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JME 4110 Final Design Report - Last Mile

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Joint Engineering Program

University of Missouri–St. Louis ▪ Washington University in St. Louis

ELEVATE YOUR FUTURE.
ELEVATE ST. LOUIS.

A simple solution to eliminate the need for package delivery drivers to leave their truck to deliver packages to their customers. This is accomplished with the use of a drop box (similar to a mailbox) large enough to safely and securely store packages up to 20 lbs. Combined with a Chute delivery system that extends out of the side of the delivery truck, the driver will no longer need to leave their truck for routine deliveries.

JME 4110 Design Report

The Last Mile

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1 INTRODUCTION

1.1 VALUE PROPOSITION / PROJECT SUGGESTION

The project will target any company that delivers packages to individual locations. These companies are most dissatisfied with the cost and difficulty of covering "the last mile". Our design is a package delivery system that allows a driver to securely deliver the package without leaving the truck. Ideally, the truck would not need to come to a complete stop. This system, when adopted, will change the way package delivery companies deal with last mile delivery and also delivery drivers will be more productive while enjoying a safer working environment. Not only delivery companies will witness an increase in productivity due to the adoption of this delivery system, they will also witness a reduction in injury due to the fact that the driver does not need to leave the delivery truck or his /her and expose to all sort of dangers such as dog biting, slippery surfaces and even thieves. Reducing time to deliver packages and reducing injuries to the drivers will increase profits and the amount of packages that can be delivered by companies.

1.2 LIST OF TEAM MEMBERS

Eric Jegel

Jason Krentz

Jornas Pierre

Jonathan Prewitt

2 BACKGROUND INFORMATION STUDY

2.1 DESIGN BRIEF

Our product will be used to retrofit a package delivery truck that will allow the driver to safely deliver a package at a specific location without leaving his driver seat or even without the need to come to a complete stop during the delivery of the package. The new product will allow delivery drivers to save time and also reduce gas consumption for idling time. Our product will satisfy retailers, delivery companies as well as customers because they will benefit from a quicker service. Therefore the new product is much better than any other system that is currently in use by any delivery company. We expect all delivery companies that are interested in reducing the cost of last mile package delivery to embrace our product because it is the best product that will allow them to save money.

2.2 BACKGROUND INFORMATION AND RELEVANT EXSISTING IDEAS

INN-BOX. THE LAST MILE DELIVERY PROBLEM SOLVED

The First product we will consider is the Inn-Box. The images below are extracted from an online video of a proposed design that will allow delivery companies to deliver packages in a safely manner without the fear of theft or vandalism.

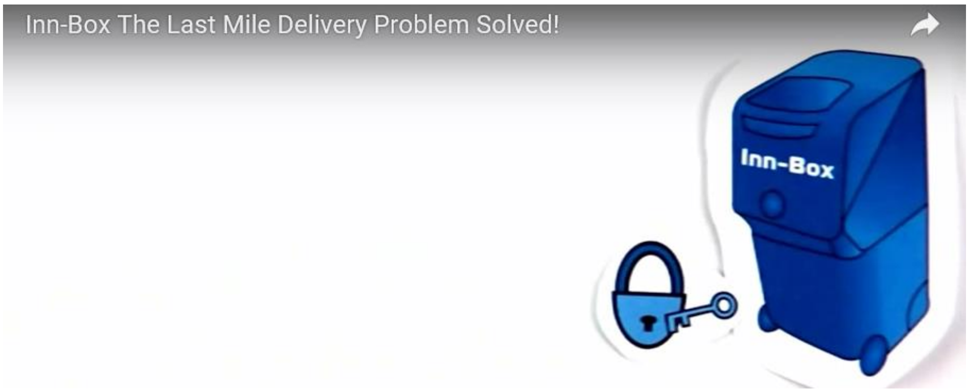

Figure 1: Depiction of the Inn-Box delivery box

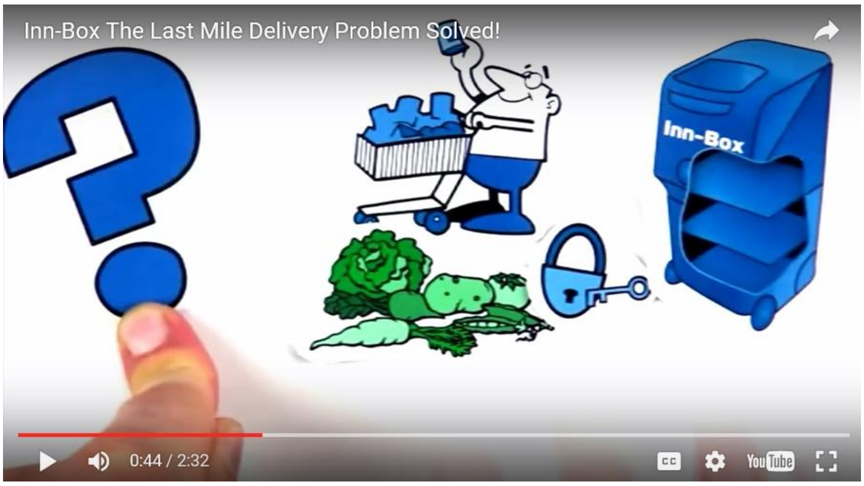

Figure 2: Consumer interacting with the Inn-Box system

Micro Distribution Center

E-Commerce Growth Brings Last Mile Headaches

During the second half of 2014, Clint Reiser worked on an extensive survey examining the Omni-channel commerce landscape. One of the key findings from that research was on the growth of e-commerce. According to our research, the lion's share of revenue is still driven by the store. Brick and mortar locations accounted for approximately 67% of all revenue for our survey respondents. However, when looking at revenue growth, our research tells us a different story. Over the last five years, survey respondents indicated revenue growth of 6% from the brick and mortar channel compared to 47% for e-commerce. Looking ahead, respondents forecasted flat growth for their brick and mortar channel compared to 40% growth for e-commerce. This is a pretty dramatic shift in the retail landscape. It shows that the convergence of channels will be more important as Omni-channel operations continue to evolve. It also poses a significant problem for retailers: how to deal with the last mile.

Figure 3: Several delivery trucks delivering packages

Last mile delivery is the final leg of the supply chain. It is the moment the customer finally receives their order. And it is generally the most expensive, least efficient, and most problematic part of the overall delivery process. In the US, last mile deliveries have their own unique set of challenges. Mostly they come down to cost issues, and a retailer's desire to control the final moment of the brand interaction. There are a few main categories for last mile deliveries. First, is parcel delivery. UPS, FedEx, and the Postal Service are the three main players in this area. These companies are delivering thousands and thousands of packages daily from retailers around the globe to customer's front doors and offices. The shipping rates have gone up recently, and these companies provide very little control over the last mile for retailers.

Figure 4: Amazon's grocery delivery system

Figure 5: Amazon's drone delivery concept

An alternative to typical parcel deliveries is in use by Amazon. To control the last mile, and to utilize its massive distribution centers, Amazon has rolled out its own private fleet of trucks to make deliveries. For Amazon, it creates more flexibility in delivery timeframes and reduces overall shipping costs (as Amazon is no longer paying UPS, FedEx, or the Postal Service for deliveries). This is not the first time Amazon has looked for creative ways to complete deliveries. As recently noted in Logistics Viewpoints, Amazon is one of a few companies testing drones for deliveries. The company has also experimented with bike messengers in New York City for small deliveries as well as delivery lockers for customers to pick up items at their convenience.

Another alternative to using the big parcel companies that has taken off is the use of crowdsourced delivery services. Deliv, for example, is a crowd sourced delivery option that stretches across multiple retail segments. This company uses a smartphone app to alert pre-qualified drivers of a pending delivery. The driver picks up the merchandise from the retailer and delivers it to the customer. Instacart is another example of crowdsourced delivery. Based in San Francisco, this company connects personal shoppers with customers to deliver local groceries. Both of these companies are proving that the crowdsourced model is growing. And all of these models show that while they may be expensive, they are doing a good job of satisfying the customer during the last mile.

Figure 6: Delivery men in India delivering packages on motor bikes

But outside of the US, it is another story. The growth of the e-commerce economy is great for retailers, and allows more people to shop for the goods they want, but it poses significant challenges to the last mile. The world's two most populated countries, which bring an awful lot of buying power, face significant challenges. In India, for example, Morgan Stanley estimates that Indian online sales will hit $100 billion a year by 2020, up from $3 billion in 2013. The difficult part is figuring out the infrastructure to make home deliveries viable. Trucks have a difficult time navigating the crowded streets and the postal service is notoriously slow. One new option in India is the use of couriers to deliver goods purchased from Flipkart, Snapdeal, and Amazon India. But, in order to actually deliver these products, couriers are turning to smaller modes of transportation. In many places, delivery trucks are simply too big to navigate. Instead, couriers are using motorcycles and scooters to carry giant backpacks filled with 100 pounds+ of merchandise. These drivers navigate narrow streets, potholes, and erratic drivers to deliver everything from soda to laser printers. Most people agree that without the use of couriers to deliver these goods, the e-commerce market as a whole would grind to a halt in India.

Figure 7: Chinese delivery man delivering a large load of packages on a motorbike

China faces its own set of challenges. The e-commerce market is growing exponentially in China and vast improvements have been made to establish more operations centers across the country. These improvements have made it possible for residents in rural China to shop online and receive orders in a timely fashion. But the last mile still remains an issue. One of the biggest roadblocks for Chinese retailers is the government policy banning freight vehicles and gas-fueled and electric tricycles in downtown areas. This poses a number of problems. First, delivery people can be detained, have their vehicles seized, and receive fines for violating regulations due to the pressure of making a delivery timeframe. Secondly, to combat the costs of tickets and seized vehicles, many companies are simply driving up their delivery costs. These costs can certainly be burdensome to the customer, but at the same time, they are necessary if they wish to receive their package. And third, if the last mile problem is not solved, and vehicles are seized or delivery personnel are detained, the packages may never be delivered. According to the operator of one such delivery service, “if the last mile problem is not solved, up to 1 million packages awaiting delivery could be stockpiled in cities around the country.” This shows just how serious the last mile problem, and the associated challenges are in China.

In conclusion, the global e-commerce market is growing. In fact, according to e-Marketer, global B2C e-commerce will reach $2.3 trillion by 2017. This explosive growth brings about new opportunities, new customers, and new challenges. One of the biggest challenges will be controlling the last mile. Logistics infrastructure, economic and political regulations, and competition have proven to be roadblocks for many companies. But as the market grows, the solutions will too.

3 CONCEPT DESIGN AND SPECIFICATION

3.1 USER NEEDS, METRICS, AND QUANTIFIED NEEDS EQUATIONS.

3.1.1 Record of the user needs interview

Table 1: User Needs interview for the last mile product

<table>
<tr><td colspan="4">Project/Product Name: Improved Package Delivery System (IPDS)</td></tr>
<tr><td colspan="2">Customer: Professor Mark J Jakiela

Address: Washington University
Willing to do follow up? Yes

Type of user: Companies that deliver packages at different locations</td><td colspan="2">Interviewer (s): Jornas Pierre, Jason Krentz, Jonathan Prewitt, Eric Jegel

Date: 06/10/2016

Currently uses: Front porch drop if owner is not home</td></tr>
<tr><td>Question</td><td>Customer Statement</td><td>Interpreted Need</td><td>Importance</td></tr>
<tr><td>How do you currently deliver packages?</td><td>Driver drop packages on the front porch

Packages are to be delivered at later date if owner is not home.</td><td>IPDS provides Secure place to leave package

IPDS allows Driver not to make a second delivery attempt</td><td>5

5</td></tr>
<tr><td>What do you like about the current delivery system?</td><td>Driver can deliver packages anytime during the day.

Driver can drop Packages on the front porch.</td><td>IPDS allows safe package delivery

IPDS prevent unsecure Packages delivery</td><td>5

3</td></tr>
<tr><td>What don’t you like about the current package delivery system?</td><td>Driver lift heavy packages to drop on front porch

Packages left unattended on porch.</td><td>IPDS prevent driver from lifting and carrying heavy packages.

IPDS prevent package theft.</td><td>5

5</td></tr>
</table>

	Driver can be attacked by dogs Increase in insurance liability due delivery related injuries.	IPDS can prevent dog biting. IPDS prevent driver from being injured	5 5
What kind of improvement would you suggest in the package delivery system to make it work better for everyone involved?	A secure Box big enough to receive multiple packages Retrofit delivery truck with a mechanism that allow truck docking with the secure box.	IPDS can hold multiple larger size packages. IPDS allows Packages from the truck to be dropped directly in the secure box.	5 4
What other improvement would you like to make?	Allows driver to remain seated while dropping package in the mailbox. Allow diver to drop fragile packages in the same mailbox. Packages do not get wet.	Driver remains seated during delivery Larger packages do not crush smaller ones. IPDS is environmentally friendly.	4 4 4
What would you say to managers of another companies who would want to continue to use the current package delivery system?	The current system is not efficient. The current system is time consuming. The current system make delivery expensive. The current is not sustainable.	IPDS is efficient IPDS help save delivery time. IPDS help save money in delivery. IPDS is affordable	5 5 5 5

3.1.2 List of identified metrics

Table 2: List of metrics for the last mile project

Metric Number	Associated Needs	Metric	Units	Min Value	Max Value
1	4,5,8,15	Length	inches	28	30
2	1,2, 3,4,5,8,15	Weight	pounds	15	20
3	1, 2,3,4,5,7,8,15	Volume	Inch cube	30,000	31,000
4	2,5,7,15,7	height	Inches	42	48
5	1,5,7,8,15	width	Inches	22	24
6	1,2,3,4,15	Number of sharp corners and point	Integer	12	18
7	10,8,15	The IPDS Sound level	dB	5	10
8	7,8,15	Number of user assemble parts	integer	2	5
9	11,3,7,8,	User assembly time	integer	2	5
10	9,15	Operates in wide range of outdoor temperatures	degree ^{o}F	-20	100
11	12,9	Number of year of service	integer	5	15
12	11,14,6	Cost	$	200	300
13	14,15,13,9,7,8	Reliable	Cycles	10,000	50,000
14	12,17	Save delivery time	Integer	3	5
15	12,16,17	IPDS saves delivery cost	%	5	10

3.1.3 Table/list of quantified needs equations

Table 3: List of needs for the last mile project

Need Number	Need	Importance
1	Improved Package Delivery System is at least 24 inches wide.	5
2	Improved Package Delivery System is at least 42 inches high.	5
3	Improved Package Delivery System door is at least 23” X 10”.	5
4	Improved Package Delivery System is at least 30 inches deep (length).	5
5	Improved Package Delivery System is at least 30,000 cubic inches.	4
6	Improved Package Delivery System needs no electrical power.	3
7	Improved Package Delivery System is easy to install	5
8	Improved Package Delivery System can be installed in any package delivery truck.	3
9	Improved Package Delivery System can be used in all weather conditions.	5
10	Improved Package Delivery System does not make noise.	4
11	Improved Package Delivery System is affordable.	3
12	Improved Package Delivery System is reliable.	5
13	Improved Package Delivery System is safe to use.	5
14	Improved Package Delivery System is easy to operate	5
15	Improved Package Delivery System mechanism can be transferred to another vehicle.	5
16	IPDS helps prevent delivery related injury to drivers	5
17	IPDS allows driver to deliver more packages in a period of time	5

3.2 CONCEPT DRAWINGS

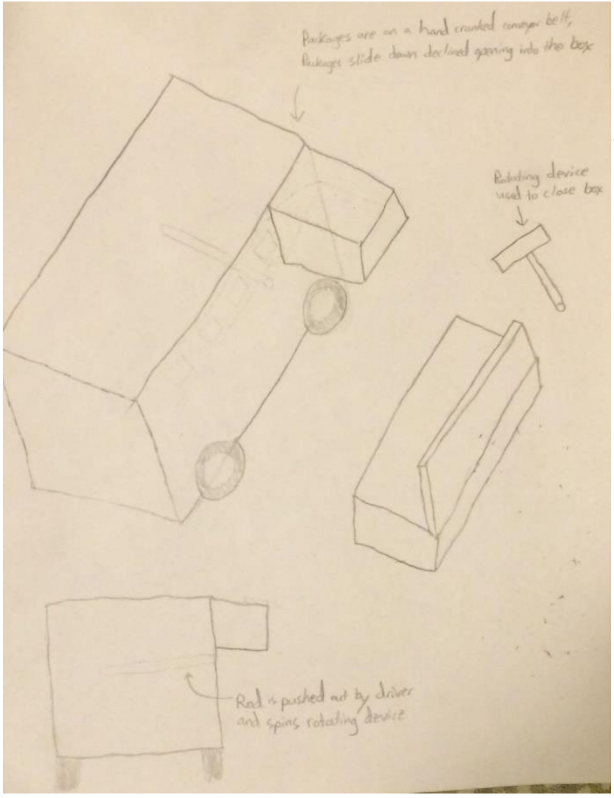

Figure 8: First design concept using a chute system

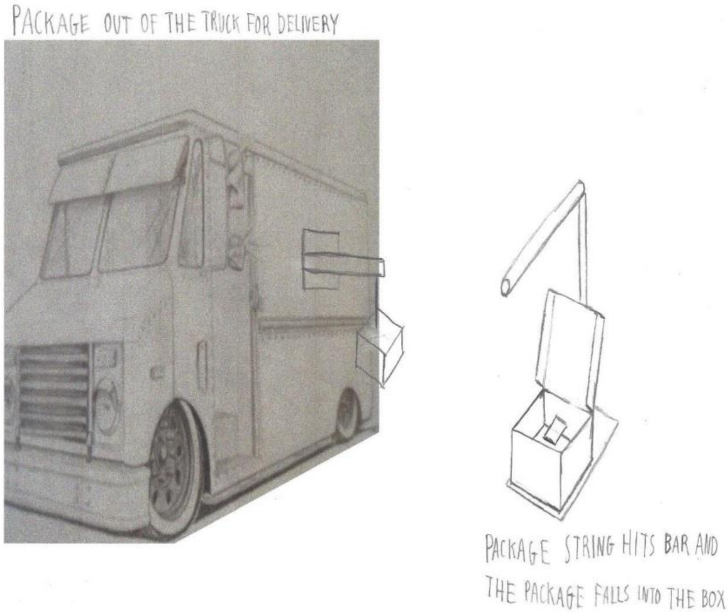

Figure 9: Second design concept using a rod

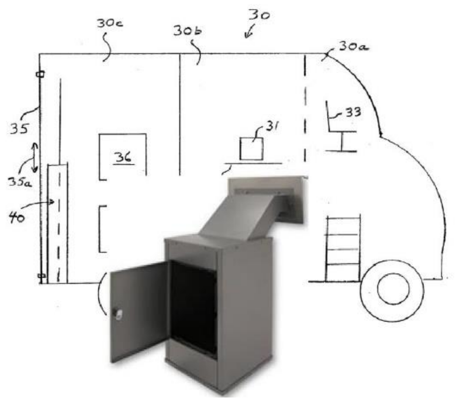

Figure 10: Third concept using a docking system

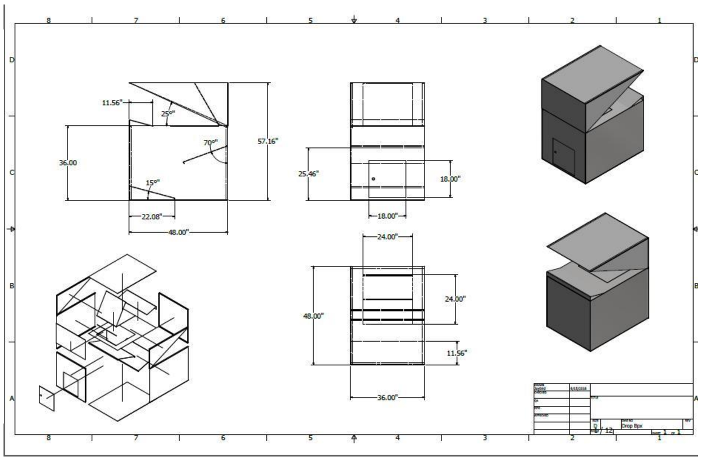

Figure 11: Fourth concept of the mailbox

3.3 CONCEPT SELECTION PROCESS.

3.3.1 Concept scoring

Table 4: Concept scoring of concept 1

Concept 1		Length	Heigth	Width	Weight	Volume	Number of Sharp Cornars & Points	The IPDS sound level	number of user assemble parts	user assmbly time	Temperature	Number of years of service	Cost	Reliability	Save delivery time	Prevent delivery related injury	Saves delivery cost	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
		Metric																		
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13						
1	The IPDS allows secure package delivery	0.1	0.1	0.1	0.05	0.2					0.05	0.1	0.1	0.1	0.1			0.87	0.1	0.087
2	The IPDS can hold larger packages	0.2	0.2	0.2	0.2	0.2												0.86	0.1	0.086
3	The IPDS is affordable											0.1	0.4	0.2	0.2		0.1	0.87	0.1	0.087
4	The IPDS is durable						0.1		0.2			0.5		0.2				0.96	0.1	0.096
5	The IPDS can be used in any environment					0.05	0.1			0.05	0.5	0.1		0.2				0.86	0.05	0.043
6	The IPDS is safe to operate						0.1							0.1		0.4	0.4	0.94	0.05	0.047
7	The IPDS is compatible to verious trucks							0.2	0.2	0.1				0.3	0.2			0.86	0.1	0.086
8	The IPDS needs no electrical power							0.2	0.2		0.1	0.2	0.1	0.2				0.94	0.05	0.047
9	The IPDS does not make noise during operation							0.6					0.2	0.2				0.96	0.1	0.096
10	The IPDS is easy to install	0.1	0.1	0.1	0.05	0.1	0.05			0.4			0.1					0.94	0.05	0.047
11	The IPDS allow driver to remain in seat					0.5								0.1	0.4			0.82	0.05	0.041
12	The IPDS help driver save time													0.1	0.5	0.1	0.3	0.75	0.1	0.075
13	The IPDS needs no parts removal								0.5	0.2			0.1		0.2			0.92	0.05	0.046
Units		in	in	in	lbs	in^3	integer	dB	Integer	min	degrees	integer	$	integer	min	%	%	Total Happiness		0.884
Best Value		30	48	20	20	31,000	12	5	5	50	80	3	300	50,000	5	70	50			
Worst Value		22	40	10	12	29,000	18	10	10	80	-25	2	500	8000	1	25	20			
Actual Value		30	40	40	25	31,000	12	5	5	50	100	3	300	40000	3	70	45			
Normalized Metric Happiness		1	1	0.5	0.8	1	1	1	1	1	0.8	1	1	0.8	0.6	1	0.9			

Table 5: Concept scoring of concept 2

Concept 2		Length	Heigth	Width	Weight	Volume	Number of Sharp Cornars & Points	The IPDS sound level	number of user assemble parts	user assmbly time	Temperature	Number of years of service	Cost	Reliability	Save delivery time	Prevent delivery related injury	Saves delivery cost	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
		Metric																		
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13						
1	The IPDS allows secure package delivery	0.1	0.1	0.1	0.05	0.2					0.05	0.1	0.1	0.1	0.1			0.93	0.1	0.093
2	The IPDS can hold larger packages	0.2	0.2	0.2	0.2	0.2												1	0.1	0.1
3	The IPDS is affordable											0.1	0.4	0.2	0.2		0.1	0.83	0.1	0.083
4	The IPDS is durable						0.1		0.2			0.5		0.2				0.926	0.1	0.0926
5	The IPDS can be used in any environment					0.05	0.1			0.05	0.5	0.1		0.2				0.86	0.05	0.043
6	The IPDS is safe to operate						0.1							0.1		0.4	0.4	0.94	0.05	0.047
7	The IPDS is compatible to verious trucks							0.2	0.2	0.1				0.3	0.2			0.866	0.1	0.0866
8	The IPDS needs no electrical power							0.2	0.2		0.1	0.2	0.1	0.2				0.886	0.05	0.0443
9	The IPDS does not make noise during operation							0.6					0.2	0.2				0.92	0.1	0.092
10	The IPDS is easy to install	0.1	0.1	0.1	0.05	0.1	0.05			0.4			0.1					0.98	0.05	0.049
11	The IPDS allow driver to remain in seat					0.5								0.1	0.4			0.9	0.05	0.045
12	The IPDS help driver save time													0.1	0.5	0.1	0.3	0.85	0.1	0.085
13	The IPDS needs no parts removal								0.5	0.2			0.1		0.2			0.855	0.05	0.04275
Units		in	in	in	lbs	in^3	integer	dB	Integer	min	degrees	integer	$	integer	min	%	%	Total Happiness		0.90325
Best Value		30	48	20	20	31,000	12	5	5	50	80	3	300	50,000	5	70	50			
Worst Value		22	40	10	12	29,000	18	10	10	80	-25	2	500	8000	1	25	20			
Actual Value		30	48	24	20	31,000	12	5	6	50	100	3	400	40000	4	70	45			
Normalized Metric Happiness		1	1	1	1	1	1	1	0.83	1	0.8	1	0.8	0.8	0.8	1	0.9			

Table 6: Concept scoring of concept 3

Concept 3		Length	Heigth	Width	Weight	Volume	Number of Sharp Cornars & Points	The IPDS sound level	number of user assemble parts	user assmbly time	Temperature	Number of years of service	Cost	Reliability	Save delivery time	Prevent delivery related injury	Saves delivery cost	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
		Metric																		
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13						
1	The IPDS allows secure package delivery	0.1	0.1	0.1	0.05	0.2					0.05	0.1	0.1	0.1	0.1			0.9187	0.1	0.09187
2	The IPDS can hold larger packages	0.2	0.2	0.2	0.2	0.2												0.946	0.1	0.0946
3	The IPDS is affordable											0.1	0.4	0.2	0.2		0.1	0.8528	0.1	0.08528
4	The IPDS is durable						0.1		0.2			0.5		0.2				0.901	0.1	0.0901
5	The IPDS can be used in any environment					0.05	0.1			0.05	0.5	0.1		0.2				0.82345	0.05	0.041173
6	The IPDS is safe to operate						0.1							0.1		0.4	0.4	0.8006	0.05	0.04003
7	The IPDS is compatible to various trucks							0.2	0.2	0.1				0.3	0.2			0.8429	0.1	0.08429
8	The IPDS needs no electrical power							0.2	0.2		0.1	0.2	0.1	0.2				0.8917	0.05	0.044585
9	The IPDS does not make noise during operation							0.6					0.2	0.2				0.9314	0.1	0.09314
10	The IPDS is easy to install	0.1	0.1	0.1	0.05	0.1	0.05			0.4			0.1					0.8638	0.05	0.04319
11	The IPDS allow driver to remain in seat					0.5								0.1	0.4			0.9	0.05	0.045
12	The IPDS help driver save time													0.1	0.5	0.1	0.3	0.8214	0.1	0.08214
13	The IPDS needs no parts removal								0.5	0.2			0.1		0.2			0.8145	0.05	0.040725
Units		in	in	in	lbs	in^3	integer	dB	Integer	min	degrees	integer	$	integer	min	%	%	Total Happiness		0.876123
Best Value		30	48	20	20	31,000	12	5	5	50	80	3	300	50,000	5	70	50			
Worst Value		22	40	10	12	29,000	18	10	10	80	-25	2	500	8000	1	25	20			
Actual Value		28	48	20	25	31,000	16	5	6	65	100	3	350	40000	4	50	45			
Normalized Metric Happiness		0.93	1	1	0.8	1	0.75	1	0.83	0.769	0.8	1	0.857	0.8	0.8	0.714	0.9			

Table 7: Concept scoring of concept 4

Concept 4		Metric																		
		Length	Heigth	Width	Weight	Volume	Number of Sharp Cornars & Points	The IPDS sound level	number of user assemble parts	user assmbly time	Temperature	Number of years of service	Cost	Reliability	Save delivery time	Prevent delivery related injury	Saves delivery cost	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	The IPDS allows secure package delivery	0.1	0.1	0.1	0.05	0.2					0.05	0.1	0.1	0.1	0.1			0.885	0.1	0.0885
2	The IPDS can hold larger packages	0.2	0.2	0.2	0.2	0.2												0.92	0.1	0.092
3	The IPDS is affordable											0.1	0.4	0.2	0.2		0.1	0.77	0.1	0.077
4	The IPDS is durable						0.1		0.2			0.5		0.2				0.927	0.1	0.0927
5	The IPDS can be used in any environment					0.05	0.1			0.05	0.5	0.1		0.2				0.827	0.05	0.04135
6	The IPDS is safe to operate						0.1							0.1		0.4	0.4	0.827	0.05	0.04135
7	The IPDS is compatible to verious trucks							0.2	0.2	0.1				0.3	0.2			0.86	0.1	0.086
8	The IPDS needs no electrical power							0.2	0.2		0.1	0.2	0.1	0.2				0.915	0.05	0.04575
9	The IPDS does not make noise during operation							0.6					0.2	0.2				0.91	0.1	0.091
10	The IPDS is easy to install	0.1	0.1	0.1	0.05	0.1	0.05			0.4			0.1					0.9385	0.05	0.046925
11	The IPDS allow driver to remain in seat					0.5								0.1	0.4			0.82	0.05	0.041
12	The IPDS help driver save time													0.1	0.5	0.1	0.3	0.73	0.1	0.073
13	The IPDS needs no parts removal								0.5	0.2			0.1		0.2			0.895	0.05	0.04475
Units		in	in	in	lbs	in^3	integer	dB	Integer	min	degrees	integer	$	integer	min	%	%	Total Happiness		0.861325
Best Value		30	48	20	20	31,000	12	5	5	50	80	3	300	50,000	5	70	50			
Worst Value		22	40	10	12	29,000	18	10	10	80	-25	2	500	8000	1	25	20			
Actual Value		30	40	20	30	31,000	14	5	5	50	100	3	350	40000	3	60	45			
Normalized Metric Happiness		1	1	1	0.6	1	0.67	1	1	1	0.8	1	0.75	0.8	0.6	0.8	0.9			

3.3.2 Preliminary analysis of each concept's physical feasibility

Concept 1's main equipment modifications include a pole that can be retracted and extended that goes through the body of the truck, a cushioned box rooted to the ground that locks once lid is closed, a spindle that when pushed by the pole spins and contacts the back of the lid which forces it to fall down and close. There is also a hand cranked conveyor belt inside the truck to move packages toward a declined opening in the truck, and this decline opening can be pulled back inside of the truck by some sort of pulley system operated by the driver if needed.

Concept 2 involves a rod that picks up the packages which are attached to strings, this rod then moves alongside another rod that is attached to the box used to hold the packages. This box has a pressure plate attached to the rod so that when the packages are on the rod the lid will fall down and lock

.

The Concept 3 involves a cart on top of a spindle being loaded inside the truck with packages and when spun packages fall out of it toward the box that has a configuration such that when one package enters and falls towards the bottom of the box a lid falls on top of the package and locks into place. The box has a door on the back so that the owner can retrieve the packages.

The Concept 4 involves a package being delivered to a box that has a lid that is about 2 feet above it, and a door is on the back of the box that the owner can use to retrieve the packages.

3.3.3 Final summary statement

The order of most to least precision necessary to deliver the packages from the truck to the box goes concept 2, concept 4, concept 3, and concept 1. The least to most moving parts goes concept 4, concept 2, concept 3, and then concept 1. The most difficult part of concept 1 is having a long pole in the body of the truck that is able to extend far enough to push the spindle next to the box. There needs to be a way to fix a long enough pole inside and ready to use, to be able to extend multiple distances. The difficulty with concept 3 is designing the box to support and securely hold multiple packages, and being able to accurately transport packages from the cart to the box without needing human input. For concept 3, loading multiple packages at the same time might cause damage to a package and the box itself if the box starts to close its lid onto a second or third package in the transport. The difficulty with concept 2 is the rod that holds the packages initially will need to go in between each string of packages being delivered, and this rod will need to be pushed out. Concept 2 will need an extreme amount of accuracy to get to two rods to line up, and releasing the packages from rod 1 to rod 2 seems to be difficult.

3.4 PROPOSED PERFORMANCE MEASURES FOR THE DESIGN

Once a concept was selected we were able to specify what parts and functions are needed for the design. We were able to focus on specifics such as how long will the pole be in the truck and how we can allow this pole to have degrees of rotation just in case the truck and spindle are not aligned correctly.

The need that is the overall performance measure is speeding up delivery time. This need was the goal that was set at the beginning of the project. This need is met for this design as it allows the driver to send packages on a conveyor through a decline opening in the truck and allows gravity and physics to send the packages toward the box. The driver can then take his hand off moving the conveyor and hold and push the pole to hit the spindle to close the box.

This process can be done while stationary or moving and will make the whole delivery process quicker and easier. This process makes things easier for the driver also because it requires less physical energy per delivery. In a normal delivery, a driver will get up out of his/her seat, walk to find the package on the shelf, and then walk out of the truck towards the porch of the house to deliver the box, and then walk back to the truck. For this concept the driver only has to rotate a crank to move along packages that are pre-sorted and push a pole toward the spindle by the box to close the box.

3.5 REVISION OF SPECIFICATIONS AFTER CONCEPT SELECTION

Table 8: Revised metrics for the chosen concept

Metric Number	Associated Needs	Metric	Units	Min Value	Max Value
1	4,5,8,15	Length	inches	28	30
2	1,2, 3,4,5,8,15	Weight	pounds	15	20
3	1, 2,3,4,5,7,8,15	Volume	Inch cube	30,000	31,000
4	2,5,7,15,7	height	Inches	42	48
5	1,5,7,8,15	width	Inches	22	24
6	1,2,3,4,15	Number of sharp corners and point	Integer	12	18
7	10,8,15	The IPDS Sound level	dB	5	10
8	7,8,15	Number of user assemble parts	integer	2	5
9	11,3,7,8,	User assembly time	integer	2	5
10	9,15	Operates in wide range of outdoor temperatures	degree °F	-20	100
11	12,9	Number of years of Service	integer	5	15
12	11,14,6	Cost	$	200	300
13	14,15,13,9,7,8	Reliable	Cycles	10,000	50,000
14	12,17	Save delivery time	Integer	3	5
15	12,16,17	IPDS saves delivery cost	%	5	10
16	1,8,12,13,14	IPDS Pole Length	Feet	3	8
17	2,4	Distance to spindle	In	6	12
18	7,8,12,14	IPDS Pole rotation	degrees	5	30

4 EMBODIMENT AND FABRICATION PLAN

4.1 EMBODIMENT/ASSEMBLY DRAWING

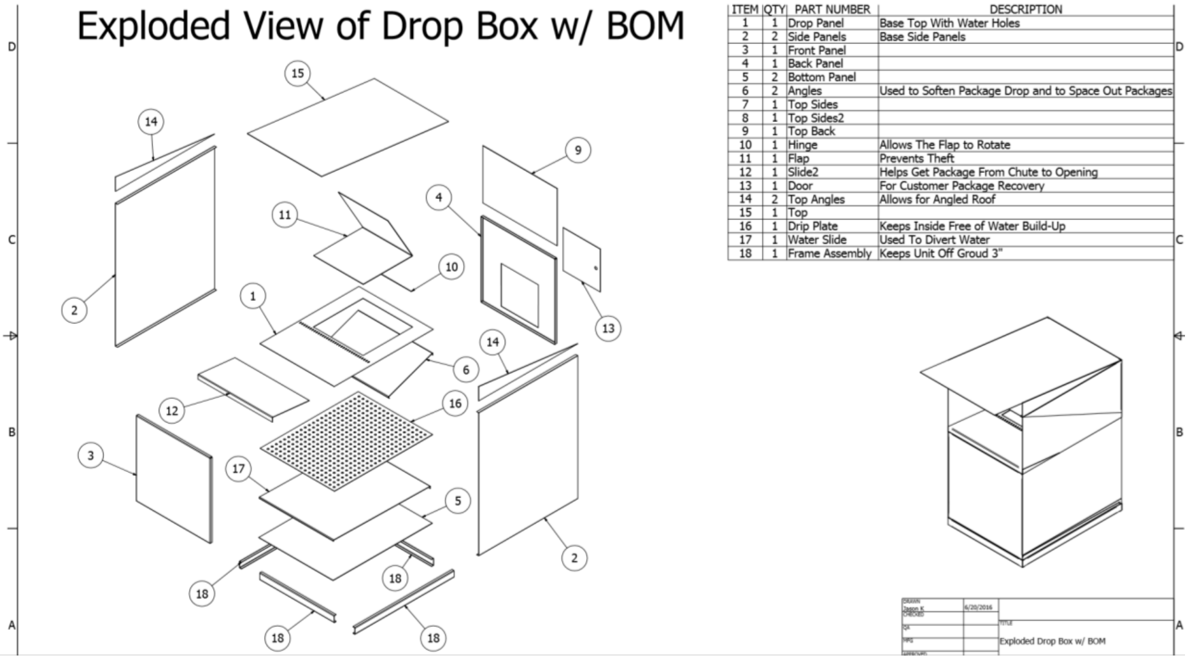

Figure 12: Exploded view of the mailbox concept

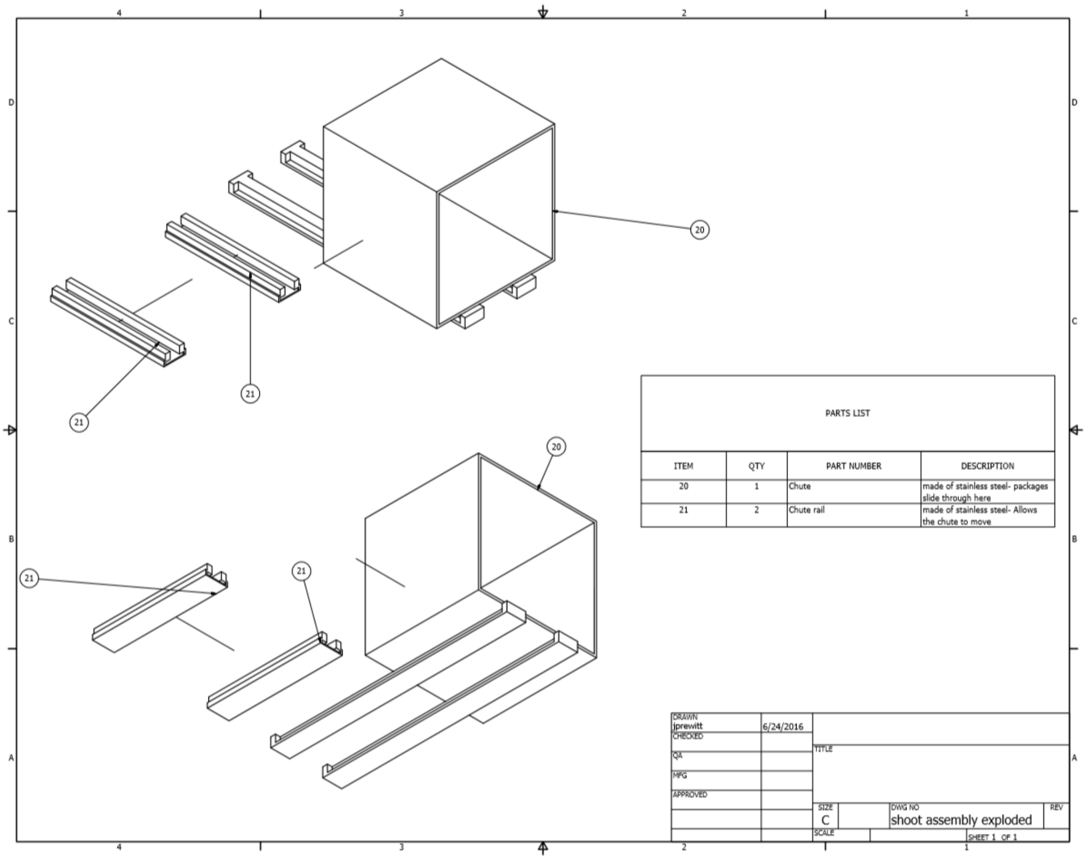

Figure 13: Exploded view of the chute concept

4.2 PARTS LIST

Table 9: Parts list for the original design concept

PART NUMBER	ITEM	QTY	Description	Material	Purchasing Location	Catalog Number	Price
1	Drop Panel	1	Base Top With Water Holes	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
2	Side Panel	2	Base Side Panels	Stainless Steel Sheet	McMaster Carr	9784K83	108.06
3	Front Panel	1	Base Front Panels	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
4	Back Panel	1	Base Back Panels	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
5	Bottom panel	2	Base Panel	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
6	Angles	2	Used to Soften Package Drop and to Space Out Packages	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
7	Top Side	1		Stainless Steel Sheet	McMaster Carr	9718K25	9.97
8	Top Side 2	1		Stainless Steel Sheet	McMaster Carr	9718K25	9.97
9	Top Back	1	Back plate covering paackage door	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
10	Hinge	1		Steel	McMaster Carr	1494A11	4.87
11	Flap	1	Prevents Theft	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
12	Slide 2	1	Helps Get Package From Chute to Opening	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
13	Door	1	For Customer Package Recovery	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
14	Top Angle	2	Allows for Angled Roof	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
15	Top	1	Roof for weather proofing	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
16	Drip Plate	1	Keeps Inside Free of Water Build-Up	Flat Steel	McMaster Carr	9302T628	50.28
17	Water Slide	1	Used To Divert Water	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
18	Frame Assembly	1	Keeps Unit Off Groud 3"	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
19	Lock	1	Prevents Theft	Padlock	McMaster Carr	1189A41	2.71
20	Chute Panels	4	Delivers Package to bo	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
21	Chute Slide	2	Extends chute out of truck	Steel	Home Depot	202200646	15.48
22	Bolts	50	Used for assembly	Steel	McMaster Carr	91280A978	8.39
23	Nuts	100	Used for assembly	Steel	McMaster Carr	90592A022	4.51
24	Brackets	24	Used for assembly	Zinc-Plated Steel	McMaster Carr	1556A24	10.32

4.3 DRAFT DETAIL DRAWINGS FOR EACH MANUFACTURED PART

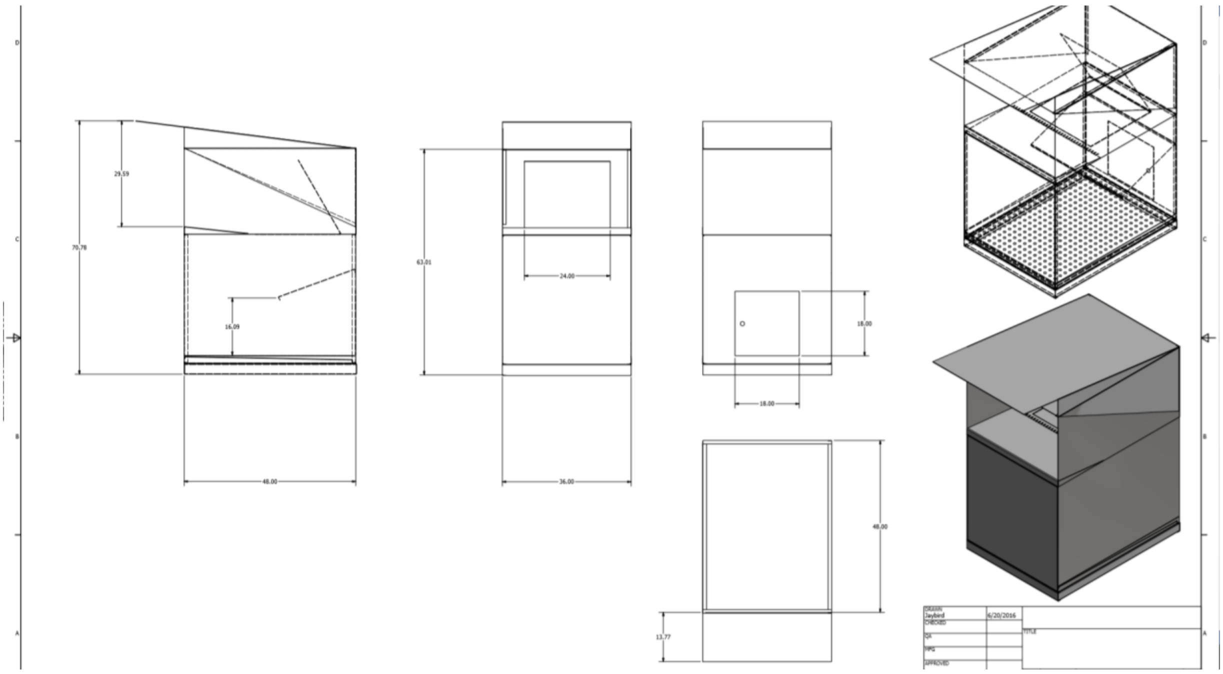

Figure 14: Dimensioned drawing of the mailbox concept

4.4 DESCRIPTION OF THE DESIGN RATIONALE FOR THE CHOICE/SIZE/SHAPE OF EACH PART

The analysis on the dimensions and the material for the mailbox and chute design were based off the assumption of the box being outside and not holding any extra weight from the package. The package will be held at the bottom of the mailbox, therefore the weight of the package will be supported by the ground beneath the mailbox. This allows the box to be made out of thin sheet metal since it only has to support its own weight. Since the mailbox will be outside the home, it will be at the mercy of the elements around it. Corrosive resistant 304 stainless steel sheet metal was chosen to keep the mailbox from succumbing to the elements. When the package is being delivered to the mailbox. The delivery chute and the mailbox will support each other as the package slides through the delivery chute. The chute size was made to hold standard packages with a small amount of wiggle room. The mailbox was made larger to accommodate multiple packages and to decrease to precision needed to deliver the packages. The mailbox will be constructed using L-brackets because welding was not an option and adds extra strength to the sheet metal panels. The drip panel uses flattened steel mesh because raised steel mesh could cause damage to the package and perforated steel was out of the range for the budget of the design. The slides chosen for the delivery chute will be mounted on the side of the chute. The particular slides were chosen because they can withstand a load of 100 pounds, which exceeds the weight of a standard package. A padlock was chosen to fit the budget and provide the necessary protection for the package. A padlock also allows the consumer to upgrade the protection on their mailbox if they decide on stiffer protection.

5 ENGINEERING ANALYSIS

5.1 ENGINEERING ANALYSIS PROPOSAL

5.1.1 Signed engineering analysis contract

ANALYSIS TASKS AGREEMENT

PROJECT: Package Drop _NAMES: Jornas Pierre JP INSTRUCTOR: Mark Jakiela
Jason Krentz JCK
Jonathan Prewitt JP
Eric Jegel EJ

The following engineering analysis tasks will be performed:

- Design–Configurations
  Selection of design methodology, materials and fabrication methods Assembly.
- Manufacturing–Tools and machine tools Fabrication processes Quality control and assurance
- Unexpected cases with potential grave consequences –
  Change of requirements
  Malfunctioning of machines and equipment Defections in products

Identification of the physical problem –specification of the problem:

- Intended application
- Possible geometry and size (dimensions)
- Materials for all components
- Loading: range in normal and overloading; nature of loading
- Other constraints and conditions, e.g., space, cost, government regulations

Idealization of actual physical situations for subsequent mathematical analysis:

- On geometry
- On loading condition:
- On boundary conditions

Mathematical modeling and analysis:

- In the case of the package chute, the solution require is:

"Will the assumed geometry and size of the chute withstand the specified maximum weight of the package?"

- The required solution is to keep the maximum stress in package chute induced by the expected maximum load BELOW the allowable limit of the chute material
- Use formulas to compute the maximum stress in the chute

Interpretation of results such as:

- Maximum stress
- Factor of safety
- Potential consequences of the product
- Weight limit of packages

Problem to solve:

- Design ambiguity
- Manufacturing in disorder
- Malfunction of equipment
- Inferior quality in production
- Run-away cost control
- Public grievances and mistrust

The work will be divided among the group members in the following way:
Jornas Pierre and Jason Krentz will work on the Package box drop design modification and fabrication of the markup unit. Jason will work on getting all the print for the box ready. And also the final dimension of each component and possible vendor to allow us to purchase materials. Jornas will compile all the documents and make sure the design analysis is complete.
Jonathan Prewit and Eric Jegel will work on getting the Chute design finalized and fabricate the markup. Also modify the cart that will be used as the truck. To install the chute. Jonathan will complete all drawings for the chute as well as possible vendor. Eric will complete the design analysis for the Chute.
It is also understood that all members of the group will work in a collaborative manner to accomplish the work on time.

Instructor signature: ; Print instructor name: Mark Jakiela

(Group members should initial near their name above.)

5.2 ENGINEERING ANALYSIS RESULTS

5.2.1 Motivation

The force to pull the chute into the truck and the beam analysis of the chute support while the chute is extended are the most important pieces of analysis for the design. The support beams need to be strong enough to support the load of the package and the chute while it is fully extended. The force to pull the chute is necessary to design a device that can pull the chute with enough force to raise it into storage position. These two functions are at the core of the working design. If the supports or the retraction fail, the design is an outright failure. Therefore these pieces of analysis are critical to the design.

5.2.2 Summary statement of analysis done

The support beams and chute were modeled and analyzed as a cantilever beam supported by a two point support load. The equilibrium equations and force diagram are shown below.

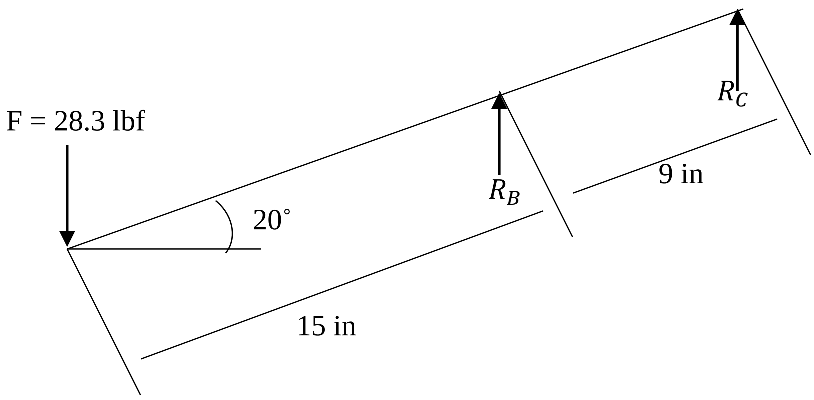

Figure 15: Diagram of the forces and reactions on the slides

$$\sum M_C = 0 = 1.25ft\cos 20^\circ (F) - 0.75ft\cos 20^\circ (R_B)$$

$$R_B = \frac{1.175\ ft(F)}{0.705\ ft}$$

$$\sum F_y = 0 = F + R_B + R_C$$

From these equations the forces and moments were calculated. Then force and bending moment diagrams were created.

The force to pull the chute up into storage position was modeled as a mass on a slope. Equilibrium equations were used to balance the forces and find the resultant force to pull the chute up the slide.

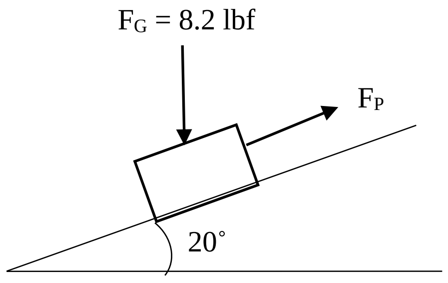

Figure 16: Force diagram of the chute being retracted

$$\sum F_y = 0 = F_G + F_{Py}$$

$$F_P \sin 20 = F_G$$

5.2.3 Methodology

In order to finish the analysis, the weight of the chute must be known. Once the chute was constructed, the weight of the chute was used in both calculations. No further experimentation was needed. The computations were carried out using the equations shown in section 5.2.2

5.2.4 Results

From the equilibrium equations in section 5.2.2 for the beam analysis the reaction forces were found. The reaction at point B was 47.17 pounds upwards, the reaction at point C was 18.87 pounds downwards. From these forces the force and moment diagrams were calculated and shown below.

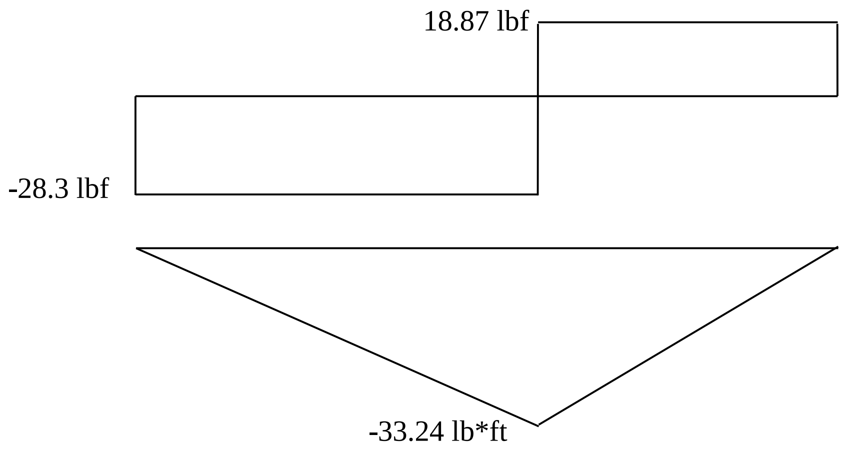

Figure 17: Shear force and bending moment diagrams for the beam analysis

The force required to pull the chute into storage position was calculated using the formula in section 5.2.2. The resulting force was 23.98 pounds.

The results from the beam analysis make sense comparing to the force of the package and chute. The force needed to pull the chute makes sense with the force being mostly in the horizontal direction. Therefore it would need more force top overcome gravity.

5.2.5 Significance

From the forces and moments applied to the support structure, wood was chosen as the material for the supports of the chute system. The force to pull the chute up the slide is small enough that a simple lever can be used to bring the chute back into its storage position. No major modifications to the design were necessary due to the analysis conducted.

6 RISK ASSESSMENT

Figure 18: Flow diagram of the risk assessment model

6.1 RISK IDENTIFICATION

Risk Include

- Correct chute angle in relation to the drop box
- Finding chute material that allows the package to slide without much friction
- Providing strong supports for the chute and slides to attach to
- Finding a slide strong enough to handle when the chute falls 1 foot at an angle of 20 degree.

- Having the chute lever actuator work every time without getting stuck or malfunctioning
- The chute being able to support a conservative load relative to the material
- The drop box being able to stay stable after the load falls into it.

6.2 RISK ANALYSIS

The chute angle and the box openings' angle should be the same. If the chutes angle was lower than 20 degrees, then the package would have a more difficult time sliding down the chute. If the chute angle was higher than the box's angle, then the package could miss the box completely. The chute's panels need to have the least amount of friction possible so that the package can slide easier. Masonite panels were chosen because of it's low friction, strength, and low cost.

The chute was stabilized by using four 1*4's of wood and four wood dowels. Drawer slides that can hold 100 pounds were used to support and move the chute. The lever which utilizes a rope, pulley, l-bracket, and a hook worked consistency. The lever is able to extend and retract the chute by 1 foot. The chute is able to support at least 20 pounds which is an average weight for packages. The slides are not subjected to much force by the packages, because the packages are sliding quickly through the chute so the full load is never resting completely on the chute. The package is going to hit

6.3 RISK PRIORITIZATION

The risk prioritization process included 3 main risks. The first risk is being able to get a package from the chute to the drop box without ever missing. The next risk is having a strong enough chute to handle a load of around 20 pounds. The last main risk is having a strong enough box to stay stable after the package transitions through the air to inside the box. The risk are higher the closer the package is to the beginning of the process. This is the appropriate prioritization because before a next step can be taken, the previous step must be achieved.

7 CODES AND STANDARDS

7.1 IDENTIFICATION

1. Codes and standards of mailboxes relates to the drop box. Generally, mailboxes are installed at a height of 41 - 45 in. from the road surface to inside floor of the mailbox or point of mail entry and are set back 6 - 8 in. from front face of curb or road edge to the mailbox door.

2. Codes and standards of delivery truck size/width. The maximum width limit for CMVs on the NN and reasonable access routes was originally established at 102 inches, except for Hawaii where it is 2.74 m (108 inches).

Trucks or straight trucks are non-articulated self-propelled cargo-carrying CMVs (Figure 15). They are subject to Federal weight requirements on the Interstate System and Federal width requirements on the NN, but not to Federal length requirements. Vehicle length regulation remains with the States.

States must allow certain devices to extend beyond the 2.6 m (102-inch) width limit of CMVs on the NN and reasonable access routes. These include rear-view mirrors, turn signal lamps, handholds for cab entry/egress, splash and spray suppressant devices, and load-induced tire bulge. Also excluded are non-property carrying devices that do not extend more than 3 inches beyond each side of the vehicle.

3. Standards of package safety. Packages are known to get damaged by ups workers.

Sources

1. "U.S. POSTAL SERVICE STANDARD MAILBOXES, CURBSIDE." *SPUSPS-STD-7B01*. N.p., n.d. Web. 11 July 2016.
2. Federal Size Regulations for Commercial Motor Vehicles - FHWA." *Federal Size Regulations for Commercial Motor Vehicles - FHWA*. N.p., n.d. Web. 11 July 2016.
3. "5 Reasons Packages Get Destroyed (Learned Working at UPS)." *Cracked.com*. N.p., n.d. Web. 11 July 2016.

7.2 JUSTIFICATION

1. The mailbox standards are relevant because this device is similar to the drop box device. Both devices receive mail from a truck, so it is expected that similar standards should be followed for the new drop box.

2. The delivery truck maximum width standard is important to know how long the slide can protrude out the side of the truck or if we would have to make the truck's width smaller so that we could fit the standard. The standard is 102 inches in width, but states may allow the delivery box drop truck to extend beyond 102 inches based on the fact that is has allowed other vehicles to extend beyond this value.

3. Delivery companies such as UPS are known to deliver packages that have been damaged. This common occurrence of damaged packages, should relieve concerned of any slight damage of packages that are being delivered from the drop box truck.

7.3 DESIGN CONSTRAINTS

For Standard 1, there wouldn't need to be constraints on the drop box system. Ergonomic standards are set for mailboxes to lessen the strain on the delivery person while placing mail into the mailbox. The mailbox standards on height being between 41 inches and 45 inches is so the mail truck delivery person can have easy access, but the drop box system uses an interaction between a chute and a box while mail delivery has an interaction between a person and a box.

For Standard 2, states would need to grant access to delivery companies to use the drop box truck, because when the chute comes out the truck would exceed 102 inches. The design doesn't necessarily have to change if the state allows it. Therefore legal constraints on the truck would have to be lessened.

For Standard 3, there would be no constraints on the design

7.4 SIGNIFICANCE

The constraints will not affect the final prototype. If a state denied the length of the chute to protrude out 12 inches, then the length would be decreased. No material choices will be affected.

8 WORKING PROTOTYPE

8.1 PHOTOGRAPHS OF WORKING PROTOTYPE

Figure 19: Last mile solution prototype

Figure 20: Last mile solution in delivery position

8.2 VIDEO OF WORKING PROTOTYPE

https://www.youtube.com/watch?v=IF9li8ns744

8.3 PROTOTYPE SUBSYSTEMS

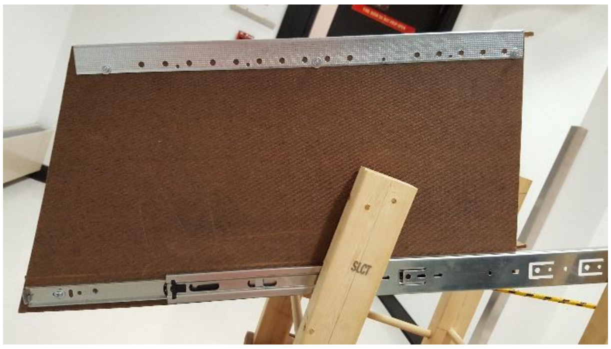

Figure 21: Chute subsystem

Package Chute – The Package chute is the device that the package slides through to move from the delivery truck into the mail box. The chute sits at a 20 degree angle and slides out a horizontal distance of 1 foot from the side of the delivery truck. A conveyor system feeds the packages into the chute. The material for the chute is Masonite board, which allows a package of any weight to safely slide from the chute into the mail box.

Figure 22: Chute support subsystem

Support System – The support system holds supports the chute system and is the mount for the slides. The support system reacts to the forces imparted by the chute and the package. Due to the small amount of force the packages impart, contactor grade wood studs reinforced by dowel rods acting as cross beams were chosen for the materials. The support system can withstand much more force than the design called for.

Figure 23: Chute control subsystem

Chute control – The chute control system allows the driver to extend and retract the chute to complete deliveries. A simple lever with a handle allows the chute to fall under gravity into the delivery position. Once the delivery is made the driver can pull the handle to retract the chute and lock it into place using the hook. This system allows the driver to deliver packages without ever leaving the driver’s seat.

Figure 24: Depiction of the mailbox subsystem

Mail Box – The specially designed mail box accepts the packages that are delivered to the customers. The mailbox is fully covered and has a trap door that stays shut to ensure that the box is not affected by the outside weather. The mailbox is equipped with a door on the back that the customer can retrieve their package. The combination of the trap door and the locked back door make the delivery safer and more secure than current delivery practices. Due to time constraints the prototype of the mail box was constructed out of cardboard.

9 DESIGN DOCUMENTATION

9.1 FINAL DRAWINGS AND DOCUMENTATION

9.1.1 CAD Drawings of the Final Prototype

See Appendix C for all CAD models of the prototype

9.1.2 Sourcing instructions

All purchased parts for the prototype were purchased from Lowes hardware store. The following table provides a description of each part and the catalog number to purchase the parts.

Table 10: Purchased materials and description of their purpose

Item Name	Item Description	Lowes Catalog Number
KD 2 in X 3 in whitewood stud	Wood used to create the supports for the chute	1030
1 in X 2 in X 4 ft Whitewood Board	Wood used for the support of the lever	1406
Hillman #8 X 3 in drywall screws	Screws to hold the dowels in place longways	755751
Hillman 1/4 in flat washer	Washers used with the 1/4 machine screws	58124
Hillman 1/4-20 X 1-1/4 machine screw with nut	Bolts that mount the lever mount to the cart	58051
Hillman 1/4-20 X 1-1/2 machine screw with nut	Bolts that mount the lever mount to the corner bracket	58052
Hillman 1/4-20 X 3/4 machine screw with nut	Bolt used to fasten the lever to the corner bracket	58049
Hillman #8 X 3/4 in wood screws	Screws used to mount the pulley	57231
Hillman #8 X 1-3/4 in wood screws	Screws to hold the dowels in place shortways	57235
Hillman 5/16 in X 3 in lag screw	Screws that mounted the chute support to the cart	63354
Hillman 5/16 in flat washers	Washers that went with the lag screws	63307
Hillman Steel gate and eye hook	The locking mechanism for the lever	330641
Stanley 5 in corner brace	Corner brace that mounts the lever horizontally	64772
Hillman 1/4 in external lock washer	Washers to keep the machine screws from loosening	136834
Stanley 8 in flat corner brace	Lever to extend and retract the chute	64767
Dietrich metal framing 8 ft corner bead	Corner brace for the top of the chute	11817
Madison mill 5/8 in X 4 ft wooden dowel	Cross beams for the chute support system	19383
Richelieu 16 in drawer slides	slides the chute extends and retracts on	380977
Elmer's wood glue 8 oz	used to strengthen screw attachments	163877
Duct Tape	Used to fasten the mailbox together	346952

The remaining parts were scrounged from leftover materials at Washington University and at team member’s homes. The following table shows the parts and their projected price.

Table 11: Scrounged parts and their projected prices

Item Name	Item Description	Projected Price
3 ft X 8 ft X 1/2 in wood board	Base for the chute and support system	40
2 ft X 4 ft Masonite board	Material used for the chute	8
1/2 in open flat mount pulley	pulley to change direction of the rope	12
1/2 in rope	Connects the chute and the lever	2
1/16 in X 1/4 in machine screw with nut and washer	Attached the corner bead to the top of the chute	10
Metal rolling utility cart	Simulates delivery truck	90
Cardboard	Material for the mailbox	6

All materials except the flat mount pulley can be purchased at a hardware store such as Lowes. The pulley can be purchased online from McMaster Carr. The parts can be scrounged from leftover contacting materials as well. The cart can be scrounged from office buildings looking to replace their current carts.

9.2 FINAL PRESENTATION

9.2.1 Final Presentation Video

https://www.youtube.com/watch?v=Mz3_Dh9XqMA

10 TEARDOWN

After the project was completed and demonstrated, the prototype was kept by a team member. All excess materials were disposed of in their correct disposal units. All work areas were cleaned immediately after the work was completed as well. The following email string confirms the teardown plan with Professor Jakiela.

Jegel, Eric
Today 2:38 PM
Professor Jakiela,

For the teardown of the package drop. All excess materials were disposed of correctly and the project is being taken home by myself. Is there anything we need from you for the teardown section of the report, or do we just state that the prototype was kept?

Eric Jegel

Jakiela, Mark
Reply all
Today 8:03 PM
Jegel, Eric

Eric Jegel:

Please consider this email reply to be equivalent to my signature.

For assignment 10, paste your email and this reply into your final report.

I approve of your teardown plan. Glad that you are able to take the project home.

Mark Jakiela

11 APPENDIX A - PARTS LIST

PART NUMBER	ITEM	QTY	Description	Material	Purchasing Location	Catalog Number	Price
1	Drop Panel	1	Base Top With Water Holes	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
2	Side Panel	2	Base Side Panels	Stainless Steel Sheet	McMaster Carr	9784K83	108.06
3	Front Panel	1	Base Front Panels	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
4	Back Panel	1	Base Back Panels	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
5	Bottom panel	2	Base Panel	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
6	Angles	2	Used to Soften Package Drop and to Space Out Packages	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
7	Top Side	1		Stainless Steel Sheet	McMaster Carr	9718K25	9.97
8	Top Side 2	1		Stainless Steel Sheet	McMaster Carr	9718K25	9.97
9	Top Back	1	Back plate covering paackage door	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
10	Hinge	1		Steel	McMaster Carr	1494A11	4.87
11	Flap	1	Prevents Theft	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
12	Slide 2	1	Helps Get Package From Chute to Opening	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
13	Door	1	For Customer Package Recovery	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
14	Top Angle	2	Allows for Angled Roof	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
15	Top	1	Roof for weather proofing	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
16	Drip Plate	1	Keeps Inside Free of Water Build-Up	Flat Steel	McMaster Carr	9302T628	50.28
17	Water Slide	1	Used To Divert Water	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
18	Frame Assembly	1	Keeps Unit Off Groud 3"	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
19	Lock	1	Prevents Theft	Padlock	McMaster Carr	1189A41	2.71
20	Chute Panels	4	Delivers Package to bo	Stainless Steel Sheet	McMaster Carr	9718K25	9.97
21	Chute Slide	2	Extends chute out of truck	Steel	Home Depot	202200646	15.48
22	Bolts	50	Used for assembly	Steel	McMaster Carr	91280A978	8.39
23	Nuts	100	Used for assembly	Steel	McMaster Carr	90592A022	4.51
24	Brackets	24	Used for assembly	Zinc-Plated Steel	McMaster Carr	1556A24	10.32

12 APPENDIX B - BILL OF MATERIALS

Item	Quantity	Cost
KD 2 in X 3 in whitewood stud	2	2.88
1 in X 2 in X 4 ft Whitewood Board	1	1.88
Hillman #8 X 3 in drywall screws	4	4.58
Hillman 1/4 in flat washer	7	1.24
Hillman 1/4-20 X 1-1/4 machine screw with nut	2	1.24
Hillman 1/4-20 X 1-1/2 machine screw with nut	2	1.24
Hillman 1/4-20 X 3/4 machine screw with nut	1	1.24
Hillman #8 X 3/4 in wood screws	4	1.24
Hillman #8 X 1-3/4 in wood screws	10	2.48
Hillman 5/16 in X 3 in lag screw	4	1.84
Hillman 5/16 in flat washers	4	0.52
Hillman Steel gate and eye hook	1	1.24
Stanley 5 in corner brace	1	2.98
Hillman 1/4 in external lock washer	4	1.15
Stanley 8 in flat corner brace	1	1.97
Dietrich metal framing 8 ft corner bead	1	1.43
Madison mill 5/8 in X 4 ft wooden dowel	2	4.96
Richelieu 16 in drawer slides	2	14.97
Elmer's wood glue 8 oz	1	4.68
3 ft X 8 ft X 1/2 in wood board	1	free
2 ft X 4 ft Masonite board	1	free
1/2 in open flat mount pulley	1	free
1/2 in rope	1	free
1/16 in X 1/4 in machine screw with nut and washer	12	free
Metal rolling utility cart	1	free
Cardboard	1	free
Duct Tape		4.98
total		58.74

13 ANNOTATED BIBLIOGRAPHY

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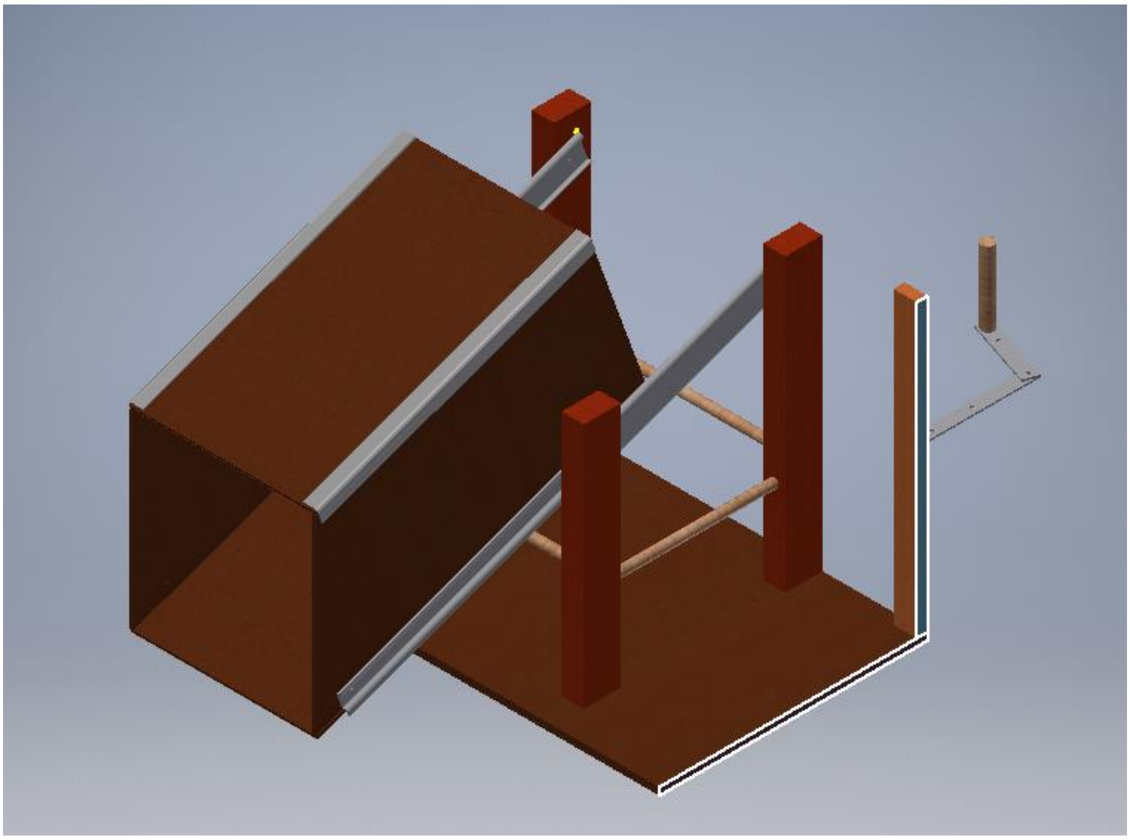
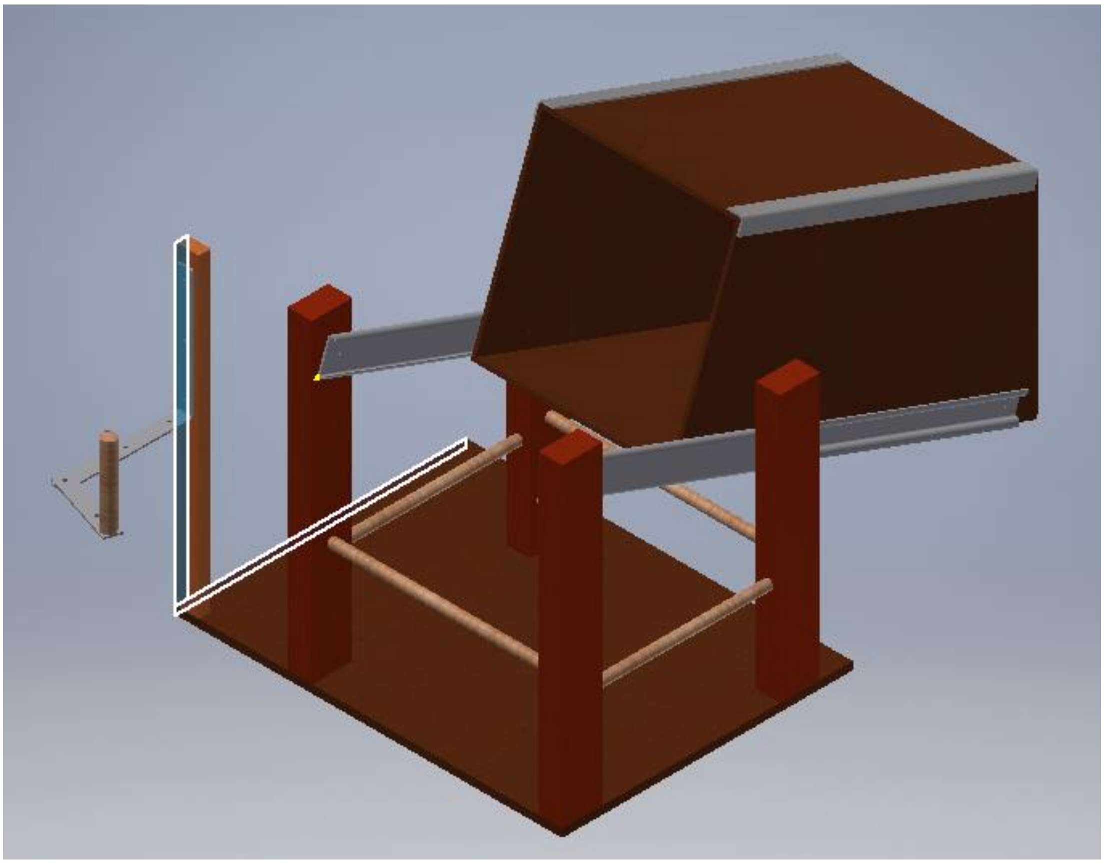
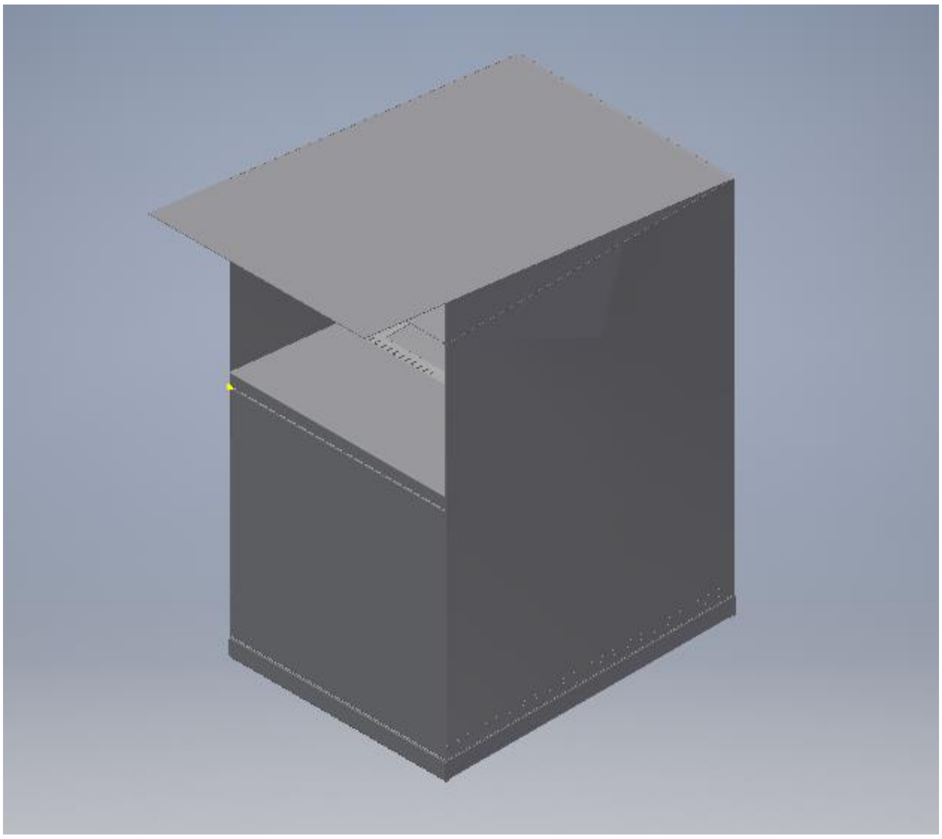
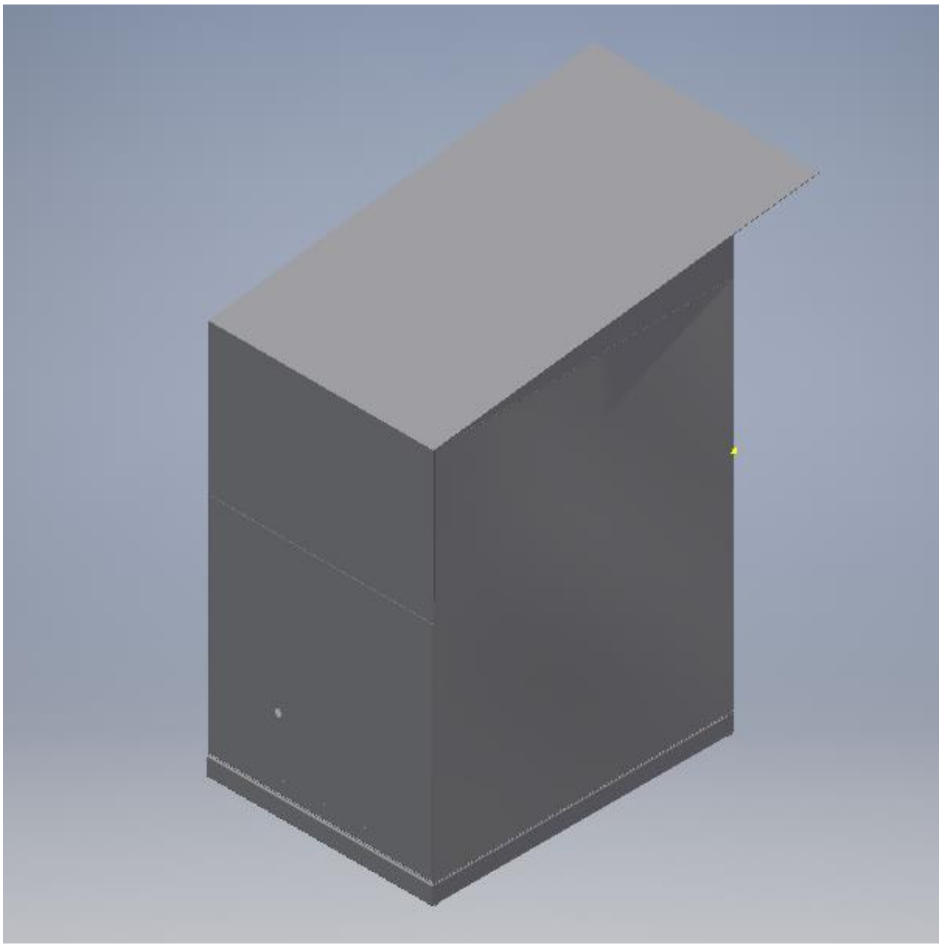
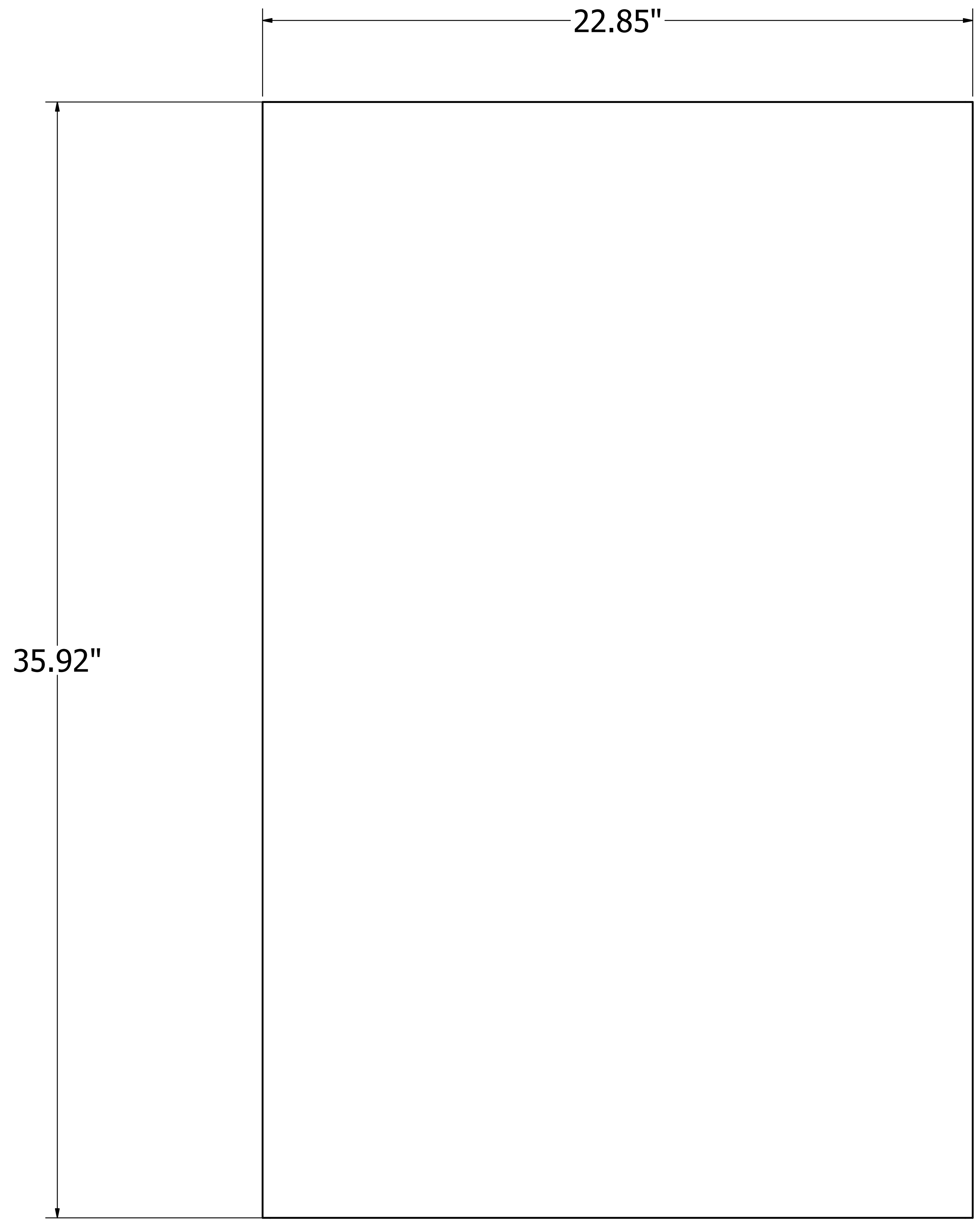
14 APPENDIX C – CAD MODELS



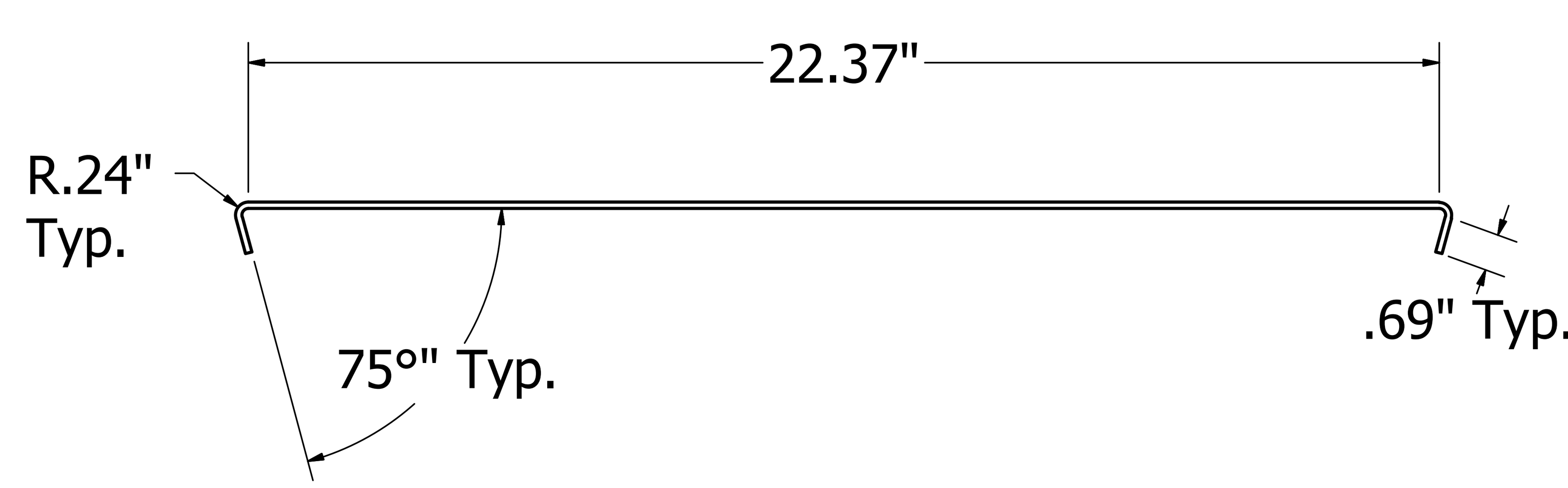


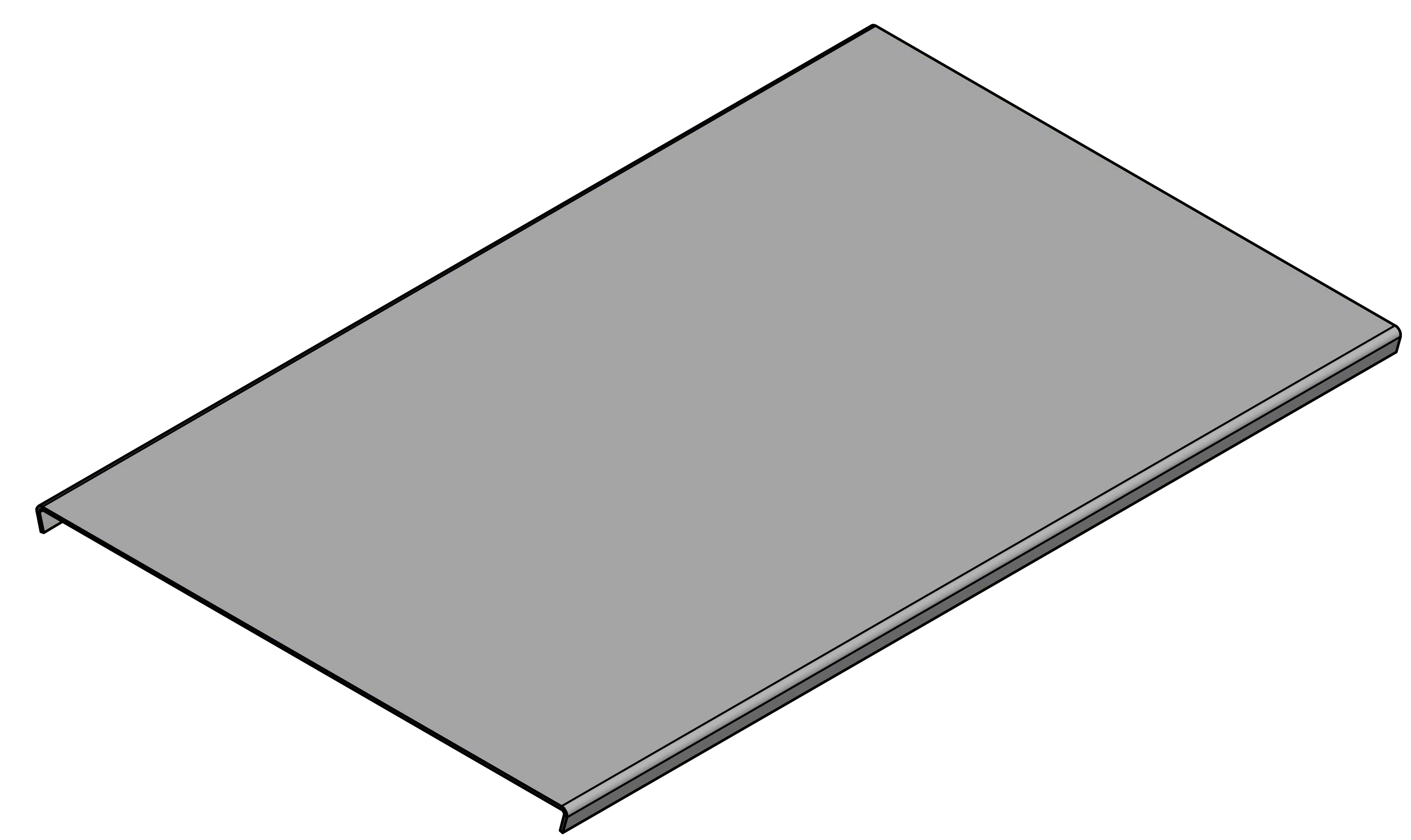




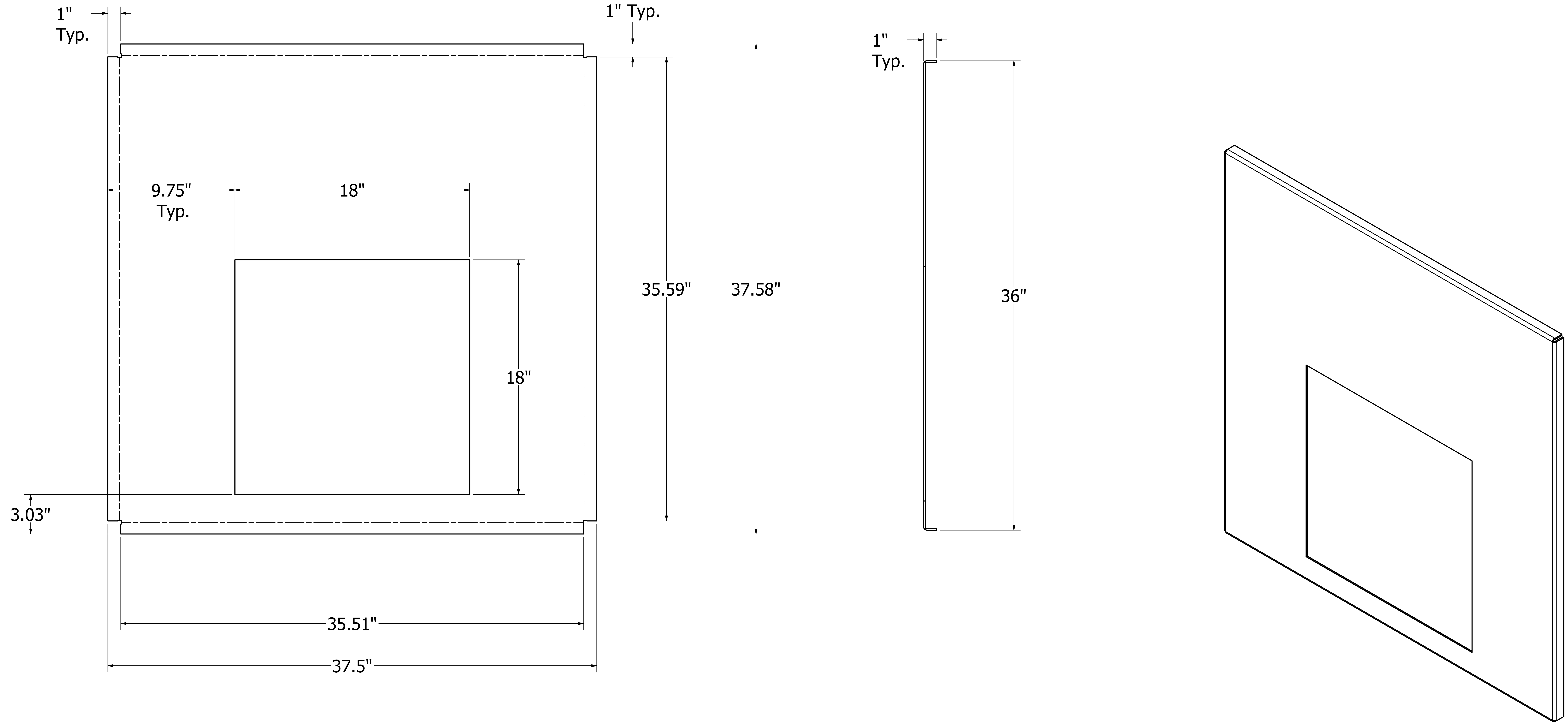


305 Stainless Steel 18 Ga.





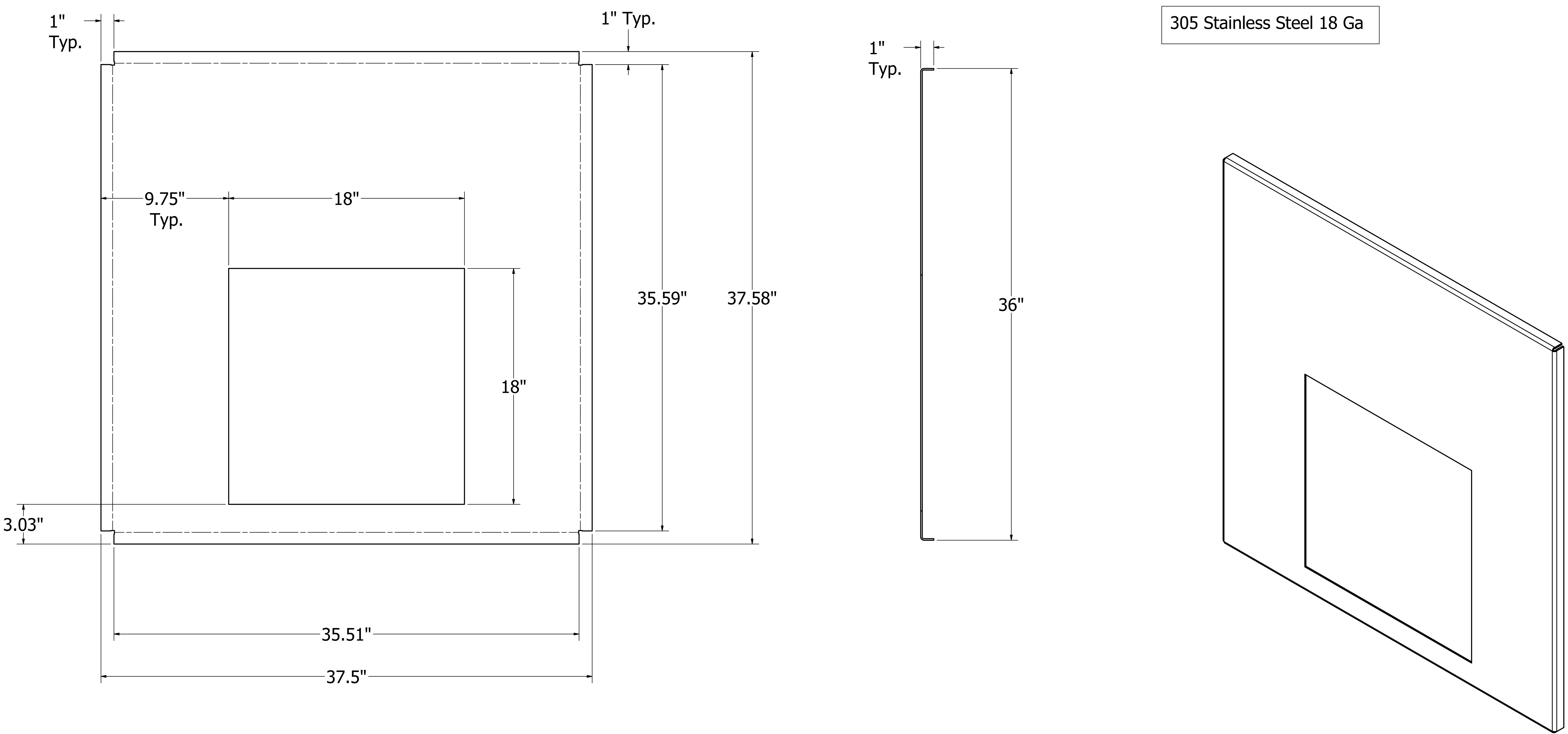
DRAWN Jaybird	8/4/2016	
CHECKED		TITLE
QA		Angles
MFG		
APPROVED		SIZE D · DWG NO Angles · REV
		SCALE 1 / 4 · SHEET 1 OF 1



DRAWN Jason K. 6/25/2016
CHECKED
QA
MFG
APPROVED

TITLE
Back Panel Drop Box

SIZE D
DWG NO
REV
SCALE 1 / 4
SHEET 1 OF 1



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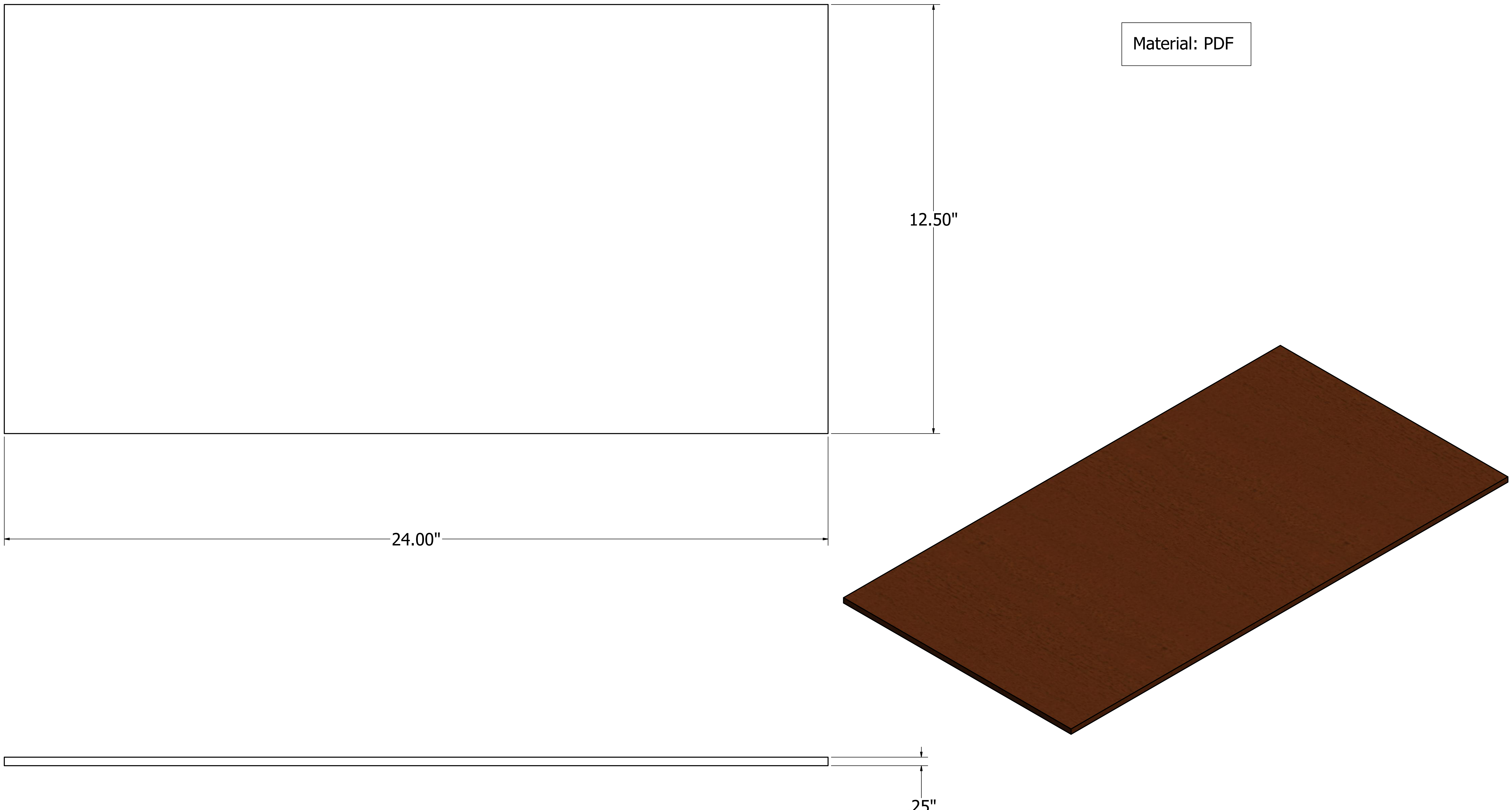
CHECKED		TITLE Back Panel Drop Box
QA		
MFG		
APPROVED		SIZE D · DWG NO · REV
		SCALE 1 / 4 · SHEET 1 OF 1

Material: PDF



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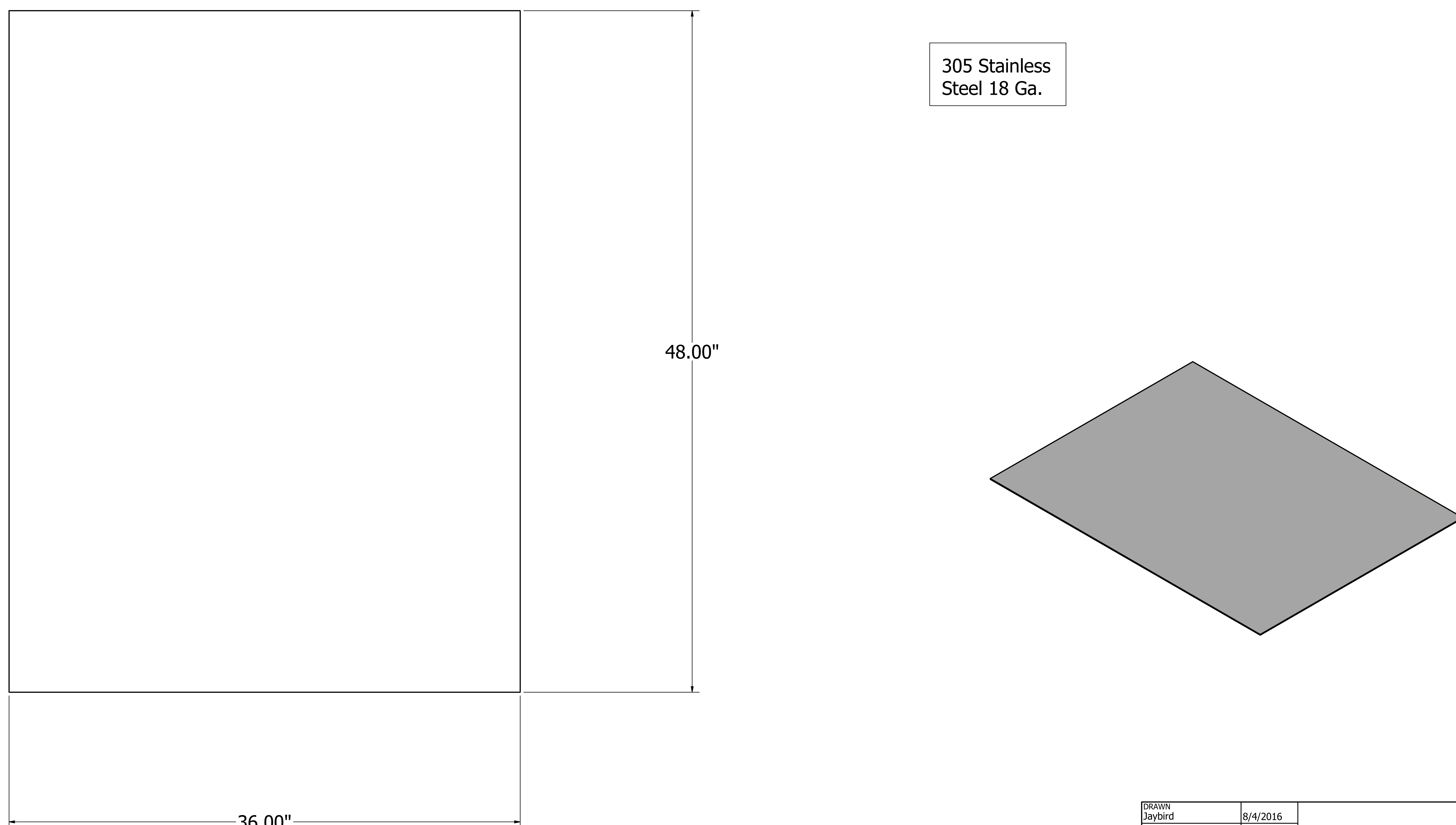
QA		Bottom Panel
MFG		
APPROVED		SIZE D · DWG NO Bottom Panel · REV
		SCALE 1 / 2 · SHEET 1 OF 1



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QA		
MFG		
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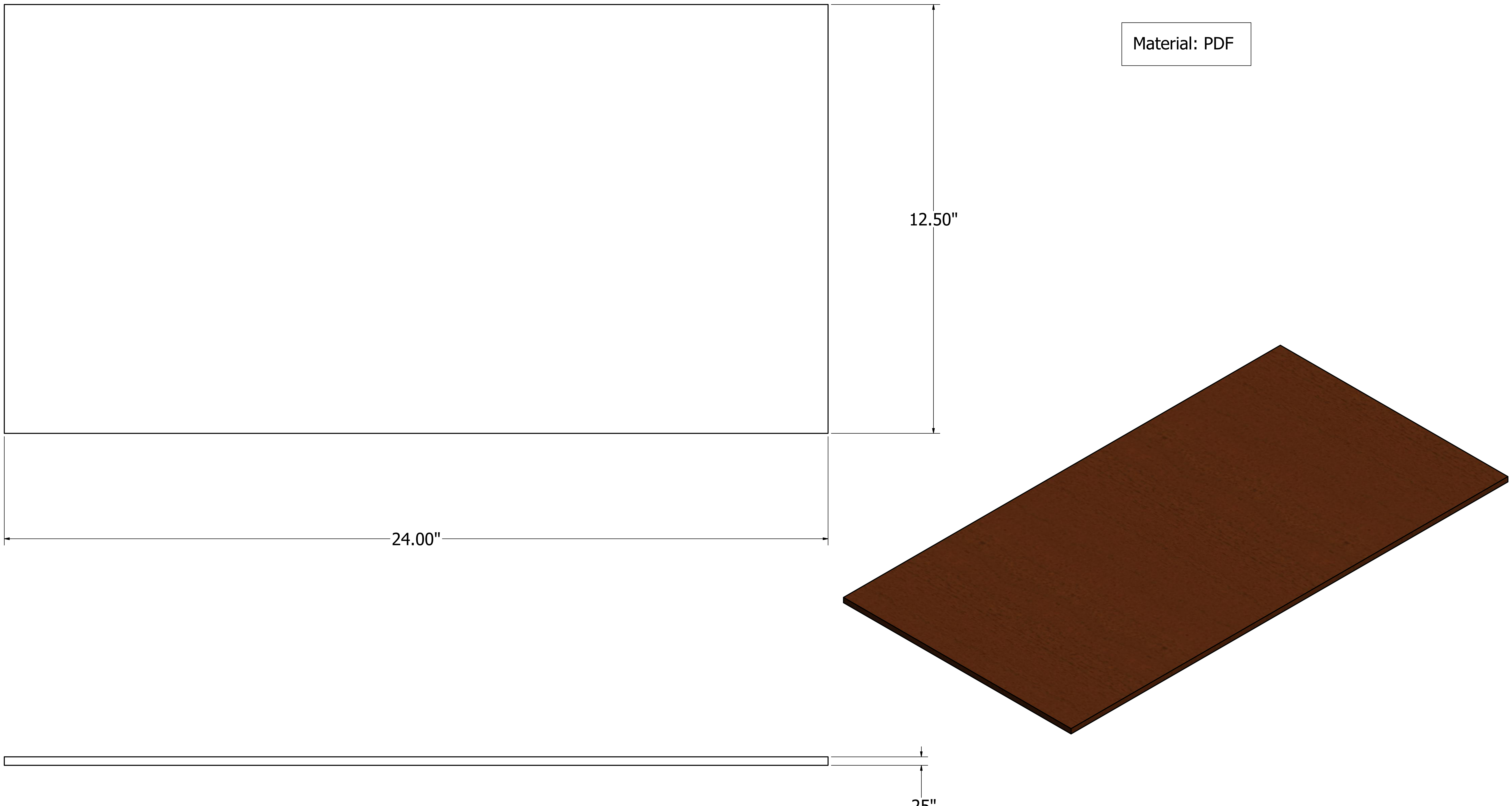

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QA		Bottom Panel
MFG		
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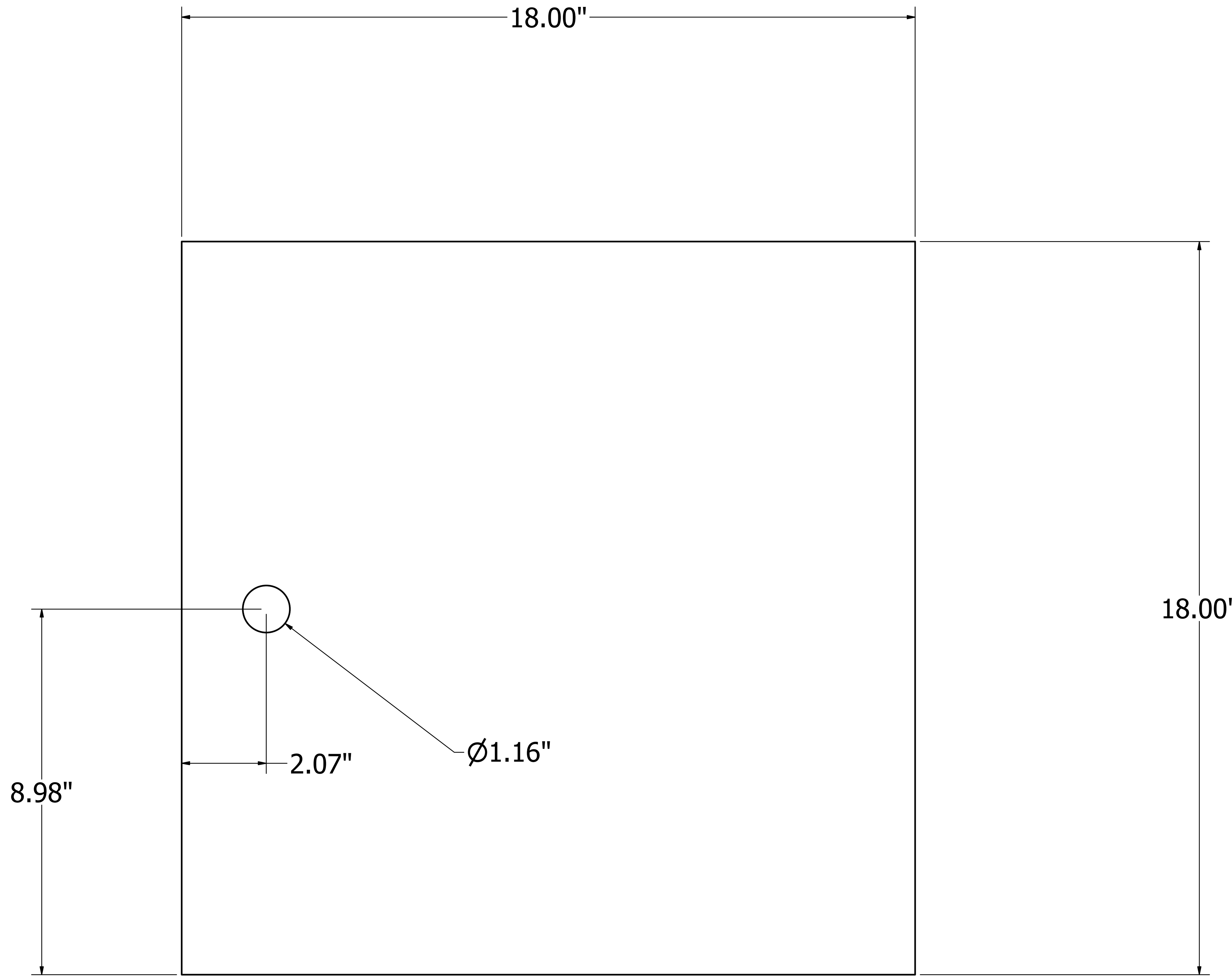
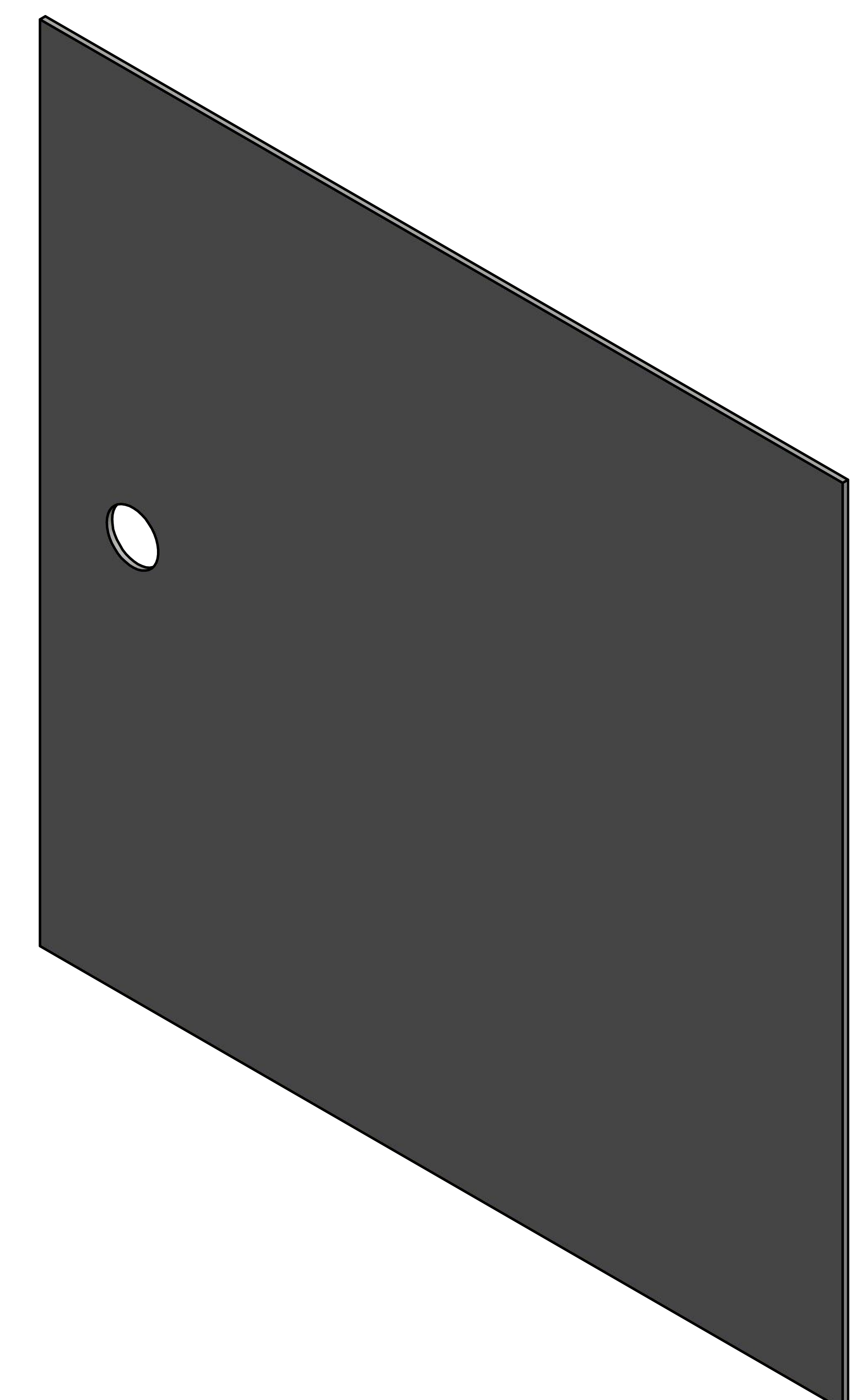
		SCALE 1 / 2 · SHEET 1 OF 1



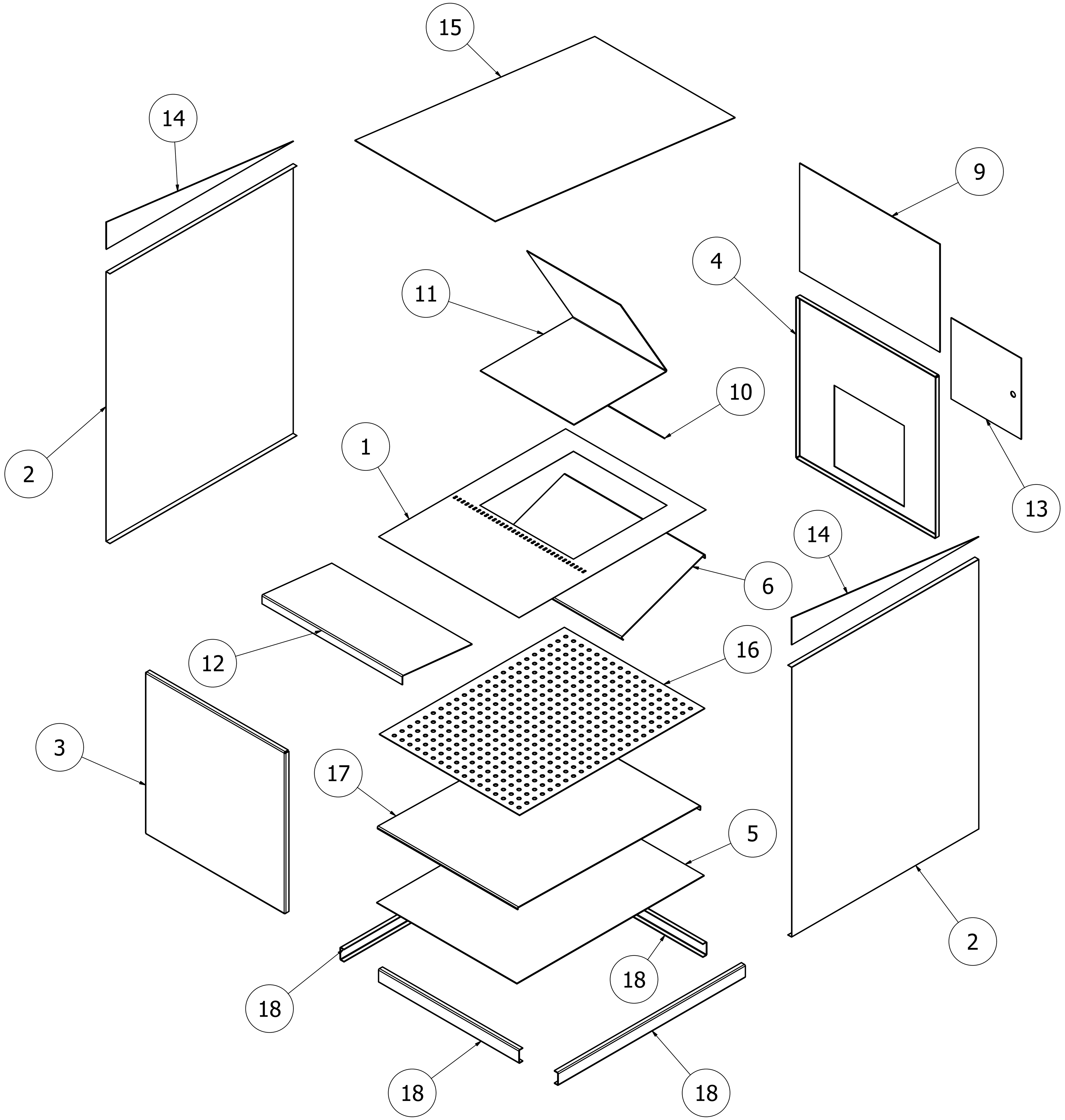


305 Stainless
Steel 18 Ga.

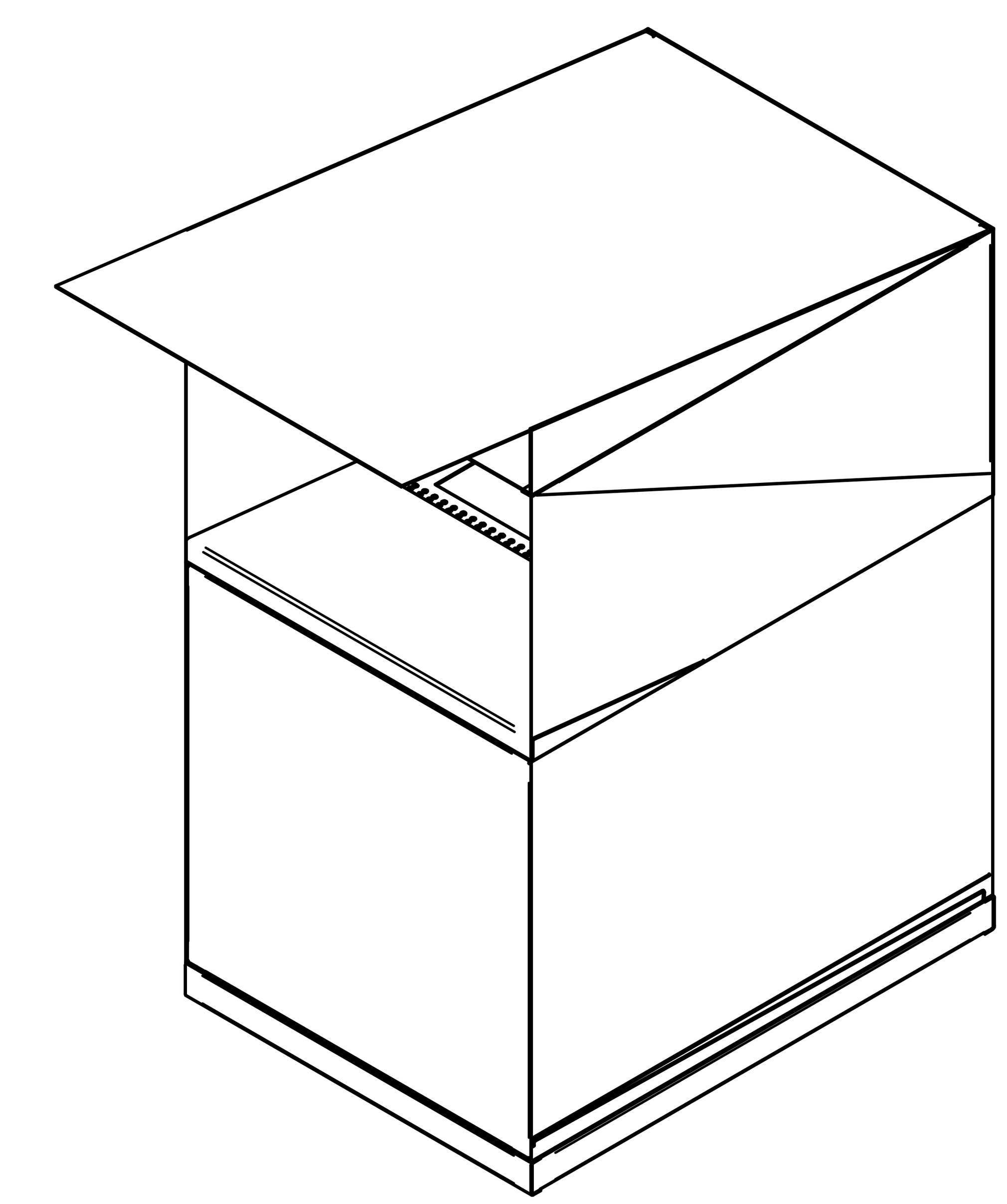
DRAWN Jaybird	8/4/2016	
CHECKED		TITLE
QA		Door
MFG		
APPROVED		SIZE D · DWG NO Door · REV
		SCALE 1 / 2 · SHEET 1 OF 1


(370) Holes @ Ø.75"
47.5"
1.59"
2.25"
2" Typ.
36"
2" Typ.
305 Stainless
Steel 18 Ga.
.12"
DRAWN
Jaybird
8/4/2016
CHECKED
QA
MFG
APPROVED
TITLE
Drip Plate
SIZE
D
DWG NO
Drip Plate
REV
SCALE
0.14 : 1
SHEET 1 OF 1

Exploded View of Drop Box w/ BOM

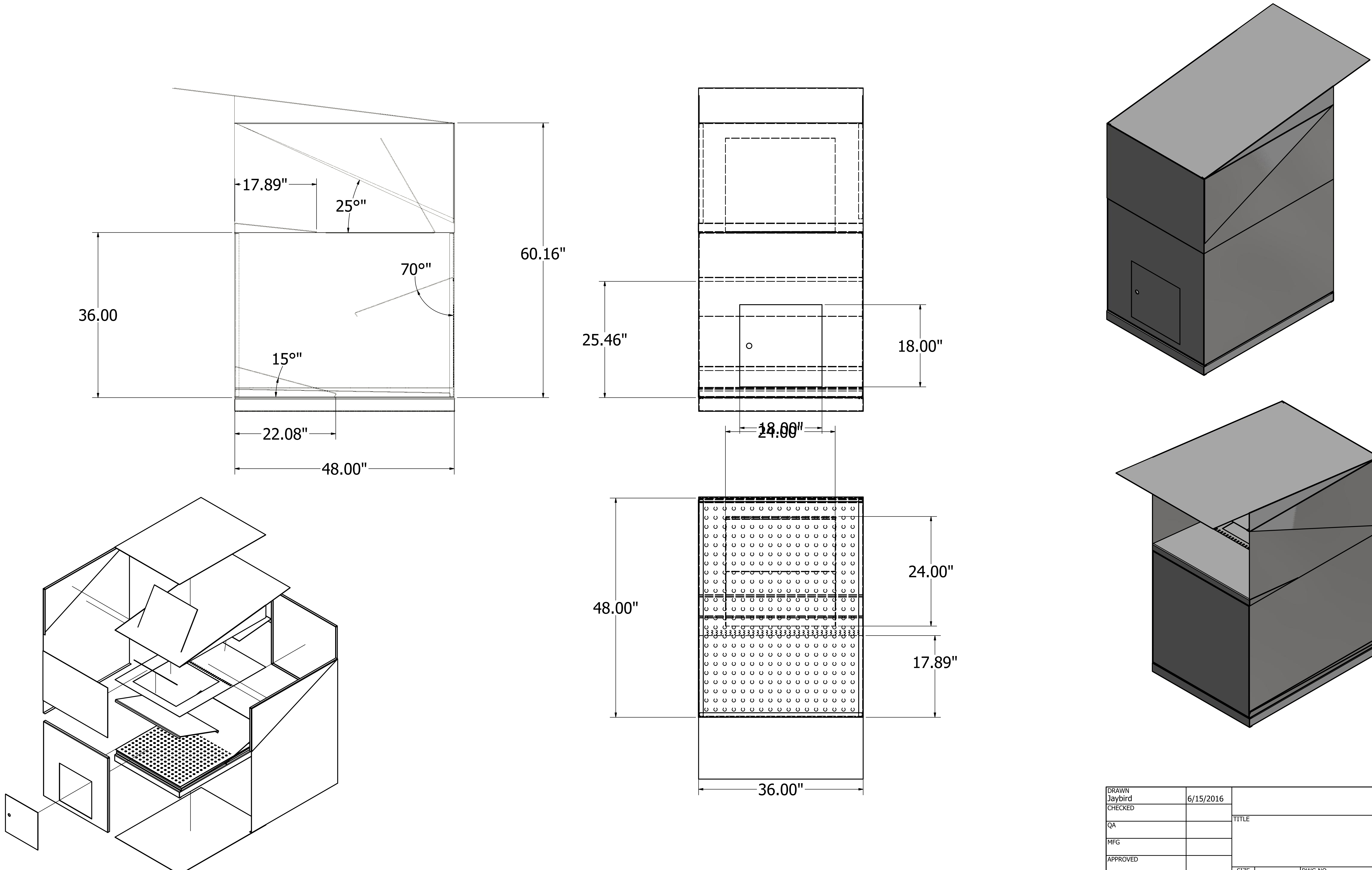


PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Drop Panel	Base Top With Water Holes
2	2	Side Panels	Base Side Panels
3	1	Front Panel	
4	1	Back Panel	
5	2	Bottom Panel	
6	2	Angles	Used to Soften Package Drop and to Space Out Packages
7	1	Top Sides	
8	1	Top Sides2	
9	1	Top Back	
10	1	Hinge	Allows The Flap to Rotate
11	1	Flap	Prevents Theft
12	1	Slide2	Helps Get Package From Chute to Opening
13	1	Door	For Customer Package Recovery
14	2	Top Angles	Allows for Angled Roof
15	1	Top	
16	1	Drip Plate	Keeps Inside Free of Water Build-Up
17	1	Water Slide	Used To Divert Water
18	1	Frame Assembly	Keeps Unit Off Groud 3"



DRAWN Jason K	6/20/2016	
CHECKED		TITLE
QA		Exploded Drop Box w/ BOM
MFG		
APPROVED		SIZE D · DWG NO Drop Box Exploded · REV
		SCALE 1:12 · SHEET 1 OF 1

DRAWN Jaybird	6/20/2016			
CHECKED		TITLE		
QA				
MFG				
APPROVED				
		SIZE D	DWG NO Drop Bpx Dimensions	REV
		SCALE 1:10		SHEET 1 OF 1



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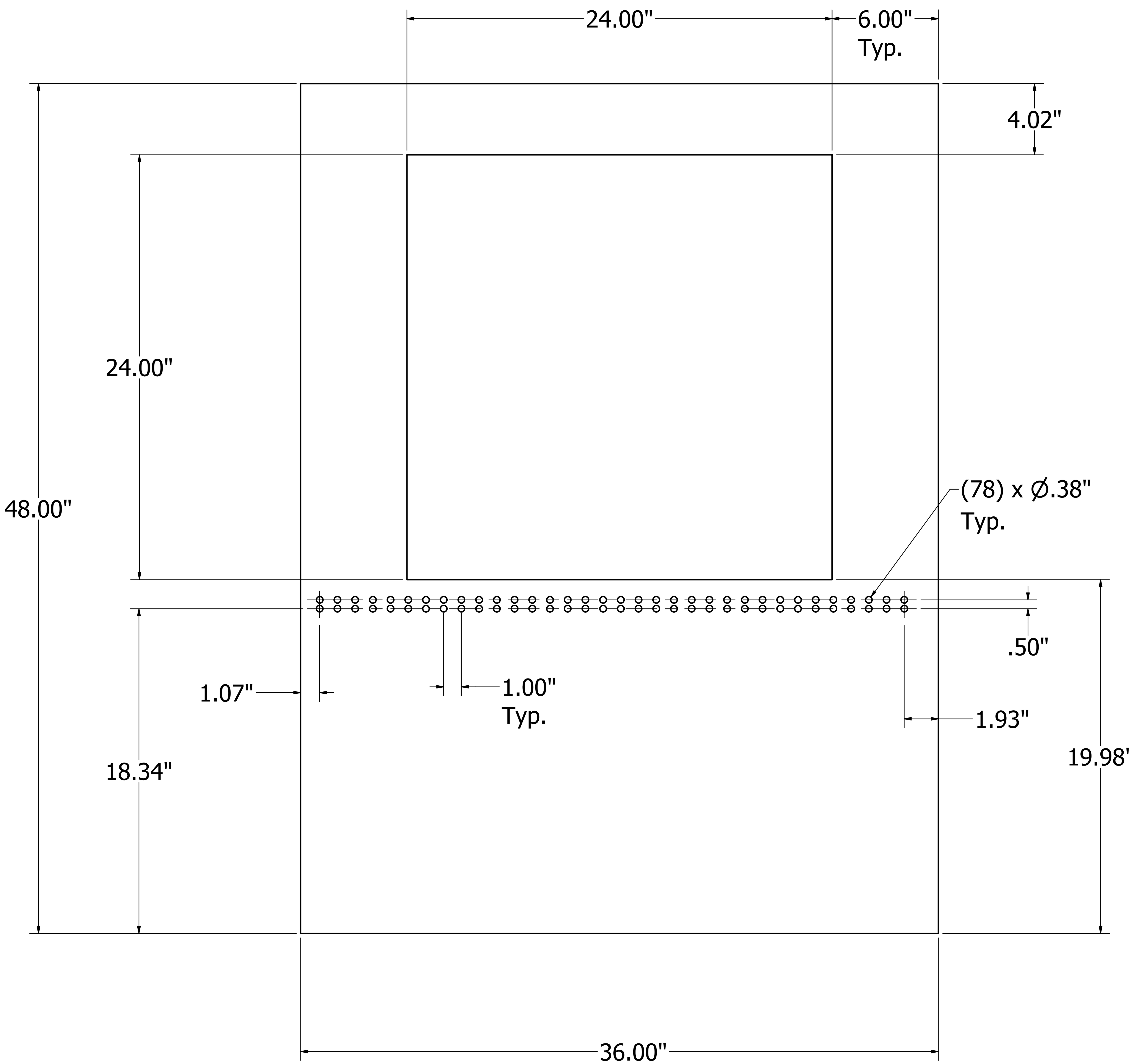
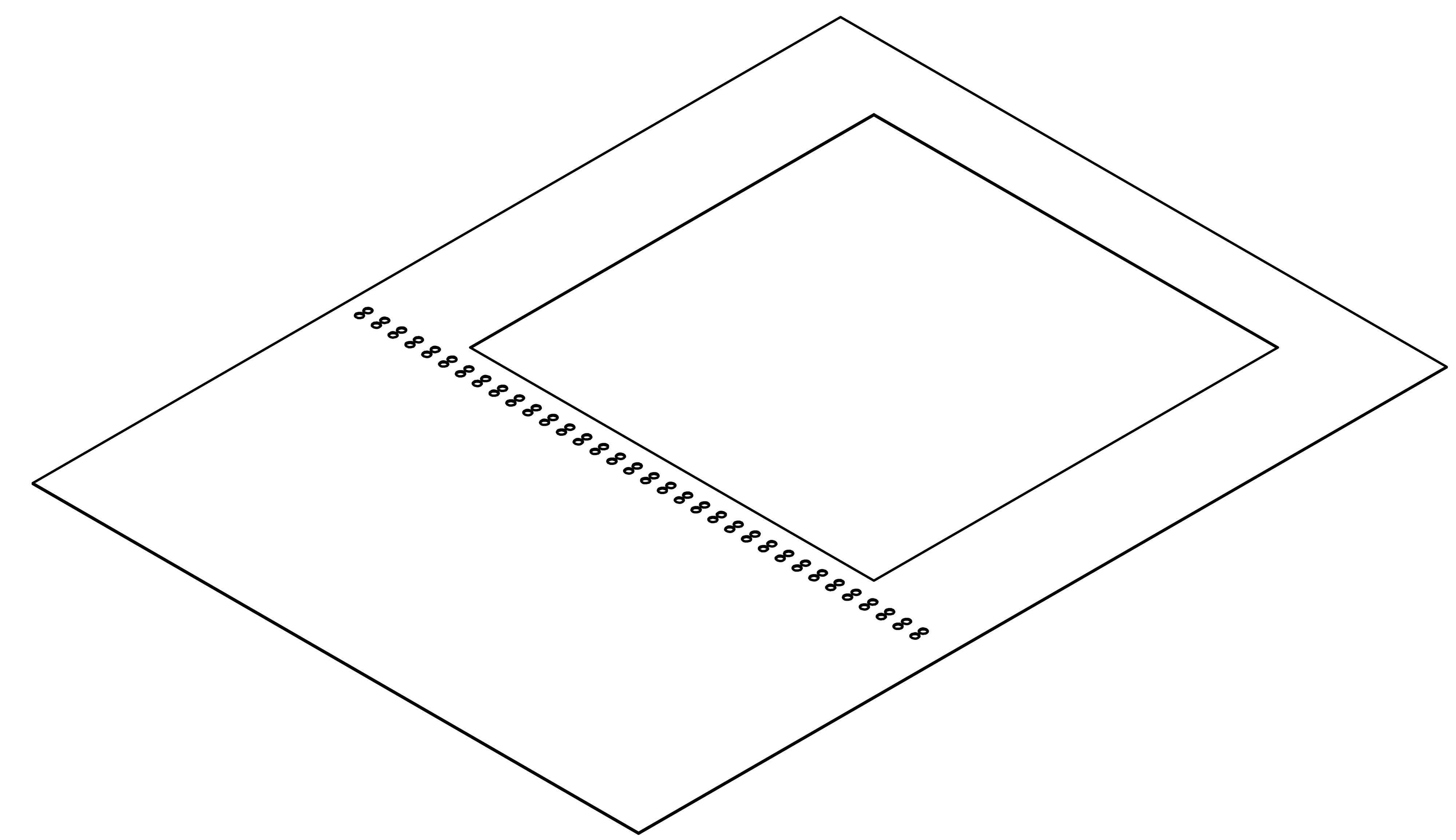
QA		
MFG		
APPROVED		SIZE D · DWG NO Drop Bpx · REV
		SCALE 1 / 12 · SHEET 1 OF 1



305 Stainless Steel 18 Ga



DRAWN Jason K	6/25/2016	
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QA		Drop Panel For Drop Box
MFG		
APPROVED		SIZE D · DWG NO · REV
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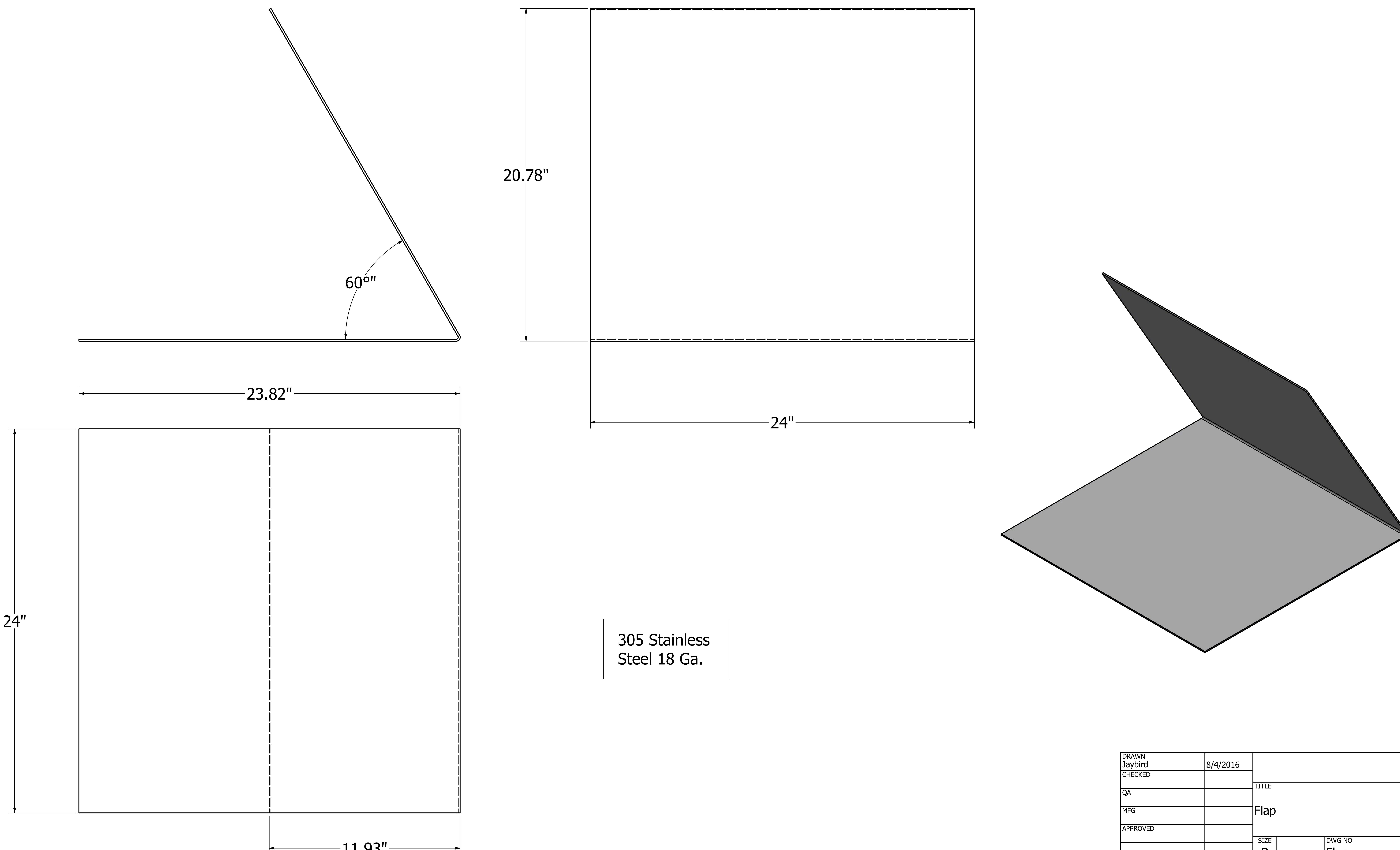

DRAWN Jaybird	8/4/2016	
CHECKED		TITLE
QA		Flap
MFG		
APPROVED		SIZE D · DWG NO Flap · REV
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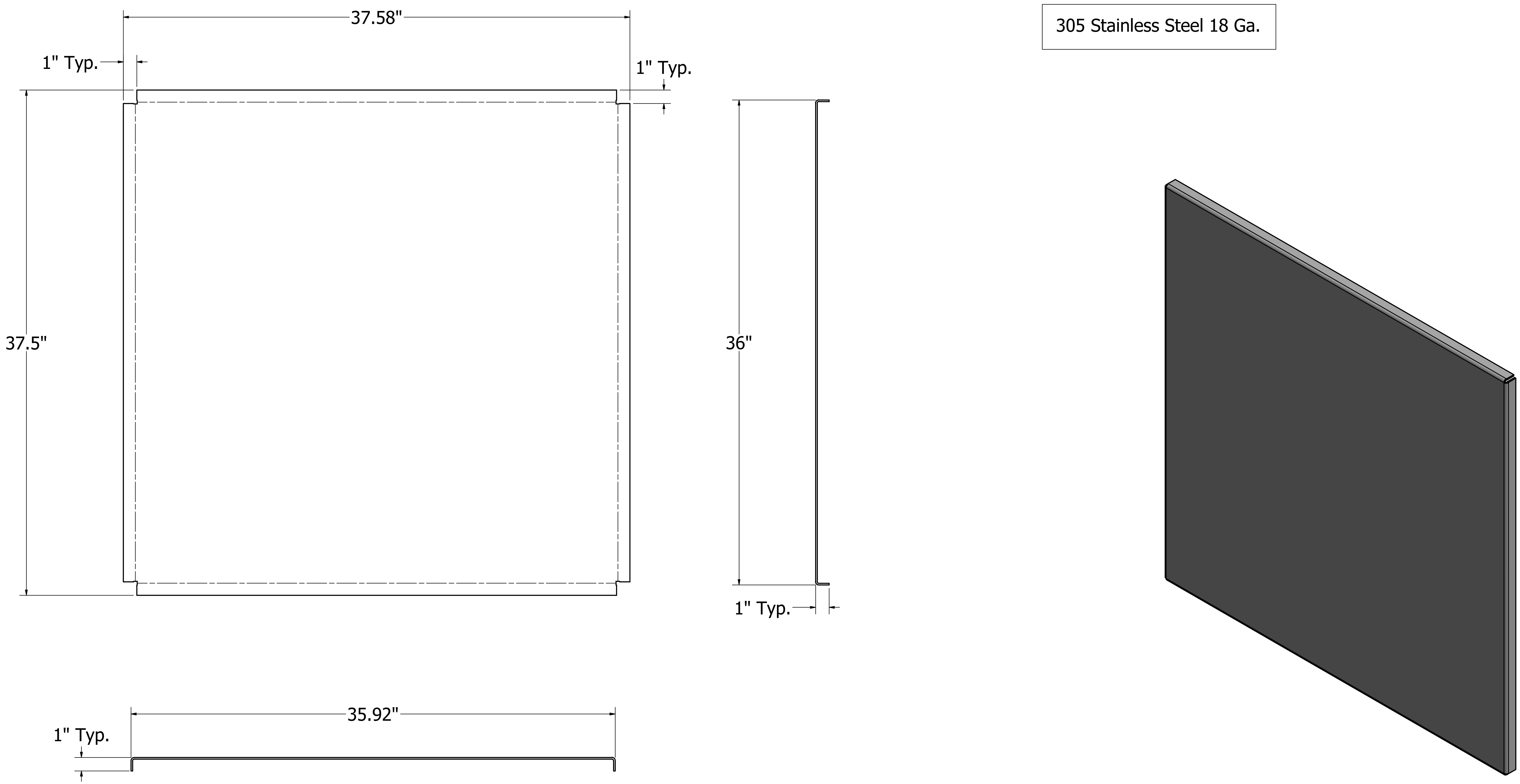

DRAWN Jaybird	8/4/2016	
CHECKED		TITLE
QA		Front Panel
MFG		
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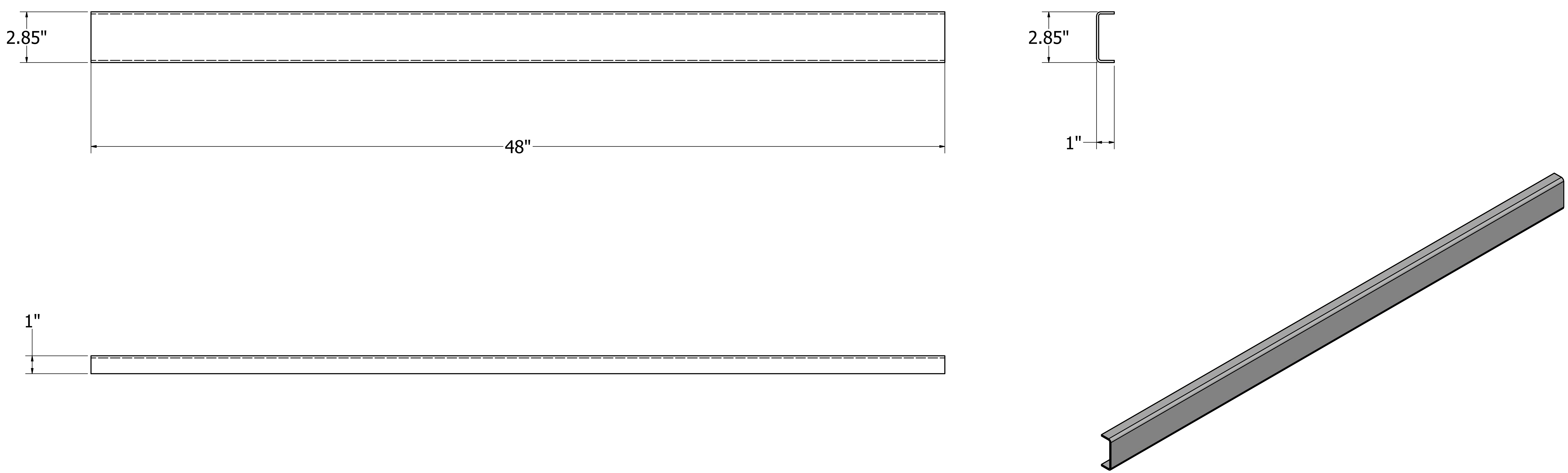
305 Stainless Steel 18 Ga.



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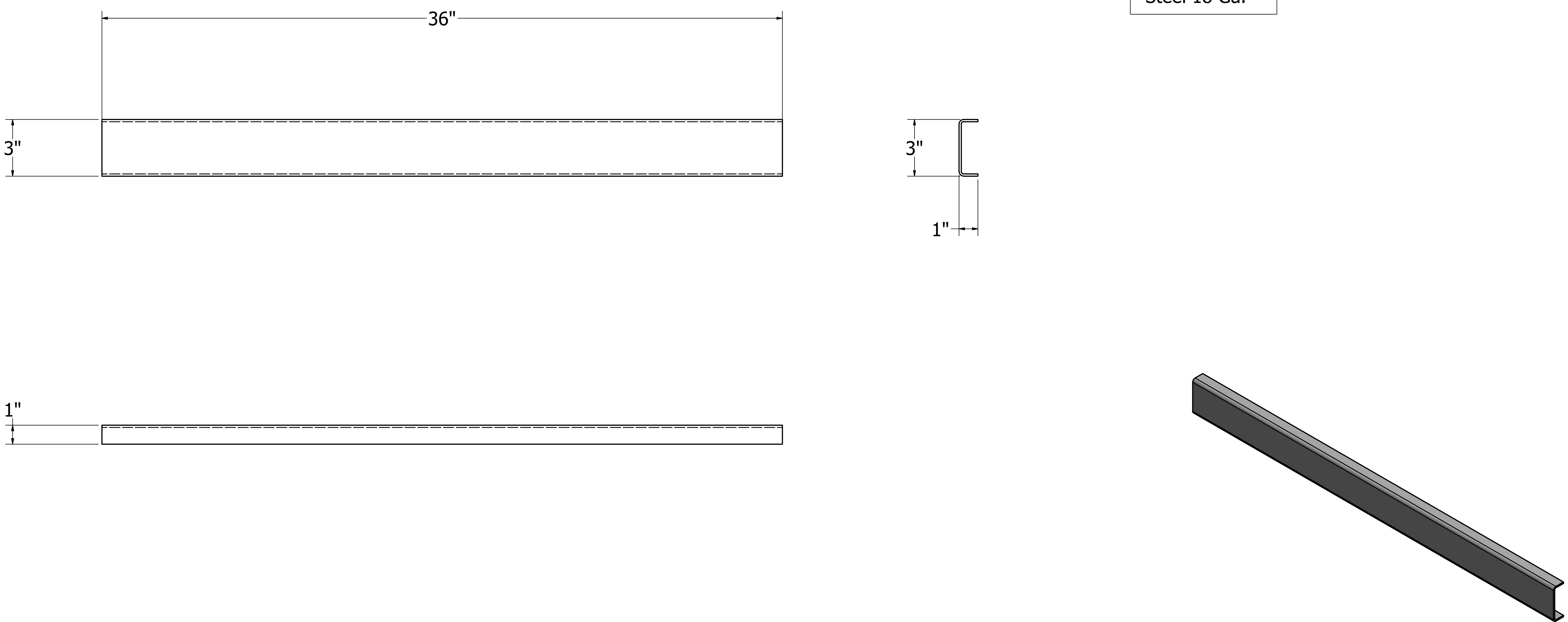
QA		Long Leg
MFG		
APPROVED		SIZE D — DWG NO Long Leg — REV
		SCALE 1 / 4 — SHEET 1 OF 1



DRAWN Jaybird	8/4/2016		
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QA			
MFG			
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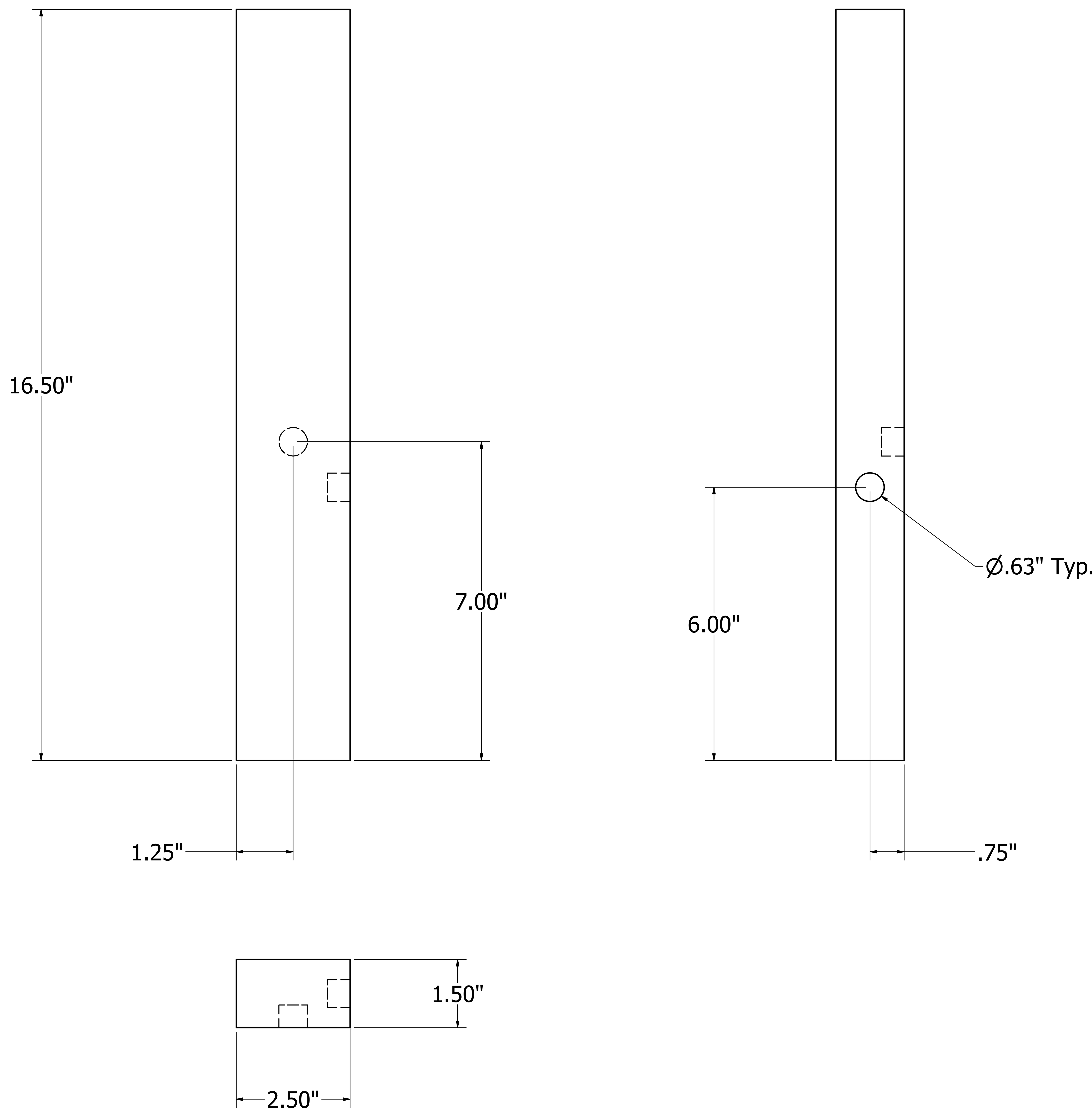
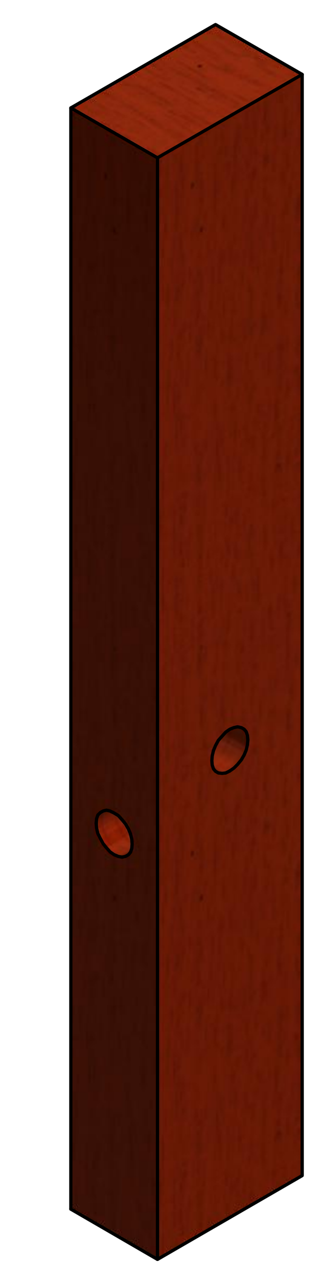
		SCALE 1 / 4	SHEET 1 OF 1

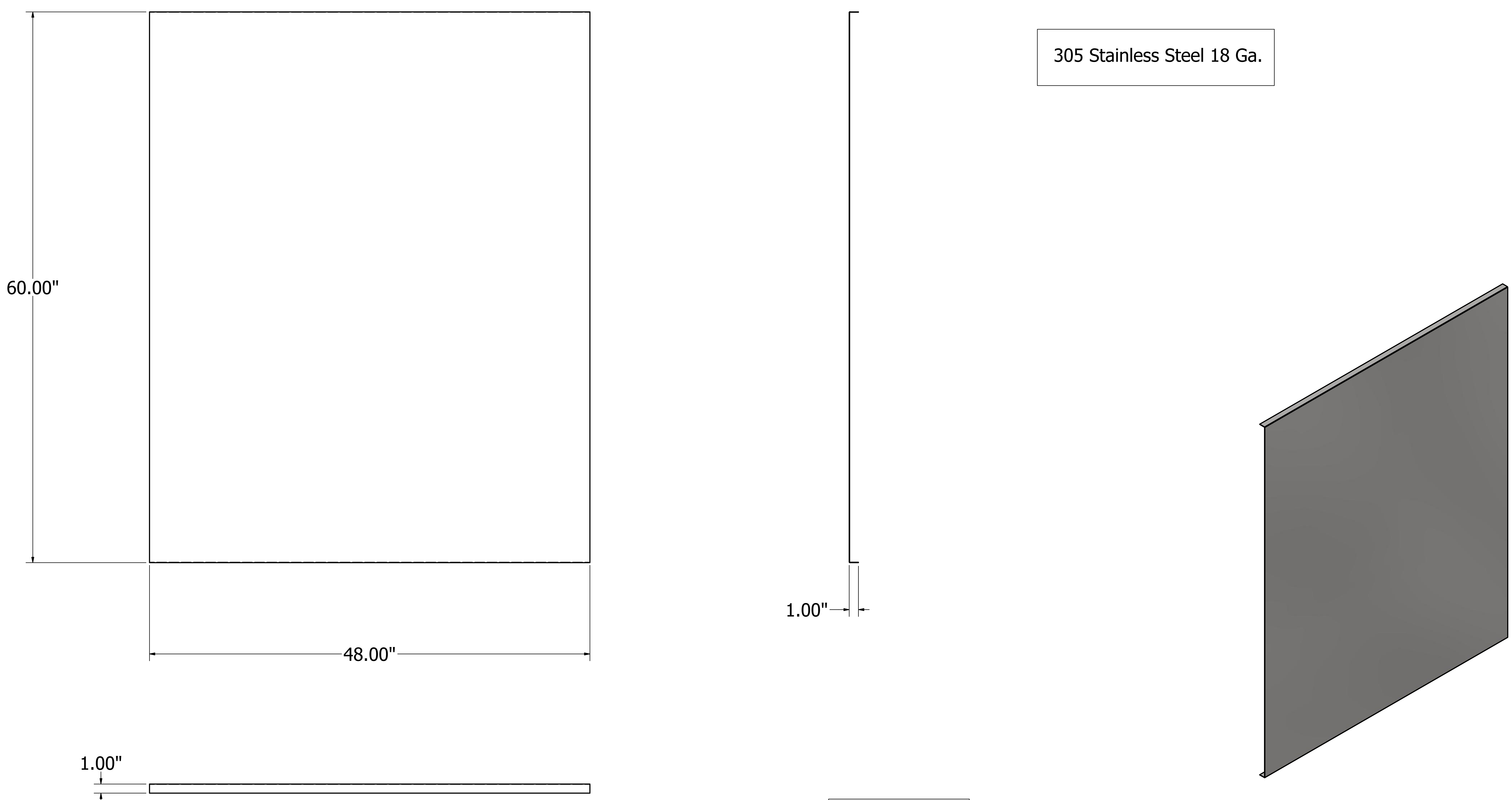


LH Shown RH Opposite

Material: Plywood



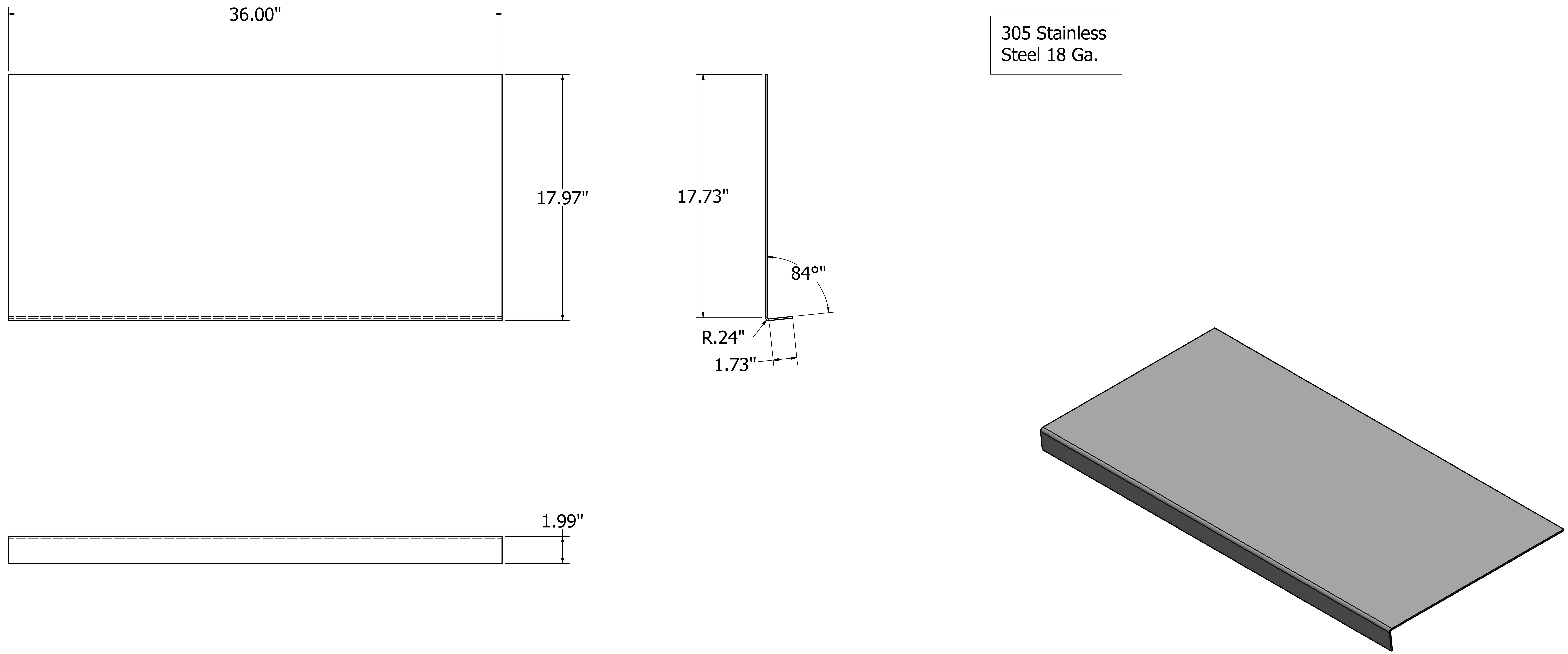
DRAWN Jaybird	8/3/2016				
CHECKED		TITLE Short Supports			
QA					
MFG					
APPROVED		SIZE D	DWG NO Short Supports		REV
		SCALE 1 / 1.5		SHEET 1 OF 1	



305 Stainless Steel 18 Ga.

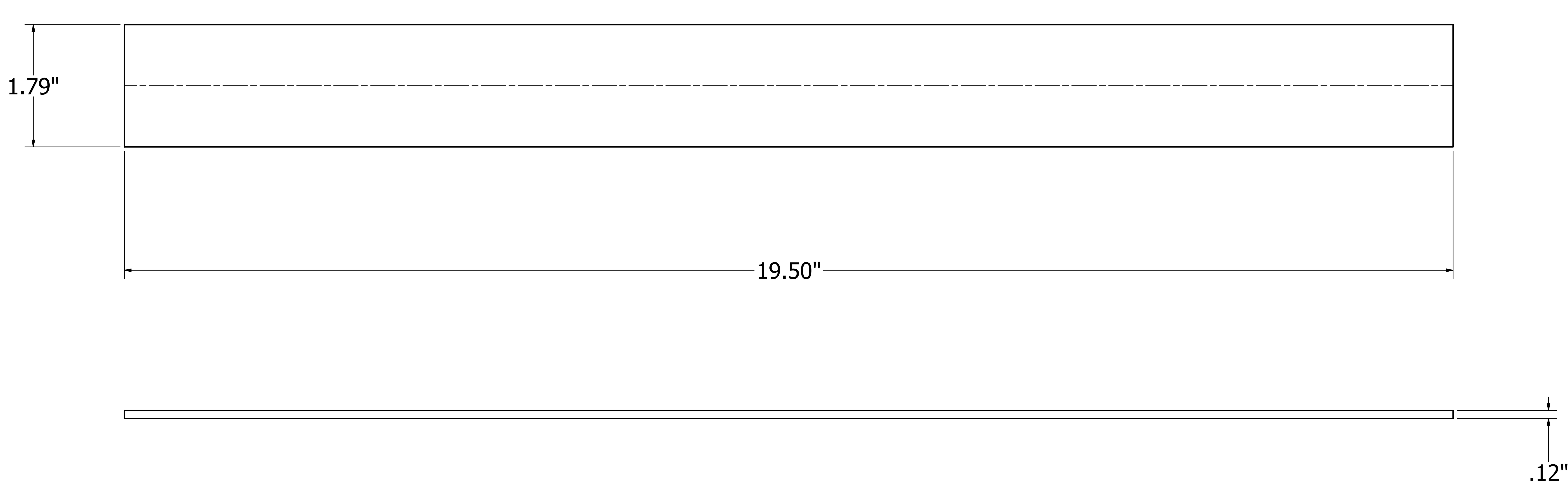
LH Shown
RH Opposite

DRAWN Jaybird	8/4/2016	
CHECKED		TITLE
QA		Side Panels
MFG		
APPROVED		SIZE D · DWG NO Side Panels · REV
		SCALE 0.13 : 1 · SHEET 1 OF 1



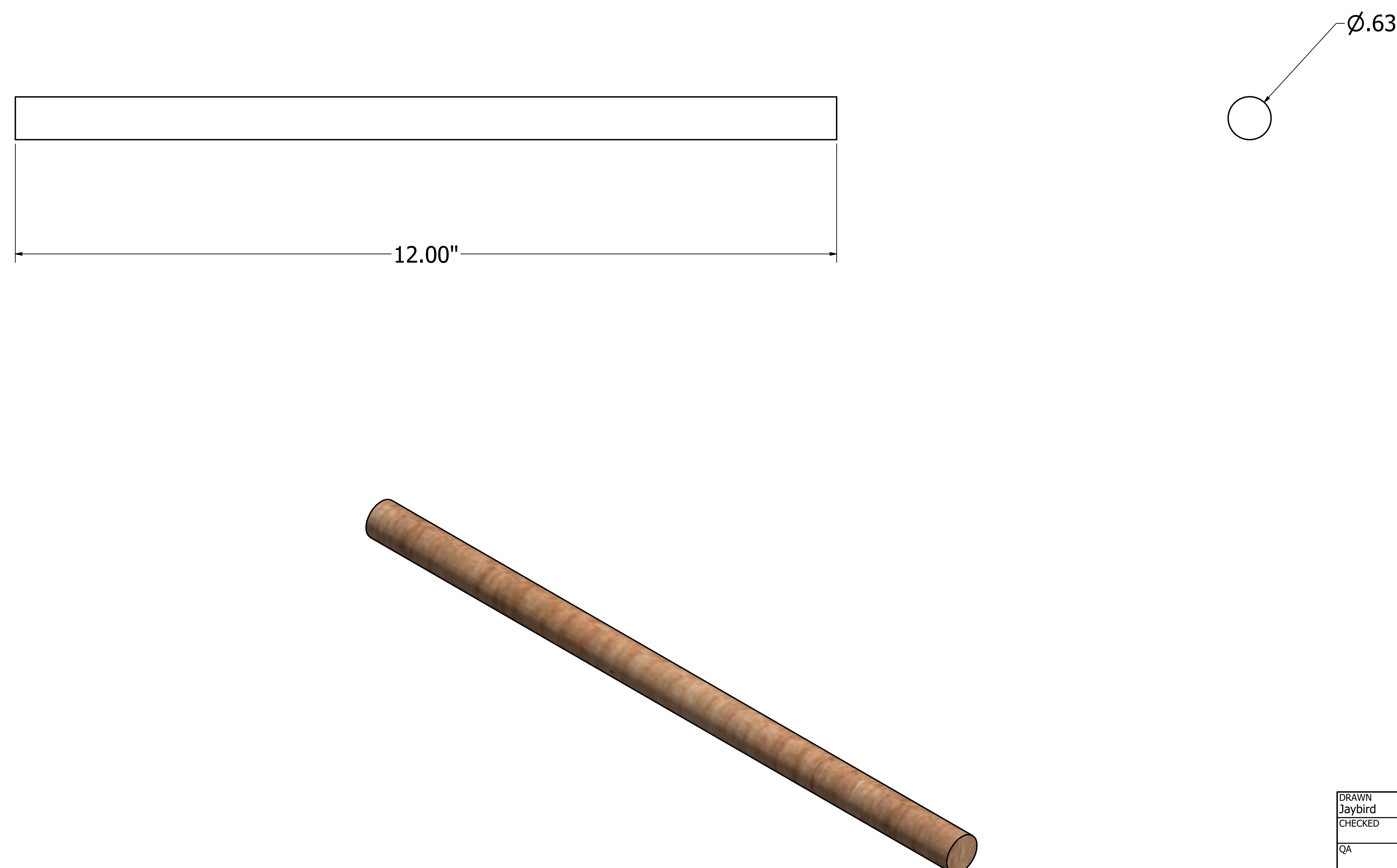
DRAWN Jaybird	8/4/2016			
CHECKED		TITLE		
QA		Slide2		
MFG				
APPROVED		SIZE D	DWG NO Slide2	REV
		SCALE 1 / 4		SHEET 1 OF 1

Material: Alluminum



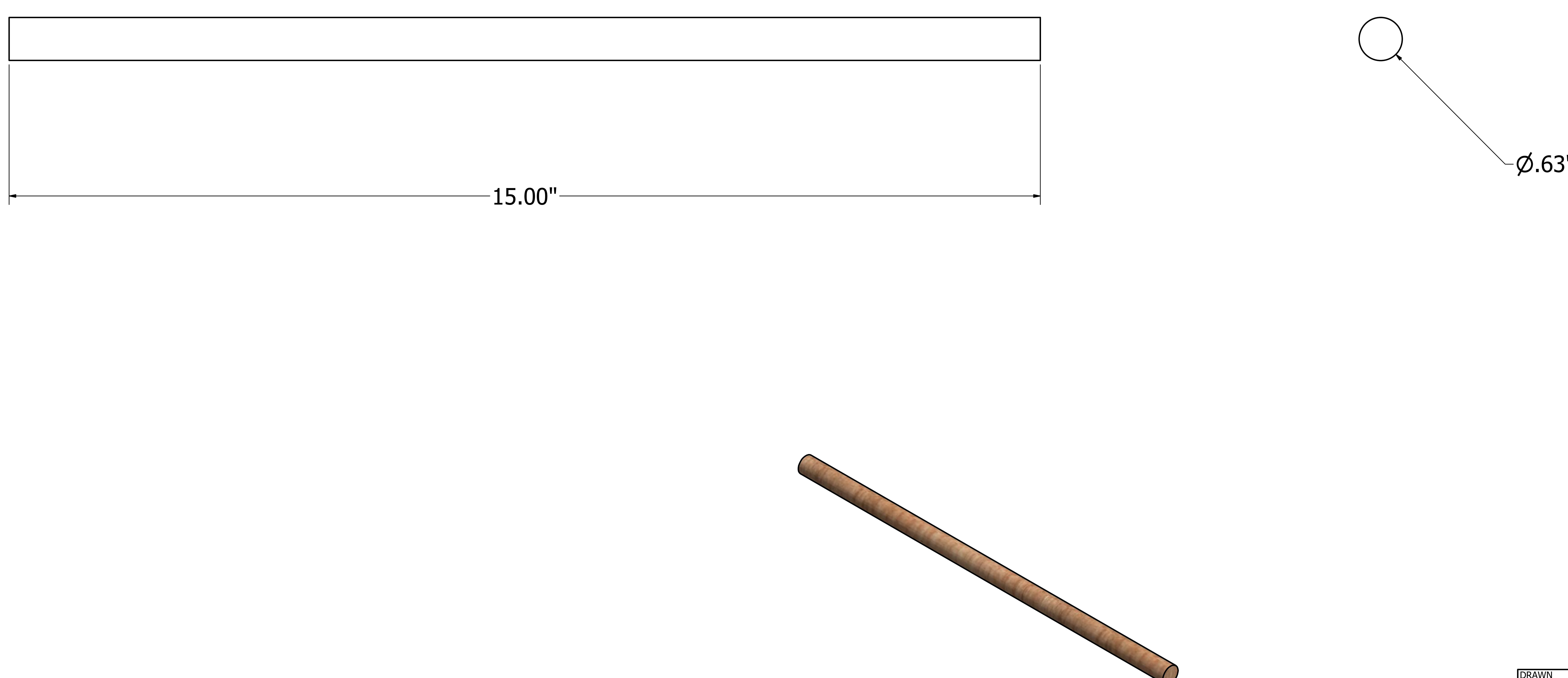
DRAWN Jaybird	8/3/2016	
CHECKED		TITLE
QA		Support Braces
MFG		
APPROVED		
SIZE D	DWG NO Support Braces	REV
SCALE 1 : 1		SHEET 1 OF 1

Material: Dowel Rod



DRAWN Jaybird	8/3/2016	
CHECKED		TITLE
QA		Short Support Rod
MFG		
APPROVED		SIZE D · DWG NO Support Rod1 · REV
		SCALE 1 : 1 · SHEET 1 OF 1

Material: Dowel Rod

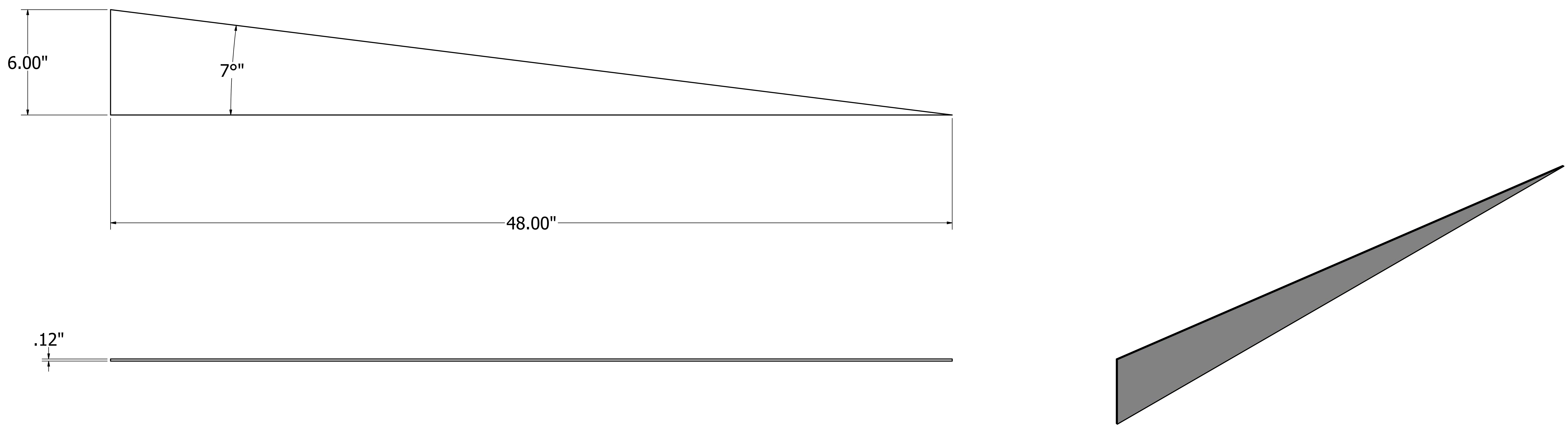


DRAWN Jaybird	8/3/2016	
CHECKED		TITLE
QA		Long Support Rod
MFG		
APPROVED		SIZE D · DWG NO Support Rod2 · REV
		SCALE 1 / 1 · SHEET 1 OF 1

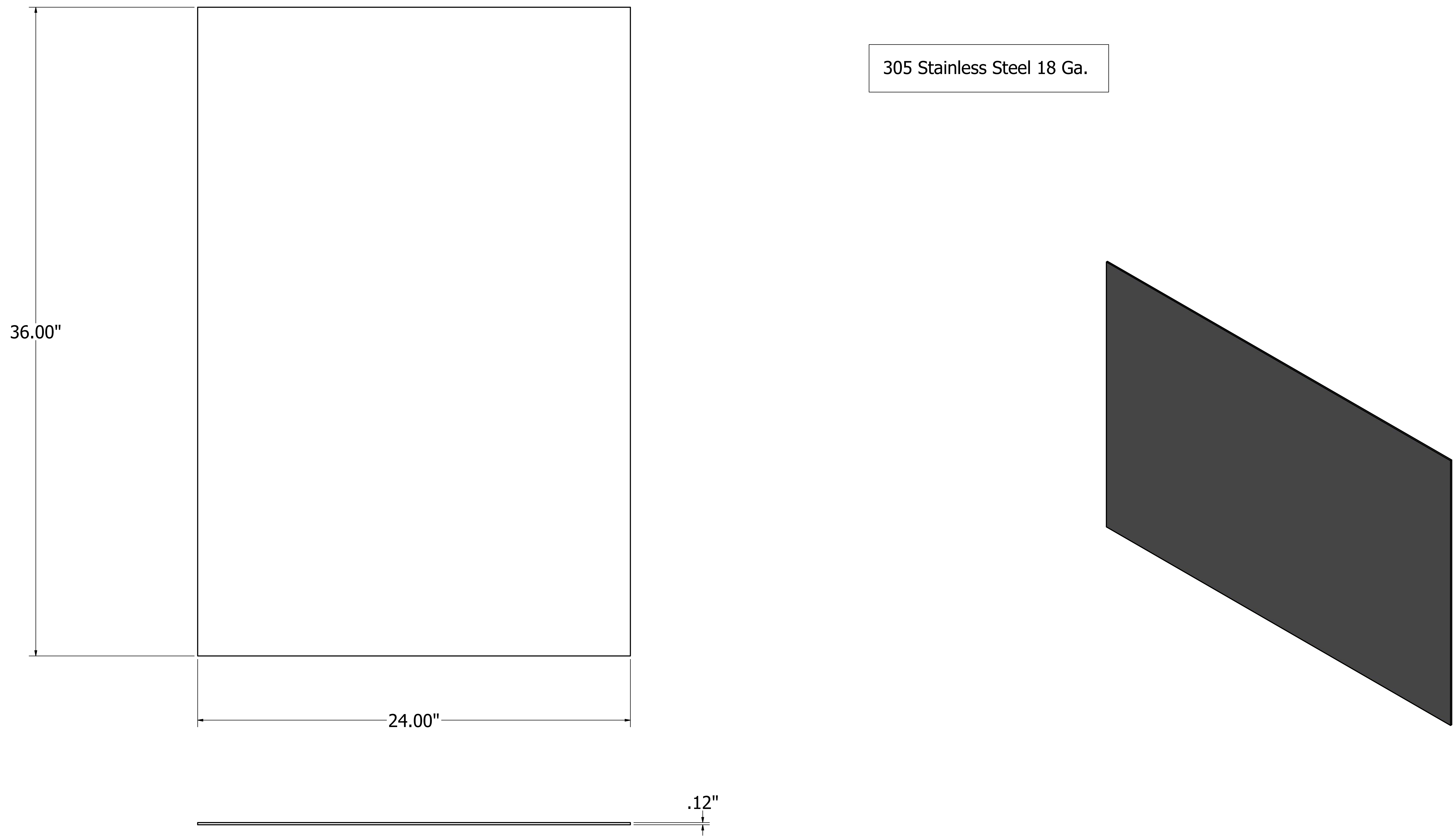

Ø.13"
19.50"
Ø.63"
7.00"
1.25"
1.50"
2.50"
2.56"
6.00"
.75"
1.50"
LH Shown
RH
Opposite
Material:
Plywood
DRAWN
Jaybird
8/3/2016
CHECKED
QA
MFG
APPROVED
TITLE
Tall Supports
SIZE
D
DWG NO
Tall Supports
REV
SCALE 1 / 2
SHEET 1 OF 1

LH Shown
RH Opposite

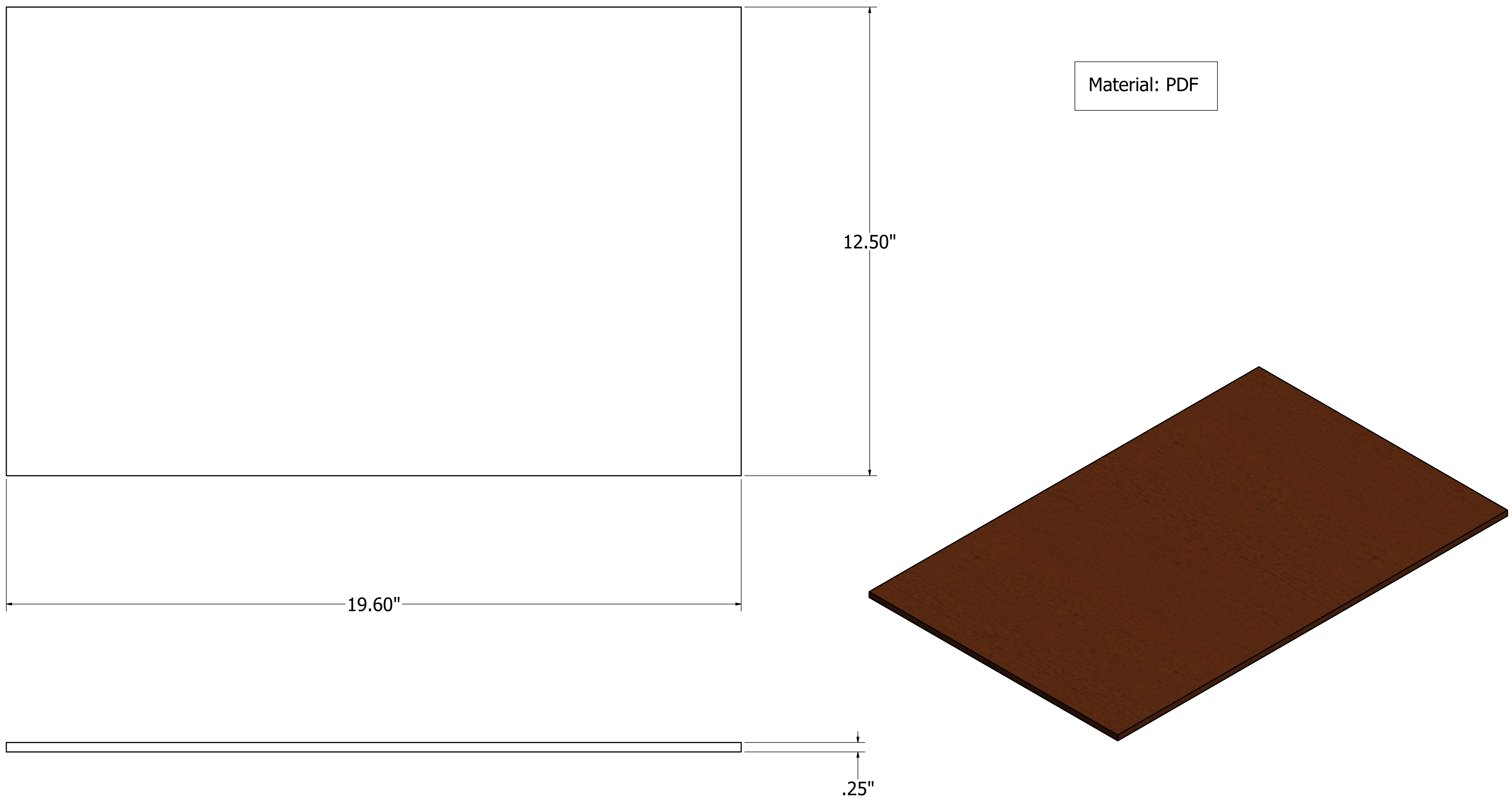
305 Stainless Steel 18 Ga.



DRAWN Jaybird	8/4/2016	
CHECKED		TITLE
QA		Top Angles
MFG		
APPROVED		SIZE D · DWG NO Top Angles · REV
		SCALE 1 / 4 · SHEET 1 OF 1

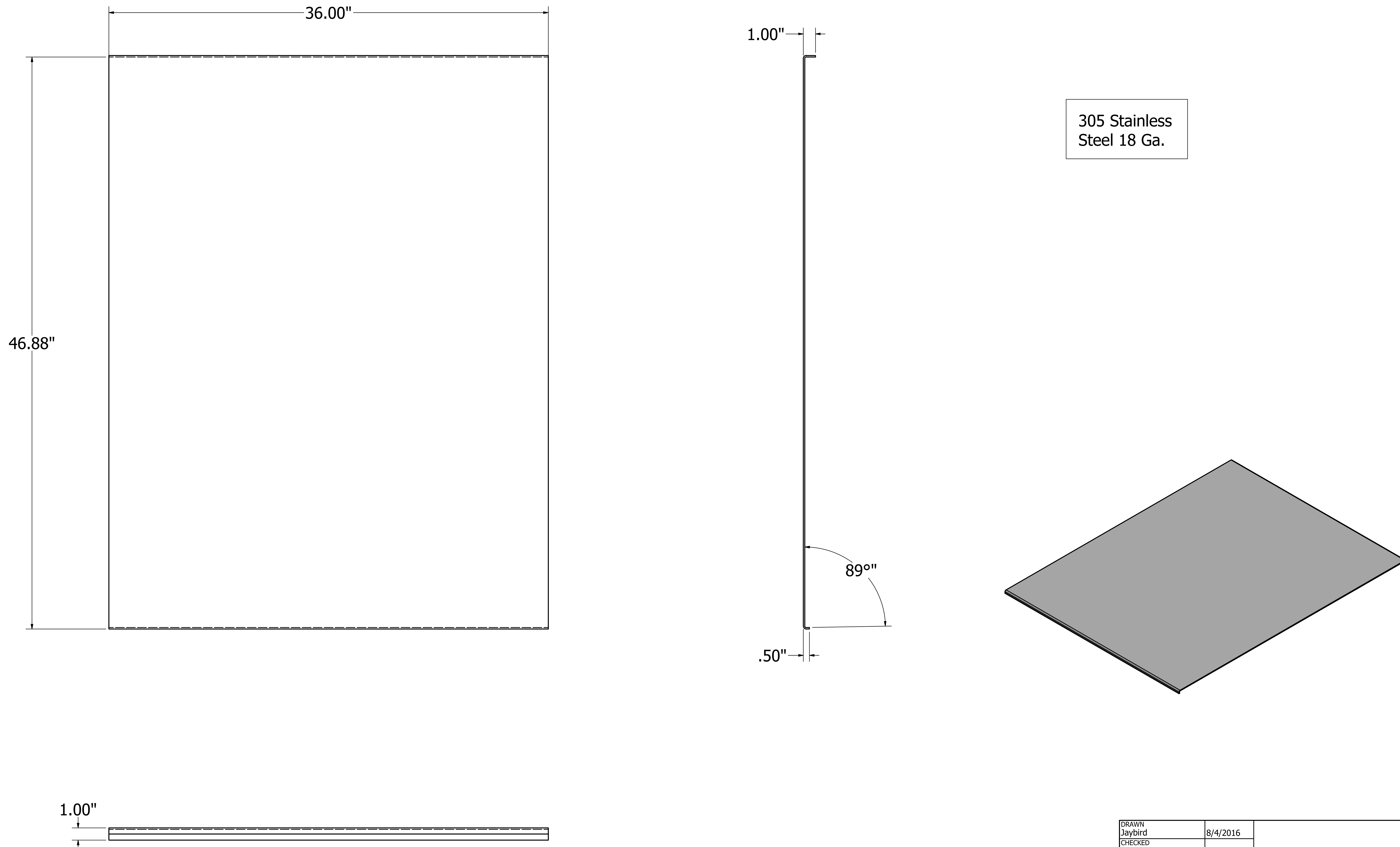


DRAWN Jaybird	8/4/2016	
CHECKED		TITLE
QA		Top Back
MFG		
APPROVED		SIZE D · DWG NO Top Back · REV
		SCALE 1 / 4 · SHEET 1 OF 1



DRAWN Jaybird	8/3/2016			
CHECKED		TITLE		
QA		Top Panel		
MFG				
APPROVED		SIZE D	DWG NO Top Pnael	REV
		SCALE 1 / 2		SHEET 1 OF 1


305 Stainless Steel 18 Ga.
36.00"
62.00"
.12"
DRAWN
Jaybird
8/4/2016
CHECKED
QA
MFG
APPROVED
TITLE
Top
SIZE
D
DWG NO
Top
REV
SCALE 1 / 4
SHEET 1 OF 1



DRAWN Jaybird	8/4/2016	
CHECKED		TITLE
QA		Water Slide
MFG		
APPROVED		
		SIZE D · DWG NO Water Slide · REV
		SCALE 0.14 : 1 · SHEET 1 OF 1