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Development of Discrete Size Measurement Methodologies for Motorcycle Helmets

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16. Abstract

FMVSS No. 218 defines the discrete size of a motorcycle helmet and requires the discrete size to be listed on the label. However, it does not specify where this measurement is taken within the helmet, and it does not provide a standard procedure for measuring this discrete size nor a tool to measure the size. In addition to the discrete size, there is no standard procedure for determining the helmet positioning index (HPI) used to align the helmet on the headform for measurements and testing. Thus, the objective of this research was to develop procedures to determine HPI and to measure discrete size of motorcycle helmets. NHTSA identified a few areas to focus efforts on while developing an objective, repeatable, and non-destructive method for measuring the discrete size of a motorcycle helmet. These areas were defining a location where the discrete size is to be taken, developing a tool to take the measurements, and incorporating use of alternative headforms (ASTM International F2220 headforms). Four methods for measuring discrete size and one method for determining the HPI were developed and evaluated in this study. NHTSA's Vehicle Research and Test Center (VRTC) evaluated a procedure for determining the HPI and compared results to the HPIs provided by the helmet manufacturer. The four methods to measure discrete size were to measure internal circumference with a handheld scissor tool, measure internal circumference with a modified scissor tool, and measure internal lateral and longitudinal distances with and without compression of the comfort liner. The internal lateral and longitudinal measurement methods did not give clear or consistent results and therefore were not continued with as part of the full study. Measurement differences were small between modified and handheld scissor tool methods; the largest difference was 1.5 cm between the two methods. A repeatability analysis for both tools used to measure discrete size was completed; the maximum percentage of coefficient of variation for the handheld scissor tool was 0.9 percent and for the modified scissor tool was 1.4 percent.

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Executive Summary

Federal Motor Vehicle Safety Standard (FMVSS) No. 218, "Motorcycle helmets," specifies minimum performance requirements for helmets designed for use by motorcyclists and other motor vehicle users. The FMVSS No. 218 final rule[1] dated May 13, 2011, provided a definition of discrete size of a helmet, and required the discrete size to be listed on the label. The discrete size was defined as "a numerical value that corresponds to the diameter of an equivalent circle representing the helmet interior in inches (± 0.25 inches) or to the circumference of the equivalent circle in centimeters (± 0.64 cm)." However, the final rule did not specify where the diameter is measured from within the helmet. And, it did not provide a consistent or standard procedure for measuring this discrete size. There is also no known industry wide tool or method that is used to measure the size. In addition to the discrete size, there is no standard procedure for determining the helmet positioning index (HPI) used to align the helmet on the headform for measurements and testing.

Thus, the objective of this research was to develop procedures to determine HPI and to measure discrete size of motorcycle helmets. NHTSA identified a few areas to focus efforts on while developing an objective, repeatable, and non-destructive method for measuring the discrete size of a motorcycle helmet. These areas were defining a location where the discrete size is to be taken, developing a tool to take the measurements, and incorporating use of alternative headforms (ASTM International F2220 headforms).

Four methods for measuring discrete size and one method for determining the HPI were developed and evaluated in this study. NHTSA's Vehicle Research and Test Center (VRTC) evaluated a procedure for determining the HPI and compared results to the HPIs provided by the helmet manufacturer. The manufacturer supplied HPIs listed were based on a DOT headform, while VRTC measured HPI using an ASTM headform; however, both were measurements of the distance from the basic plane to brow opening. The HPI difference between manufacturer supplied and VRTC measured ranged from 6 to 29 mm. Because the HPI locates a measurement plane used in all methods in this study, having an accurate HPI was needed to ensure consistent discrete size measurements. Additionally, a consistent method of determining HPI would ensure consistency between manufacturer supplied HPI and that determined in the test lab.

The four methods to measure discrete size were measure internal circumference with a handheld scissor tool, measure internal circumference with a modified scissor tool, and measure internal lateral and longitudinal distances with and without compression of the comfort liner. The internal lateral and longitudinal measurement methods included in the preliminary study with four helmets did not give clear or consistent results and therefore were not continued with as part of the full study. The modified scissor tool included a helmet holder, a fixture to hold the scissor tool level, a torque wrench to control compression, and a rotary potentiometer to digitally output the size measurement. For each method, three independent measurements were taken and recorded. The largest of these three measurements was determined to be the discrete size. Corresponding ASTM headforms were identified from the measured size and compared with the size determined by the manufacturer's discrete size label.

The modified scissor tool allowed for more control over the compression of the comfort liner, however measurement differences were small between the modified and handheld scissor tool

[1] 76 FR 28132.

methods. The largest difference was 1.5 cm between the two methods, which is less than three percent of the average headform circumference of 57 cm. Torques achieved with the modified scissor tool ranged from 2.3 to 4.9 N-m, with an average of 3.6 N-m.

A repeatability analysis for both tools (handheld scissor tool and modified scissor tool) used to measure discrete size was completed. The maximum percentage of coefficient of variation (%CV) for the handheld scissor tool was 0.9 percent and for the modified scissor tool was 1.4 percent. Both tools had excellent repeatability, with the handheld scissor tool having a slightly lower %CV. However, this lower %CV could be due to the handheld scissor tool being recorded to the nearest 0.25 cm while the modified scissor tool was recorded to the nearest 0.1 cm.

Discrete size measurement results showed that most of the helmets measured did not correspond to the size supplied on the label. Helmets that did not correspond to the label size tended to be one smaller headform size than the label indicated; this could be due to how the helmet is measured, including where the measurement was taken. It is unknown how manufacturers determine the label size. Following the robust procedure with the ASTM headforms could provide consistency in the manufacturer supplied and test lab measured discrete sizes.

1 Introduction

Federal Motor Vehicle Safety Standard (FMVSS) No. 218, "Motorcycle helmets," specifies minimum performance requirements for helmets designed for use by motorcyclists and other motor vehicle users. The FMVSS No. 218 final rule[2] dated May 13, 2011, provided a definition of discrete size of a helmet, and required the discrete size to be listed on the label. The discrete size was defined as "a numerical value that corresponds to the diameter of an equivalent circle representing the helmet interior in inches (± 0.25 inches) or to the circumference of the equivalent circle in centimeters (± 0.64 cm)." However, the final rule did not specify where the diameter is measured from within the helmet. And it did not provide a consistent or standard procedure for measuring this discrete size. There is also no known industry wide tool or method that is used to measure the size. In addition to the discrete size, there is no standard procedure for determining the helmet positioning index (HPI) used to align the helmet on the headform[3] for measurements and testing.

Thus, the objective of this research was to develop procedures to determine HPI and to measure discrete size of motorcycle helmets. NHTSA identified a few areas to focus efforts on while developing an objective, repeatable, and non-destructive method for measuring the discrete size of a motorcycle helmet. These areas were defining a location where the discrete size is to be taken, developing a tool to take the measurements, and incorporating use of alternative headforms.

There are a large variety of motorcycle helmet sizes and shapes, and as a result, the discrete size that manufacturers list on the label may correspond to a headform size that is not the best fit for that helmet. A helmet that does not fit well on a headform could influence test results. Department of Transportation (DOT) headforms are used with helmets that have a range of discrete sizes, and because there are only three headforms (small, medium, large) specified in FMVSS No. 218, helmets that vary in size by as much as five centimeters would be tested on the same headform. For example, a 55 cm helmet can fit on a medium sized headform, but a 60 cm helmet can also fit on the medium sized headform.

NHTSA is researching ASTM International F2220 headforms that includes six headform sizes, labeled A, C, E, J, M, and O. These headforms will be referred to as ASTM headforms throughout this report. Table 1 shows the sizing table used for determining what ASTM headform size is associated with a discrete size.[4]

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[2] 76 FR 28132.

[3] Per S6.1 of FMVSS No. 218, the appropriate headform must be selected before subjecting the helmet to the testing sequence. The discrete size is used to determine which size headform to use.

[4] Snell Foundation. (2014, October 1). *2015 standard for protective headgear for use with motorcycles and other motorized vehicles* (Report No. M2015). https://smf.org/standards/m/2015/M2015FinalFinal.pdf

Table 1. ASTM Headform Sizing Table

		Largest Size Specified (cm) and Largest US Hat Size					
		< 51 *< 6 3/8*	52 - 53 *6 4/8 – 6 5/8*	54 - 56 *6 6/8 - 7*	57 - 59 *7 1/8 – 7 3/8*	60 - 61 *7 4/8 – 7 5/8*	> 61 *> 7 5/8*
Smallest Size Specified (cm)	< 51	A	A - C	A - E	A - J	A – M	A - O
	52-53		C	C - E	C - J	C – M	C - O
	54-56			E	E - J	E – M	E - O
	57-59				J	J – M	J - O
	60-61					M	M - O
	> 61						O

The location to measure the discrete size used in this study was a line in the interior of the helmet along the reference plane. The reference plane is established in FMVSS No. 218 and is defined as a plane above and parallel to the basic plane[5], on a reference headform or test headform, at a specified distance per headform size. The reference plane is part of the test line and is shown in Figure 1. FMVSS No. 218 does not currently incorporate ASTM headforms, therefore reference plane and reference headform are terms specified based on DOT headforms as defined in FMVSS No. 218.

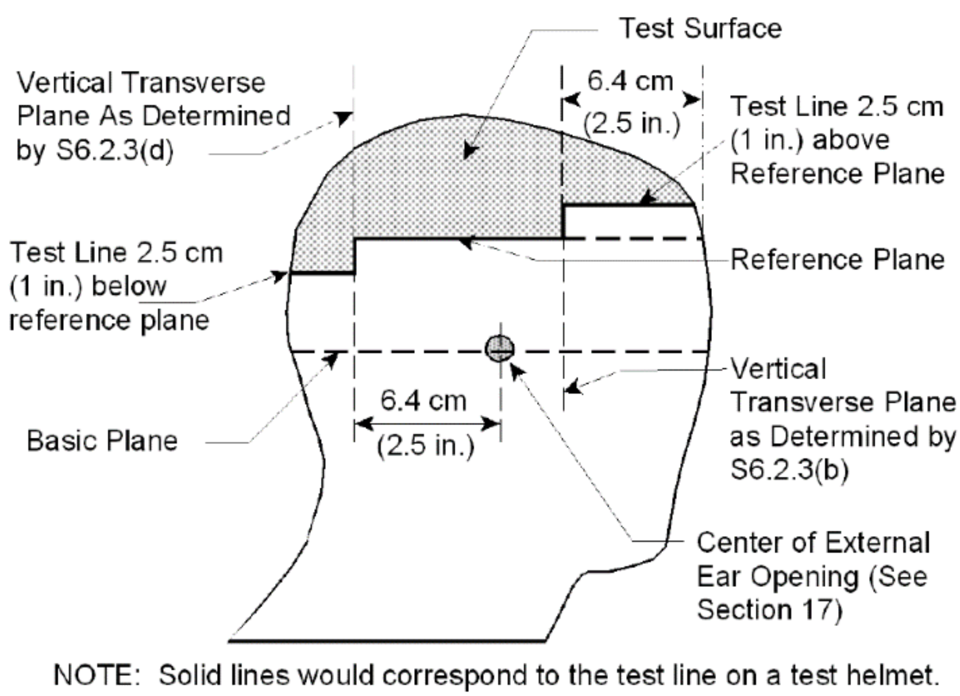


Figure 1. FMVSS No. 218 Reference Plane

[5] Per S4 of FMVSS No. 218, the basic plane is a plane through the centers of the right and left external ear opening and the lower edge of the eye sockets of a reference headform or test headform.

One tool that was identified and evaluated for measuring helmet internal circumference is a handheld hat-sizing scissor tool. This tool requires the user to squeeze the tool handles to compress the helmet comfort liner until maximum force is reached. Maximum force is subjective depending on the user, which could influence the discrete size measurement. In addition to the handheld scissor tool, the VRTC developed and evaluated other methods to create an objective test procedure for measuring the discrete size of motorcycle helmets including measuring internal circumference with a modified scissor tool and measuring internal lateral and longitudinal distances with and without compression of the comfort liner.

1.1 DOT Versus ASTM Headforms Comparison

During the setup for this study, VRTC observed differences between the DOT and ASTM headforms. One of these was the location of the reference plane in relation to the basic plane. The DOT headform's reference plane (labeled Ref. Plane on the left diagram) is located approximately 34.9 mm above the ASTM headform's reference plane (labeled Ref. Plane on the right diagram) as shown in Figure 2. Due to the difference in reference planes between the two headform types, NHTSA decided to establish a "test reference plane" on the ASTM headform that translated the location of the FMVSS No. 218 reference plane to the ASTM headform so that the same measurement methodologies could be applied.

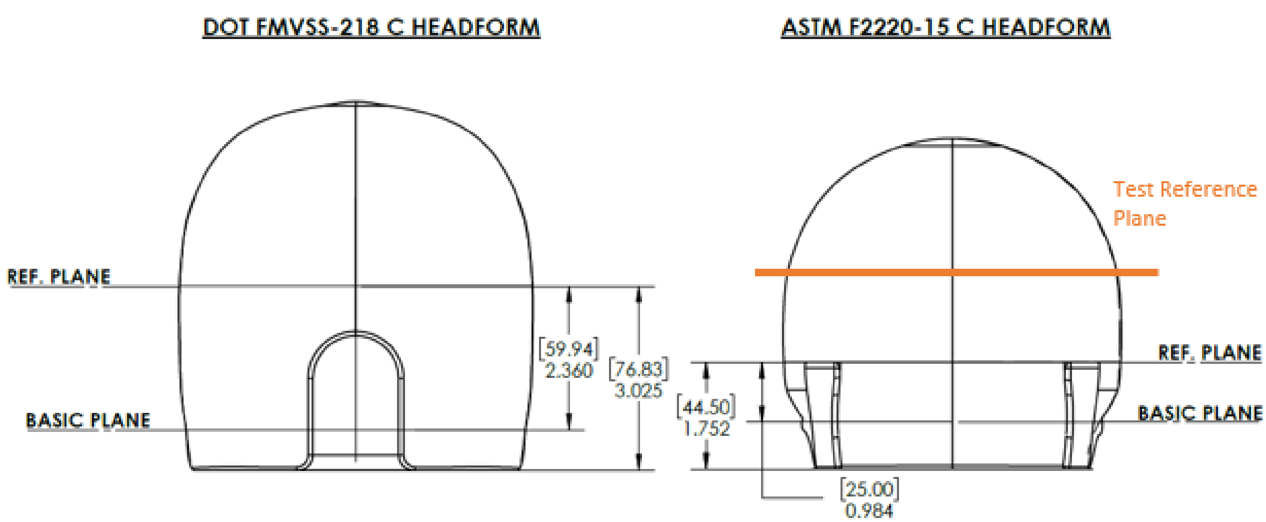


Figure 2. DOT Versus ASTM Headform

To find the location of the test reference plane for each of the six ASTM headforms, the distance from the basic to reference plane on the three DOT headforms was determined. Then ASTM headforms were categorized into each of the DOT headform sizes by weight and circumference: A and C with small, E between medium and small, J with medium, M and O with large. In each category, the distance from the basic plane to reference plane on the ASTM headform was subtracted from the distance between the basic to reference plane on the DOT headform. This difference was then averaged and added to the ASTM headform distance from the basic plane to reference plane to create a new test reference plane. The new test reference plane distance from the basic plane for each of the six ASTM headforms is shown in Table 2. Appendix A shows the measurement comparisons and calculations. The corresponding test reference plane was then marked on each of the six ASTM headforms (shown in Figure 3) using the measurements in Table 2.

Table 2. Test Reference Plane to Basic Plane Distances (ASTM Headform)

ASTM Headform	**Distance of Test Reference Plane From Basic Plane of ASTM Headform (cm)**
A	5.3
C	5.4
E	5.7
J	6.0
M	6.4
O	6.5

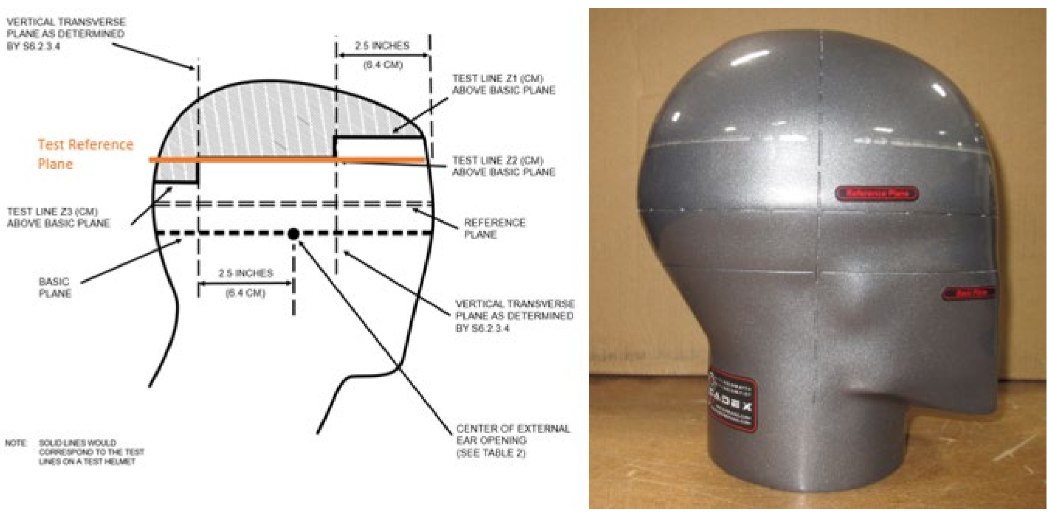


Figure 3. Test Reference Plane Location

2 Methods

The objective of this research was to develop procedures to determine HPI and to measure discrete size of motorcycle helmets. Determining the HPI is required before any of the other discrete size measurements methods can be used. Section 2.1 details the method for HPI determination, and the discrete size measurements methods are described in Sections 2.2.1 through 2.2.4. The full procedure used, including each method evaluated, can be found in Appendix B.

2.1 HPI Determination

The first step to determine HPI[6] was to select a headform. The ASTM headform was selected based on the numerical value on the helmet label. If two headforms fell in the label range, the measurement was completed with each headform. For example, a helmet with label size 59 – 60 cm would fit both size J and size M ASTM headforms and would be measured with each. The helmet was placed on the headform, a 4.5 kg (10 lb) weight was placed on the apex of the helmet to apply a vertical load[7], and the helmet was aligned to be centered along the mid-sagittal plane of the headform.

The brow opening was positioned so it was parallel to the basic plane and passed the peripheral vision requirement of FMVSS No. 218. An inclinometer was placed on the brow opening to set it parallel (+/- 1 degree). The peripheral vision was checked using a 25.4-mm (1-inch) square brow block and a peripheral vision go/no-go gauge with the go/no-go angle of 105 degrees (Figure 4). This procedure, developed with OVSC, was used to position each helmet for HPI measurement (see section 4.2 and Appendix B). The HPI was then measured and recorded as the distance from the basic plane to the brow opening along the mid-sagittal plane. The angle of the brow opening was also recorded after it was set to parallel (zero +/- 1 degree).

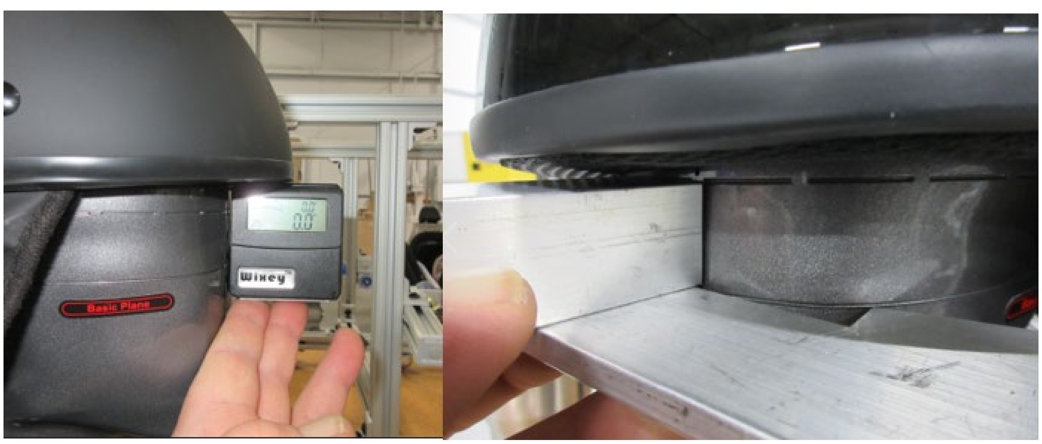


Figure 4. Setting Brow Level (Left) and Peripheral Vision Requirement Check (Right)

[6] Per S4 of FMVSS No. 218, the helmet position index (HPI) is the distance, as specified by the manufacturer, from the lowest point of the brow opening at the lateral midpoint of the helmet to the basic plane of a reference headform, when the helmet is firmly and properly positioned on the headform.
[7] As required by S6.2.2 of FMVSS 218.

2.2 Discrete Size Measurement Methods

Regardless of method used, the test reference line needed to be drawn on the exterior of the helmet. Only the reference line was needed for the discrete size study, not the full test line as no testing was conducted as a part of this research. The test reference line was drawn by referencing step 12.5.5 of TP-218-07.[8] To draw the test reference line, the helmet was positioned on the headform using the HPI determined in the previous section. Then, the test reference line was drawn on the exterior of the helmet using a marker stand that was aligned to the test reference plane on the headform prior to placing the helmet (Figure 5).

Figure 5. Test Reference Line Drawn on Helmet

The procedure described above allows for the test reference line to be drawn on the exterior of the helmet. However, the discrete size is measured on the interior surface. Therefore, the line was translated to the interior of the helmet to remove the subjectivity of aligning the measurement tool with a line on the exterior. To do this, a marking tool and procedure were developed by VRTC. A drawing package for the marking tool can be found in Appendix C.

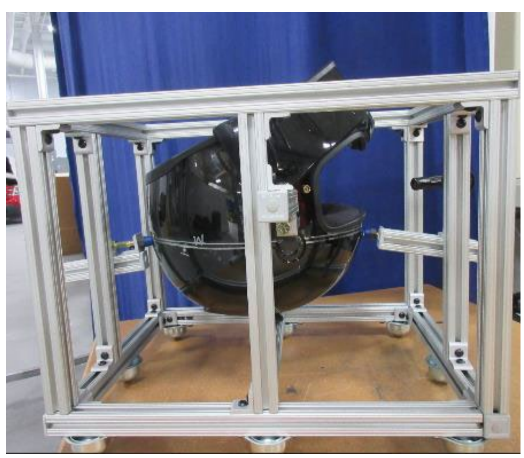


Figure 6. Helmet Holder Box

[8] TP-218-07. https://www.nhtsa.gov/vehicle-manufacturers/test-procedures

The marking tool consisted of a helmet holder box (Figure 6) and marking jig (Figure 7). The helmet holder box was set on rollers and snuggly held and positioned a helmet with the helmet opening upward and the external test reference line level to horizontal.

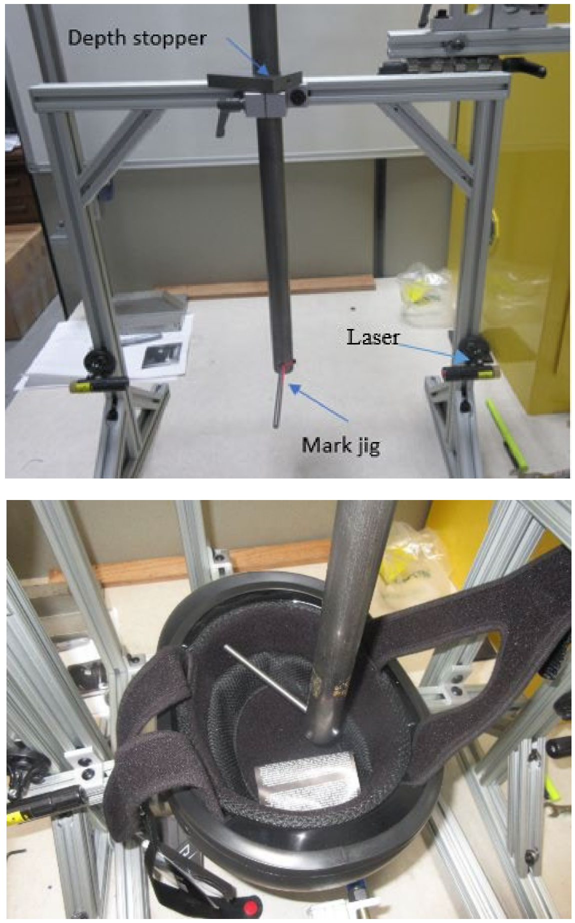


Figure 7. Marking Jig Used to Mark Internal Reference Line

The marking jig consisted of a mark jig, depth stopper, and alignment lasers (Figure 7). With the helmet placed in the holder box and the external test reference line horizontal, the lasers were aligned to the height of the external test reference line. The helmet and holder were then removed, and the mark jig was lowered to align with the lasers; the depth stopper was adjusted to this depth. Then, the mark jig was raised, the helmet and holder placed below the jig, and the jig lowered into the helmet until the depth stopper was reached. The pointer of the mark jig could be rotated to allow the user to draw the internal test reference line along the same plane as the external test reference line (Figures 7 and 8).

Figure 8. Internal Test Reference Line

After the internal test reference line was drawn, the discrete size was measured. Four discrete size measurement methods were evaluated as part of this study. The four methods were measure internal circumference with a handheld scissor tool, measure internal circumference with a modified scissor tool, measure internal lateral and longitudinal distances without compression of the comfort liner, and measure internal lateral and longitudinal distances with compression of the comfort liner. Each method was evaluated by measuring the discrete size at the internal test reference line. For each method, three independent measurements were taken and recorded. The largest of these three measurements was determined to be the discrete size as this reflects the size of the helmet due to the natural compression of the comfort liner during regular use. The full procedure used, including each method evaluated, can be found in Appendix B.

2.2.1 Handheld Scissor Tool

One method used during this research was to measure helmet internal circumference with a handheld scissor tool. The scissor tool consists of a 24 mm wide and 620 mm long flexible metal band that is connected to a scissor handle mechanism (Figure 9).

Figure 9. Handheld Scissor Tool

To use this tool, the operator aligned the center of the band with the internal test reference line and squeezed the handles until the comfort liner was fully compressed using estimated hand force (Figure 10). The internal circumference measurement was read from the scale on the tool, to the nearest ¼ cm. For this study, two tools were available for use, a medium size tool (scale measures 48 – 62 cm) and a large size tool (scale measures 55 to 68 cm). The large size tool was used for helmets whose size exceeded the scale on the medium tool.

Figure 10. Measuring Discrete Size With Handheld Scissor Tool

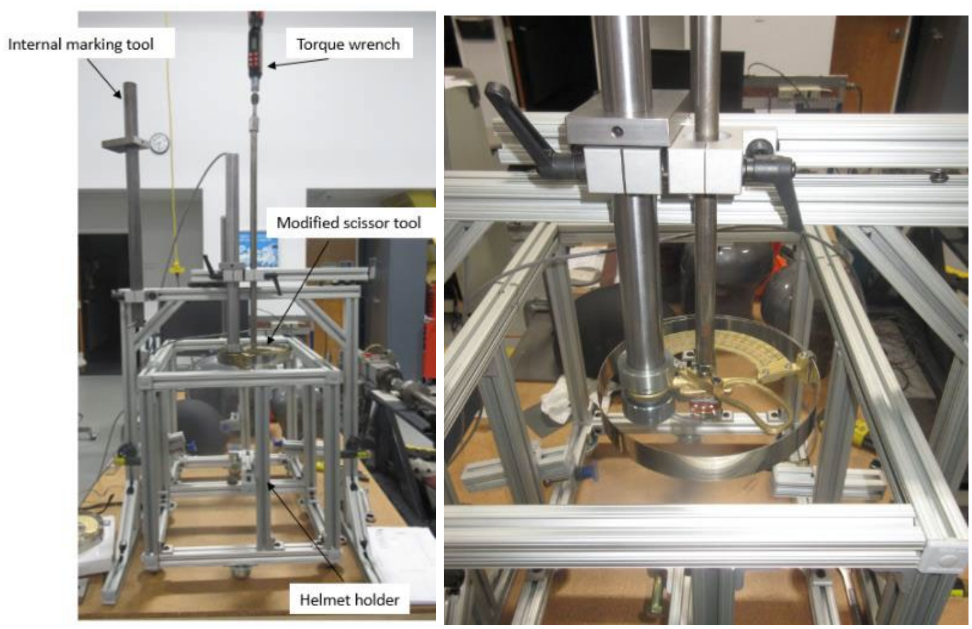


Figure 11. Modified Scissor Tool and Helmet Holder

2.2.2 Modified Scissor Tool

Another method was to measure helmet internal circumference with a modified scissor tool. This method used a modified scissor tool and the helmet holder fixture. Modifications made to the scissor tool included fixing the tool to a stand so that it was held horizontally, adding a depth stopper, adding a torque wrench to control and measure compression, and adding a rotary potentiometer to digitally record the discrete size measurement (Figure 11). A drawing package of the modified scissor tool can be found in Appendix C.

To use the modified scissor tool, the lasers were aligned with the external test reference line on the helmet while it was held horizontally in the helmet holder box. Then the helmet and holder were removed, and the modified scissor tool was lowered until the center of the tool band aligned with the lasers. The depth stopper was set, and the tool was raised so that the helmet could be moved back into place. Then the tool was lowered into the helmet until the depth stopper was reached, aligning the tool with the test reference line (Figure 12). The torque wrench was applied to the top of the shaft to expand the scissor tool until the maximum compression of the liner was reached; the value of the torque required for this action was recorded. Three independent measurements of both the torque and discrete size were collected. The time-history of the rotary potentiometer data was collected, and the maximum value recorded. Both a medium (scale measures 48 to 62 cm) and large (scale measures 55 to 68 cm) tool were fabricated for use with this method.

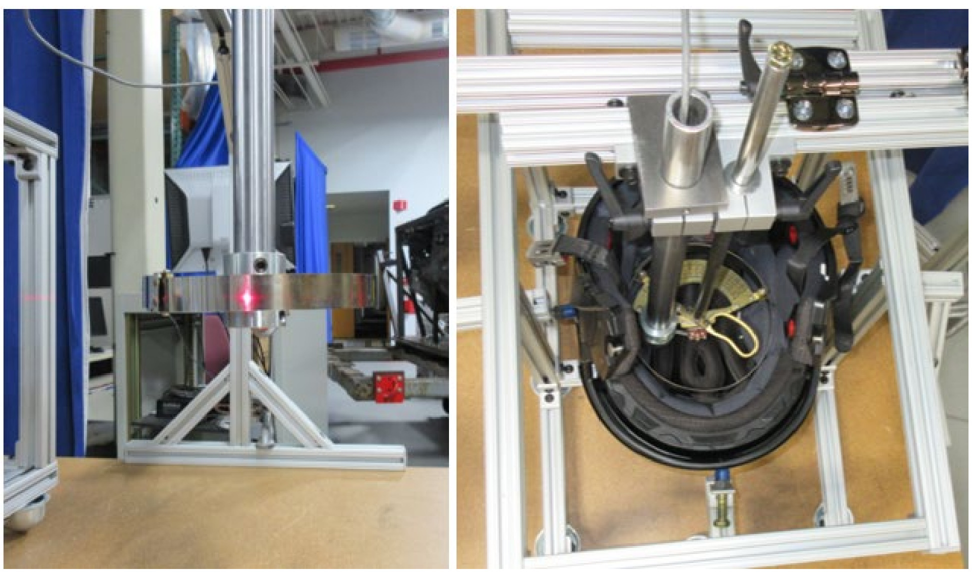


Figure 12. Aligning Modified Scissor Tool and Taking Measurement

2.2.3 Internal Measurement (Uncompressed)

The third method was to measure the internal lateral and longitudinal distances without compression of the comfort liner. This was done on the interior of the helmet at the internal test reference line, using a firm joint inside caliper to measure width and a tape measure to record numerical distance in millimeters (Figure 13).

Figure 13. Internal Measurement (Uncompressed)

The headforms were also measured in order to select a headform for comparison with the other methods. Headforms were measured using a coordinate measuring machine (CMM, FARO). Measurements were made for the lateral and longitudinal distances at the intersection of the test reference plane with the transverse and mid-sagittal planes, respectively (Figure 14). Results of these measurements can be found in Table 3.

Table 3. Lateral and Longitudinal Headform Reference Table

Headform	Lateral (mm)	Longitudinal (mm)
A	<138.1	<176.8
C	138.1 - 144.6	176 - 181
E	144.6 - 156.8	181 - 192.6
J	156.8 - 165.7	192.6 - 203.2
M	165.7 - 171.9	203.2 - 207.2
O	>171.9	>207.2

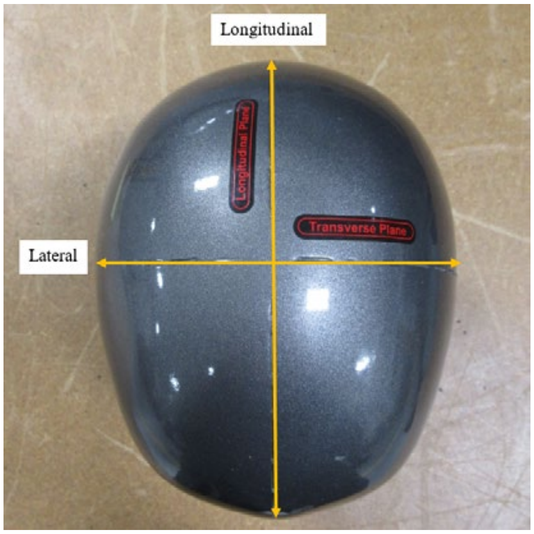


Figure 14. Lateral and Longitudinal Headform Measurement

2.2.4 Internal Measurement (Compressed)

The fourth method used the same method for longitudinal and lateral distances as the previous method 3, except in this method the comfort liner was compressed. To compress the liner, the modified scissor tool and torque wrench were used. The tool was torqued and held expanded while the measurements were taken (Figure 15). The torque used for this was recorded. Table 3 was used to determine the corresponding headform for comparisons.

Figure 15. Internal Measurement (Compressed)

3 Test Matrix

Helmets selected for this study are shown in Table 4. Helmets were selected to include a variety of manufacturers, types, and sizes. Three of each helmet type (half helmet, full-face, open face, and modular) were selected. Sizes of helmets ranged from small to double extra-large (XXL) and varied within helmet type.

The study was completed in two phases. Four helmets were used in the preliminary study and were measured with each of the four methods. In the full study, only the handheld and modified scissor tools were used. The internal longitudinal and lateral measurement methods in the preliminary study did not give clear or consistent results and therefore were not continued with as part of the full study.

Four of the helmets were labeled with manufacturer determined discrete size that correlated to two different ASTM headforms: Biltwell Lane Splitter, Cyber U-72, Icon Airflite, and Fuel WS001. Therefore, the evaluation of discrete size for each of these helmets was repeated twice: once on each of the two applicable ASTM headforms.

Table 4. Matrix of Helmets

Preliminary Study

	Brand	Model	Size	Type	Label Size	ASTM (Reference) Headform Used	Methods			
1	Speed and Strength	SS510	S	Half Helmet	55-56 cm	E	Handheld Scissor Tool	Modified Scissor Tool	Internal Measurement (Uncompressed)	Internal Measurement (Compressed)
2	Biltwell	LANE SPLITTER	L	Full-Face	59-60 cm	J				
						M				
3	AFX	FX-75	M	Open Face	58-59 cm (outside label), 57-58cm (inside label)	J				
4	Scorpion	EXO-AT950	M	Modular	57-58 cm	J				

Full Study

5	HCI	100 (M)	M	Half Helmet	57-58 cm	J	Handheld Scissor Tool	Modified Scissor Tool
6	Cyber Helmets	U-72 Solid (XL)	XL	Half Helmet	61-62 cm	M		
						O		
7	Bell	Qualfier	M	Full-Face	57-58 cm	J		
8	Icon	Airflite	L	Full-Face	59-60 cm	J		
						M		
9	Fuel	WS001	L	Open Face	59-60 cm	J		
						M		
10	Scorpion	EXO-Belfast	XXL	Open Face	63-64 cm	O		
11	LS2	Vortex	S	Modular	56 cm	E		
12	HJC	RPHA 90	L	Modular	58-59 cm	J		

4 Results

4.1 HPI Results

VRTC evaluated a procedure for determining the HPI and compared results to the HPIs provided by the helmet manufacturer. Table 5 shows the results from the HPI measurements. The manufacturer supplied HPIs listed were based on a DOT headform, while VRTC measured HPI using an ASTM headform; however, both were measurements of the distance from the basic plane to brow opening.

Table 5. HPI Results

Brand	Model	Size	Type	Mfg HPI (mm) - DOT Headform	ASTM (Reference) Headform Used	VRTC Measured HPI Angle (Degrees)	VRTC Measured HPI (mm) – ASTM Headform	HPI Difference (mm)
Speed and Strength	SS510	S	Half Helmet	70	E	0	41	29
HCI	100 (M)	M	Half Helmet	54	J	0	35	19
Cyber Helmets	U-72 Solid (XL)	XL	Half Helmet	53	M	0	29	24
					O	0	42	11
Bell	Qualfier	M	Full-Face	58	J	0	47	11
Biltwell	LANE SPLITTER	L	Full-Face	49	J	0	39	10
					M	0	42	7
Icon	Airflite	L	Full-Face	28	J	0	35	-7
					M	0	47	-19
AFX	FX-75	M	Open Face	47	J	0	36	11
Fuel	WS001	L	Open Face	52	J	0	31	21
					M	0	42	10
Scorpion	EXO-Belfast	XXL	Open Face	54	O	0	33	21
LS2	Vortex	S	Modular	na	E	0	31	na
Scorpion	EXO-AT950	M	Modular	49	J	0	43	6
HJC	RPHA 90	L	Modular	40	J	0	31	9

The difference in HPI between what the manufacturer supplied and what VRTC measured ranged from 6 mm to 29 mm. While 29 mm is a large difference, differences could be due to differences in the headforms used or the method for measuring the HPI. It is unknown exactly how the manufacturers determine this measurement and therefore could not be clearly compared. The large differences between the manufacturer supplied HPI and what VRTC measured emphasizes the need to clearly define and set the HPI to ensure consistent discrete size measurements and the resulting headform for use in testing.

4.2 Discrete Size Measurement Results

For each discrete size measurement method evaluated, three independent measurements were taken and recorded. The largest of these three measurements was reported as the discrete size. All measurements were made by one operator using each of the tools. The appropriate corresponding ASTM headform size was reported based on the maximum of the three measurements. Full results can be found in Appendix D.

Results from the discrete size measurements are shown in Table 6. In the method columns, the corresponding headform size based on the discrete size measured is listed in the table with the discrete size recorded in centimeters in parenthesis. Red highlighted cells indicate when the measured headform size did not correspond to the label indicated size. For example, the HCI 100 label size (57 to 58 cm) indicated use of a J headform, while the measurement (55.5 cm, 56 cm) resulted in an E headform. Yellow highlighted cells indicate when the measured size partially corresponded to the label size; for example, the Icon Airflite label size (59 to 60 cm) indicated use of both the J and M reference headforms, while the discrete size measured on the M reference headform (57.25 cm) led to a J headform, which partially corresponded to the label. Green highlighted blocks mean the measured headform size did correspond to the label indicated size.

In the internal measurement columns, corresponding headform sizes were identified separately by lateral measurement and by longitudinal measurement; these distinctions are shown in Appendix D. In Table 6, the smallest of the headform sizes identified is shown as the resulting headform. For the internal measurement columns, red highlighted blocks indicate neither direction's measurement corresponded to the label indicated size, yellow highlight means one of the two direction's headform corresponded to the label indicated size, and green highlight means both headform measurements corresponded to the label indicated size. For example, the Speed and Strength SS510 used an E headform (label size 55 to 56 cm); the internal measurement without compression had a lateral measurement resulting in a C headform and a longitudinal measurement resulting in an E headform, which was partially corresponded to the label indicated size.

Table 6. Discrete Size Measurement Results

	Brand	Model	Type	Size	Label Size	ASTM Reference Headform Selected From Label	Handheld Scissor Tool Headform Size	Modified Scissor Tool Headform Size	Internal Msmt Uncompressed	Internal Msmt Compressed
Preliminary Study										
1	Speed and Strength	SS510	Half Helmet	S	55-56 cm	E	E (54)	E (54.4)	C	E
2	Biltwell	LANE SPLITTER	Full-Face	L	59-60 cm	J	J (58.5)	J (58.8)	E	J
						M	J (59.25)	J (59.6)	J	J
3	AFX	FX-75	Open Face	M	58-59 cm (outside label), 57-58cm (inside label)	J	E (56)	E (56.3)	C	J
4	Scorpion	EXO-AT950	Modular	M	57-58 cm	J	E (55.5)	E (55.9)	A	E
Full Study										
5	HCI	100 (M)	Half Helmet	M	57-58 cm	J	E (55.5)	E (56.0)		
6	Cyber Helmets	U-72 Solid (XL)	Half Helmet	XL	61-62 cm	M	J (58.25)	J (58.4)		
						O	M (60)	J (59.7)		
8	Bell	Qualfier	Full-Face	M	57-58 cm	J	J (57)	J (57.7)		
7	Icon	Airflite	Full-Face	L	59-60 cm	J	E (56.75)	E (55.5)		
						M	J (57.25)	E (56.3)		
9	Fuel	WS001	Open Face	L	59-60 cm	J	E (55)	E (55.5)		
						M	J (58)	E (56.5)		
10	Scorpion	EXO-Belfast	Open Face	XXL	63-64 cm	O	J (57.75)	J (57.4)		
11	LS2	Vortex	Modular	S	56 cm	E	C (53)	C (53.5)		
12	HJC	RPHA 90	Modular	L	58-59 cm	J	J (58)	J (57.4)		

(discrete size in cm)

Key
- does not match label size
- partial match to label size
- matches label size

From the Table 6 results, it was observed that the headform size resulting from discrete size measurements tended to be one smaller headform size than the helmet label indicated; however, best fit analysis was not completed. Therefore, it is not known whether the measured size gave any better or worse fit to the headform than the label.

The discrete size measurement values were compared between the handheld and modified scissor tools and are shown in Figure 16. Measurement differences were small between the two tools; the largest difference was for the Fuel WS001 with reference headform M, which had a difference of 1.5 cm. The smallest difference of 0.2 cm was seen with the Cyber U-72 helmet with reference headform M. Only three helmets had discrete size measurements that resulted in different headforms selected between the modified and handheld scissor tools. The Icon Airflite with reference headform M, which had a difference in measurement of 0.9 cm between the two tools, the Cyber with reference headform O that had a difference of 0.3 cm, and the Fuel WS001 with reference headform M that had a difference of 1.5 cm. Additionally, as shown in Figure 16, some discrete size measurements were close to the top or bottom of a headform size range meaning that a small variation in the discrete size measurement could result in a different headform being selected.

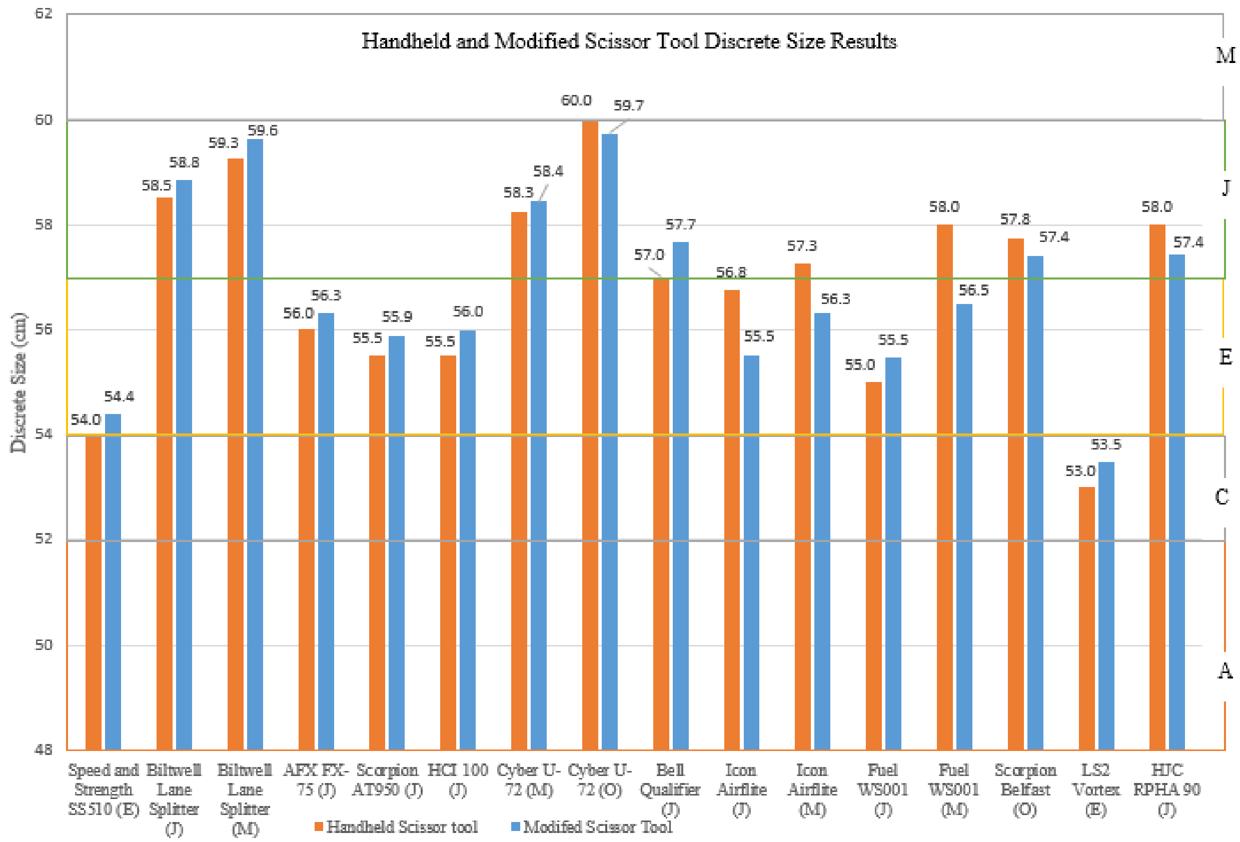


Figure 16. Comparison of Handheld and Modified Scissor Tools Discrete Size Results

4.3 Discrete Size Measurements Repeatability

A repeatability analysis for both tools (handheld scissor tool and modified scissor tool) used to measure discrete size was completed. The results are shown in Table 7 and Table 8 for the handheld scissor tool and modified scissor tool, respectively. In each table the three repeat measurements, average, standard deviation, and percent coefficient of variation (%CV) are shown. The %CV was calculated using the standard deviation divided by the average and multiplying by 100 to get a percentage.

Measurements and %CVs for each helmet measured with the handheld scissor tool are shown in Table 7.

Table 7. Repeatability Analysis With Handheld Scissor Tool

					Handheld Scissor Tool					
Brand	**Model**	**Size**	**Type**	**ASTM (Reference) Headform Used**	**Msmt 1 (cm)**	**Msmt 2 (cm)**	**Msmt 3 (cm)**	**Average**	**St. Dev.**	**%CV**
Speed and Strength	SS510	S	Half Helmet	E	**54.0**	**54.0**	**54.0**	54.0	0.0	0.0%
HCI	100 (M)	M	Half Helmet	J	**55.5**	55.0	55.0	55.2	0.3	0.5%
Cyber Helmets	U-72 Solid (XL)	XL	Half Helmet	M	**58.3**	58.0	58.0	58.1	0.1	0.2%
				O	**60.0**	**60.0**	**60.0**	60.0	0.0	0.0%
Bell	Qualfier	M	Full-Face	J	**57.0**	**57.0**	**57.0**	57.0	0.0	0.0%
Biltwell	Lane Splitter	L	Full-Face	J	**58.5**	**58.5**	58.0	58.3	0.3	0.5%
				M	59.0	**59.3**	59.0	59.1	0.1	0.2%
Icon	Airflite	L	Full-Face	J	**56.8**	56.3	56.5	56.5	0.3	0.4%
				M	56.8	56.5	**57.3**	56.8	0.4	0.7%
AFX	FX-75	M	Open Face	J	**56.0**	**56.0**	**56.0**	56.0	0.0	0.0%
Fuel	WS001	L	Open Face	J	**55.0**	**55.0**	**55.0**	55.0	0.0	0.0%
				M	**58.0**	57.8	57.0	57.6	0.5	0.9%
Scorpion	EXO-Belfast	XXL	Open Face	O	**57.8**	57.3	57.3	57.4	0.3	0.5%
LS2	Vortex	S	Modular	E	**53.0**	**53.0**	**53.0**	53.0	0.0	0.0%
Scorpion	EXO-AT950	M	Modular	J	**55.5**	**55.5**	**55.5**	55.5	0.0	0.0%
HJC	RPHA 90	L	Modular	J	57.8	**58.0**	**58.0**	57.9	0.1	0.2%

Measurements and %CVs for each helmet measured with the modified scissor tool are shown in Table 8.

Table 8. Repeatability Analysis With Modified Scissor Tool

					Modified Scissor Tool					
Brand	**Model**	**Size**	**Type**	**ASTM (Reference) Headform Used**	**Msmt 1 (cm)**	**Msmt 2 (cm)**	**Msmt 3 (cm)**	**Average**	**St. Dev.**	**%CV**
Speed and Strength	SS510	S	Half Helmet	E	54.1	54.0	**54.4**	54.1	0.2	0.4%
HCI	100 (M)	M	Half Helmet	J	55.5	55.8	**56.0**	55.8	0.2	0.4%
Cyber Helmets	U-72 Solid (XL)	XL	Half Helmet	M	**58.4**	58.3	**58.4**	58.4	0.1	0.1%
				O	**59.7**	59.4	59.5	59.5	0.2	0.3%
Bell	Qualfier	M	Full-Face	J	**57.7**	57.4	57.6	57.5	0.1	0.2%
Biltwell	Lane Splitter	L	Full-Face	J	57.7	57.3	**58.8**	57.9	0.8	1.4%
				M	**59.6**	58.8	58.6	59.0	0.5	0.9%
Icon	Airflite	L	Full-Face	J	54.3	**55.5**	54.4	54.7	0.7	1.2%
				M	55.7	**56.3**	55.8	55.9	0.3	0.6%
AFX	FX-75	M	Open Face	J	55.3	55.1	**56.3**	55.6	0.6	1.1%
Fuel	WS001	L	Open Face	J	**55.5**	55.1	55.4	55.3	0.2	0.4%
				M	**56.5**	56.2	56.1	56.3	0.2	0.4%
Scorpion	EXO-Belfast	XXL	Open Face	O	57.0	**57.4**	57.0	57.1	0.2	0.4%
LS2	Vortex	S	Modular	E	**53.5**	53.2	53.2	53.3	0.2	0.3%
Scorpion	EXO-AT950	M	Modular	J	55.7	**55.9**	55.1	55.6	0.4	0.8%
HJC	RPHA 90	L	Modular	J	56.9	**57.4**	**57.4**	57.2	0.3	0.5%

The maximum %CV for the handheld scissor tool was 0.9 percent and for the modified scissor tool was 1.4 percent. Both tools had excellent repeatability[9,10] with the handheld scissor tool having a slightly lower %CV. However, this could be due to the handheld scissor tool being recorded to the nearest 0.25 cm while the modified scissor tool was recorded to the nearest 0.1 cm.

[9] From literature, the closer the %CV is to zero, the more precise the estimate is. *Uncertainty and how we measure it for our surveys* - Office for National Statistics (ons.gov.uk) www.ons.gov.uk/methodology/methodologytopicsandstatisticalconcepts/uncertaintyandhowwemeasureit

[10] Often, responses with a %CV less than five percent are considered highly repeatable. *THOR-50M Repeatability and Reproducibility of Qualification Tests* (bts.gov). https://rosap.ntl.bts.gov/view/dot/64430

5 Discussion

5.1 HPI Considerations

The difference between the manufacturer supplied and VRTC measured HPIs ranged from 6 mm to 29 mm. To determine if positioning the helmet differently would give different results, VRTC looked at comparisons of the helmets where the label gave two headform sizes and therefore two test reference lines on the helmet, as shown in Figure 17.

Figure 17. Helmet With Two Test Reference Lines

Table 9 shows the four helmets where two reference headforms were used. The distance between the external test reference lines was measured and recorded. In all but the Fuel helmet, a smaller difference between test reference lines on the headform corresponded to smaller difference in the measured discrete size. On average, a difference of 8 mm between the test reference lines resulted in 1.0 cm difference in discrete size with the modified tool and 1.5 cm difference with the handheld scissor tool. This demonstrates that the differences in placement of the line on the helmet could change the measured discrete size, which in turn could influence the headform size used for testing. Additionally, it shows that determining the HPI, and the associated procedure, could affect the discrete size when using the measurement methods developed in this report. However, with a standardized procedure and tool, there could be better consistency in HPI and discrete size measurements.

Table 9. Comparison of Reference Line Location and Measured Discrete Size

Brand	Model	Size	Type	ASTM (Reference) Headform Used	Difference Between Test Reference Lines	Handheld Scissor Tool		Modified Scissor Tool	
						Measured Size at Reference Plane (cm) (Max)	Difference Between Measured Size (cm)	Measured Size at Reference Plane (cm) (Max)	Difference Between Measured Size (cm)
Cyber Helmets	U-72 Solid (XL)	XL	Half Helmet	M	15 mm	58.25	-1.8	58.4	-1.3
				O		60		59.7	
Biltwell	LANE SPLITTER	L	Full-Face	J	7 mm	58.5	-0.8	58.8	-0.8
				M		59.25		59.6	
Icon	Airflite	L	Full-Face	J	5 mm	56.75	-0.5	55.5	-0.8
				M		57.25		56.3	
Fuel	WS001	L	Open Face	J	5 mm	55	-3.0	55.5	-1.0
				M		58		56.5	
				Average	8 mm		-1.5		-1.0

The angle of the brow opening of the helmet could be set at zero degrees consistently; however, there was some subjectivity with placing the inclinometer on the helmet, especially with helmets that had an uneven surface at the brow opening. Additionally, it was observed that when the helmets were placed following this procedure, they did not always appear to be in the correct position. When this occurred, the helmet appeared to have been designed for a slight brow angle, and when placed according to FMVSS No. 218, the helmet appeared to be tilted too far forward.

5.2 Size Comparisons

In terms of discrete size measurements, when measuring with the handheld scissor tool, out of 16 measurements, 4 corresponded to the label, 4 partially corresponded to the label, and 8 did not correspond to the label. Out of the 16 measurements made using the modified scissor tool methods, 4 corresponded to the label, 1 partially corresponded to the label, and 11 did not correspond to the label. When measuring the internal lateral and longitudinal distances without compression, of the five measurements, two partially corresponded to the label and three did not corresponded to the label. Out of the five measurements for the internal measurement with compression method, two corresponded to the label and three partially corresponded to the label.

The internal longitudinal and lateral measurement methods in the preliminary study did not give clear or consistent results and therefore were not continued with as part of the full study. For example, the Scorpion EXO-AT950 was measured using the internal measurement without compression method and the resulting headform sizes were size A from the lateral measurement and size J from the longitudinal measurement. These headform sizes do not correspond and were two headform sizes apart. Therefore, it was not clear which headform size would be the best fit for the helmet. Of the ten sets of measurements done, only four resulted in the lateral and longitudinal measurement indicating the same headform size.

Most of the helmets measured did not correspond to the size supplied on the label. Headforms that did not correspond the label size headform tended to be one smaller headform size than the label indicated. However, in the future, there could be consistency between the label and measured discrete sizes if manufacturers used ASTM headforms and a standardized procedure.

5.3 Compression of the Comfort Liner

One of the uncertainties identified with using the handheld scissor tool for measuring discrete size was the subjectivity of compressing the comfort liner. A torque wrench was added to the modified scissor tool to quantify the amount of compression of the liner. During the study, the torque was recorded for each discrete size measurement with the modified scissor tool as well as the internal measurement with compression. Torque ranged from 2.3 to 4.9 N-m, with an average of 3.6 N-m. Differences in torque can be attributed to differences in shape and padding in the helmets. Torque values can be found in Appendix D. Recording the torque during the measurement or defining a target torque could be used in the future. Overall, the modified scissor tool method allowed for more control over the compression of the comfort liner and provided similar results as the handheld scissor tool method.

6 Summary

The objective of this research was to develop procedures to determine HPI and to measure discrete size of motorcycle helmets. NHTSA identified a few areas to focus efforts on while developing an objective, repeatable, and non-destructive method for measuring the discrete size of a motorcycle helmet. These areas were defining a location where the discrete size is to be taken, developing a tool to take the measurements, and incorporating use of alternative headforms.

VRTC evaluated a procedure for determining the HPI and compared results to the HPIs provided by the helmet manufacturer. The manufacturer supplied HPIs listed were based on a DOT headform, while VRTC measured HPI using an ASTM headform; however, both were measurements of the distance from the basic plane to brow opening. The HPI difference between manufacturer supplied and VRTC measured ranged from 6 mm to 29 mm. Having a consistent method of determining HPI would ensure consistency between manufacturer supplied HPI and that determined in the test lab.

Four methods for measuring discrete size were developed and evaluated in this study. The four methods to measure discrete size were measure internal circumference with a handheld scissor tool, measure internal circumference with a modified scissor tool, and measure internal lateral and longitudinal distances with and without compression of the comfort liner. The internal lateral and longitudinal measurement methods included in the preliminary study with four helmets did not give clear or consistent results and therefore were not continued with as part of the full study.

The modified scissor tool allowed for more control over the compression of the comfort liner however measurement differences were small between modified and handheld scissor tool methods; the largest difference was 1.5 cm between the two methods.

A repeatability analysis for both tools (handheld scissor tool and modified scissor tool) used to measure discrete size was completed. The maximum %CV for the handheld scissor tool was 0.9 percent and for the modified scissor tool was 1.4 percent. Both tools had excellent repeatability, with the handheld scissor tool having a slightly lower %CV. However, this could be due to the handheld scissor tool being recorded to the nearest 0.25 cm while the modified scissor tool was recorded to the nearest 0.1 cm.

Discrete size measurement results showed that most of the helmets measured did not correspond to the size supplied on the label. Helmets that did not correspond to the label size tended to be one smaller headform size than the label indicated; this could be due to how the helmet is measured, including where the measurement is taken. It is unknown how manufacturers determine the label size. Following the robust procedure with the ASTM headforms could provide consistency in the manufacturer supplied and test lab measured discrete sizes.

Appendix A: DOT Versus ASTM Headform Comparison

Location of Reference Plane From Basic Plane

DOT Headforms				ASTM Headforms					
Size	**Distance (cm)**	**Weight (kg)**	**Circumference (mm)**	**Size**	**Distance (cm)**	**Weight (kg)**	**Circumference (mm)**	**Difference (cm)**	**Distance of Test Reference Plane From Basic Plane of ASTM Headform (cm)**
S	5.36	3.5	490	A	2.40	3.1	495	2.91	5.3
				C	2.50	3.6	515	2.91	5.4
M	5.99	5.0	560	E	2.60	4.1	535	3.08	5.7
				J	2.75	4.7	575	3.24	6.0
L	6.41	6.1	600	M	2.90	5.6	605	3.46	6.4
				O	3.00	6.1	625	3.46	6.5

Distance Column: Refers to the distance between the reference plane and the basic plane.

Difference Column: Refers to the difference between the DOT and ASTM distance columns.

ASTM A and C: The differences are the average of the distances for these two headforms subtracted from the DOT small headform distance, since the ASTM A and C headforms closely resemble the DOT small headform.

ASTM E: The difference is the ASTM E headform distance subtracted from the average of the DOT small and medium headform distances, since the ASTM E headform more closely resembles a headform in-between these DOT headforms.

ASTM J: The difference is the DOT medium headform distance minus the ASTM J headform distance since they resemble each other in circumference and weight.

ASTM M and O: The differences are the average of the distances for these two headforms subtracted from the DOT large headform distance, since the ASTM M and O headforms closely resemble the DOT large headform.

Appendix B: Discrete Size Measurement Procedure

Drawing Test Reference Line (Outside Surface of Helmet)

1. Condition helmets in ambient conditions.
2. Remove any non-permanent, non-essential accessories from helmet (e.g., remove visors from half helmet). Make notes of what was removed.
3. Using the reference label on helmet (supplied by manufacturer) select the correct ASTM reference headform using Table B-1. If the label numerical value falls into more than one headform size, the procedure will be followed using both headform sizes.

Table B-1. Headform Size Selection Chart

		Largest Size Specified (cm) and Largest US Hat Size					
		< 51 *< 6 3/8*	52 - 53 *6 4/8 – 6 5/8*	54 - 56 *6 6/8 - 7*	57 - 59 *7 1/8 – 7 3/8*	60 - 61 *7 4/8 – 7 5/8*	> 61 *> 7 5/8*
Smallest Size Specified (cm)	< 51	A	A - C	A - E	A - J	A – M	A - O
	52-53		C	C - E	C - J	C – M	C - O
	54-56			E	E - J	E – M	E - O
	57-59				J	J – M	J - O
	60-61					M	M - O
	> 61						O

4. After selecting the reference headform, place headform with basic, reference, and test reference planes horizontal on a rotating stand and align marker from drawing jig with the test reference line (Figure B-1).

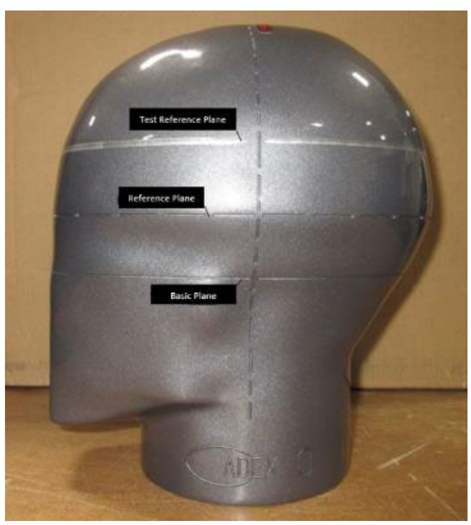


Figure B-1. Reference Headform with Test Reference Plane

5. Place helmet on the headform and apply a 4.5 kg (10 lb) static vertical load through the helmet's apex. Center the helmet laterally and seat firmly on the reference headform according to helmet positioning index (HPI).

a. The HPI is the distance from the lowest point of the brow opening at the lateral midpoint of the helmet to the basic plane of the reference headform. The HPI is used to ensure consistent and proper placement of the helmet on the headform.

1. Position the helmet onto the reference headform so that the brow opening is parallel to the basic plane and centered on the mid-sagittal plane and allows for the test reference line to remain on the outer shell when drawn.
2. Use an inclinometer, placed against the brow opening, to set the brow opening parallel to the basic plane, horizontal (0 degrees) +/- 1 degree.
3. Check the peripheral vision using the go/no-go gauge and brow block (25.4 mm (1 inch) block) measured at the intersection of the mid-sagittal and basic planes.
4. Record the angle measurement and note any observations about the angle measurement.
5. Record the distance from the lowest point of the brow opening to the basic plane at the front of the reference headform along the mid-sagittal plane of the headform ("VRTC measured HPI").
6. Maintain load in Step 5 and draw the "test reference line" on the outer surface of the helmet, as shown by the red line in Figure B-2. Use the line drawing jig to do this.

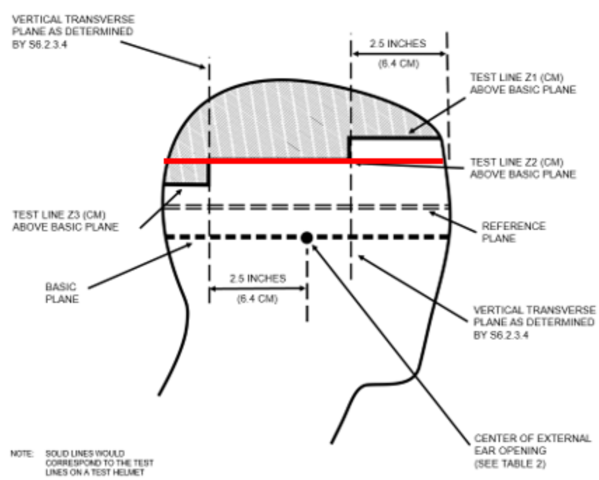


Figure B-2. Test Reference Line on Helmet

Drawing Internal Reference Line and Modified Scissor Tool Measurement

1. Place the helmet into the helmet holder. Align the test reference line on the outer shell of the helmet with the lasers so that the test reference line is horizontal. Once aligned, tighten the holder clamps so that the helmet is held firmly in place.

   a. Laser height may need adjusted depending on helmet.

2. Keeping the lasers in the same position, remove the helmet holder from below the fixture.
3. Lower the modified scissor tool so that the center of the band aligns with the lasers. Set the depth stopper.
4. Bring the tool back up and swing it out of the way. Slide over the marking jig. Lower the marking jig until aligned with the lasers. Set depth stopper.

5. Slide the marking jig up and slide the helmet back into place. Lower the jig until the depth stopper is reached and mark the inside of the helmet.
6. Remove the marking jig and swing the modified scissor tool down. Lower the tool into the helmet until it reaches the depth stopper.
7. The modified scissor tool has a torque wrench and rotary potentiometer. The potentiometer is calibrated to read the internal circumference measurement. Using the torque wrench apply the maximum force on the modified scissor tool to compress the comfort liner.
8. Record the torque value and internal circumference measurement.
9. Repeat Step 8 to take at least 3 independent measurements, with a three-minute wait time between repeats.
10. The maximum of all measured discrete sizes shall be designated the overall discrete size measurement for the helmet model.
11. Use the headform size selection chart (Table B-1) to determine the appropriate ASTM headform for testing.

Handheld Scissor Tool Measurement

1. Place the handheld scissor tool in the helmet and align the center of the band with the internal reference line marked in Step 5 of the Modified Scissor Tool Procedure.
2. Squeeze the scissor tool to compress the comfort liner to maximum compression.
3. Record the measurement from the scale on the tool to the nearest ¼ cm.

Internal Measurement (Uncompressed)

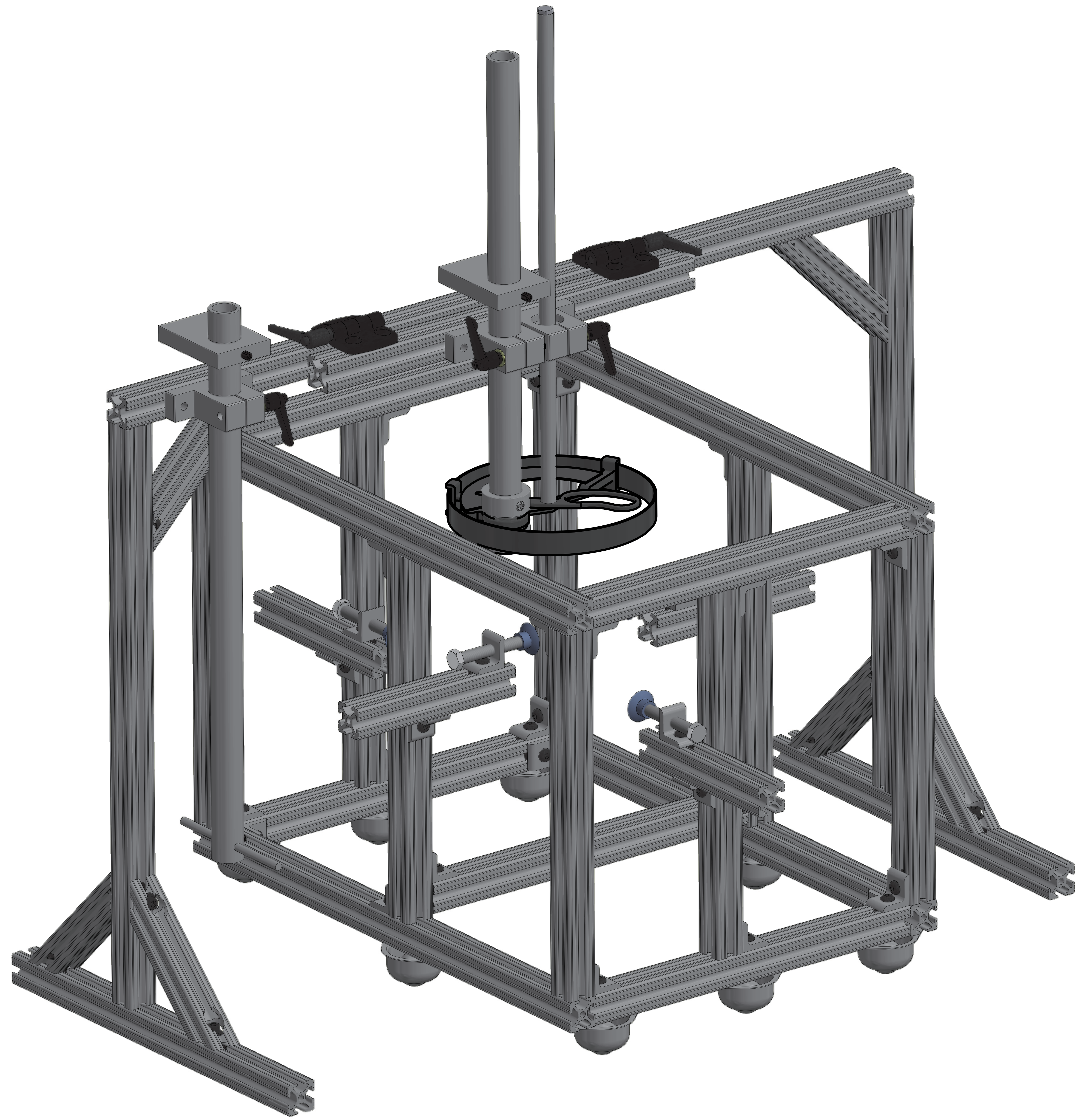
1. Using a firm joint inside caliper and flexible tape measure, measure the longitudinal and lateral distance at the internal test reference line without the comfort liner compressed.
2. Record both longitudinal and lateral distances.
3. Use the lateral and longitudinal headform size selection chart to determine appropriate ASTM headform for testing.

Internal Measurement (Compressed)

1. Using step 7 of the modified scissor tool measurement use the firm joint inside caliper and flexible tape measure to record the longitudinal and lateral distances with the comfort liner compressed.
2. Record both longitudinal and lateral distances.
3. Use the lateral and longitudinal headform size selection chart to determine appropriate ASTM headform for testing.

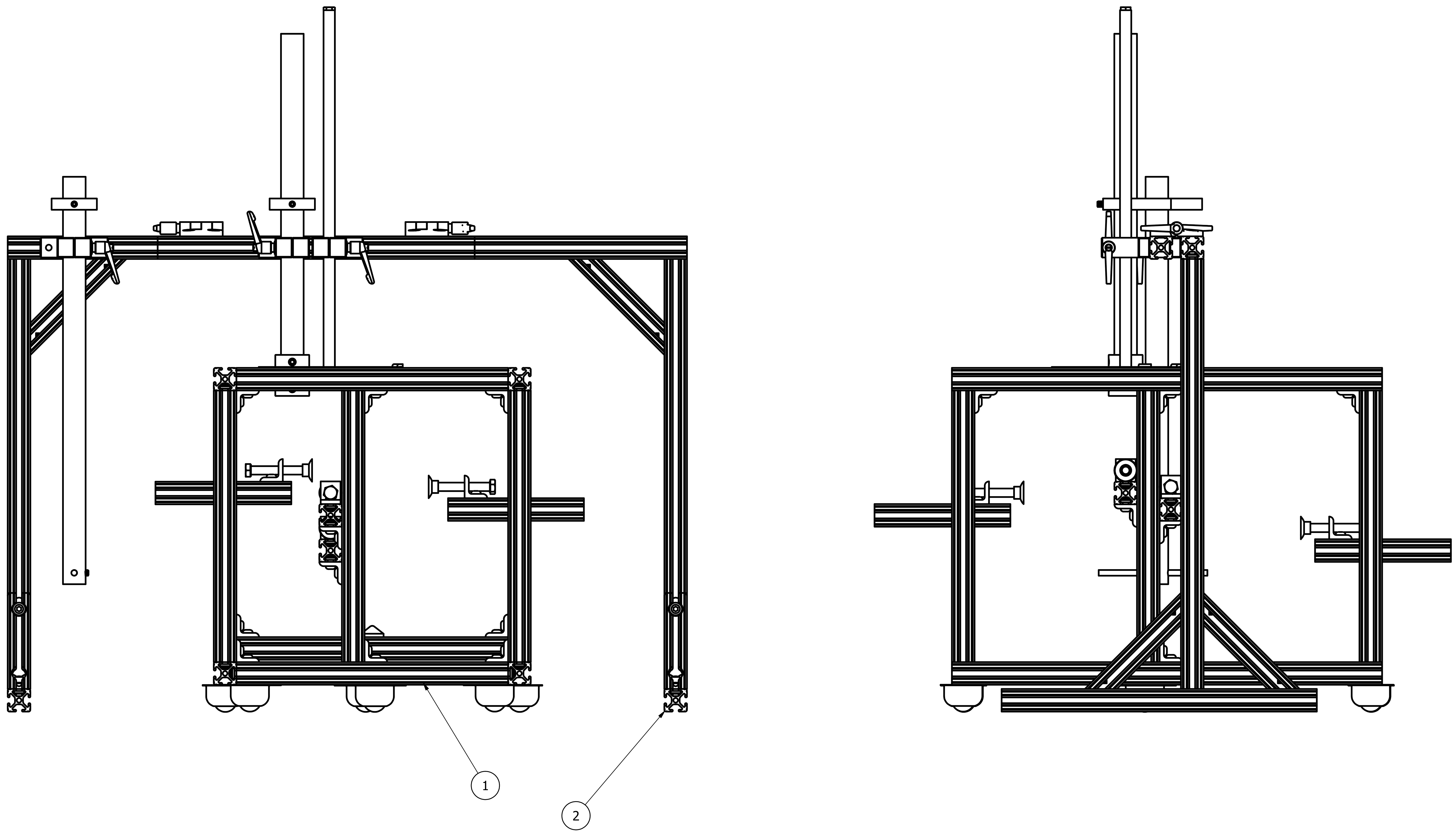
Appendix C: Modified Tool Drawing Package

National Highway Transportation Safety Administration
Vehicle Research and Test Center



Motorcycle Helmet Discrete Size Measurement

-Modified Scissor Tool, Marking Tool and Helmet Holder
July 2023



PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
2	1	DSMT-2000	MODIFIED SCISSOR TOOL AND MARKING TOOL ASSEMBLY
1	1	DSMT-1000	HELMET HOLDER FRAME ASSEMBLY

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

DECIMAL: .X ±.1, .XX ±.01, .XXX ±.005
MACHINED 125
ANGLES ±.5°
FRACTION ±1/64

ASME Y14.5M - 1994
DO NOT SCALE DRAWING

VEHICLE RESEARCH and TEST CENTER

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

APPROVALS		DATE
DRAWN	JIM CLEVENGER	3/24/2021
CHECKED		
ENG		3/24/2021
APPROVED		

MATERIAL

HEAT TREAT

FINISH

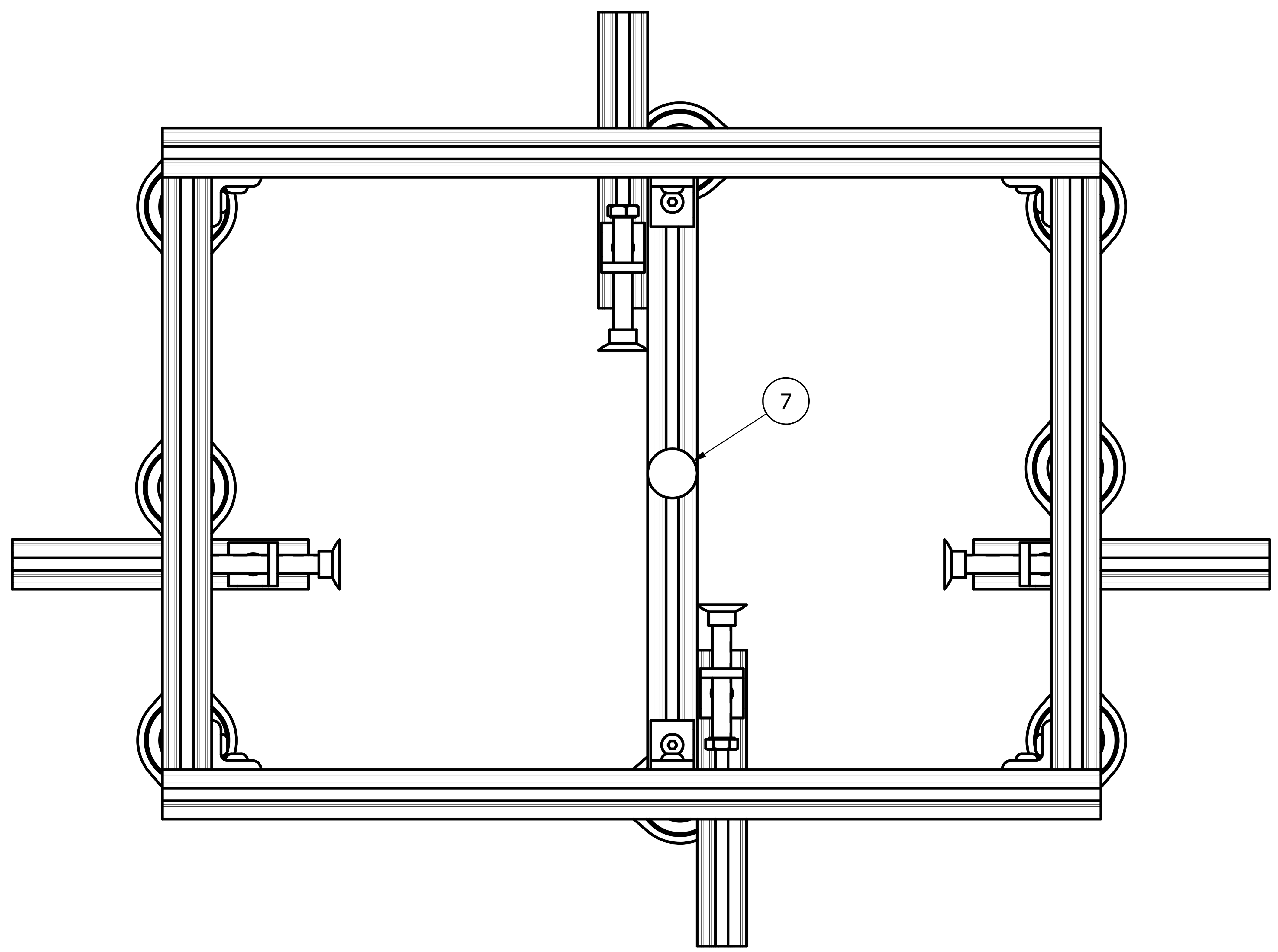
DISCRETE SIZE MEASURING TOOL ASSEMBLY
DISCRETE SIZE MEASURING TOOL

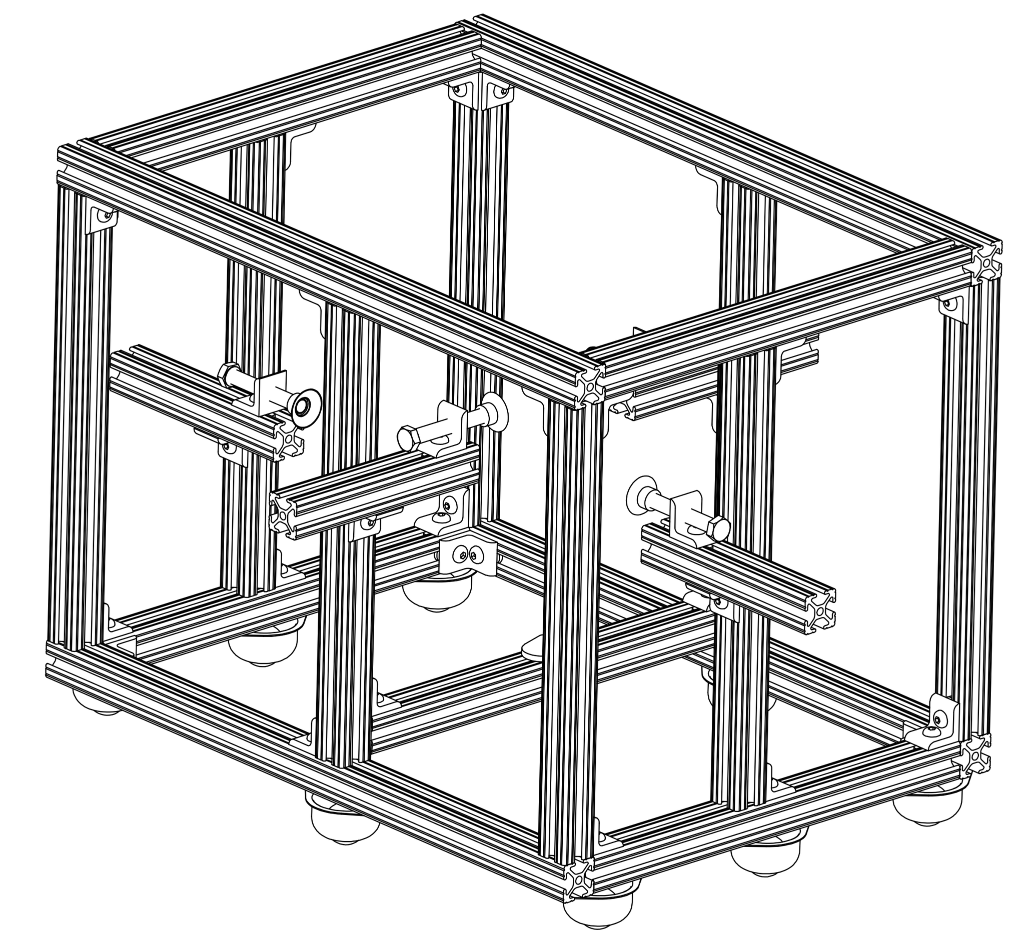
THIRD ANGLE PROJECTION

SIZE	DRAWING NUMBER	REV
D	DSMT-0000	

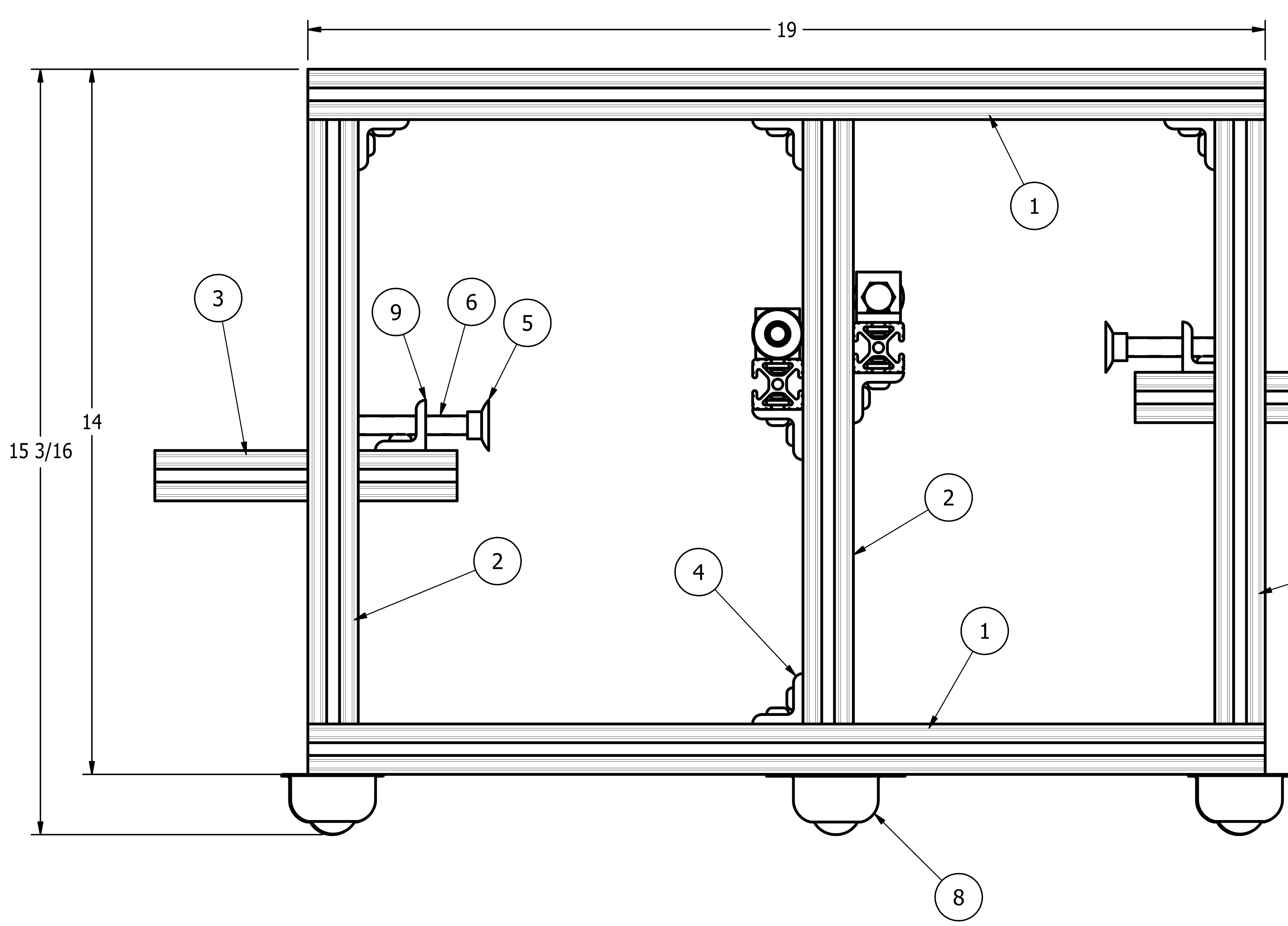
SCALE: 3/8 SHEET 1 OF 1

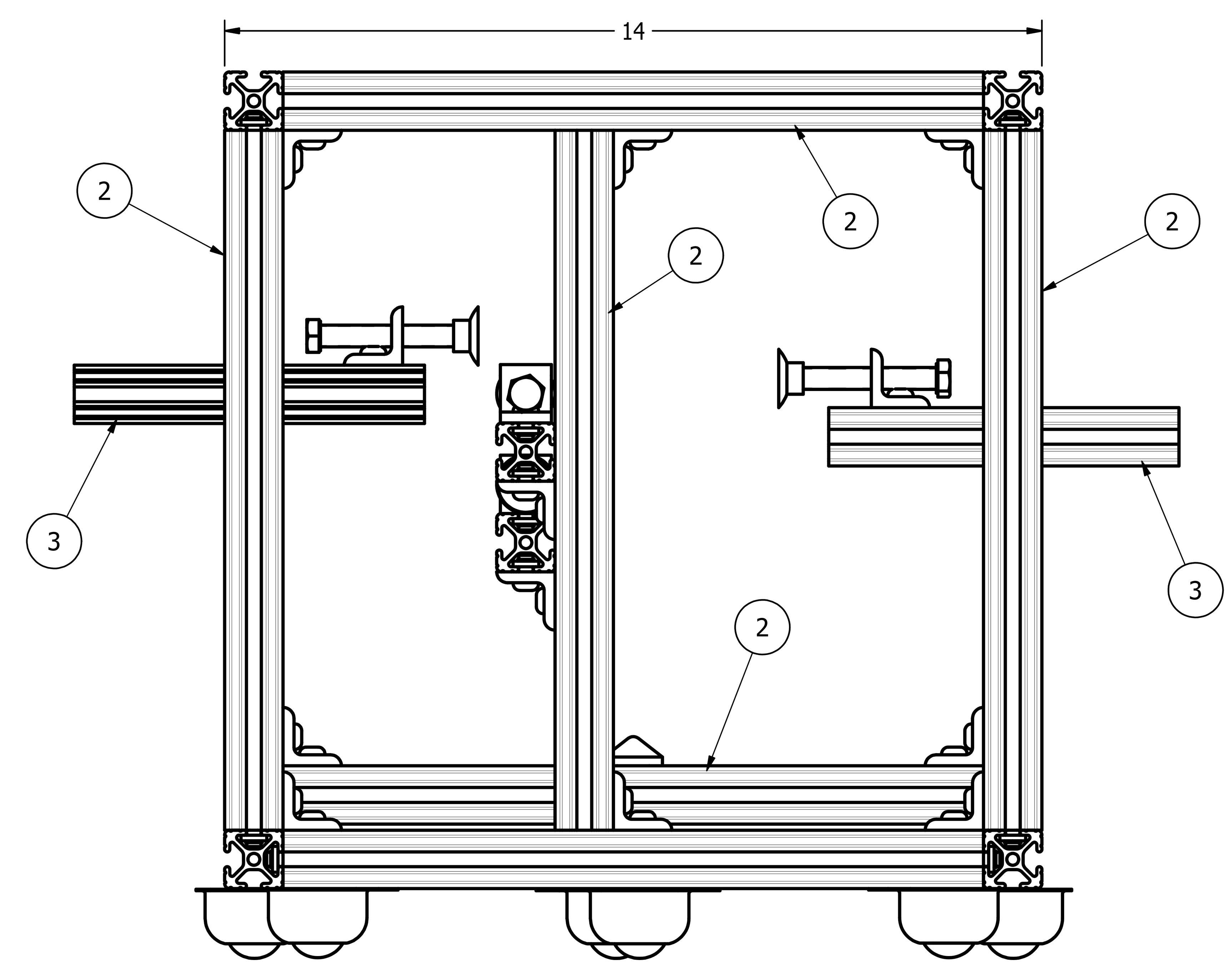
MODEL FILENAME: discreet measuring tool 2.iam





PARTS LIST				
ITEM	QTY	PART NUMBER	DESCRIPTION	CUT LENGTH
1	4	47065T101-5	1" x 1" SLOTTED ALUMINUM EXTRUSION	19
2	13	47065T101-6	1" x 1" SLOTTED ALUMINUM EXTRUSION	12
3	4	47065T101-7	1" x 1" SLOTTED ALUMINUM EXTRUSION	6
4	30	47065T236	CORNER BRACKET	
5	4	7275A201	PUSH ON VACUUM CUP	
6	4	92865A223	HHCS, 3/8-24 x 2 1/2	
7	1	9377K53	THREADED RUBBER BUMPER	
8	8	5674K1	FLANGE MOUNT BALL ROLLER	
9	4	DSMT-1010	HOLDER ANGLE CLIP ASSEMBLY	





UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: DECIMAL: .X ±.1 .XX ±.01 .XXX ±.005 MACHINED 125 ANGLES ±.5° FRACTION ±1/64 ASME Y14.5M - 1994 **DO NOT SCALE DRAWING**	VEHICLE RESEARCH and TEST CENTER	**NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION**
	APPROVALS / DATE	HELMET HOLDER FRAME ASSEMBLY
	DRAWN JIM CLEVENGER / 3/24/2021	DISCRETE SIZE MEASURING TOOL
MATERIAL	CHECKED	THIRD ANGLE PROJECTION
HEAT TREAT	ENG / 3/24/2021	SIZE D / DRAWING NUMBER DSMT-1000 / REV
FINISH	APPROVED	SCALE: 1 / 2 / SHEET 1 OF 1

MODEL FILENAME:
Helmet Holder Frame Assembly.iam

3/8-24 UNF - THRU
CENTERED ON EXISTING HOLE
THRU ONE LEG

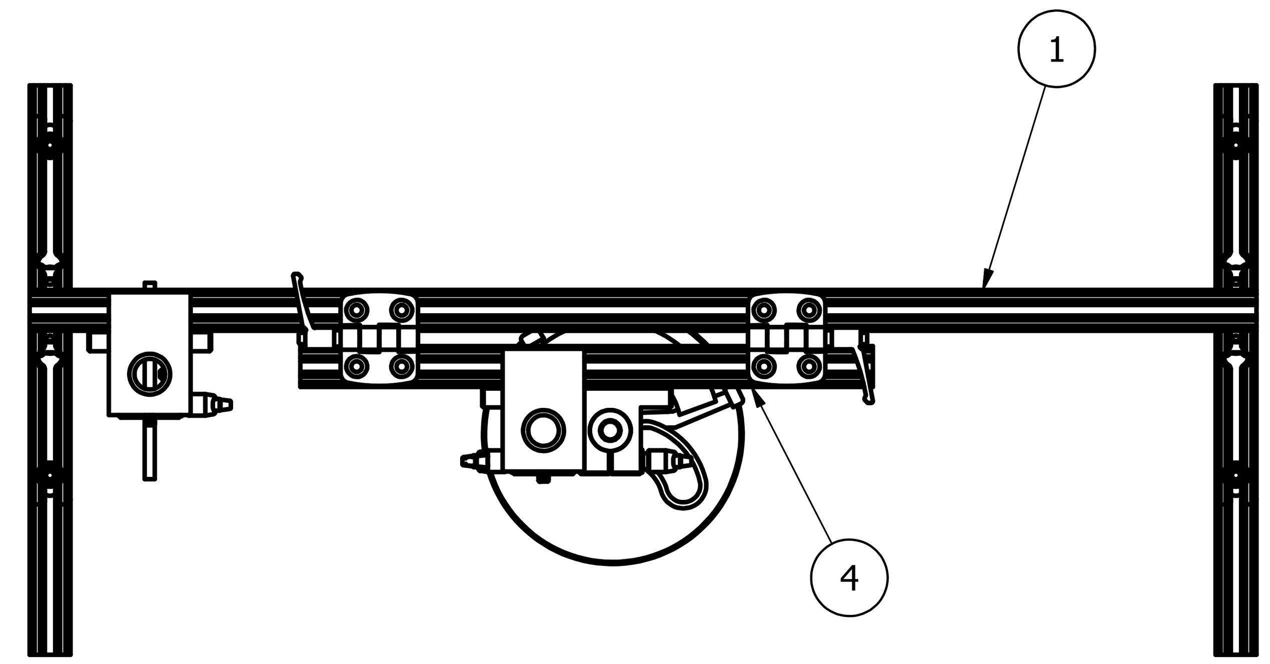
MATERIAL: PART #47065T236 CORNER BRACKET
(REWORK AS INDICATED)

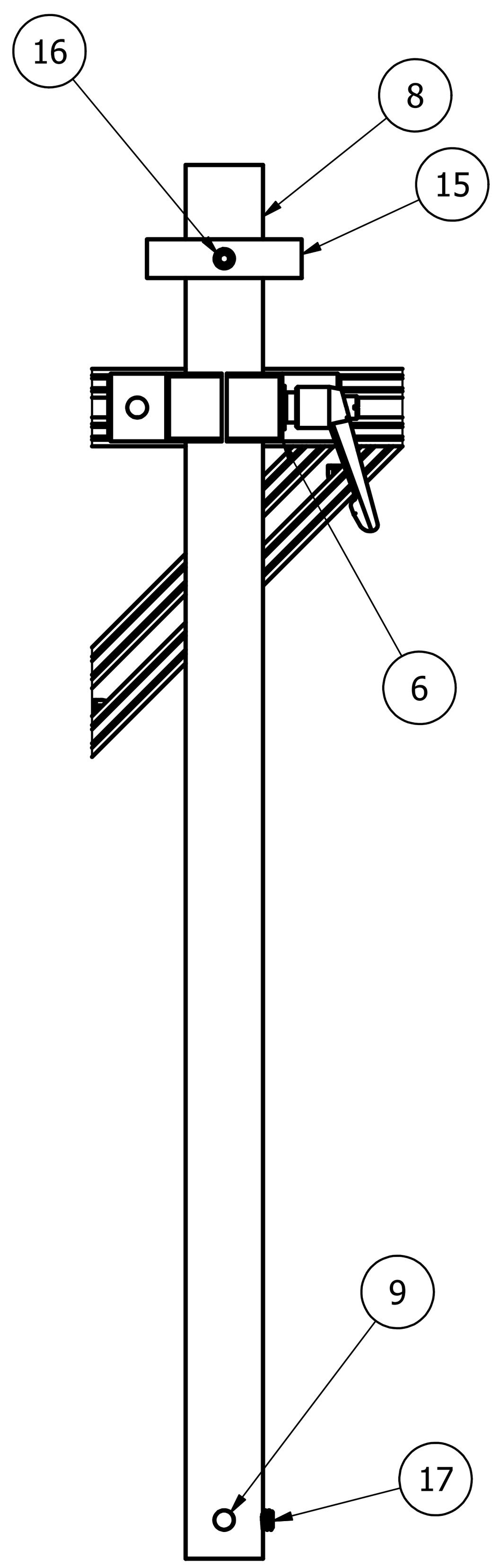
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: DECIMAL: .X ±.1 .XX ±.01 .XXX ±.005 MACHINED 125 ANGLES ±.5° FRACTION ±1/64 ASME Y14.5M - 1994 **DO NOT SCALE DRAWING**	VEHICLE RESEARCH and TEST CENTER	**NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION**
	APPROVALS / DATE	HOLDER ANGLE CLIP ASSEMBLY
	DRAWN: JIM CLEVENGER 3/29/2021	DISCRETE SIZE MEASURING TOOL
MATERIAL: Aluminum 6061	CHECKED	
HEAT TREAT	ENG: 3/29/2021	THIRD ANGLE PROJECTION; SIZE: **B**; DRAWING NUMBER: DSMT-1010; REV
FINISH	APPROVED	SCALE: 1 : 1; SHEET 1 OF 1

MODEL FILENAME:
Holder Angle Clip Assembly.ipt

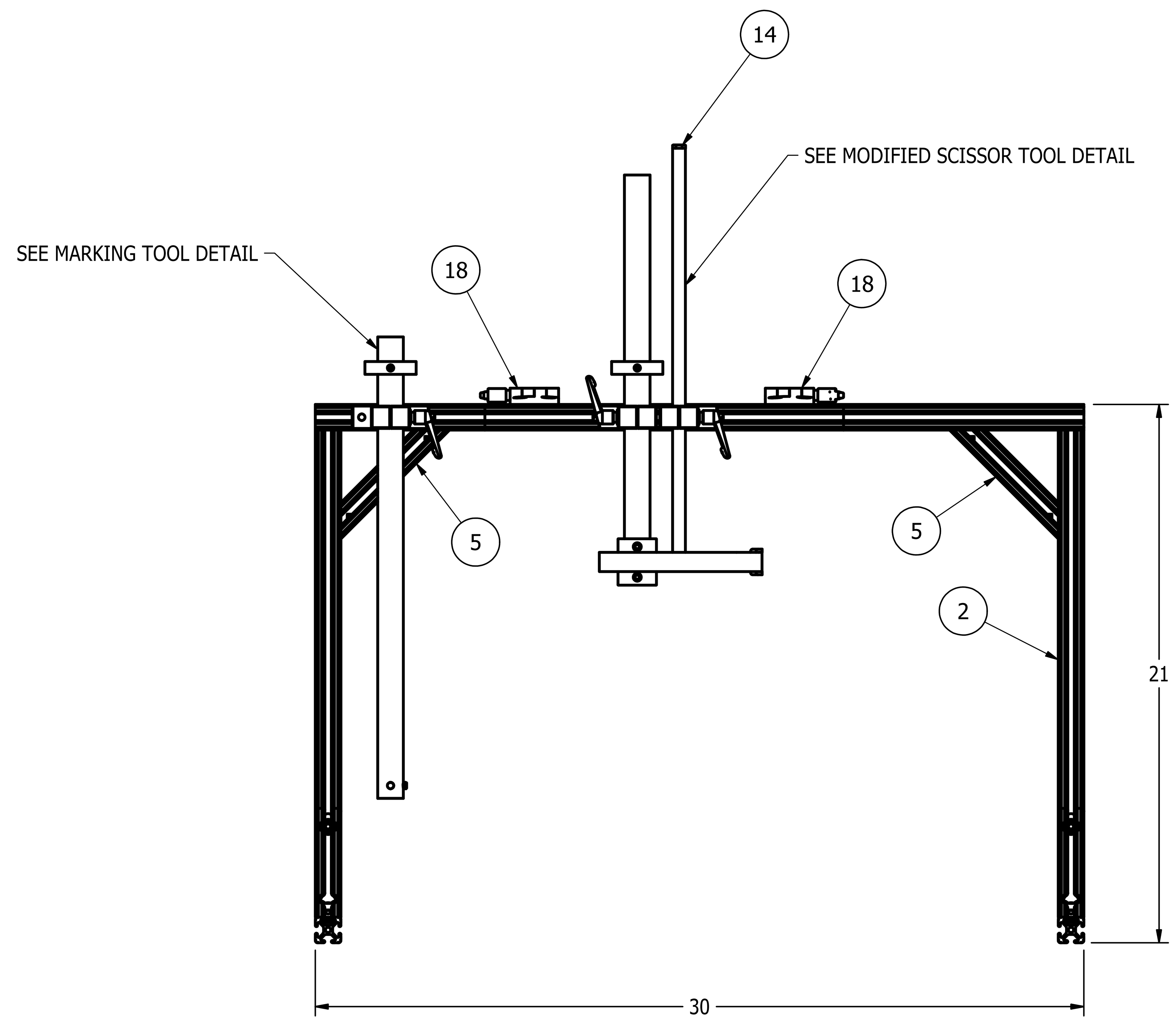
PARTS LIST

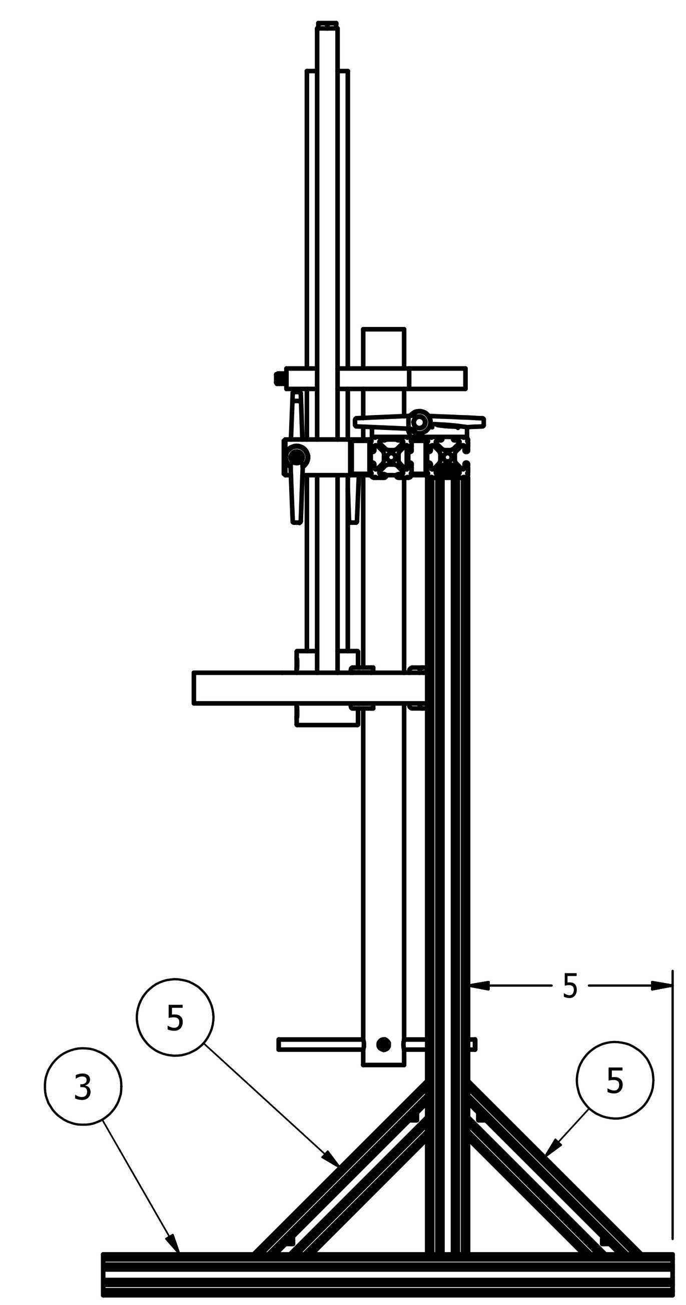
ITEM	QTY	PART NUMBER	DESCRIPTION	CUT LENGTH
1	1	47065T101-1	1" x 1" SLOTTED ALUMINUM EXTRUSION	30
2	2	47065T101-2	1" x 1" SLOTTED ALUMINUM EXTRUSION	19
3	2	47065T101-3	1" x 1" SLOTTED ALUMINUM EXTRUSION	13.92
4	1	47065T101-4	1" x 1" SLOTTED ALUMINUM EXTRUSION	14
5	6	47065T186	DIAGONAL SUPPORT	
6	1	47065T206	STANCHION QUICK CLAMP	
7	2	DSMT-2060	STANCHION QUICK CLAMP (MODIFIED)	
8	1	DSMT-2050	MARKING TOOL MOUNTING BAR	
9	1	DSMT-2010	MARKING TOOL PIN	
10	1	DSMT-2040	MODIFIED SCISSOR TOOL MOUNTING BAR	
11	1	6432K16	SET COLLAR, 1/2"	
12	2	6432K25	SET COLLAR, 1"	
13	1	DSMT-2020	MODIFIED SCISSOR TOOL ADJUSTMENT SHAFT	
14	1	90006963V	SCREW, HEX HD. CAP, 1/4-20 x 3/4	
15	2	DSMT-2030	DEPTH STOPPER BAR	
16	2	91375A537	SSCP, 1/4-20 x 1/2	
17	1	91375A535	SSCP, 1/4-20 x 3/8	
18	2	47065T356	LEVER LOCK HINGE	
19	1	DSMT-2070	SCISSOR TOOL	
20	2	9452K350	O-RING, 1.062 ID x 1/8 WALL	

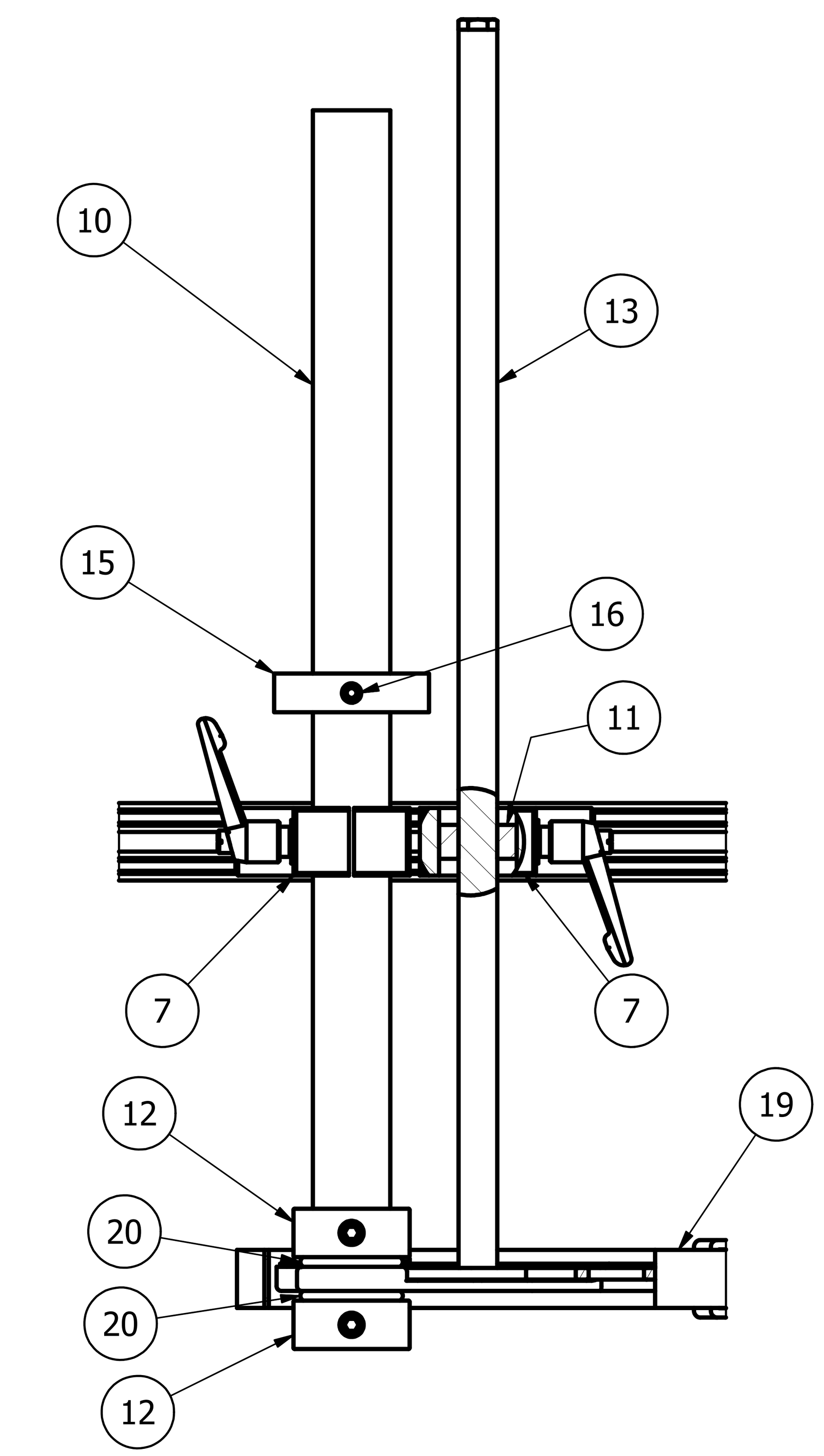




MARKING TOOL DETAIL
SCALE 1 / 2



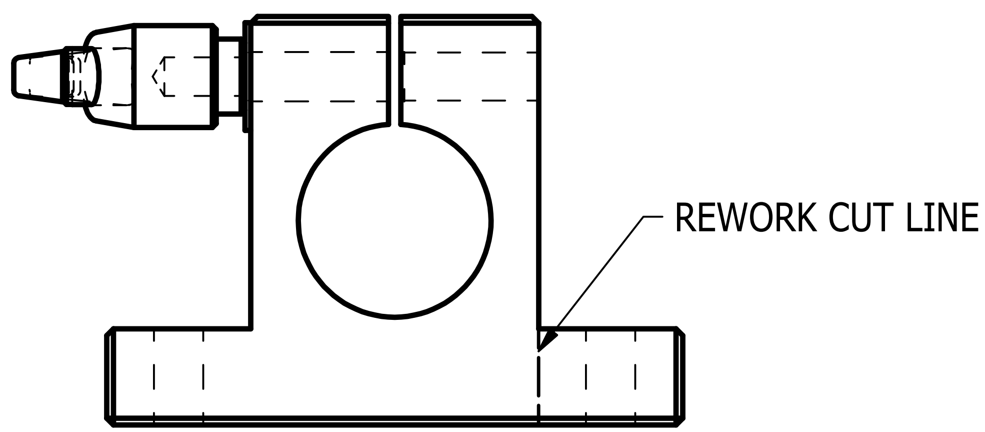




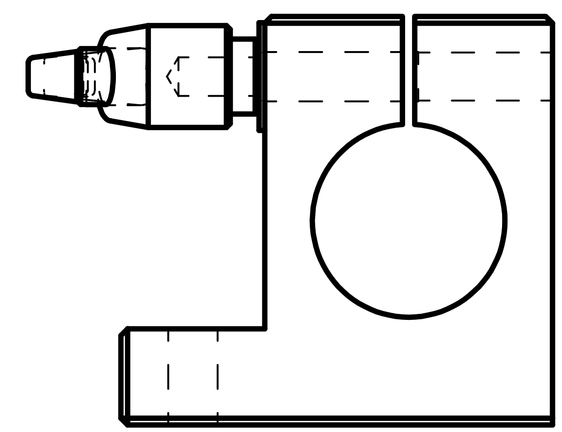
MODIFIED SCISSOR TOOL DETAIL
SCALE 1 / 2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: DECIMAL: .X ±.1 .XX ±.01 .XXX ±.005 MACHINED 125 ANGLES ±.5° FRACTION ±1/64 ASME Y14.5M - 1994 **DO NOT SCALE DRAWING**	VEHICLE RESEARCH and TEST CENTER	**NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION**
	APPROVALS / DATE	MODIFIED SCISSOR TOOL AND MARKING TOOL ASSEMBLY DISCRETE SIZE MEASURING TOOL
	DRAWN JIM CLEVENGER 3/24/2021	
MATERIAL	CHECKED	SIZE **D** DRAWING NUMBER DSMT-2000 REV
HEAT TREAT	ENG 3/24/2021	THIRD ANGLE PROJECTION
FINISH	APPROVED	SCALE: 1/4 SHEET 1 OF 1

MODEL FILENAME:
Marking Gantry Frame Assembly.iam



BEFORE MODIFICATION
SCALE 1 : 1

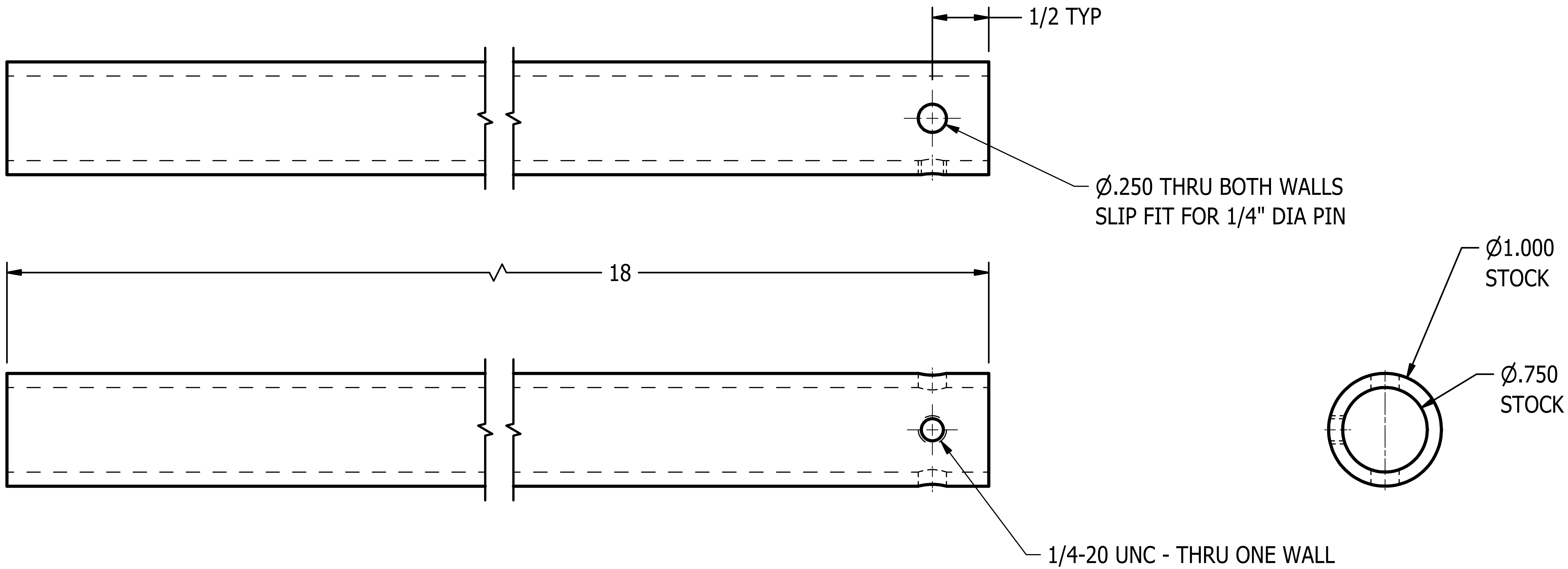


AFTER MODIFICATION
SCALE 1 : 1

MATERIAL: PART #47065T206 STANCHION QUICK CLAMP

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: DECIMAL: .X ±.1 .XX ±.01 .XXX ±.005 MACHINED 125 ANGLES ±.5° FRACTION ±1/64 ASME Y14.5M - 1994 **DO NOT SCALE DRAWING**	VEHICLE RESEARCH and TEST CENTER		**NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION**
	APPROVALS	DATE	STANCHION QUICK CLAMP (MODIFIED) DISCRETE SIZE MEASURING TOOL
	DRAWN JIM CLEVENGER	3/29/2021	
MATERIAL Aluminum 6061	CHECKED		SIZE **B** DRAWING NUMBER DSMT-2060 REV
HEAT TREAT	ENG	3/29/2021	THIRD ANGLE PROJECTION
FINISH	APPROVED		SCALE: 1 : 1 SHEET 1 OF 1

MODEL FILENAME:
47065T206 (1).ipt



MATERIAL: 1" OD x 3/4" ID TUBING

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

DECIMAL: .X ±.1 .XX ±.01 .XXX ±.005
MACHINED 125
ANGLES ±.5°
FRACTION ±1/64

ASME Y14.5M - 1994
DO NOT SCALE DRAWING

MATERIAL: Aluminum 6061	APPROVALS	DATE	
HEAT TREAT	DRAWN: JIM CLEVENGER	3/29/2021	
FINISH	CHECKED		
	ENG	3/29/2021	
	APPROVED		

*V*EHICLE *R*ESEARCH and *T*EST *C*ENTER

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

MARKING TOOL MOUNTING BAR

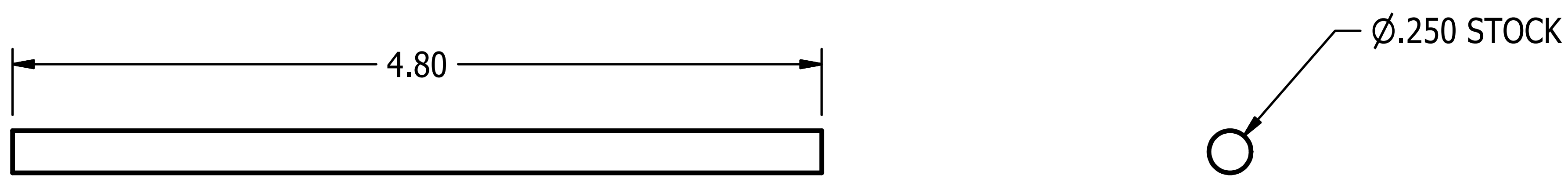
DISCRETE SIZE MEASURING TOOL

THIRD ANGLE PROJECTION

SIZE: **B** DRAWING NUMBER: DSMT-2050 REV:

SCALE: 1 : 1 SHEET 1 OF 1

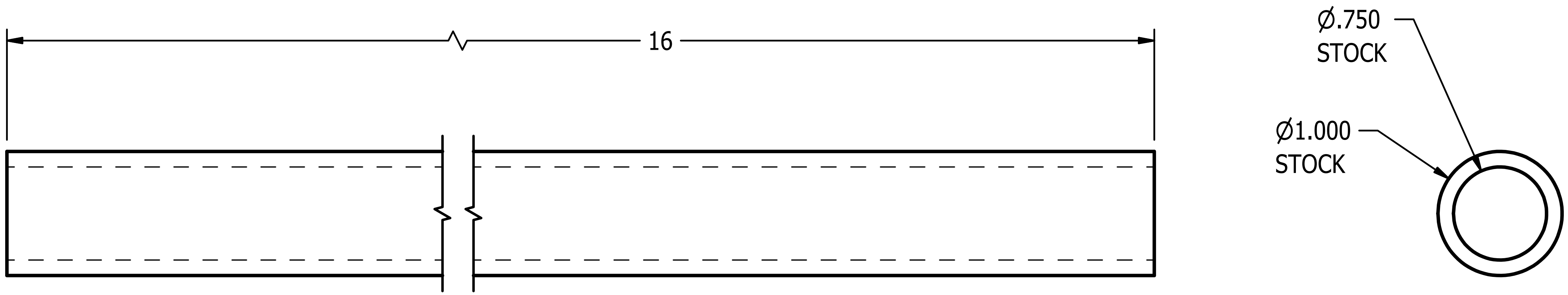
MODEL FILENAME:
47065T208.ipt



MATERIAL: 1/4 ROUND BAR

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: DECIMAL: .X ±.1 .XX ±.01 .XXX ±.005 MACHINED 125 ANGLES ±.5° FRACTION ±1/64 ASME Y14.5M - 1994 **DO NOT SCALE DRAWING**	VEHICLE RESEARCH and TEST CENTER	**NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION**
	APPROVALS / DATE	MARKING TOOL PIN
	DRAWN: JIM CLEVENGER 3/29/2021	DISCRETE SIZE MEASURING TOOL
MATERIAL: Aluminum 6061	CHECKED	SIZE: **B** DRAWING NUMBER: DSMT-2010 REV
HEAT TREAT	ENG: 3/29/2021	THIRD ANGLE PROJECTION
FINISH	APPROVED	SCALE: 1 : 1 SHEET 1 OF 1

MODEL FILENAME:
8920K112_LOW-CARBON STEEL ROD.ipt



MATERIAL: 1" OD x 3/4" OD TUBING

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

DECIMAL:		
.X ±.1	MACHINED	125
.XX ±.01	ANGLES	±.5°
.XXX ±.005	FRACTION	±1/64

ASME Y14.5M - 1994
DO NOT SCALE DRAWING

MATERIAL: Aluminum 6061
HEAT TREAT
FINISH

VEHICLE **R**ESEARCH and **T**EST **C**ENTER

APPROVALS	DATE
DRAWN JIM CLEVENGER	3/29/2021
CHECKED	
ENG	3/29/2021
APPROVED	

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

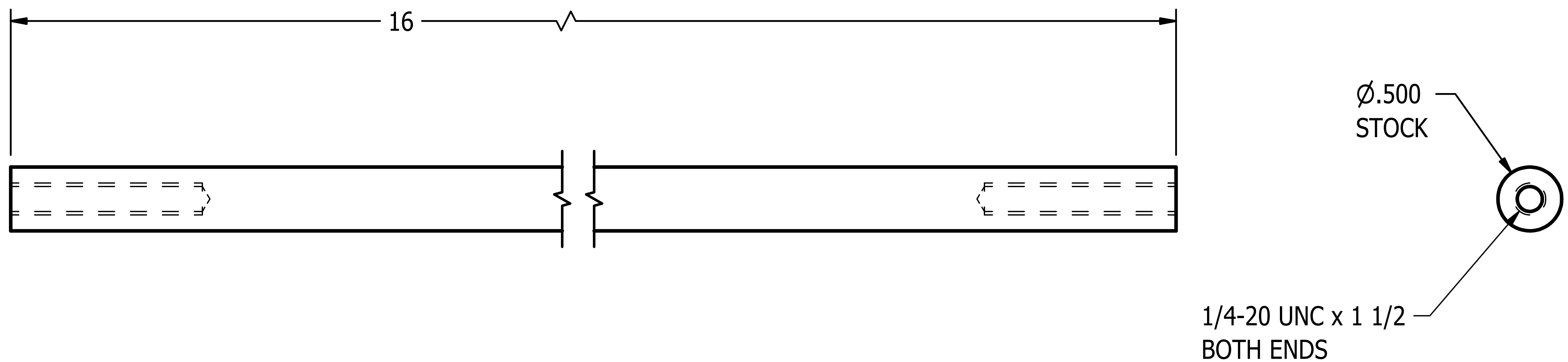
MODIFIED SCISSOR TOOL
MOUNTING BAR
DISCRETE SIZE MEASURING TOOL

THIRD ANGLE PROJECTION

SIZE	DRAWING NUMBER	REV
B	DSMT-2040	

SCALE: 1 : 1 SHEET 1 OF 1

MODEL FILENAME:
47065T208 (1).ipt



MATERIAL: 1/2" ROUND BAR

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

DECIMAL:		MACHINED	125
.X	±.1	ANGLES	±.5°
.XX	±.01	FRACTION	±1/64
.XXX	±.005		

ASME Y14.5M - 1994
DO NOT SCALE DRAWING

VEHICLE RESEARCH and TEST CENTER

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

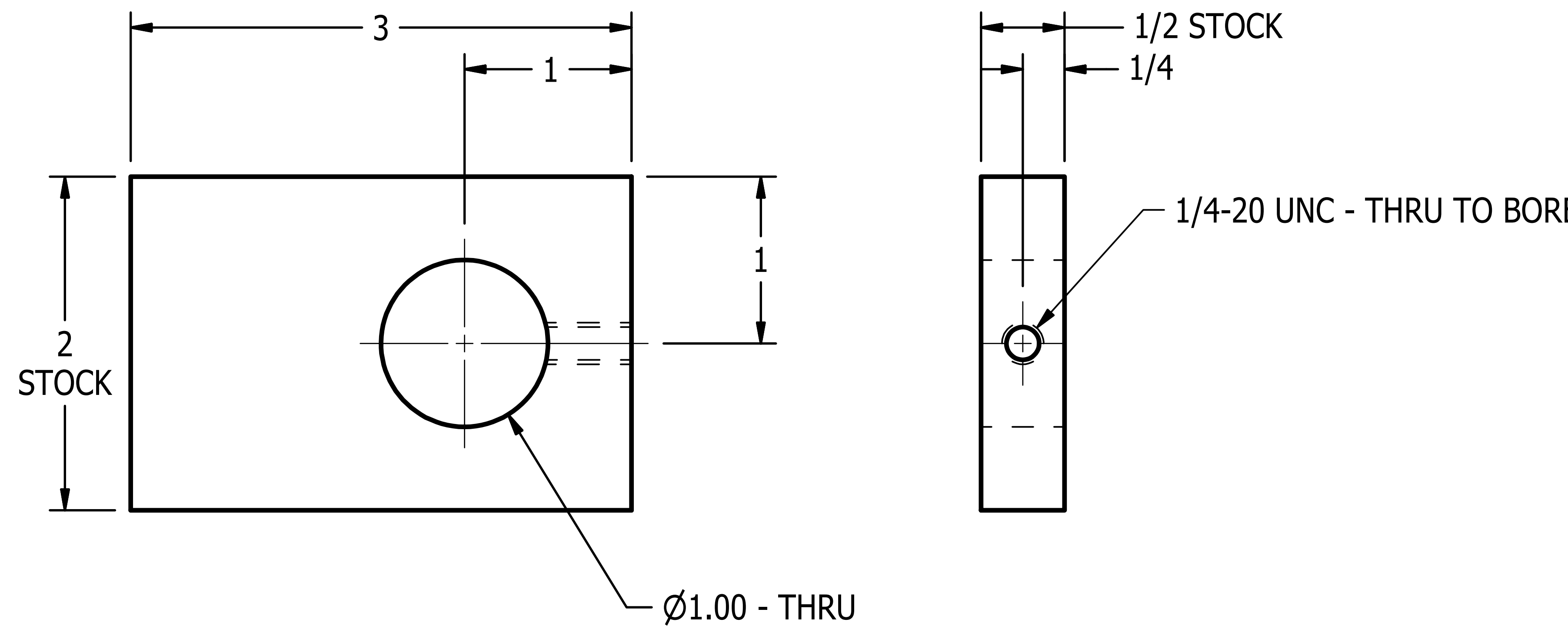
	APPROVALS	DATE
MATERIAL: Steel, Mild	DRAWN: JIM CLEVENGER	3/29/2021
HEAT TREAT	CHECKED	
FINISH	ENG	3/29/2021
	APPROVED	

MODIFIED SCISSOR TOOL
ADJUSTMENT SHAFT
DISCRETE SIZE MEASURING TOOL

THIRD ANGLE PROJECTION

SIZE	DRAWING NUMBER	REV
B	DSMT-2020	
SCALE: 1 : 1	SHEET 1 OF 1	

MODEL FILENAME:
8920K154_LOW-CARBON STEEL ROD.ipt



UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

DECIMAL:		
.X ±.1	MACHINED	125
.XX ±.01	ANGLES	±.5°
.XXX ±.005	FRACTION	±1/64

ASME Y14.5M - 1994
DO NOT SCALE DRAWING

MATERIAL: Steel, Mild	APPROVALS	DATE
	DRAWN: JIM CLEVENGER	3/29/2021
HEAT TREAT	CHECKED	
	ENG	3/29/2021
FINISH	APPROVED	

*V*EHICLE *R*ESEARCH and *T*EST *C*ENTER

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

DEPTH STOPPER BAR

DISCRETE SIZE MEASURING TOOL

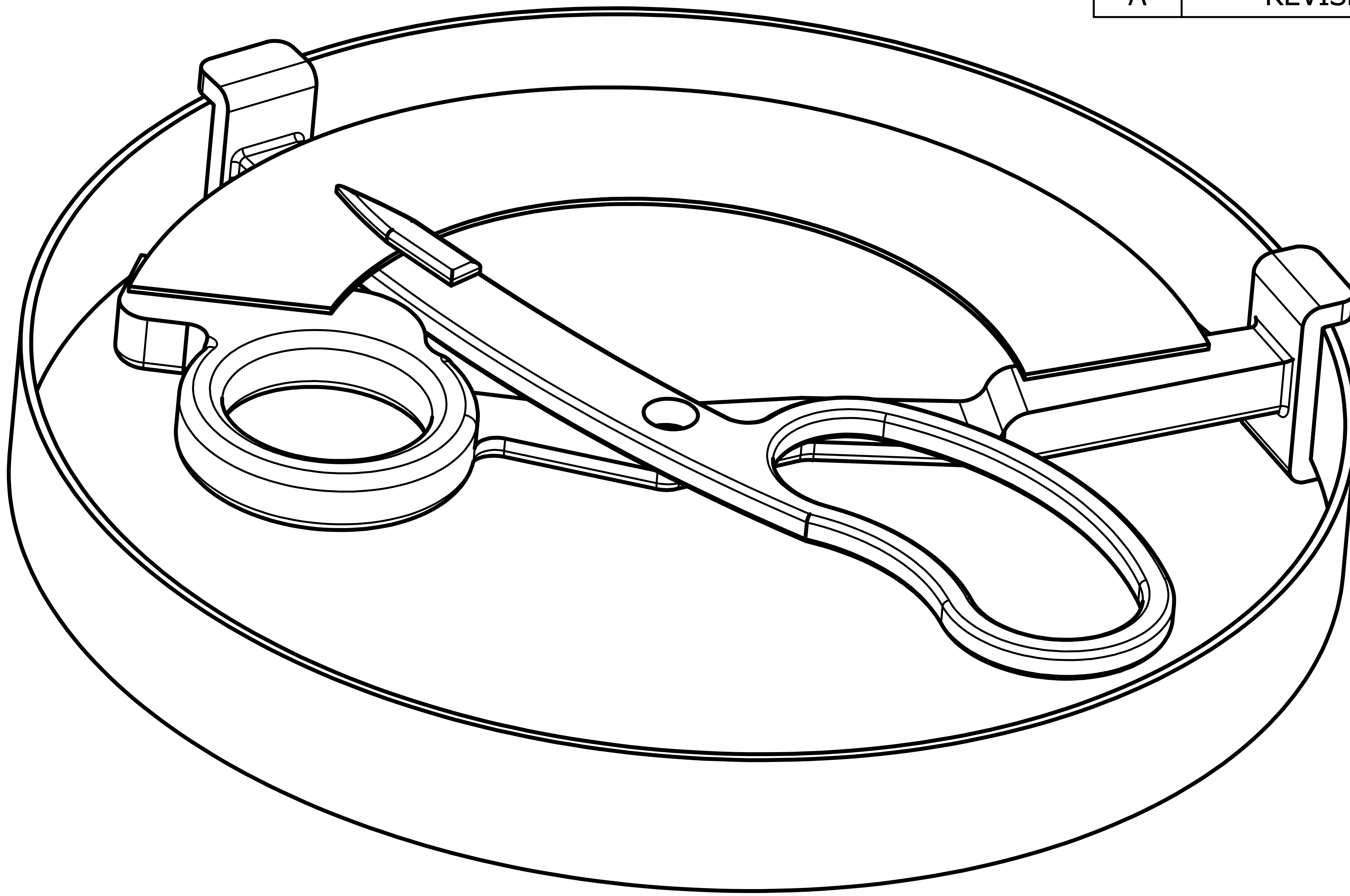
THIRD ANGLE PROJECTION

SIZE	DRAWING NUMBER	REV
B	DSMT-2030	

SCALE: 1 : 1 SHEET 1 OF 1

MODEL FILENAME:
8910K951_LOW-CARBON STEEL BAR.ipt

REVISION HISTORY			
REV	DESCRIPTION	DATE	BY
A	REVISED MATERIAL DESCRIPTION	7/10/2023	JHC



A

SCISSORS TYPE HAT SIZE MEASURING TOOL

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

DECIMAL:		MACHINED	125
.X	±.1	ANGLES	±.5°
.XX	±.01	FRACTION	±1/64
.XXX	±.005		

ASME Y14.5M - 1994
DO NOT SCALE DRAWING

VEHICLE **R**ESEARCH and **T**EST **C**ENTER

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

MATERIAL: Copper	APPROVALS	DATE	
HEAT TREAT	DRAWN: JIM CLEVENGER	3/30/2021	
FINISH	CHECKED		
	ENG	3/30/2021	
	APPROVED		

SCISSOR TOOL

DISCRETE SIZE MEASURING TOOL

THIRD ANGLE PROJECTION	SIZE	DRAWING NUMBER	REV
	B	DSMT-2070	A
	SCALE: 1.5:1	SHEET 1 OF 1	

MODEL FILENAME:
discreet measuring tool - Detailed 2 v5.ipt

Appendix D: Discrete Size Measurement Results Tables

HPI Measurement Results

Brand	Model	Size	Type	Label Size	Mfg. HPI (mm) - DOT Headform	ASTM (Reference) Headform Used	VRTC Measured HPI Angle (Degrees)	VRTC Measured HPI (mm) – ASTM Headform	HPI Difference (mm)	Notes
Speed and Strength	SS510	S	Half Helmet	55-56 cm	70	E	0	41	29	
Biltwell	LANE SPLITTER	L	Full-Face	59-60 cm	49	J	0	39	10	Removed shield, chin guard, and ear pads
						M	0	42	7	
AFX	FX-75	M	Open Face	58-59 cm (outside label), 57-58cm (inside label)	47	J	0.2	36	11	Removed exterior visor
Scorpion	EXO-AT950	M	Modular	57-58 cm	49	J	0	43	6	Removed visor, shield, chin bar, and ear pads
HCI	100 (M)	M	Half Helmet	57-58 cm	54	J	0	35	19	Removed visor
Cyber Helmets	U-72 Solid (XL)	XL	Half Helmet	61-62 cm	53	M	0	29	24	Removed visor
						O	0	42	11	
Bell	Qualfier	M	Full-Face	57-58 cm	58	J	0	47	11	Removed the shield, ear foam, and neck guard
Icon	Airflite	L	Full-Face	59-60 cm	28	J	0	35	-7	Removed the shield, ear foam, and chin cover
						M	0	47	-19	
Fuel	WS001	L	Open Face	59-60 cm	52	J	0	31	21	Removed the shield and ear pads
						M	0	42	10	
Scorpion	EXO-Belfast	XXL	Open Face	63-64 cm	54	O	0	33	21	Did not remove the ear pads since they are connected to foam; removal will affect the size.
LS2	Vortex	S	Modular	56 cm	na	E	0	31	na	Removed the visor, chin bar, ear foam, and neck guard
HJC	RPHA 90	L	Modular	58-59 cm	40	J	0	31	9	Removed the shield, chin bar, and ear foam

Modified Scissor Tool Method Measurement Results

						Modified Scissor Tool							
Brand	**Model**	**Size**	**Type**	**Label Size**	**ASTM (Reference) Headform Used**	**Torque Applied (N-m)**	**Msmt 1 (cm)**	**Torque Applied (N-m)**	**Msmt 2 (cm)**	**Torque Applied (N-m)**	**Msmt 3 (cm)**	**Measured Size at Reference Plane (cm) (Max)**	**Corresponding ASTM Headform Size**
Speed and Strength	SS510	S	Half Helmet	55-56 cm	E	2.5	54.1	2.4	54.0	2.6	54.4	**54.4**	**E**
Biltwell	LANE SPLITTER	L	Full-Face	59-60 cm	J	4.3	57.7	3.5	57.3	3.8	58.8	**58.8**	**J**
					M	3.6	59.6	3.7	58.8	3.6	58.6	**59.6**	**J**
AFX	FX-75	M	Open Face	58-59 cm (outside label), 57-58cm (inside label)	J	3.1	55.3	3.9	55.1	3.4	56.3	**56.3**	**E**
Scorpion	EXO-AT950	M	Modular	57-58 cm	J	3.5	55.7	3.8	55.9	3.9	55.1	**55.9**	**E**
HCI	100 (M)	M	Half Helmet	57-58 cm	J	3.1	55.5	3.8	55.8	3.2	56.0	**56.0**	**E**
Cyber Helmets	U-72 Solid (XL)	XL	Half Helmet	61-62 cm	M	3.6	58.4	4.0	58.3	3.7	58.4	**58.4**	**J**
					O	3.6	59.7	3.7	59.4	3.4	59.5	**59.7**	**J**
Bell	Qualfier	M	Full-Face	57-58 cm	J	3.4	57.7	3.4	57.4	3.5	57.6	**57.7**	**J**
Icon	Airflite	L	Full-Face	59-60 cm	J	3.5	54.3	3.4	55.5	3.9	54.4	**55.5**	**E**
					M	3.9	55.7	3.4	56.3	3.4	55.8	**56.3**	**E**
Fuel	WS001	L	Open Face	59-60 cm	J	3.8	55.5	3.4	55.1	3.7	55.4	**55.5**	**E**
					M	3.9	56.5	3.8	56.2	3.7	56.1	**56.5**	**E**
Scorpion	EXO-Belfast	XXL	Open Face	63-64 cm	O	4.3	57.0	4.3	57.4	4.0	57.0	**57.4**	**J**
LS2	Vortex	S	Modular	56 cm	E	3.3	53.5	3.3	53.2	3.5	53.2	**53.5**	**C**
HJC	RPHA 90	L	Modular	58-59 cm	J	4.4	56.9	4.9	57.4	4.1	57.4	**57.4**	**J**

Handheld Scissor Tool Measurement Method Results

						Handheld Scissor Tool				
Brand	**Model**	**Size**	**Type**	**Label Size**	**ASTM (Reference) Headform Used**	**Msmt 1 (cm)**	**Msmt 2 (cm)**	**Msmt 3 (cm)**	**Measured Size at Reference Plane (cm) (Max)**	**Corresponding ASTM Headform Size**
Speed and Strength	SS510	S	Half Helmet	55-56 cm	E	54	54	54	**54**	**E**
Biltwell	LANE SPLITTER	L	Full-Face	59-60 cm	J	58.5	58.5	58	**58.5**	**J**
					M	59	59.25	59	**59.25**	**J**
AFX	FX-75	M	Open Face	58-59 cm (outside label), 57-58cm (inside label)	J	56	56	56	**56**	**E**
Scorpion	EXO-AT950	M	Modular	57-58 cm	J	55.5	55.5	55.5	**55.5**	**E**
HCI	100 (M)	M	Half Helmet	57-58 cm	J	55.5	55	55	**55.5**	**E**
Cyber Helmets	U-72 Solid (XL)	XL	Half Helmet	61-62 cm	M	58.25	58	58	**58.25**	**J**
					O	60	60	60	**60**	**M**
Bell	Qualfier	M	Full-Face	57-58 cm	J	57	57	57	**57**	**J**
Icon	Airflite	L	Full-Face	59-60 cm	J	56.75	56.25	56.5	**56.75**	**E**
					M	56.75	56.5	57.25	**57.25**	**J**
Fuel	WS001	L	Open Face	59-60 cm	J	55	55	55	**55**	**E**
					M	58	57.75	57	**58**	**J**
Scorpion	EXO-Belfast	XXL	Open Face	63-64 cm	O	57.75	57.25	57.25	**57.75**	**J**
LS2	Vortex	S	Modular	56 cm	E	53	53	53	**53**	**C**
HJC	RPHA 90	L	Modular	58-59 cm	J	57.75	58	58	**58**	**J**

Internal Measurement Method Results

						Internal Msmt (Uncompressed)			Internal Msmt (Compressed)			
Brand	**Model**	**Size**	**Type**	**Label Size**	**ASTM (Reference) Headform Used**	**Lateral (mm)**	**Longitudinal (mm)**	**Corresponding ASTM Headform Size (Lat/Long)**	**Torque Applied (N-m)**	**Lateral (mm)**	**Longitudinal (mm)**	**Corresponding ASTM Headform Size (Lat/Long)**
Speed and Strength	SS510	S	Half Helmet	55-56 cm	E	142	187	**C/E**	2.3	150	184	**E/E**
Biltwell	LANE SPLITTER	L	Full-Face	59-60 cm	J	151	185	**E/E**	4.3	177	197	**O/J**
					M	157	193	**J/J**	3.6	169	200	**M/J**
AFX	FX-75	M	Open Face	58-59 cm (outside label), 57-58cm (inside label)	J	143	189	**C/E**	3.7	157	197	**J/J**
Scorpion	EXO-AT950	M	Modular	57-58 cm	J	136	194	**A/J**	3.8	152	192	**E/J**
HCI	100 (M)	M	Half Helmet	57-58 cm	J							
Cyber Helmets	U-72 Solid (XL)	XL	Half Helmet	61-62 cm	M							
					O							
Bell	Qualfier	M	Full-Face	57-58 cm	J							
Icon	Airflite	L	Full-Face	59-60 cm	J							
					M							
Fuel	WS001	L	Open Face	59-60 cm	J							
					M							
Scorpion	EXO-Belfast	XXL	Open Face	63-64 cm	O							
LS2	Vortex	S	Modular	56 cm	E							
HJC	RPHA 90	L	Modular	58-59 cm	J							

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