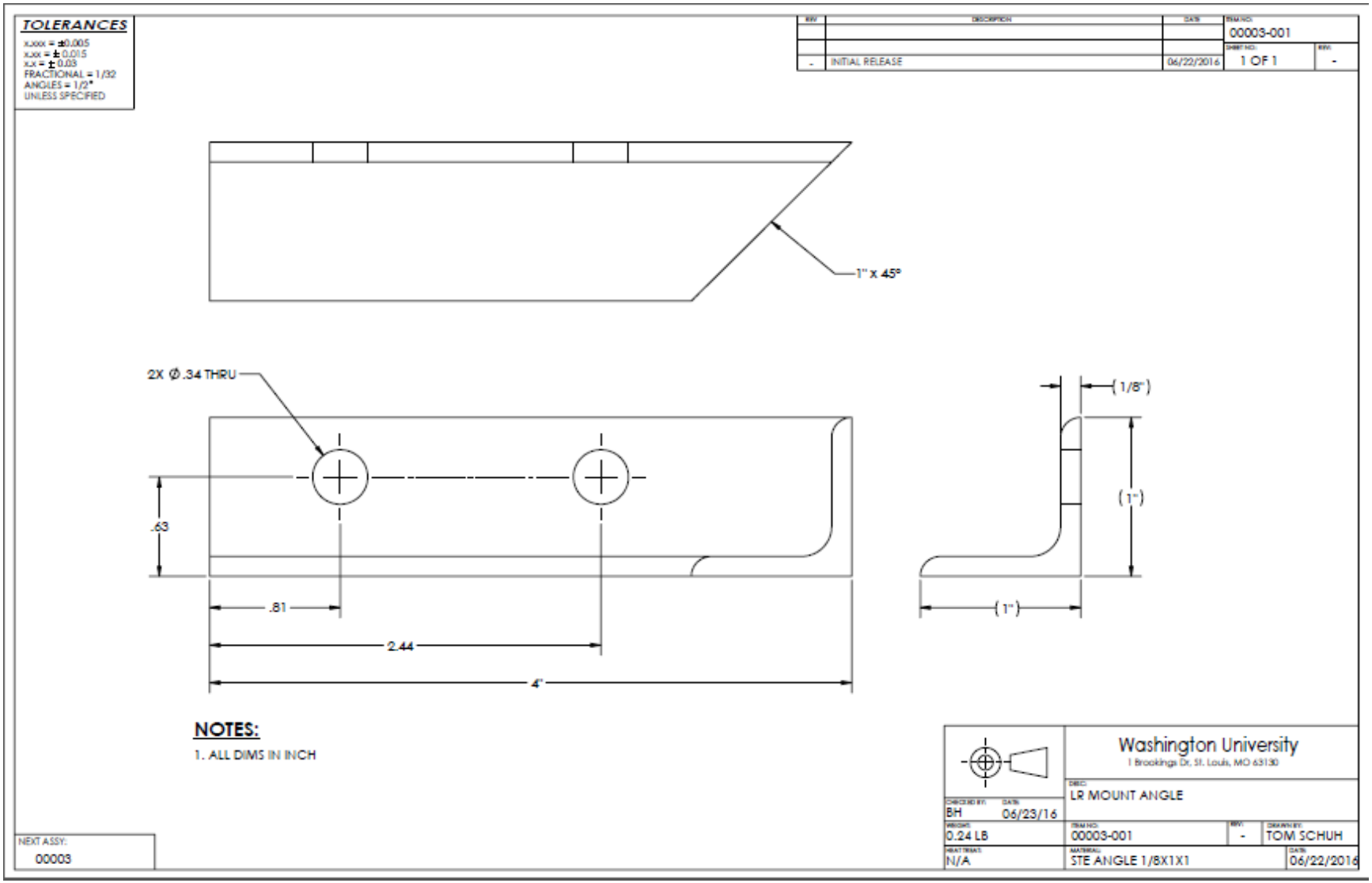
NOTES:

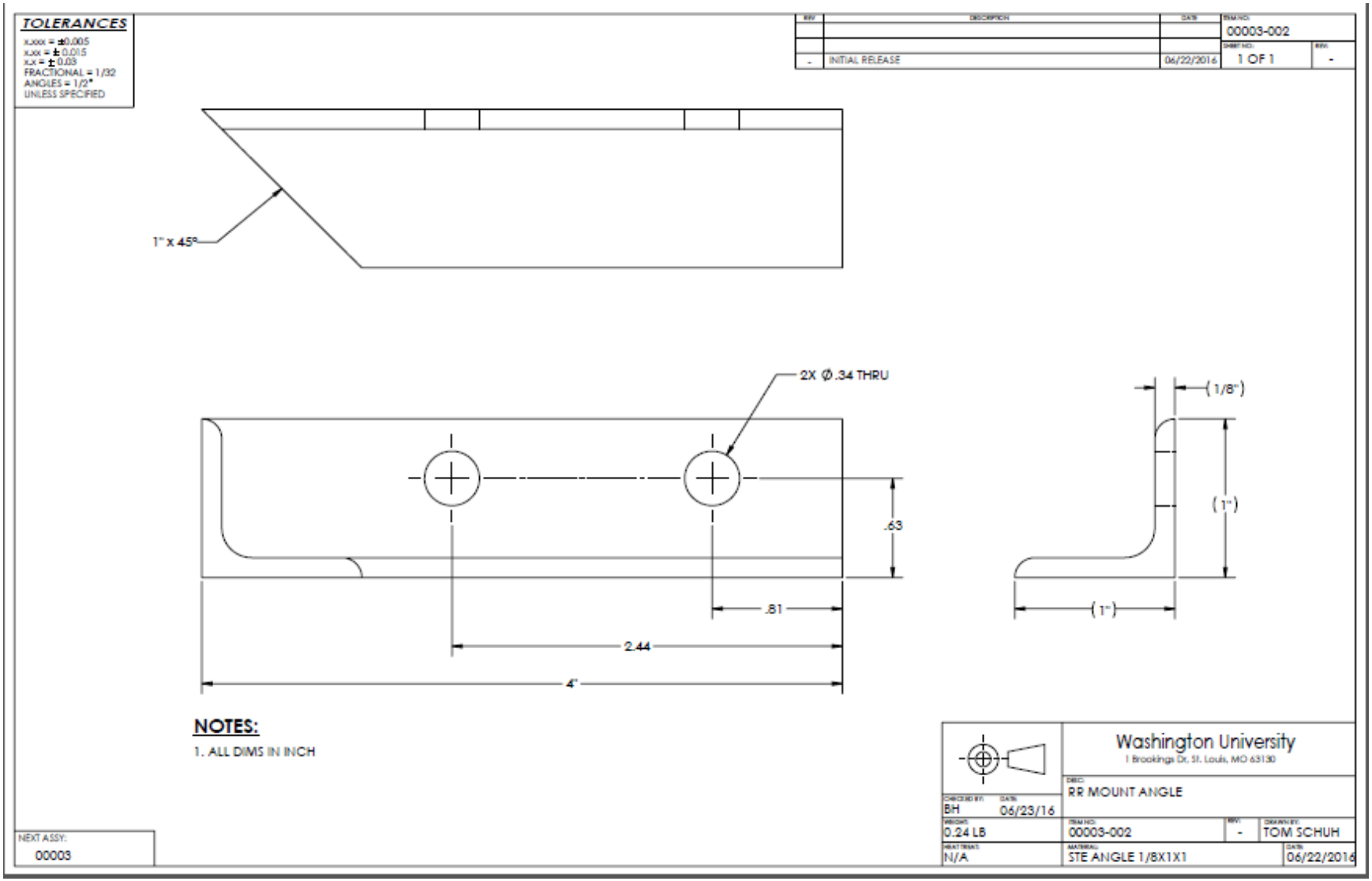
1. ALL DIMS IN INCH

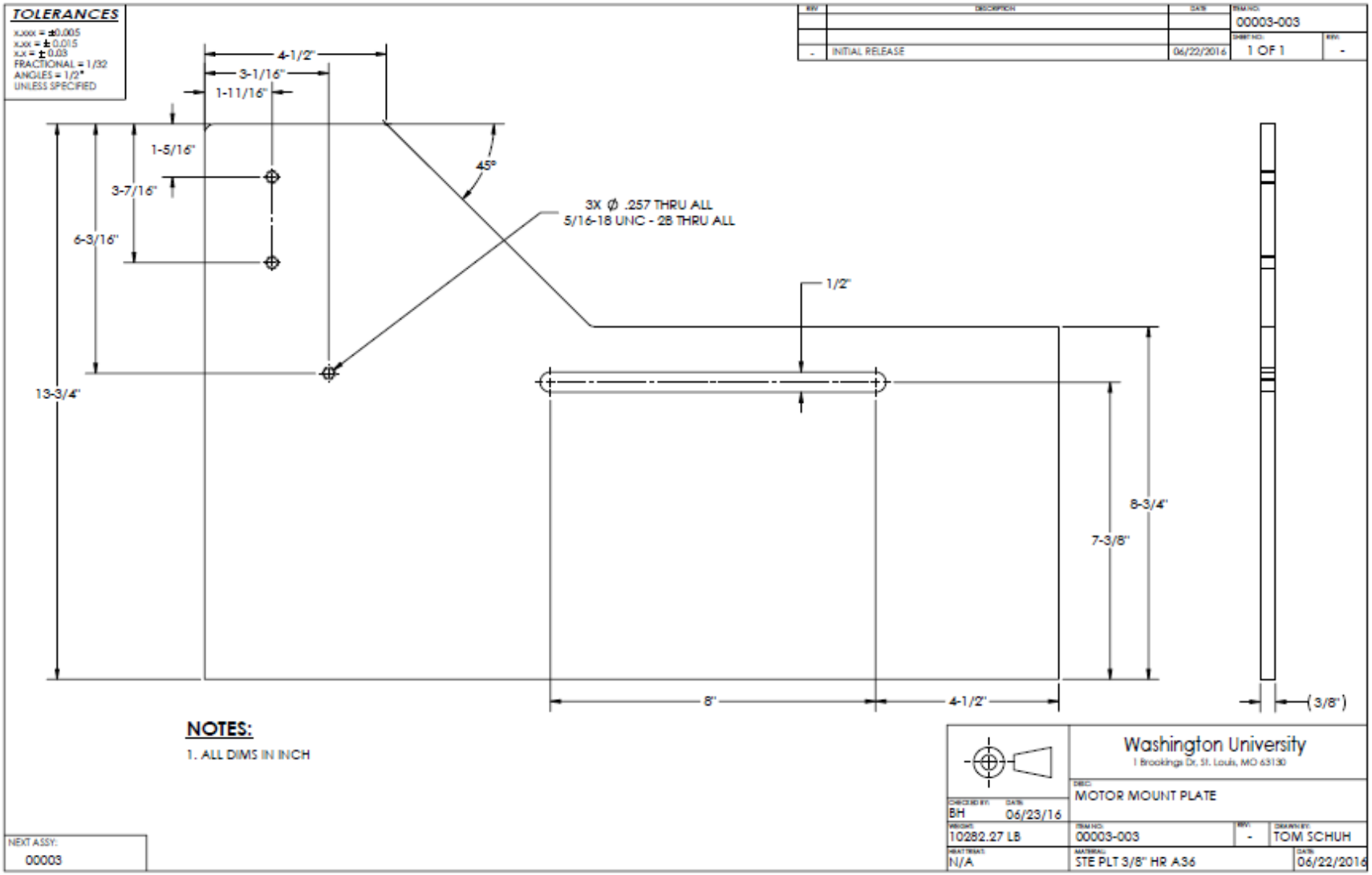
NEXT ASSY:
VARIOUS

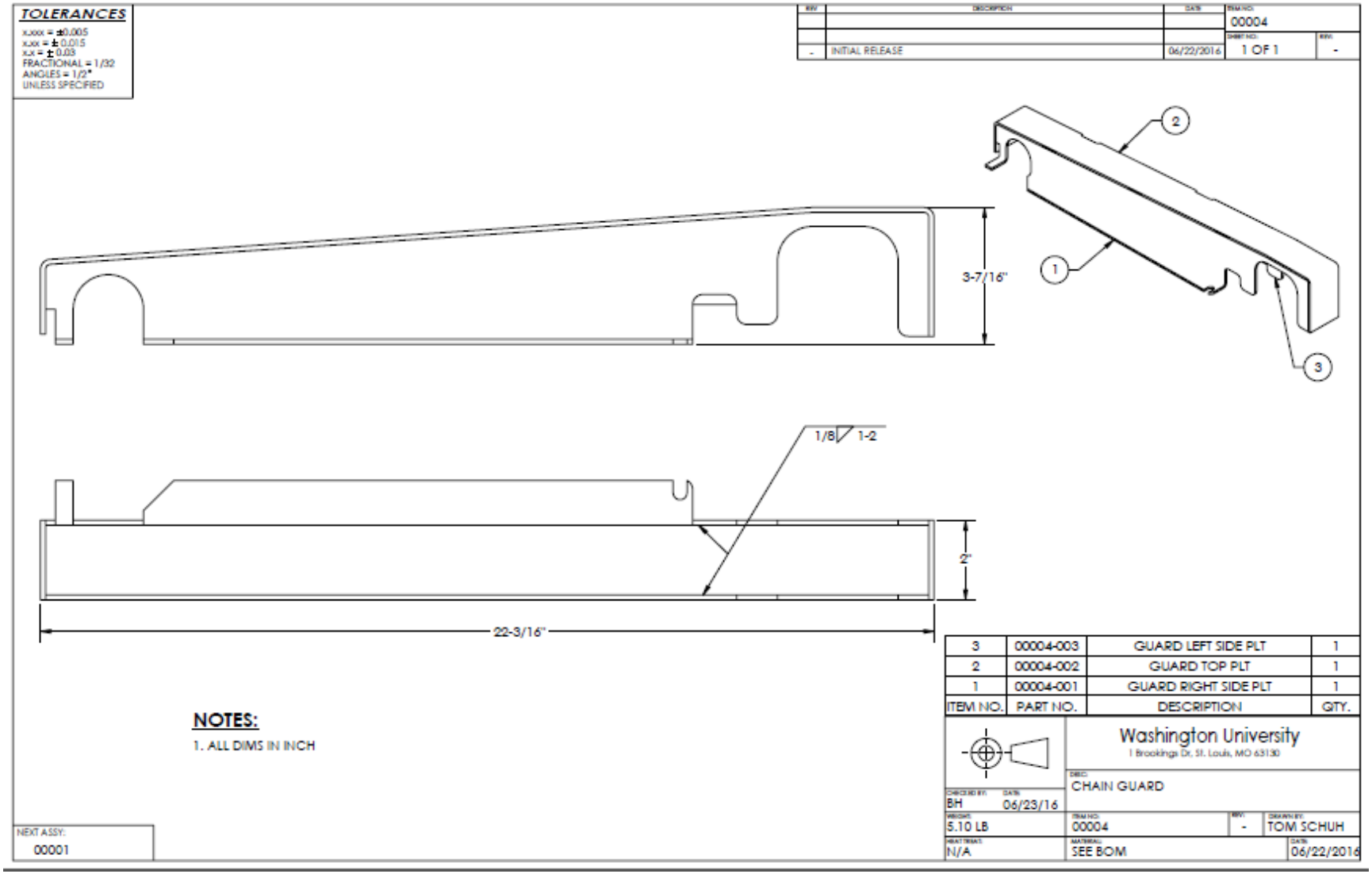
Washington University
1 Brookings Dr, St. Louis, MO 63130

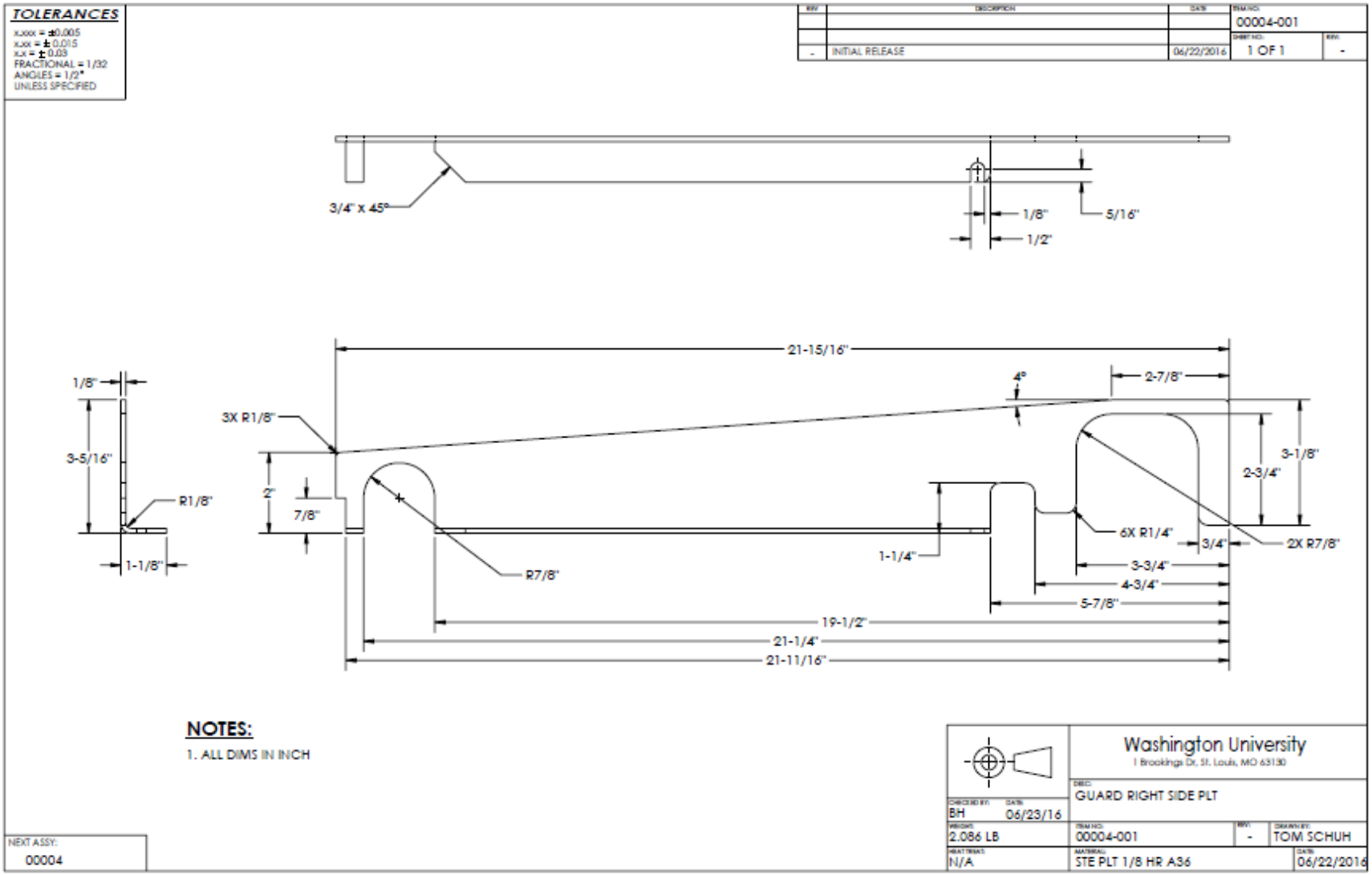
CHECKED BY: BH	DATE: 06/23/16	DESC: FRONT/REAR BASE ANGLE	
WEIGHT: 1.35 LB		ITEM NO: 00001-008	REV: - DRAWN BY: TOM SCHUH
HEAT TREAT: N/A		MATERIAL: STE ANGLE 1/8X1X1	DATE: 06/22/2016


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO.
00003-001
SHEET NO.
1 OF 1
REV.
-
INITIAL RELEASE
06/22/2016
1" x 45°
2X Ø .34 THRU
.63
.81
2.44
4"
(1/8")
(1")
(1")
NOTES:
1. ALL DIMS IN INCH
Washington University
1 Brookings Dr. St. Louis, MO 63130
DESC.
LR MOUNT ANGLE
CHECKED BY:
BH
DATE
06/23/16
WEIGHT:
0.24 LB
ITEM NO.
00003-001
REV.
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE ANGLE 1/8X1X1
DATE
06/22/2016
NEXT ASSY:
00003


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO.
00003-002
SHEET NO.
1 OF 1
REV.
-
INITIAL RELEASE
06/22/2016
1" x 45°
2X Ø .34 THRU
.63
.81
2.44
4"
(1/8")
(1")
(1")
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00003
Washington University
1 Brookings Dr. St. Louis, MO 63130
DESC:
RR MOUNT ANGLE
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
0.24 LB
ITEM NO.
00003-002
REV.
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE ANGLE 1/8X1X1
DATE:
06/22/2016


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO:
00003-003
SHEET NO:
1 OF 1
REV:
-
-
INITIAL RELEASE
06/22/2016
4-1/2"
3-1/16"
1-11/16"
1-5/16"
3-7/16"
6-3/16"
13-3/4"
45°
3X Ø .257 THRU ALL
5/16-18 UNC - 2B THRU ALL
1/2"
8-3/4"
7-3/8"
8"
4-1/2"
(3/8")
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00003
Washington University
1 Brookings Dr, St. Louis, MO 63130
DESC:
MOTOR MOUNT PLATE
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
10282.27 LB
ITEM NO:
00003-003
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE PLT 3/8" HR A36
DATE:
06/22/2016

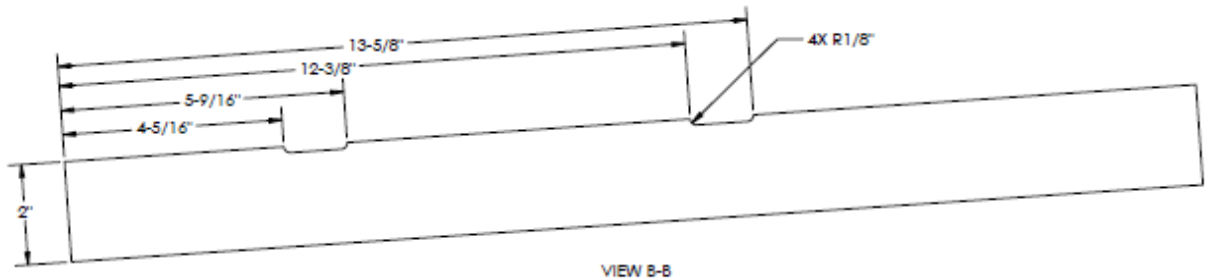

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
PART NO.
00004
SHEET NO.
1 OF 1
REV
-
INITIAL RELEASE
06/22/2016
3-7/16"
2
1
3
1/8
1-2
2"
22-3/16"
3
00004-003
GUARD LEFT SIDE PLT
1
2
00004-002
GUARD TOP PLT
1
1
00004-001
GUARD RIGHT SIDE PLT
1
ITEM NO.
PART NO.
DESCRIPTION
QTY.
NOTES:
1. ALL DIMS IN INCH
Washington University
1 Brookings Dr, St. Louis, MO 63130
DWG:
CHAIN GUARD
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
5.10 LB
PART NO.
00004
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
SEE BOM
DATE:
06/22/2016
NEXT ASSY:
00001


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO:
00004-001
SHEET NO:
1 OF 1
REV:
-
-
INITIAL RELEASE
06/22/2016
3/4" x 45°
1/8"
1/2"
5/16"
21-15/16"
4°
2-7/8"
3X R1/8"
3-1/8"
2-3/4"
2"
7/8"
6X R1/4"
3/4"
2X R7/8"
R7/8"
1-1/4"
3-3/4"
4-3/4"
5-7/8"
19-1/2"
21-1/4"
21-11/16"
1/8"
3-5/16"
R1/8"
1-1/8"
NOTES:
1. ALL DIMS IN INCH
NEXT ASSY:
00004
Washington University
1 Brookings Dr, St. Louis, MO 63130
DESC:
GUARD RIGHT SIDE PLT
CHECKED BY:
BH
DATE:
06/23/16
WEIGHT:
2.086 LB
ITEM NO:
00004-001
REV:
-
DRAWN BY:
TOM SCHUH
HEAT TREAT:
N/A
MATERIAL:
STE PLT 1/8 HR A36
DATE:
06/22/2016

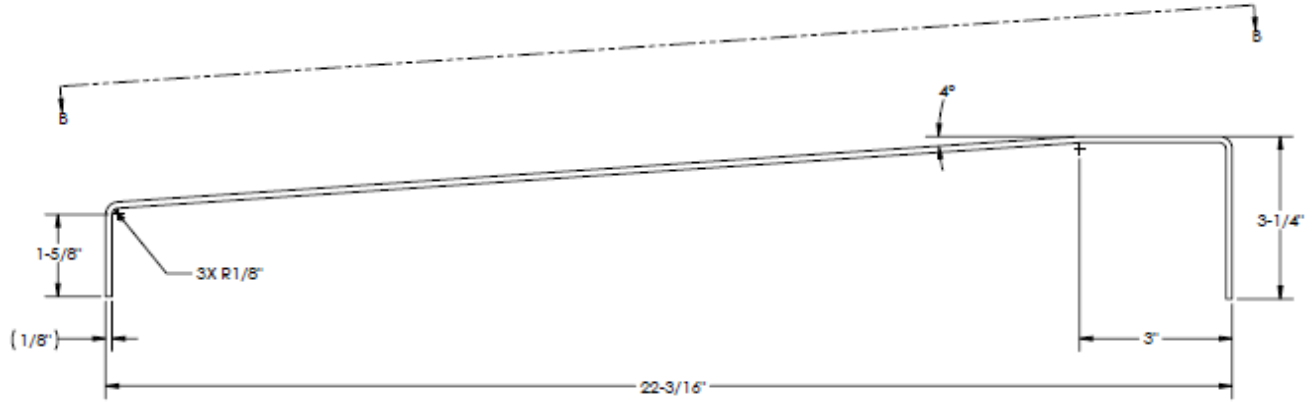
TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO.
			00004-002
			SHEET NO. 1 OF 1
-	INITIAL RELEASE	06/22/2016	REV. -



VIEW B-B
SCALE 1 : 2



NOTES:

1. ALL DIMS IN INCH

NEXT ASSY: 00004

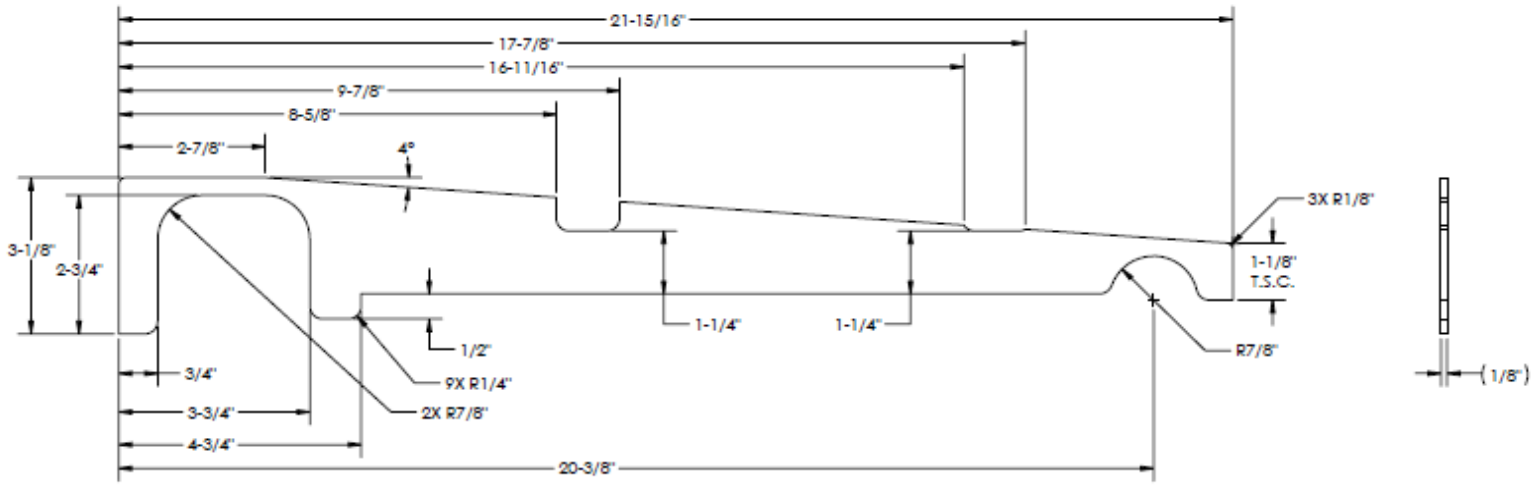
Washington University
1 Brookings Dr, St. Louis, MO 63130

CHECKED BY: BH	DATE: 06/23/16	DESC: GUARD TOP PLT	
WEIGHT: 1.890 LB		ITEM NO: 00004-002	REV: - DRAWN BY: TOM SCHUH
HEAT TREAT: N/A		MATERIAL: STE PLT 1/8 HR A36	DATE: 06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV.	DESCRIPTION	DATE	ITEM NO.
			00004-003
			SHEET NO. 1 OF 1
-	INITIAL RELEASE	06/22/2016	REV. -



NOTES:

1. ALL DIMS IN INCH

NEXT ASSY:
00004

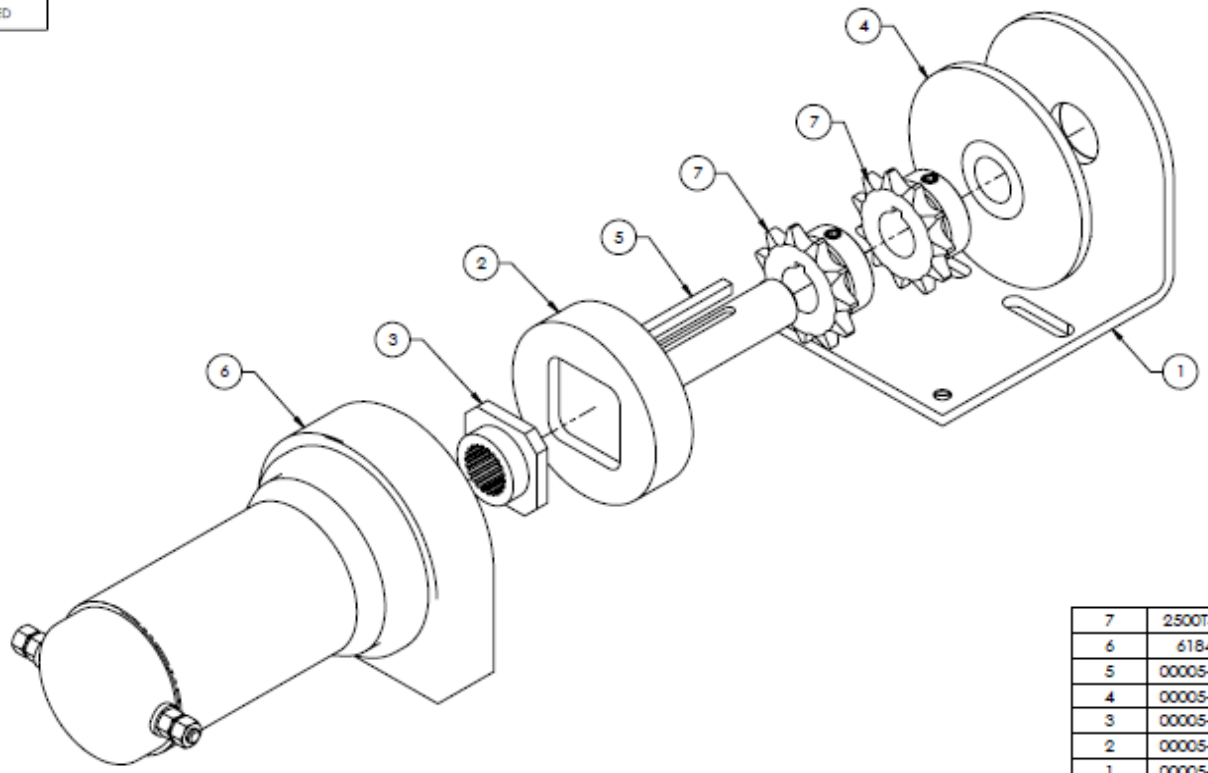
Washington University
1 Brookings Dr, St. Louis, MO 63130

CHECKED BY: BH	DATE: 06/23/16	DWG: GUARD LEFT SIDE PLT	
WEIGHT: 1.129 LB		ITEM NO: 00004-003	REV: - DRAWN BY: TOM SCHUH
HEAT TREAT: N/A		MATERIAL: STE PLT 1/8 HR A36	DATE: 06/22/2016

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV.	DESCRIPTION	DATE	ITEM NO.
			00005
			SHEET NO. 1 OF 1
-	INITIAL RELEASE	06/22/2016	REV. -



NOTES:

1. ALL DIMS IN INCH

ITEM NO.	PART NO.	DESCRIPTION	QTY.
7	2500T433	ANSI #40 11T ROLLER SPROCKET	2
6	61840	12VDC 2500LB WINCH	1
5	00005-005	WINCH DRIVE KEY	1
4	00005-004	WINCH DRIVE IDLER	1
3	00005-003	WINCH DRIVE ADAPTOR	1
2	00005-002	WINCH DRIVE SHAFT	1
1	00005-001	WINCH MOUNT PLATE	1

Washington University
1 Brookings Dr, St. Louis, MO 63130

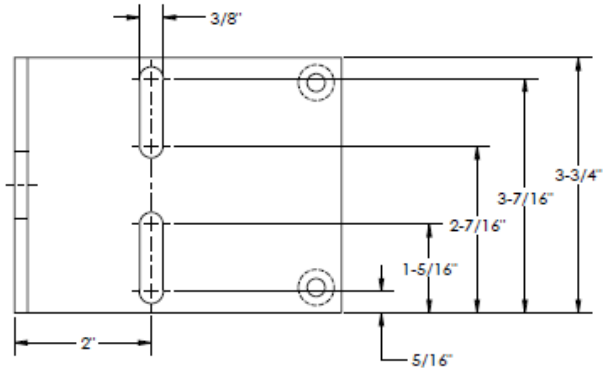
DWG: WINCH ASSEMBLY

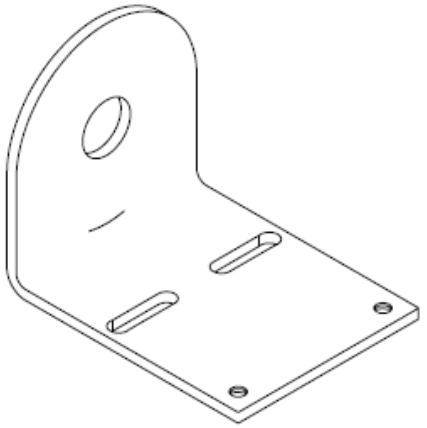
CHECKED BY: BH — DATE: 06/23/16
WEIGHT: 1.814 LB
ITEM NO.: 00005
REV.: -
DRAWN BY: TOM SCHUH
HEAT TREAT: N/A
MATERIAL: SEE BOM
DATE: 06/22/2016

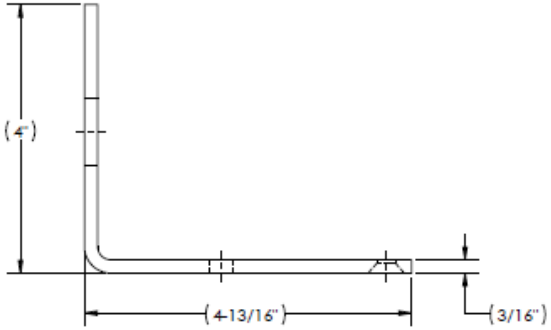
NEXT ASSY: 00001

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO:
			00005-001
-	INITIAL RELEASE	06/22/2016	SHEET NO: 1 OF 1 / REV: -



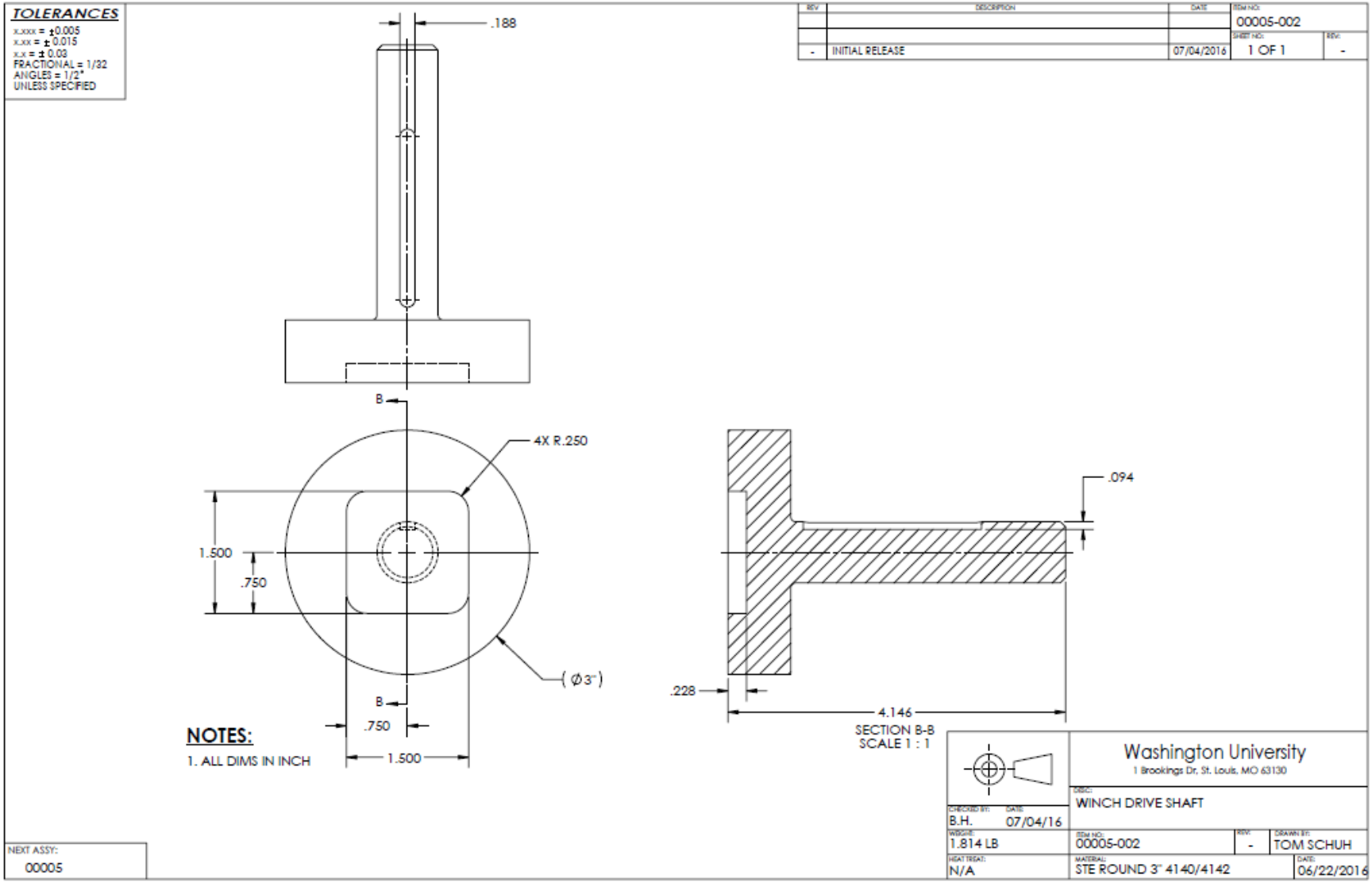




NOTES:
1. ALL DIMS IN INCH

NEXT ASSY: 00005

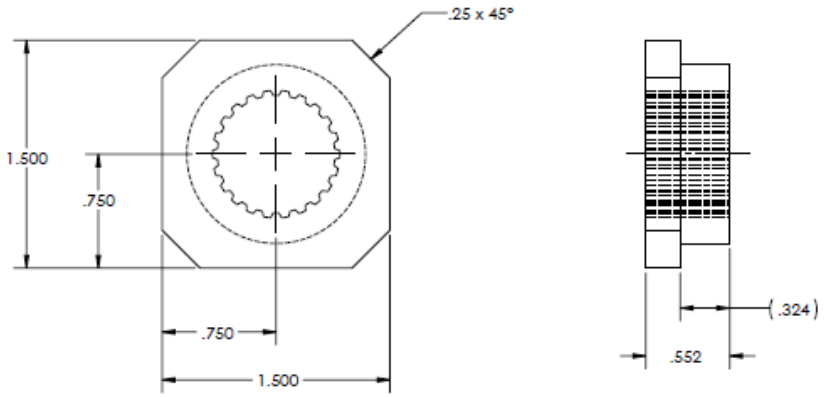
CHECKED BY: BH / DATE: 06/23/16	Washington University, 1 Brookings Dr, St. Louis, MO 63130		
	DESC: WINCH MOUNT PLATE		
WEIGHT: 92.53 LB	ITEM NO: 00005-001	REV: -	DRAWN BY: TOM SCHUH
HEAT TREAT: N/A	MATERIAL: 61840-17		DATE: 06/22/2016


TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED
REV
DESCRIPTION
DATE
ITEM NO:
00005-002
SHEET NO:
REV:
- INITIAL RELEASE 07/04/2016 1 OF 1 -
.188
B
4X R.250
1.500
.750
(Ø3")
B
.750
1.500
NOTES:
1. ALL DIMS IN INCH
.094
.228
4.146
SECTION B-B
SCALE 1 : 1
Washington University
1 Brookings Dr. St. Louis, MO 63130
DESC:
WINCH DRIVE SHAFT
CHECKED BY: B.H.
DATE: 07/04/16
WEIGHT: 1.814 LB
ITEM NO: 00005-002
REV: -
DRAWN BY: TOM SCHUH
HEAT TREAT: N/A
MATERIAL: STE ROUND 3" 4140/4142
DATE: 06/22/2016
NEXT ASSY:
00005

TOLERANCES

x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO: 00005-003
			SHEET NO: 1 OF 1 / REV: -
-	INITIAL RELEASE	07/04/2016	



NOTES:

1. ALL DIMS IN INCH

NEXT ASSY: 00005

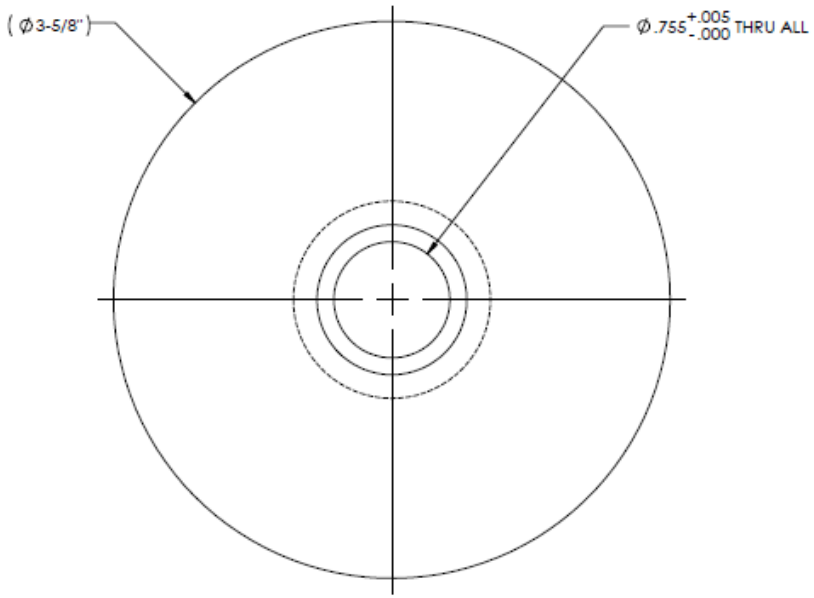
Washington University
1 Brookings Dr, St. Louis, MO 63130

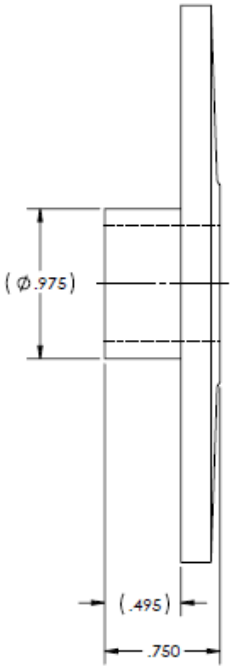
DESC: WINCH DRIVE ADAPTOR

CHECKED BY: B.H.	DATE: 07/05/16		
WEIGHT: 0.157 LB	ITEM NO: 00005-003	REV: -	DRAWN BY: TOM SCHUH
HEAT TREAT: N/A	MATERIAL: 61840-11		DATE: 06/22/2016

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO:
			00005-004
			SHEET NO: 1 OF 1
-	INITIAL RELEASE	07/04/2016	REV: -





NOTES:
1. ALL DIMS IN INCH

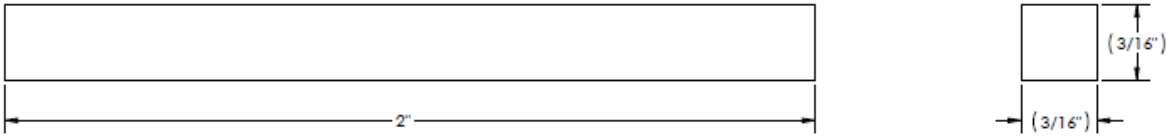
NEXT ASSY:
00005

Washington University
1 Brookings Dr. St. Louis, MO 63130

CHECKED BY: B.H. DATE: 07/05/16	DESC: WINCH DRIVE IDLER		
WEIGHT: 0.646 LB	ITEM NO: 00005-004	REV: -	DRAWN BY: TOM SCHUH
HEAT TREAT: N/A	MATERIAL: 61840-11		DATE: 06/22/2016

TOLERANCES
x.xxx = ±0.005
x.xx = ± 0.015
x.x = ± 0.03
FRACTIONAL = 1/32
ANGLES = 1/2°
UNLESS SPECIFIED

REV	DESCRIPTION	DATE	ITEM NO:
			00005-005
			SHEET NO: 1 OF 1 / REV: -
-	INITIAL RELEASE	06/22/2016	



NOTES:

1. ALL DIMS IN INCH

NEXT ASSY:
00005

Washington University
1 Brookings Dr. St. Louis, MO 63130

CHECKED BY: BH / DATE: 06/23/16	DESC: WINCH DRIVE KEY		
WEIGHT: 0.020 LB	ITEM NO: 00005-005	REV: -	DRAWN BY: TOM SCHUH
HEAT TREAT: N/A	MATERIAL: STE 3/16X3/16 KEYSTOCK		DATE: 06/22/2016

9.1.2 Sourcing Instructions

Refer to Appendix B, utilizing the columns labeled “SOURCE” and “VENDOR PART NO.” for sourcing information.

9.2 FINAL PRESENTATION

A video displaying our final presentation can be viewed at:

https://youtu.be/Fl0aaBQXjbI

9.3 TEARDOWN

TEARDOWN TASKS AGREEMENT

PROJECT: TRUNK LIFT ASSIST NAMES: KYLE COPELAND INSTRUCTOR: JAKIELA

BEN HOGAN

JON KREMS

TOM SCHUH

The following teardown/cleanup tasks will be performed:

NO NECESSARY TEARDOWN/CLEANUP REQUIRED

Instructor comments on completion of teardown/cleanup tasks:

Instructor signature: Mark J. Jakiela Print instructor name: JAKIELA

Date: 8/03/2016

10 APPENDIX A - PARTS LIST

Table 12 – Part No 00001 Final Parts List

25	90272A081	#2-56X1/2" MACHINE SCREW	4
24	2750017	SPDT LIMIT SWITCH	2
23	94579A500	5/16-18 WELD NUT	4
22	94239A105	5/16-18X1/2 FLNG HD CAP SCREW	3
21	92670A783	5/16-18X1 ELEVATOR BOLT	4
20	92316A591	5/16-18X2 FLNGE HD CAP SCREW	8
19	91259A630	5/16-18X2-1/4 SHOULDER BOLT	6
18	90949A025	5/16-18 FLANGED LOCKNUT	16
17	7265K324	ANSI #40H CONNECTING LINK	2
16	7265K304	ANSI #40H ROLLER CHAIN	2
15	5101T447	24"X36" HEAVY DUTY WIRE SHELF	1
14	3043T611	1/4-20 UBOLT FOR 9/16 OD	4
13	2500T433	ANSI #40 11T ROLLER SPROCKET	4
12	00005	WINCH ASSEMBLY	1
11	00004	CHAIN GUARD	1
10	00003	REAR BASE MOUNT	1
9	00002	FRONT BASE MOUNT	1
8	00001-017	STOP BLOCK	1
7	00001-016	DRIVESHAFT KEY	1
6	00001-012	OUTER PARALLEL LINK ANGLE	4
5	00001-009	MOUNTING TUBE	1
4	00001-007	LINK DRIVE SHAFT	1
3	00001-004	PLATFORM FRAME TUBE	2
2	00001-002	INNER PARALLEL LINK BAR	4
1	00001-001	FRAME BASE TUBE	2
ITEM NO.	PART NO.	DESCRIPTION	QTY

Table 13 - Part No 00002 Final Parts List

ITEM NO.	PART NO.	DESCRIPTION	QTY.
4	00002-003	FRONT BASE MNT BASE PLT	1
3	00002-002	FR MOUNT ANGLE	1
2	00002-001	FL MOUNT ANGLE	1
1	00001-008	FRONT/REAR BASE ANGLE	1

Table 14 - Part No 00003 Final Parts List

ITEM NO.	PART NO.	DESCRIPTION	QTY.
4	00003-003	MOTOR MOUNT PLATE	1
3	00003-002	RR MOUNT ANGLE	1
2	00003-001	LR MOUNT ANGLE	1
1	00001-008	FRONT/REAR BASE ANGLE	1

Table 15 - Part No 00004 Final Parts List

ITEM NO.	PART NO.	DESCRIPTION	QTY.
3	00004-003	GUARD LEFT SIDE PLT	1
2	00004-002	GUARD TOP PLT	1
1	00004-001	GUARD RIGHT SIDE PLT	1

Table 16 - Part No 00005 Final Parts List

ITEM NO.	PART NO.	DESCRIPTION	QTY.
7	2500T433	ANSI #40 11T ROLLER SPROCKET	2
6	61840	12VDC 2500LB WINCH	1
5	00005-005	WINCH DRIVE KEY	1
4	00005-004	WINCH DRIVE IDLER	1
3	00005-003	WINCH DRIVE ADAPTOR	1
2	00005-002	WINCH DRIVE SHAFT	1
1	00005-001	WINCH MOUNT PLATE	1

11 APPENDIX B - BILL OF MATERIALS

Table 17 - Final BOM with Sourcing Information

MATERIAL DESCRIPTION	SOURCE	VENDOR PART NO.	QTY.	PRICE/UNIT	EXTENDED PRICE
1.5"X1.5"X0.120" WALL STEEL TUBING	SPEEDYMETALS.COM	ts1.5x.120	114.5	$0.38	$43.51
1"X1"X0.125" STEEL ANGLE	SPEEDYMETALS.COM	ha.125x1	103.0	$0.17	$17.51
0.125" HOT ROLLED A36 PLATE	SPEEDYMETALS.COM	hf.125x8-48	9.2	$2.38	$21.90
0.25"X4" STEEL BAR	SPEEDYMETALS.COM	hf.25x4-24	23.5	$0.50	$11.75
.375"X7" STEEL BAR	SPEEDYMETALS.COM	hf.375x7-24	42.0	$1.30	$54.60
1" ROUND 4140/4142	SPEEDYMETALS.COM	42gr1-36	25.5	$1.14	$29.07
3" ROUND 1018	SPEEDYMETALS.COM	18r3	4.3	$4.37	$18.57
0.1875X0.1875 KEY STOCK	MCMASTER.COM	98535A140	3.5	$0.16	$0.56
ANSI #40 11T ROLLER SPROCKET	MCMASTER.COM	2500T433	4.0	$16.12	$64.48
1/4-20 UBOLT FOR 9/16 OD	MCMASTER.COM	3043T611	4.0	$0.47	$1.88
24"X36" HEAVY DUTY WIRE SHELF	MCMASTER.COM	5101T447	1.0	$47.15	$47.15
ANSI #40H ROLLER CHAIN	MCMASTER.COM	7265K304	2.0	$49.72	$99.44
ANSI #40H CONNECTING LINK	MCMASTER.COM	7265K324	2.0	$2.24	$4.48
5/16-18 FLANGED LOCKNUT	MCMASTER.COM	90949A025	16.0	$0.09	$1.44
5/16-18X2-1/4 SHOULDER BOLT	MCMASTER.COM	91259A630	6.0	$1.45	$8.70
5/16-18X2 FLNGE HD CAP SCREW	MCMASTER.COM	92316A591	8.0	$0.41	$3.28
5/16-18X1 ELEVATOR BOLT	MCMASTER.COM	92670A783	4.0	$0.36	$1.44
5/16-18X1/2 FLNG HD CAP SCREW	MCMASTER.COM	94239A105	3.0	$0.22	$0.66
5/16-18 WELD NUT	MCMASTER.COM	94579A500	4.0	$0.29	$1.16
SPDT LIMIT SWITCH	RADIO SHACK	2750017	2.0	$3.49	$6.98
#2-56X1/2" MACHINE SCREW	MCMASTER.COM	90272A081	4.0	$0.05	$0.20
12VDC 2500LB WINCH	HARBOR FREIGHT	61840	1.0	$49.99	$49.99
				TOTAL	$488.75

12 APPENDIX C – FINAL CAD MODELS

A complete set of Solidworks part, assembly and drawing files can be found as a link at the bottom of the open scholarship web page or at the following link:

https://drive.google.com/file/d/0B4u5693vUdhjaXpxMHNucVc2c00/view?usp=sharing

13 ANNOTATED BIBLIOGRAPHY

§ 571.401 Standard No. 401, National Highway Traffic Safety Administration, United States Government, 10/20/2000. Web. 29 June 2016. https://www.federalregister.gov/articles/2000/10/20/00-27038/federal-motor-vehicle-safety-standards-interior-trunk-release

This website provided many applications of codes and standards relevant to the automobile industry. The information gathered from this source informed the designers of potential problems that the design would encounter, and allowed the device to be modified to comply with safety regulations.

OSHA Regulation 1910.219, United States Department Of Labor, United States Government, 03/13/1990. Web. 29 June 2016. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9847

While this website provided information that did not necessarily pertain to our design, OSHA regulations provided the designers with a framework to fabricate a safe device. OSHA identified many of the safety concerns related to mechanical portions of the design. Integrating these safety precautions provided the consumer with a safer device.

Budynas, Richard G., and J. Keith Nisbett**,** ***Shigley's Mechanical Engineering Design 10th Edition***, McGraw-Hill Education, New York, 2015.

This publication proved indispensable in the design and analysis phase of this project. Information located in this text allowed the designers to properly analyze the components of the device. Equations from this book led to proper sizing of the many integrated parts to avert a catastrophic and dangerous failure.