SUMMARY REPORT
FMVSS NO. 213 R&R: UPDATED FRONTAL STANDARD SEAT ASSEMBLY

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REPEATABILITY AND REPRODUCIBILITY OF THE UPDATED FMVSS NO. 213 FRONTAL STANDARD SEAT ASSEMBLY

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Report Submitted 23 October 2019

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This report presents the results of a child restraint system frontal test series performed at Calspan test facility for the National Highway Traffic Safety Administration (NHTSA) to evaluate the repeatability and reproducibility of the updated frontal seating assembly. The test series was conducted using an accelerating (HYGE) sled system. These compliance-type tests were conducted on various child restraint systems in accordance with the specifications of the Office of Vehicle Safety Compliance Test Procedure No. TP-213-10, with additional requirements as provided by NHTSA.</td></tr>
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Table of Contents

Technical Report Documentation Page 2

1 Introduction 5

1.1 Purpose 5

2 Methods 6

2.1 Overview 6

2.2 Bench Fabrication 7

2.3 Bench Seat and Back Covers 7

2.4 Foam Calibration 9

2.4.1 Foam Test Procedure 9

2.5 Anthropomorphic Test Devices 10

2.6 Sled and Restraints 10

2.7 Data Acquisition and Reduction 11

2.8 High-Speed Video 11

2.9 Test Procedure 13

2.9.1 Pre-test 13

2.9.2 FARO Measurements 14

2.9.3 Test 17

2.9.4 Post-test 17

3 Results 18

3.1 Crash Pulse Comparison w/ VRTC 18

3.2 Sled Test Results 19

3.2.1 Repeatability 19

3.2.2 Reproducibility 35

3.2.3 Single Point Data 38

4 Discussion 44

4.1 Future Work 45

5 References 46

6 Appendix - Bench Dimensional Verification 47

6.1 Drawing 3021-015, sheet 1 47
6.2 Drawing 3021-015, sheet 2 48
6.3 Drawing 3021-015, sheet 3 50
6.4 Drawing 3021-750, sheet 1 51
6.5 Drawing 3021-1000, sheet 1 52
7 Appendix – Sled, Tool and ATD Sensor Calibrations 53
7.1 Sled and Facility Calibrations 53
7.2 CRABI-12mo Calibrations 54
7.3 H3-3yo Calibrations 55
7.4 H3-6yo Calibrations 57
7.5 H3-10yo Calibrations 58
8 Appendix – Seat Cushion Cover Methods (Spring 2018) 61
8.1 Warp Definition 61
8.2 Grommet Method 62
8.3 Sand Paper 65
8.4 Foam Wrapping 66
9 Appendix – Bench drawings 71

1 Introduction

1.1 Purpose

The National Highway Traffic Safety Administration (NHTSA) is an agency of the U.S. Department of Transportation (DOT). NHTSA's mission is to save lives, prevent injuries, and reduce traffic-related economic costs. The agency develops, promotes, and implements effective educational, engineering, and enforcement programs with the goal of ending preventable tragedies and reducing economic costs associated with vehicle use and highway travel. Federal Motor Vehicle Safety Standard (FMVSS) No. 213, Child Restraint Systems, specifies requirements for child restraint systems (CRS) used in motor vehicles and aircraft. NHTSA specifies the test equipment that NHTSA uses to dynamically assess the compliance of child restraint systems with this federal regulation. More specifically, FMVSS No. 213 includes a so-call "sled test" in which a child restraint is subjected to a simulated frontal crash. One component of the sled test is the standard seat assembly, which simulates the role of the vehicle seat in the sled test.

Consistent with the Moving Ahead for Progress in the 21st Century Act (MAP-21), the NHTSA is required to amend the standard seat assembly to better simulate a representative vehicle rear seat. Thus, the NHTSA recently developed an updated standard seat assembly to replicate the rear seat environment (Wietholter, Echemendia, and Louden 2017). Before an FMVSS is incorporated into a regulation, it must be established that the FMVSS is both repeatable and reproducible. Repeatable means that a person or persons skilled in the practice of performing crashworthiness experiments, can perform multiple tests with identical initial conditions (CRS make and model, ATD, and fixation method) in accordance with the FMVSS and achieve nominally similar results from all tests. Reproducible means that persons skilled in the practice of performing crashworthiness experiments located at multiple laboratories, can perform the same tests in the manner prescribed in the FMVSS and achieve nominally similar results. The extent to which an FMVSS, or a component thereof, is repeatable and reproducible is known as the repeatability and reproducibility, respectively. The purpose of this project was to determine the repeatability and reproducibility of the updated FMVSS No. 213 frontal standard seat assembly.

2 Methods

2.1 Overview

To evaluate repeatability and reproducibility, preceding the engagement of the authors of this report and the Calspan Corporation, the NHTSA developed an updated seat assembly (Wietholter, Echemendia, and Louden 2017) and conducted a series of sled tests with various child restraints. The measurements and documentation from those tests included:

- measured engineering drawings of the seat assembly,
- procedures for construction of the seat assembly,
- test methods to evaluate the mechanical performance of the seat assembly foams,
- 3D positional data of each anthropomorphic test device (ATD) and CRS after installation on the seat assembly and immediately prior to each sled test, and
- kinematic, kinetic and injury criteria measurements from the ATD and CRS recorded during each sled test.

Tests with the same CRS, ATD and test condition were performed multiple times, thus constituting repeatability tests.

Then, NHTSA selected the authors of this report and Calspan who, in the context of this project, collectively represents a CRS manufacturer attempting to conduct testing in accordance with the new seat assembly and the current FMVSS test procedure. As a representative CRS manufacturer in the context of this project, the Calspan laboratories were equipped with the same capabilities that a CRS manufacturer would use to comply with FMVSS No. 213, including in-house test fixture fabrication capability, an ATD inventory and associated calibration laboratory, a HYGE sled accelerator used ubiquitously in the industry, and a full-time sled testing team that conducts thousands of sled test per year. In addition, many CRS manufacturers outsource all of their compliance testing to third party test laboratories including Calspan. Thus, for many CRS manufacturers Calspan or another third party laboratory *is* their test facility for FMVSS compliance, and thus our activities herein exactly represent what a manufacturer would do to comply with the FMVSS.

To evaluate reproducibility, Calspan repeated many of the tests previously conducted by NHTSA. In most cases, we conducted three repeat tests, and thus we were positioned to evaluate repeatability in addition to reproducibility. In general, the specific procedures used to conduct this test program are in accordance with the specifications of the Office of Vehicle Safety Compliance

Test Procedure No. TP-213-10 (National Highway Traffic Safety Adminstration 2014), with additional requirements by NHTSA and described below.

2.2 Bench Fabrication

Calspan fabricated a new bench for this project per the NHTSA-provided drawing package dated April 2018 (Figure 1) and per noted changes from NHTSA concerning the foam backing plates. The bench was measured both with FARO arm and laser setups. Critical dimensions (see Results section) were compared to the dimensions in the drawing package. Dimensions that exceeded ±3 mm tolerance were noted and the bench was approved by the NHTSA as acceptable.

Figure 1 – NHTSA drawing package cover page.

2.3 Bench Seat and Back Covers

Bench seat bottom and seat backs were constructed as follows in accordance with the technique developed by the Vehicle Research and Test Center (VRTC) of NHTSA (Appendix 8). Seat back and seat bottom plates were fabricated in accordance with bench drawing package. Then, 50 garnet paper was adhered to the side of the plate that was to be in contact with the foam (the side of the plates without the bolts). Polyacrylate Fiber fabric (Fabric Weight: 9 oz. Break Strength: 285 lbs Warp and 180 lbs Filling), was cut to the dimensions for the seat back and seat bottom

(Figure 2). Grommets (size #1) were added to the fabric where the cover slips over the mounting bolts on the backing plate.

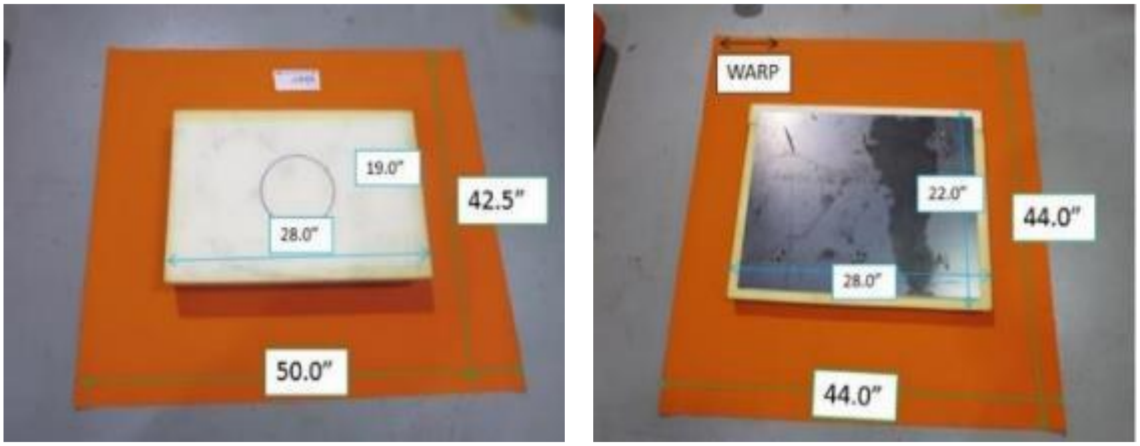


Figure 2 – Seat pan (left) and back (right) foam and cover dimensions.

To assemble the seat bottom, the cover was placed on a flat surface. Then, the foam was placed on the cover, and the plate then placed on the foam with 1 inch spacing on all sides (Figure 3a). The bolts were placed through the holes in the fabric and the fabric was adhered using Dr. Shrink tape as shown in Figure 3b. Then, the fabric on the short edge of the plate was pushed into the side of the foam creating a triangle (Figure 3c), and then the edge was folded down on both sides (Figure 3d). Finally, the fabric point was pulled upward and taut, then secured with shrink tape (Dr. Shrink, Manistee, Michigan, United States). All folds were finished by taping down along edges (Figure 3e). See Appendix 8.4 for detailed steps of assembly.

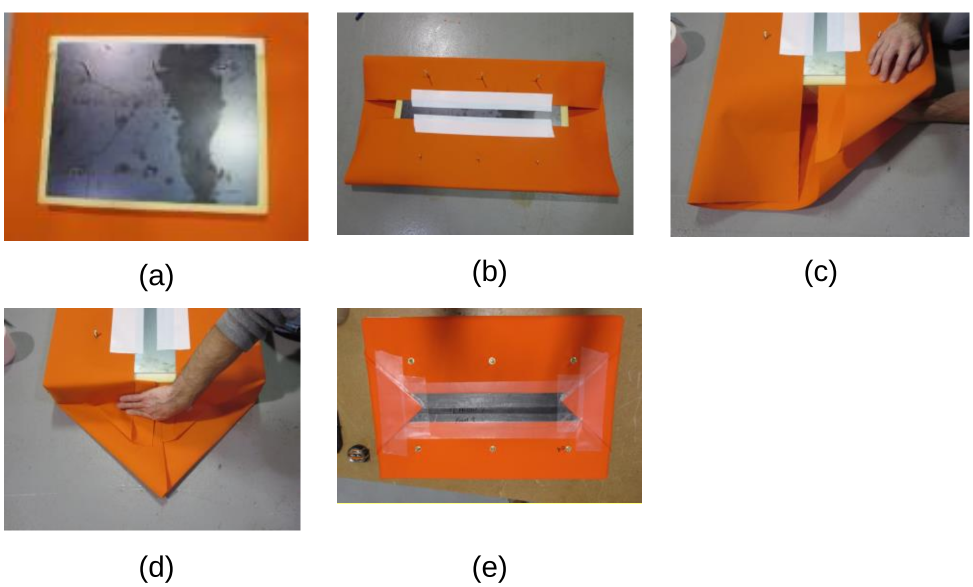


Figure 3 – Seat bottom and back assembly.

2.4 Foam Calibration

The foam was tested per the calibration procedure (outlined in section 2.4.1) after every 4 to 6 tests. Foam calibration testing was conducted at the beginning of the day after the foam soaked in the laboratory overnight. Each foam is tested at 25%, 50% and 65% compression consecutively per ASTM D3574 Standards and NHTSA guidance. An apparatus (aka a compression test machine) having a flat circular indenter foot 200 +3/-0mm in diameter was used to deflect the specimen. The apparatus was on a level horizontal plate which was perforated with approximately 6.5 mm holes on approximately 20-mm centers to allow for rapid escape of air during the test.

2.4.1 Foam Test Procedure

The foam was placed on a compression test machine. The specimen was pre-conditioned by compressing it to 75% deflection two times at 250 ± 25 mm/min. The indenter completely cleared the top of the specimen after each pre-conditioning compression cycle. After resting the specimen for 6 minutes, the indenter was actuated into the specimen to a force of 4.5 Newtons. Then, the specimen was compressed to 25% deflection at a rate of 50 ± 5 mm/min and held for one minute; the (Indention Force Deflection) IFD value was recorded at the end of this minute and the specimen was immediately compressed to 50% deflection at a rate of 50 ± 5 mm/min, at which time the specimen compression was held again for one minute. Immediately after one minute, the IFD value was recorded and the specimen was compressed to 65% deflection at a rate of 50 ± 5 mm/min, at which time the deflection was held constant for one minute, and then the IFD value was recorded at the end of this minute. The indenter was returned to the starting position, clearing the top of the specimen. IFD values of the foam must fall within the specifications in Table 1.

Table 1 – Density, Indentation Force Deflection (IFD) and Compression Force Deflection (CFD) specifications for seat pan and seat back foam.

Foam Location	Density Kg/m^3	IFD @ 25% N	IFD @ 50% N	IFD @ 65% N	CFD @ 50% kPa
Seat Pan	47 ± 10%	237 ± 15%	440 ± 10%	725 ± 15%	6.6 ± 10%
Seat Back	47 ± 10%	157	300 ± 15%	480	6.6 ± 10%

2.5 Anthropomorphic Test Devices

The CRABI-12mo and Hybrid III 3 year old, 6 year old and 10 year old anthropomorphic test device (ATD)s were used. ATDs were calibrated before the test series and inspected after each test for damage. Instrumentation specifications and calibration dates are shown in Appendix 6.

2.6 Sled and Restraints

A belt tension load cell (MG Sensor F1B1B11A or MSI EL20-S458-16kn) was affixed to the seatbelt webbing at the fixed lap belt buckle and between the d-ring and shoulder anchor (**Error! Reference source not found.**).

(a) (b)

Figure 4 – Seat belt webbing load cells at the lap belt proximal to the buckle (a) and shoulder sash (b).

LATCH lower anchor load cells were used on each side of CRS in most tests. However, in some tests the geometry of the CRS and test fixture did not allow sufficient space for the load cell. Top tether load cells were placed midway on the tether strap (Figure 5).

Figure 5 – LATCH lower (a and b) anchor and top tether (c) webbing load cells.

Accelerometers (Appendix 7.1) were attached to the sled carriage at the underside of the carriage on the center cross beam.

2.7 Data Acquisition and Reduction

All accelerometer and load cell signals were captured using a high-speed data acquisition system (DTS Slice Pro) sampling at 20,000 samples per second and a 4000 Hz. anti-aliasing filter. Polarity and additional filtering was conducted as per SAE J211 (SAE Safety Test Instrumentation Standards Committee 2007).

2.8 High-Speed Video

Two high speed video cameras (Model NX8, Integrated Design Tools Pasadena, CA) were used to qualitatively and quantitatively assess head and knee excursion. Each camera lens had a focal length of 12.5 mm and the sampling rate for each video camera was 2000 frames per second. To measure head excursion, video cameras were placed 32 inches forward of the Z-point (see drawing package for location of Z-point on the bench) for non-tether tests and 28.4 inches forward of the Z-point when using top tether to measure head excursion. Similarly, to measure knee excursion a second camera was placed at 36 inches forward of the Z-point. Motion analysis software (TEMA 2D, Image Systems Motion Analysis, Linköping, Sweden) was used to measure maximum forward (x) head and knee excursion. Additional cameras were placed on the sled carriage and to the overhead laboratory frame to qualitatively assess kinematics (Figure 7). A photo target board (Figure 6) was also fabricated to allow calculation of head and knee excursions using the method developed by NHTSA / VRTC. Also, to support the NHTSA / VRTC method, a FARO arm was used to document the location of cameras relative to the Z-point, and lens calibration was conducted on the cameras (TEMA Manual, Image Systems AB, Linköping, Sweden).

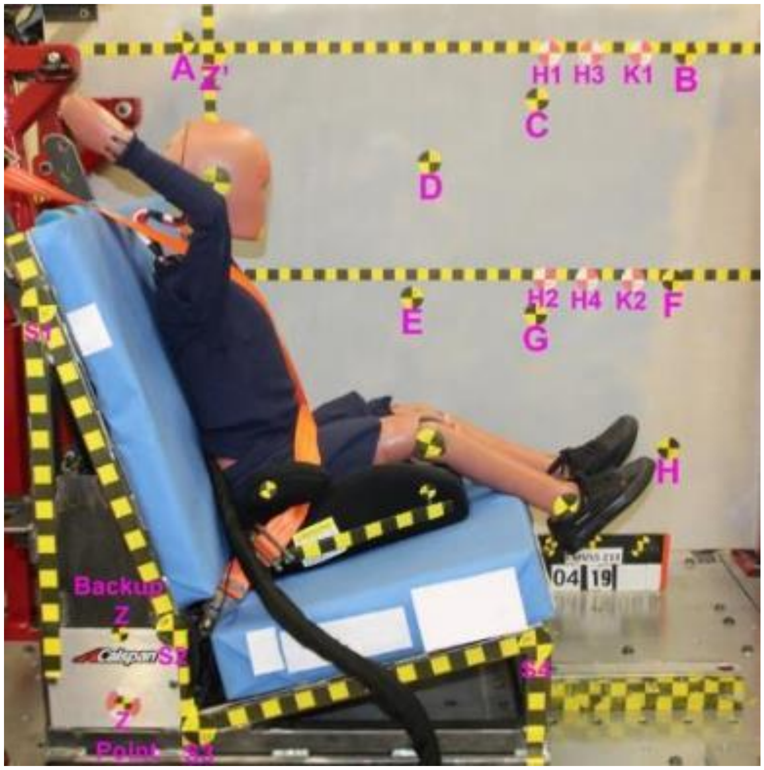


Figure 6 - Target board for calculation of head and knee excursion via the NHTSA/VRTC method.

Figure 7 - Camera layout

2.9 Test Procedure

2.9.1 Pre-test

A fresh piece of foam that had been in a soak room was prepared as described in Section 2.4. The ATD underwent a polarity check to ensure all channels were working and being accurately recorded. The CRS was installed on the bench and the ATD was installed in the CRS per the compliance test procedure (National Highway Traffic Safety Adminstration 2014) and in consultation with NHTSA as outlined herein. Excess belt webbing was secured with tape. Five different installers were used throughout the test series. Belt and harness tensions were adjusted to be within prescribed targets (Table 2). Both 5 and 7 panel webbing were used during this program. The first 4 tests were conducted with the 5 panel webbing (supplied by Calspan) and the remaining tests were conducted using the 7 panel webbing (supplied by VRTC). After initial placement, the FARO arm was used to measure the dummy and adjustments made as necessary to maintain consistent installations. Then, pre-test photographs were taken.

Table 2 - Targets for sled belt and CRS harness tension.

Belt Type	Tension (N)	Tension (lbs)
Harness	8.90 - 13.3	2 - 4
Lower Anchorages	53.4 - 66.7	12 - 15
Tether Anchorage	44.5 - 53.4	10 - 12
Belts for Convertible Child Restraint Systems	53.4 - 66.7	12 - 15
Belts for Belt Positioning Boosters	8.90 - 13.3	2 - 4

2.9.2 FARO Measurements

A FARO arm was used to ensure consistent positioning of the ATD and CRS from test-to-test. Positioning points are described in Table 3 and shown in Figure 8 and Figure 9. For all tests grouped for repeatability analysis, each measurement shown in Table 3 were within ±10 mm of each other.

Table 3 – FARO arm measurement location descriptions.

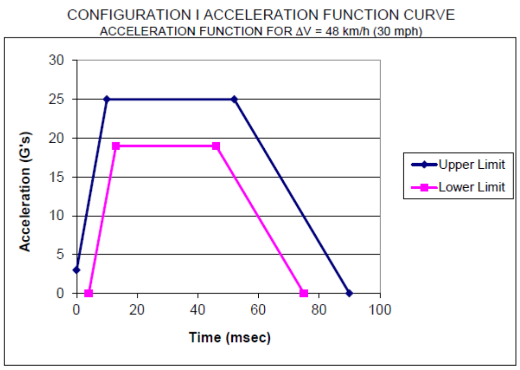
Infant/Rear Facing Seats		Forward Facing
Target	**Description**	**Description**
1	Z-Point - should be 0,0,0	Z-Point - should be 0,0,0
2	Center of Seat Frame Back (on buck)	Center of Seat Frame Back (on buck)
3	CRS Bottom Center (near strap adjuster)	Top of CRS
4	CRS Top of the Base (on base - if it has a base)	CRS Top of Headrest (if applicable)
5	Top of CRS	Top of Head
6	CRS Handle Center (if applicable)	Neck Center (center mark on neck if applicable)
7	Top of Head	Bridge of Nose
8	Bridge of Nose	Head CG Outboard
9	Head CG Outboard	Chest Clip
10	Chest Clip	Buckle
11	Buckle	Knee
12	CRS mid height (on back of CRS)	Ankle
13	CRS Base Center or bottom of CRS at centerline	CRS Base Center (on Front of seat)
14	Center of Seat Frame Bottom	Center of Seat Frame Bottom
15	CRS Side Handle (if applicable)	Seat Side Upper
16	Seat Side Upper	Seat Base H-Point
17	Seat Base H-Point	Seat Base Side
18	Seat Base Side	Seat Side Lower
19	Seat Side Lower	N/A

Figure 8 – FARO measurement locations for forward-facing CRS

Figure 9 – FARO arm measurement locations for rear-facing CRS.

2.9.3 Test

The initially stationary sled carriage was subjected to negative x acceleration time-history that is within the corridor shown in Figure 10. Video and data acquisition systems were triggered at the time of the acceleration pulse onset.



TEST CONFIGURATION I ACCELERATION FUNCTION ENVELOPE

UPPER LIMIT		LOWER LIMIT	
TIME (msec)	ACCELERATION (G's)	TIME (msec)	ACCELERATION (G's)
0	3	4	0
10	25	13	19
52	25	46	19
90	0	75	0

Figure 10 – Sled carriage acceleration corridor.

2.9.4 Post-test

Immediately following the test, photographs were taken at all angles of the final rest position of the ATD and CRS. Any damage to the ATD, CRS or test fixture was noted and documented with photographs. The foam was removed and inspected for signs of damage. For assessment of repeatability of the test conditions, maximum acceleration and change in velocity (via integration of the sled acceleration) of the sled carriage were determined. Head Injury Criterion (HIC) at both 15 and 36 millisecond time windows, head and chest 3 millisecond clip, Nij values were calculated. Coefficient of variation (CV) was calculated as per the following formula (Saunders and Parent 2013; McFadden, Moorhouse, and Hagedorn 2015):

$$\%CV = \frac{|\sigma_{sample}|}{\bar{x}_{sample}}$$

Where $\bar{x}$ is mean and σ is the standard deviation of the repeated responses.

The CVs will become large in some cases when the magnitude of the measured quantity is low, as in neck injury data, but the repeatability calculation is valid. Said another way, the test showed low (or high) repeatability in range of the quantities measured. One could argue that the relevance of the repeatability measurement is low for metrics that are well below injury assessment reference values (IARV)s.

3 Results

3.1 Crash Pulse Comparison w/VRTC

Figure 11 shows the VRTC and Calspan pulses overlaid on the same time scale. The Calspan pulse has a higher peak g when run at same velocity, but was within the prescribed corridor (Figure 10).

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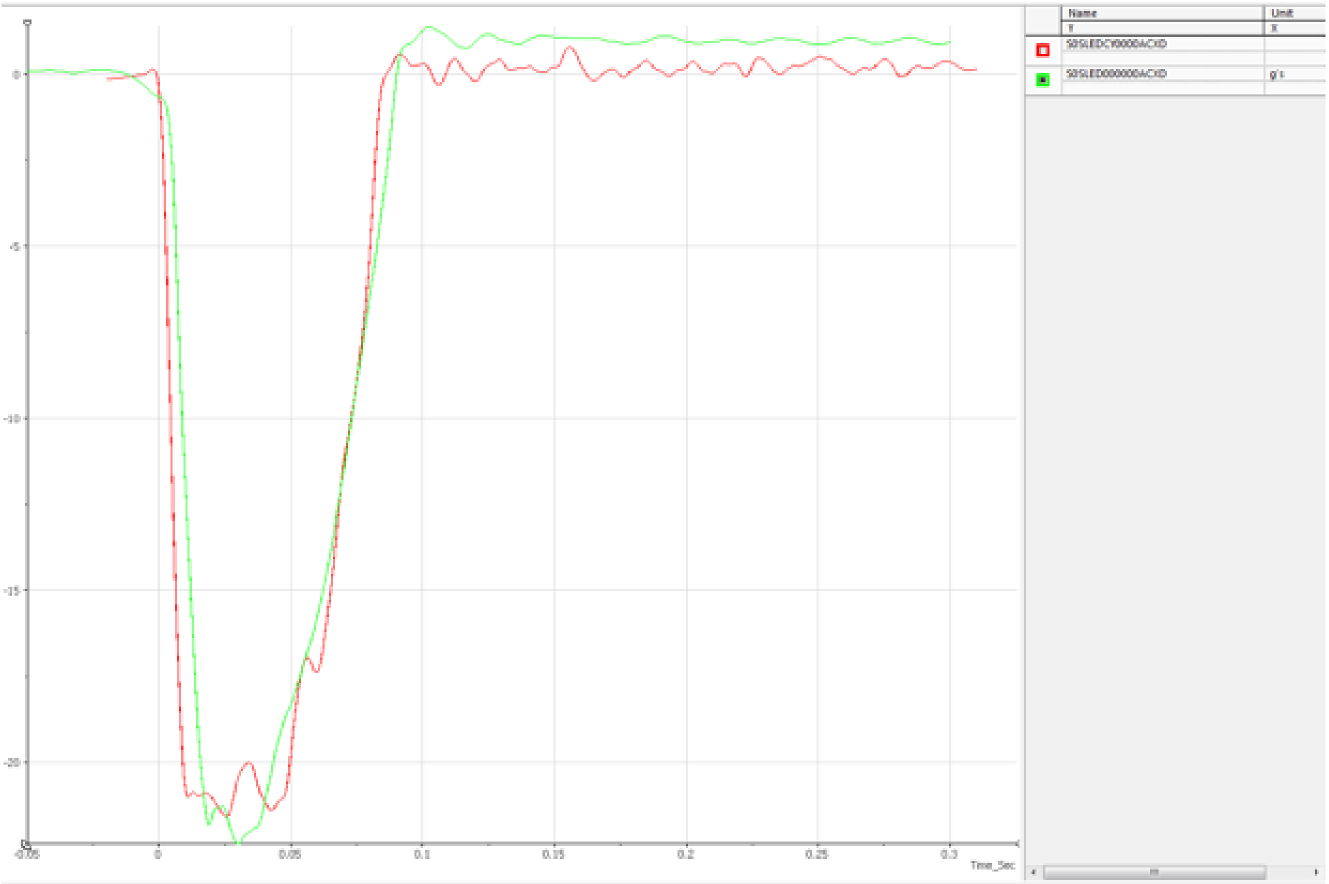


Figure 11 - Calspan (green) and VRTC (red) sled acceleration.

3.2 Sled Test Results

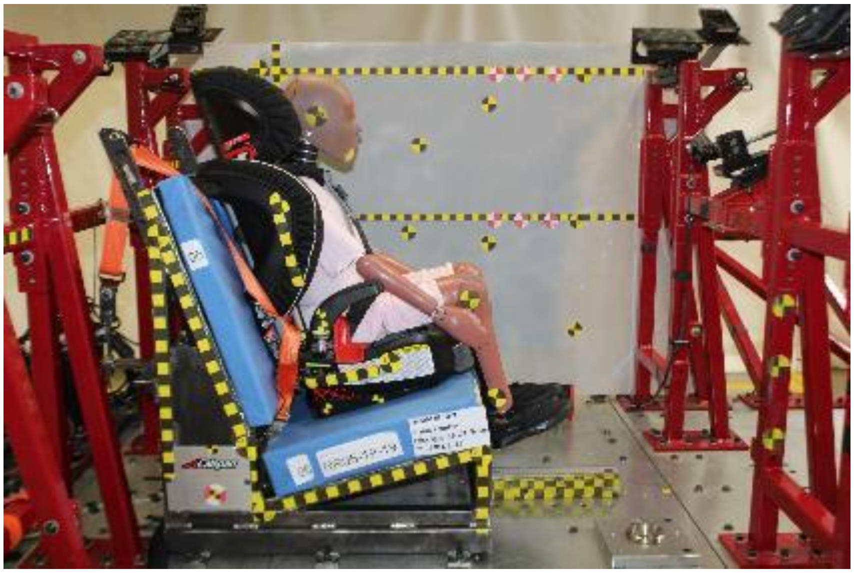
3.2.1 Repeatability

Repeatability results are shown in the following sections. There are 11 different combinations of CRS and ATD configurations reported, with three repeat tests per configuration. The coefficient of variation (CV) is reported for all injury criteria and kinematic and kinetic values.
It is worth noting that sled acceleration and delta V %CV were below 1% with the exception of the Dorel Scenera where the CV was 1.5%. In that case, the sled maximum acceleration was lower for the first test (22.6 g) compared to the other two tests (23.2 g). That said, the injury criteria and other kinetic and kinematic measures for the first test were not outliers compared to the others, and thus all tests in the Scenera series can be considered valid repeats.

Figure 12 shows an overlay of two tests performed using the Britax Frontier. Overlaying videos of repeat tests allows for comparison between test setups and final results.

Figure 12 – Video Overlay of two repeat tests of the Britax Frontier.

3.2.1.1 Britax Frontier – 10yo



Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
5/03/2019	RR05-19-19, 20, 21	Britax Frontier	10-YO H3	FF	Lap & Shoulder	Y	8	F	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR05-19-19	23.3	47.8	383	248	51.6	-8.4	38.4	716	825
RR05-19-20	23.4	47.9	347	215	47.3	-7.6	38.5	699	806
RR05-19-21	23.4	47.9	352	197	46.4	-9.1	43.6	702	836
Mean	23.4	47.9	354	220	48.4	-8.4	40.2	706	822
Std Dev	0.6	0.6	26.2	25.9	2.78	0.75	2.97	9.1	15.2
%CV	**0.2%**	**0.1%**	**7.4%**	**11.8%**	**5.7%**	**9.0%**	**7.4%**	**1.3%**	**1.8%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shldr (N)	Lap Right (N)	TT (N	Installer	Foam
RR05-19-19	0.533	0.634	0.001	0.031	3384	1959	6120	MB	6
RR05-19-20	0.492	0.533	0.002	0.002	4226	1561	5862	BH	7
RR05-19-21	0.511	0.542	0.094	0.002	3230	1797	6276	MB	6
Mean	0.512	0.570	0.032	0.012	3613	1772	6086		
Std Dev	0.021	0.056	0.053	0.017	586	200	209		
%CV	**4.0%**	**9.8%**	**165.2%**	**143.5.8%**	**14.8%**	**11.3%**	**3.4%**		

3.2.1.2 Dorel Pronto HB Booster – 6 YO

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
5/1/2019	RR05-19-13, 14, 15	Dorel Pronto HB Booster	6-YO H3	FF	Lap & Shoulder	N	N/A	N/A	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR05-19-13	23.3	48.1	650	383	60	-39.3	58.7	557	624
RR05-19-14	23.3	48.1	621	377	60	-39.7	51,9	555	611
RR05-19-15	23.3	48.1	664	394	61	-38.4	52.5	560	616
Mean	23.3	48.1	645	385	60.3	-39.1	54.4	557	617
Std Dev	0.0	0.0	21.9	8.6	0.6	0.7	3.8	2.5	7.0
%CV	**0.0%**	**0.0%**	**3.4%**	**2.2%**	**1.0%**	**1.7%**	**6.9%**	**0.5%**	**1.1%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shldr / TT (N)	Lap Right (N)	Installer	Foam
RR05-19-13	0.945	1.082	0.002	0.003	4527	3312	BH	6
RR05-19-14	0.854	1.132	0.061	0.003	4377	3052	MB	7
RR05-19-15	0.955	1.225	0.002	0.004	4424	3284	MB	6
Mean	0.918	1.146	0.022	0.003	4443	3216		
Std Dev	0.056	0.073	0.034	0.001	76.7	143		
%CV	**6.1%**	**6.3%**	**157%**	**17%**	**1.7%**	**4.4%**		

3.2.1.3 Dorel Scenera Next – 12mo

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
6/14/2019	RR06-19-31, 32, 33	Dorel Scenera Next	CRABI 12mo	FF	Lower anchor	N	5	M	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR06-19-31	23.3	48.0	354	272	53.0	-	43.3	583	562
RR06-19-32	23.4	48.1	391	305	57.3	-	42.9	575	563
RR06-19-33	23.3	48.0	389	319	57.8	-	48.6	579	558
Mean	23.3	48.0	378	299	56.0	-	44.9	579	561
Std Dev	0.06	0.06	20.8	24.1	2.64	-	3.18	4.0	2.6
%CV	**0.2%**	**0.1%**	**5.5%**	**8.1%**	**4.7%**	**-**	**7.1%**	**0.7%**	**0.5%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	TT (N)	Lower Right (N)	Lower Left (N)	Installer	Foam
RR06-19-31	0.875	1.211	0.040	0.330	-	2502	2529	MB	6
RR06-19-32	0.980	1.295	0.075	0.321	-	2504	2304	BH	7
RR06-19-33	0.991	1.352	0.057	0.357	-	2558	2540	MB	6
Mean	0.949	1.286	0.057	0.336	-	2521	2458		
Std Dev	0.064	0.071	0.018	0.019	-	32	133		
%CV	**6.7%**	**5.5%**	**30.5%**	**5.6%**	**-**	**1.3%**	**5.4%**		

3.2.1.4 Dorel Scenera Next – 3yo

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
6/12/2019	RR06-19-22, 23, 35	Dorel Scenera Next	3-YO H3	FF	Lower anchor	Y	5	F	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR06-19-22	22.6	47.8	374	222	49.4	-20.7	40.7	607	643
RR06-19-23	23.2	47.9	350	183	45.6	-20.5	41.7	604	645
RR06-19-35	23.2	47.9	354	208	47.9	-19.3	39.0	599	634
Mean	23.0	47.9	359	204	47.6	-20.2	40.5	603	641
Std Dev	0.35	0.06	12.9	19.8	1.91	0.76	1.37	4.2	5.8
%CV	**1.5%**	**0.1%**	**3.6%**	**9.7%**	**4.0%**	**3.8%**	**3.4%**	**0.7%**	**0.9%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	TT (N)	Lower Right (N)	Lower Left (N)	Installer	Foam
RR06-19-22	0.197	0.972	0.075	0.474	1834	2809	2628	MB	7
RR06-19-23	0.206	0.901	0.081	0.433	2128	2766	2627	MB	6
RR06-19-35	0.335	0.853	0.078	0.356	2315	2417	1337	MB	6
Mean	0.246	0.909	0.078	0.421	2092	2664	2197		
Std Dev	0.077	0.060	0.003	0.060	242	215	745		
%CV	**31.4%**	**6.6%**	**3.8%**	**14.2%**	**11.6%**	**8.1%**	**33.9%**		

3.2.1.5 Evenflo Big Kid LX (Amp)

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
5/2/2019	RR05-19-16, 17, 18	Evenflo Big Kid LX (Amp)	10-YO H3	FF	Lap & Shoulder	N	6	N/A	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR05-19-16	23.2	48.0	482	323	65.5	-28.3	43.3	547	692
RR05-19-17	23.3	48.1	483	280	59.5	-26.7	42.6	547	680
RR05-19-18	23.2	47.9	447	277	61.1	-26.6	44.0	542	697
Mean	23.2	48.0	471	293	62.0	-27.2	43.3	545	690
Std Dev	0.1	0.1	20.5	25.7	3.1	1.0	0.7	2.9	8.7
%CV	**0.2%**	**0.2%**	**4.4%**	**8.8%**	**5.0%**	**3.5%**	**1.6%**	**0.5%**	**1.3%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shldr / TT (N)	Lap Right (N)		Installer	Foam
RR05-19-16	1.112	0.680	0.002	0.002	4305	3806		BH	7
RR05-19-17	1.014	0.737	0.001	0.002	4499	3860		BH	6
RR05-19-18	0.996	0.637	0.002	0.161	4457	3883		MB	7
Mean	1.041	0.685	0.002	0.055	4420	3850			
Std Dev	0.062	0.050	0.001	0.092	102.1	39.5			
%CV	**6.0%**	**7.3%**	**34.6%**	**166.9%**	**2.3%**	**1.0%**			

3.2.1.6 Evenflo Embrace 35 – 12mo

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
6/13/2019	RR06-19-28, 29, 30	Evenflo Embrace 35	CRABI – 12mo	RF	Lower anchor	N	3	M	2

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Pre SB Exc (deg)	Post SB Exc (deg)
RR06-19-28	23.6	48.4	660	483	74.7	-	54.8	38	50.8
RR06-19-29	23.5	48.3	632	461	72.0	-	54.6	38	51
RR06-19-30	23.5	48.3	637	462	72.8	-	55.9	37	52.1
Mean	23.5	48.3	643	469	73.2	-	55.1	38	51
Std Dev	0.06	0.06	14.9	12.4	1.39	-	0.70	0.6	0.7
%CV	**0.2%**	**0.1%**	**2.3%**	**2.7%**	**1.9%**	**-**	**1.3%**	**1.5%**	**1.4%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shoulder (N)	Lower Right (N)	TT (N)	Installer	Foam
RR06-19-28	0.190	1.723	0.669	0.332	-	3225	-	MB	6
RR06-19-29	0.192	1.669	0.535	0.351	-	3254	-	AA	7
RR06-19-30	0.197	1.670	0.593	0.354	-	3302	-	MB	6
Mean	0.193	1.687	0.599	0.346	-	3260	-		
Std Dev	0.004	0.031	0.067	0.012	-	39	-		
%CV	**1.9%**	**1.85**	**11.2%**	**3.5%**	**-**	**1.2%**	**-**		

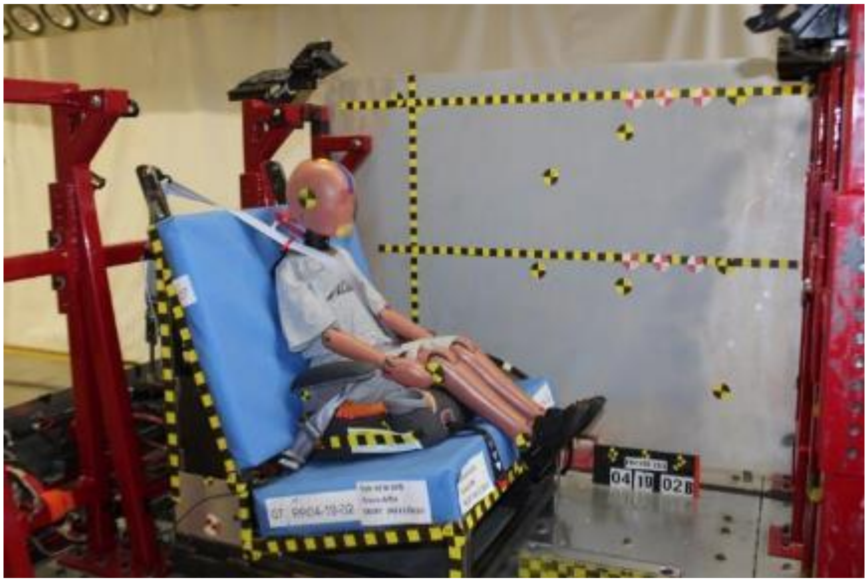
3.2.1.7 Evenflo Sure Ride 65

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
5/1/2019	RR05-19-10, 11, 12	Evenflo Sure Ride 65	6-YO H3	FF	Lower anchor	Y	5	F	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR05-19-10	23.3	48.0	412	232	50.7	-15.6	42.3	650	810
RR05-19-11	23.2	47.8	384	215	49.2	-16.7	42.7	649	811
RR05-19-12	23.4	48.1	411	236	50.4	-14.9	43.2	651	808
Mean	23.3	48.0	402	228	50.1	-15.7	42.7	650	810
Std Dev	0.1	0.2	15.8	11.2	0.8	0.9	0.5	1.0	1.5
%CV	**0.4%**	**0.3%**	**3.9%**	**4.9%**	**1.6%**	**5.8%**	**1.1%**	**0.2%**	**0.2%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shldr / TT (N)	Lower Right (N)	Lower Left (N)	Installer	Foam
RR05-19-10	0.690	0.607	0.115	0.002	2704	3635	3297	MB	7
RR05-19-11	0.670	0.670	0.119	0.002	2593	3446	2988	MB	6
RR05-19-12	0.656	0.651	0.122	0.003	2704	3545	2879	ZR	7
Mean	0.672	0.643	0.119	0.002	2667	3542	3055		
Std Dev	0.017	0.032	0.004	0.001	64.1	94.5	217		
%CV	**2.5%**	**5.0%**	**3.0%**	**24.7%**	**2.4%**	**2.7%**	**7.1%**		

3.2.1.8 Graco Affix Backless Booster



Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
4/10/2019	RR04-19-02, 3, 5	Graco Affix Backless Booster	6-YO H3	FF	Lap & Shoulder	N	N/A	N/A	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR04-19-02	23.3	48.6	521	309	54.7	-37.7	51.5	490	580
RR04-19-03	23.2	48.5	429	254	51.1	-38.8	51.2	476	586
RR04-19-05	23.3	47.4	457	293	54.9	-36.6	52.2	497	609
Mean	23.2	48.2	469	285	53.6	-37.7	51.5	487.7	591.7
Std Dev	0.2	0.7	47.2	28.3	2.1	1.1	0.6	10.7	15.3
%CV	**0.7%**	**1.4%**	**10.1%**	**9.9%**	**4.0%**	**2.9%**	**1.2%**	**2.2%**	**2.6%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shldr / TT (N)	Lap Right (N)		Installer	Foam
RR04-19-02	0.900	1.100	0.0	0.400	5267	2489		BH	7
RR04-19-03	0.873	0.952	0.061	0.017	5571	2475		MB	6
RR04-19-05	0.927	1.080	0.002	0.133	4949	2732		BH	6
Mean	0.900	1.044	0.021	0.183	5262	2565			
Std Dev	0.027	0.080	0.035	0.196	311	144.5			
%CV	**3.0%**	**7.7%**	**165.0%**	**107.1%**	**5.9%**	**5.6%**			

3.2.1.9 Graco My Ride – 3yo

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
6/13/2019	RR06-19-25, 26, 27	Graco My Ride	3-YO H3	RF	Lap & Shoulder	N	3	-	2

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Pre SB Exc (deg)	Post SB Exc (deg)
RR06-19-25	23.2	47.8	558	418	65.6	-13.2	51.0	38	52.5
RR06-19-26	23.3	47.9	523	340	57.1	-12.9	49.2	39	53.9
RR06-19-27	23.4	48.1	531	350	63.9	-13.1	50.0	39	55.3
Mean	23.3	47.9	537	369	62.2	-13.1	50.1	39	54.0
Std Dev	0.10	0.15	18.5	42.4	4.50	0.15	0.90	0.6	1.4
%CV	**0.4%**	**0.3%**	**3.5%**	**11.5%**	**7.2%**	**1.2%**	**1.8%**	**1.5%**	**2.6%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shoulder (N)	Lap (N)	TT (N)	Installer	Foam
RR06-19-25	0.199	1.099	0.167	0.274	1273	2761		BH	6
RR06-19-26	0.330	0.928	0.171	0.329	1336	2792		BH	6
RR06-19-27	0.243	1.015	0.171	0.195	1343	2788		MB	7
Mean	0.257	1.014	0.170	0.266	1317	2780			
Std Dev	0.067	0.086	0.002	0.067	39	17			
%CV	**25.9%**	**8.4%**	**1.4%**	**25.3%**	**2.9%**	**0.6%**			

3.2.1.10 Graco Nautilus 65LX

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
4/10/2019	RR04-19-01, 4, 9	Graco Nautilus 65LX	6-YO H3	FF	Lap & Shoulder	N	4	M	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR04-19-01	22.9	47.3	456	285	53.3	-12.5	44.6	670	737
RR04-19-04	23.3	48.4	490	299	54.2	-13.4	45,6	703	749
RR05-19-09	23.5	47.9	474	284	53.8	-14.5	45.7	694	752
Mean	23.2	47.9	473.3	289.3	53.8	-13.5	45.3	689	746
Std Dev	0.3	0.6	17.0	8.4	0.5	1.0	0.6	17.1	7.9
%CV	**1.3%**	**1.2%**	**3.6%**	**2.9%**	**0.8%**	**7.4%**	**1.3%**	**2.5%**	**1.1%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shldr / TT (N)	Lap Right (N)		Installer	Foam
RR04-19-01	0.674	0.590	0.043	0.029	5393	5211		MB	6
RR04-19-04	0.600	0.700	0.0	0.0	5480	5586		BH	7
RR05-19-09	0.617	0.628	0.002	0.024	4964	5236		MB	6
Mean	0.630	0.639	0.015	0.018	5279	5344.3			
Std Dev	0.039	0.056	0.024	0.016	276.2	209.7			
%CV	**6.1%**	**8.7%**	**161.8%**	**87.8%**	**5.2%**	**3.9%**			

3.2.1.11 Harmony Youth Backless Booster

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
4/30/2019	RR04-19-06, 7, 8	Harmony Youth Backless Booster	6-YO H3	FF	Lap & Shoulder	N	N/A	N/A	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR04-19-06	23.1	47.6	489	291	53.9	-39.9	50.6	496	604
RR04-19-07	23.4	48.0	460	269	51.0	-41.0	49.3	494	591
RR04-19-08	23.3	48.0	463	270	51.4	-40.5	49.4	491	592
Mean	23.3	47.9	471	277	52.1	-40.5	49.8	494	596
Std Dev	0.2	0.2	15.9	12.4	1.6	0.6	0.7	2.5	7.2
%CV	**0.7%**	**0.5%**	**3.4%**	**4.5%**	**3.0%**	**1.4%**	**1.5%**	**0.5%**	**1.2%**

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shldr / TT (N)	Lap Right (N)		Installer	Foam
RR04-19-06	0.994	1.074	0.002	0.657	4912	2585		ZR	7
RR04-19-07	0.858	0.916	0.002	0.667	4700	2414		ZR	6
RR04-19-08	0.930	0.919	0.002	0.676	4714	2389		ZR	7
Mean	0.927	0.970	0.002	0.667	4775	2463			
Std Dev	0.068	0.090	0.000	0.010	119	107			
%CV	**7.3%**	**9.3%**	**0.0%**	**1.4%**	**2.5%**	**4.3%**			

3.2.1.12 Repeatability by Injury Criteria

Repeatability results broken down by injury criteria are shown in Figure 13 through Figure 19. There are six injury criteria called out using data from the 11 different combinations of CRS tested. The variation of repeatability from restraint to restraint is an indication that different CRS themselves can be a factor of repeatability in test data.

The Britax Frontier has a higher repeatability variance across all injury criteria than the Evenflo SureRide. Some CRS have one or two outlying high injury criteria as opposed to an overall trend across criteria.

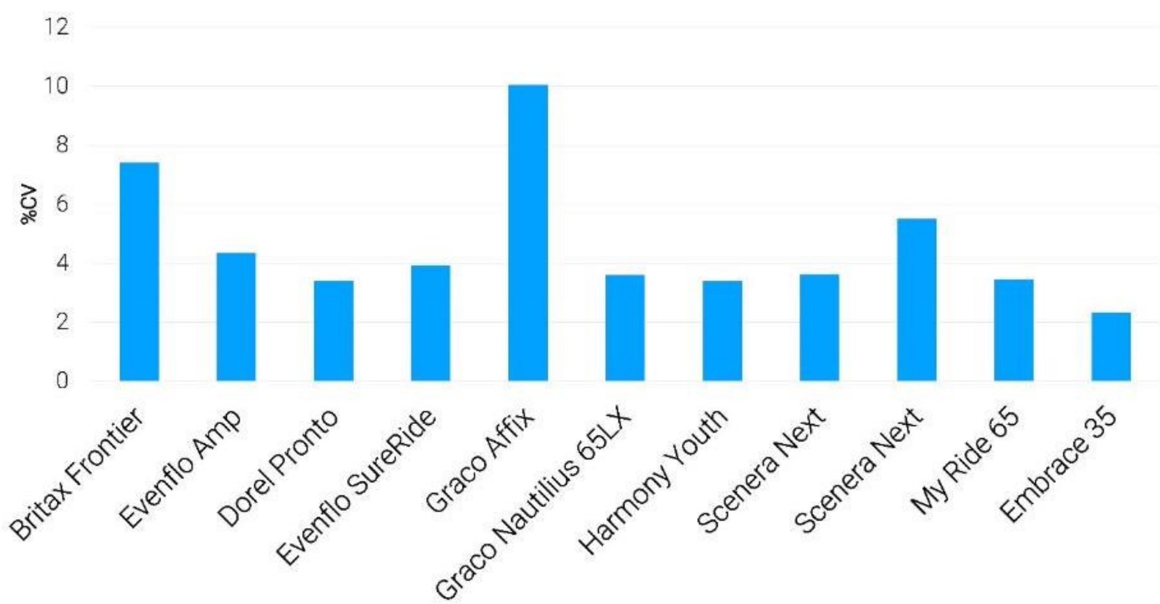


Figure 13 – Repeatability of HIC 36

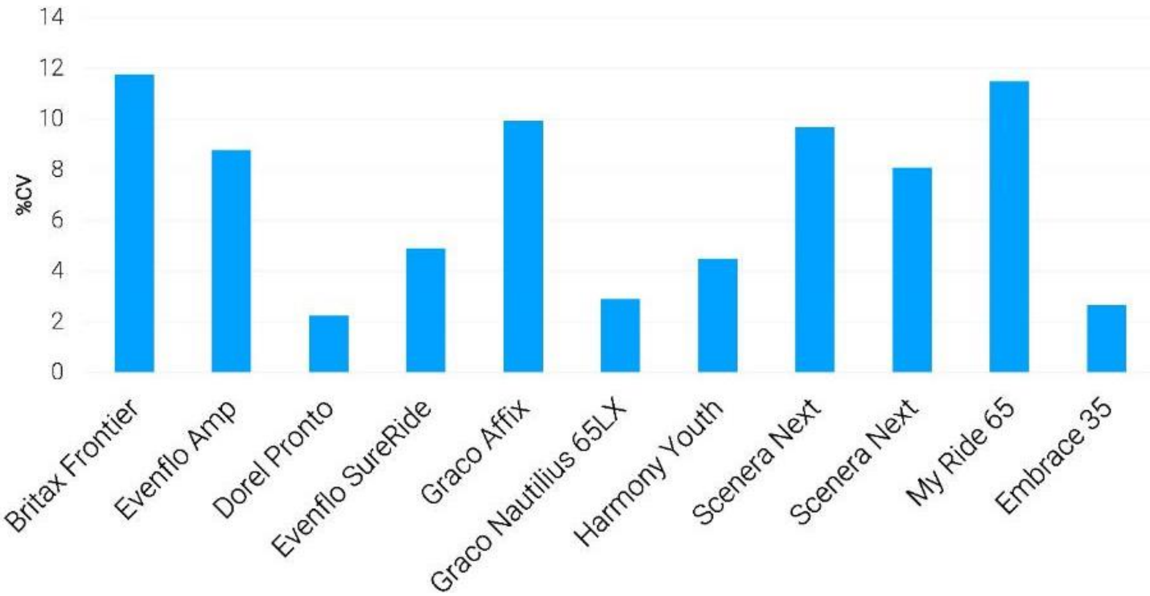


Figure 14 - Repeatability of HIC 15

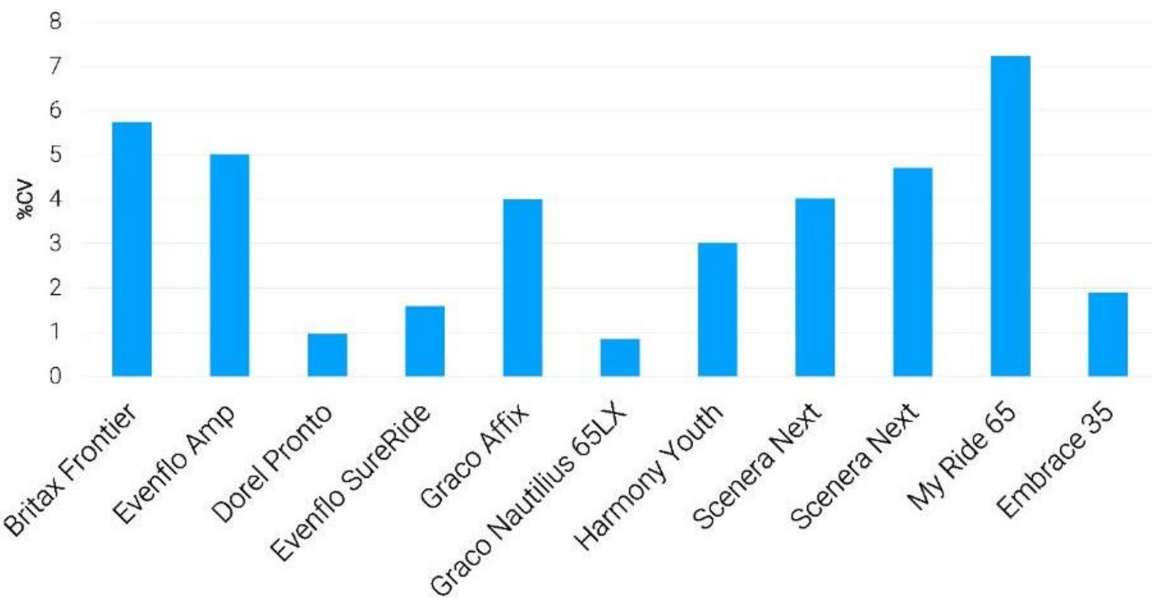


Figure 15 - Repeatability of 3ms clip head resultant acceleration

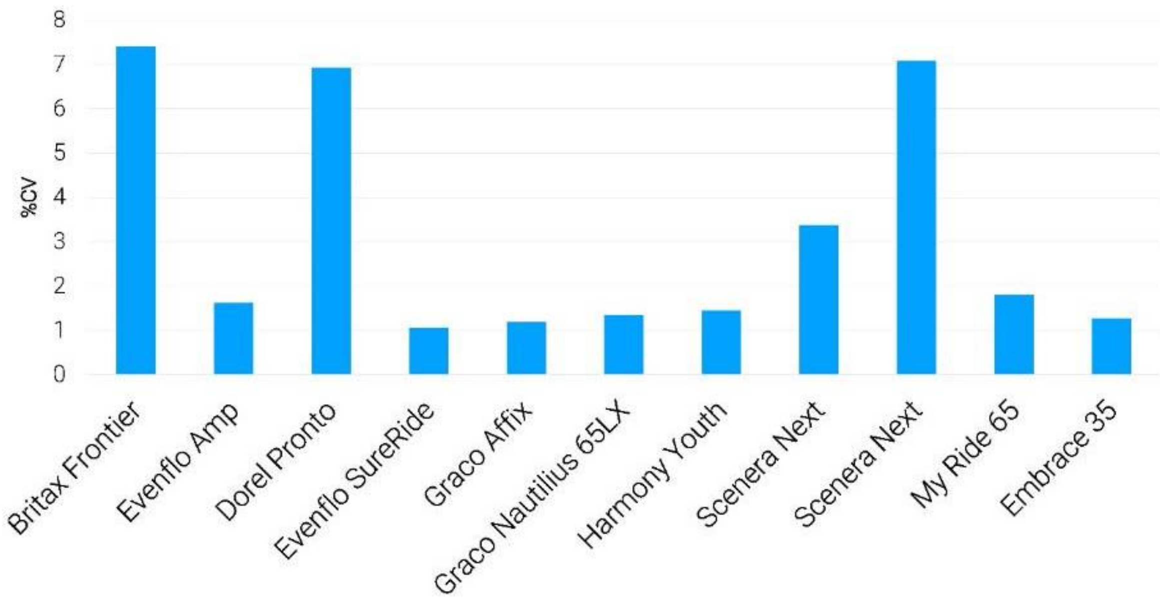


Figure 16 - Repeatability of 3ms resultant chest acceleration

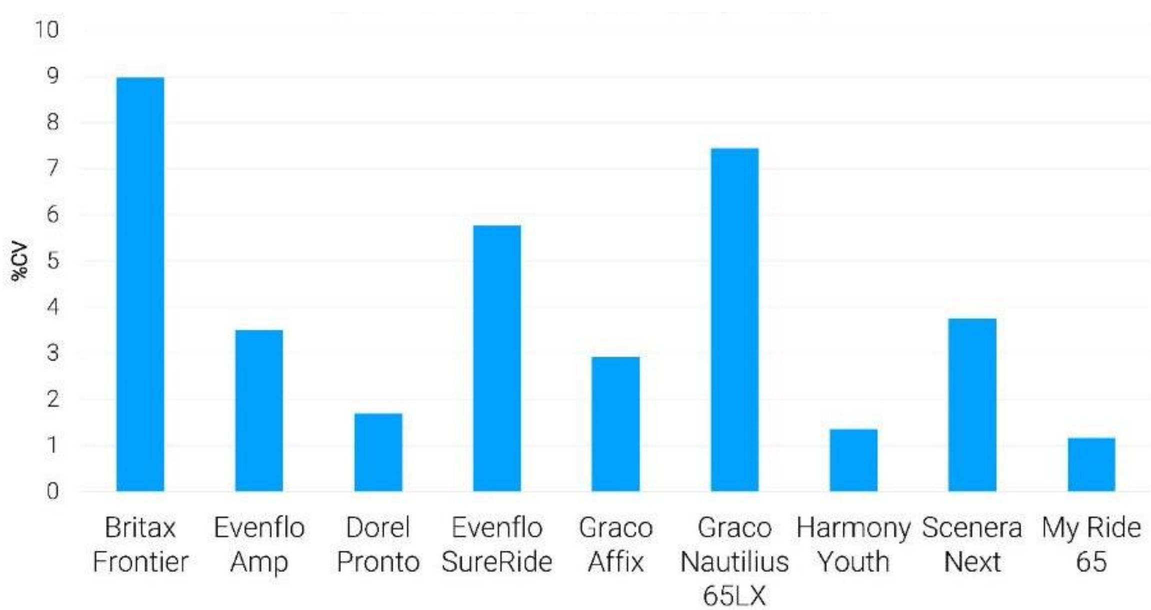


Figure 17 - Repeatability of chest displacement

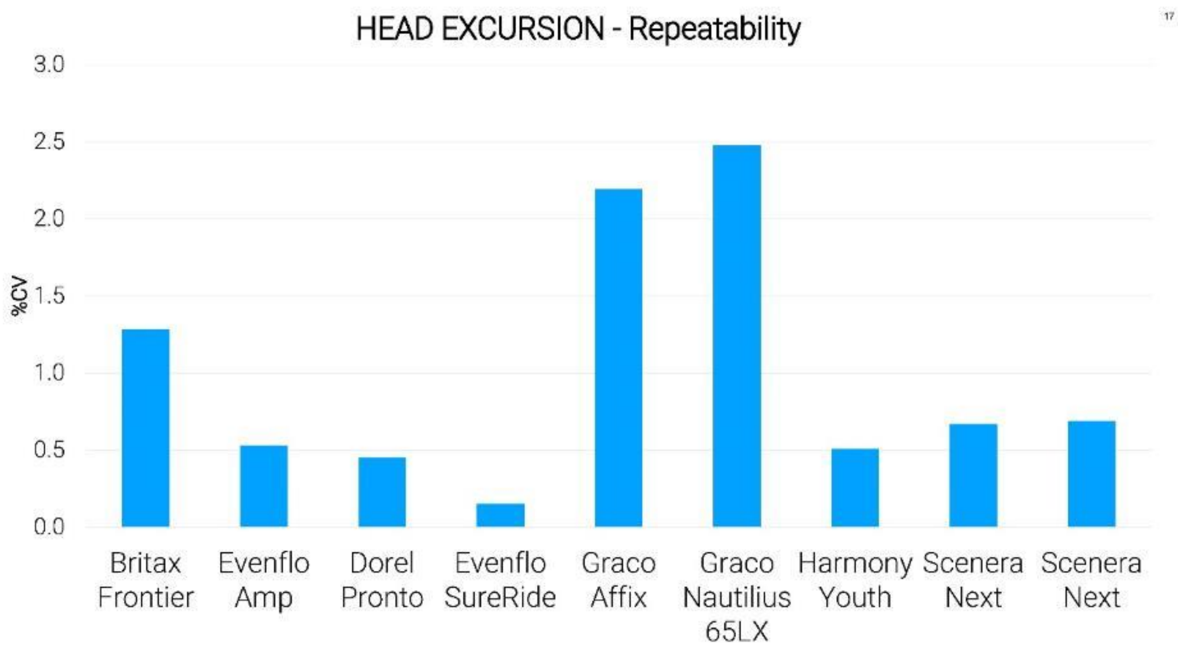


Figure 18 - Repeatability of head excursion

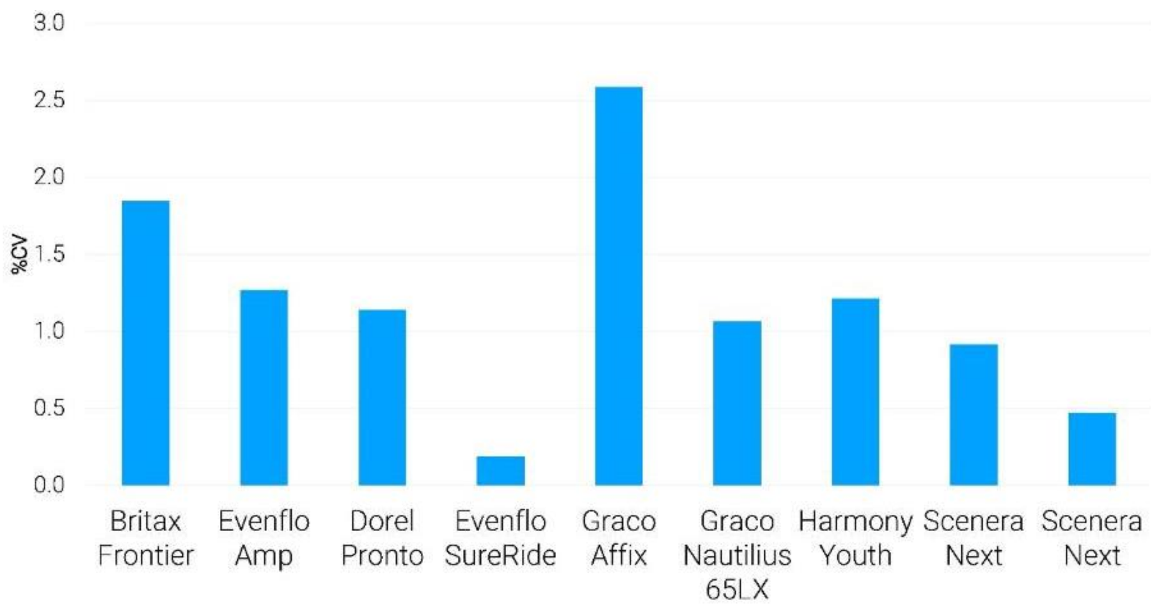


Figure 19 - Repeatability of knee excursion

3.2.2 Reproducibility

For the reproducibility study, two test groupings were compared between VRTC and Calspan. The data from VRTC was generated on the updated bench. The data from Calspan was generated on another bench built from drawings of the VRTC bench.

Reproducibility assessments are shown in Table 4, Table 5, Figure 20 and Figure 21. Two CRS – the Graco Affix and Nautilus, both with a 6 year old ATD and 3 point belt – were analyzed for reproducibility. Laboratory results from VRTC and Calspan were compared. Delta V and peak sled acceleration were higher at Calspan by 0.6 to 0.9 kph and 1.3 to 1.5 g, respectively, than at VRTC. Overall, mean HIC and head clip trended lower at Calspan in the both series, and there was no strong magnitude bias toward Calspan or VRTC in mean chest injury metrics or excursions. Thus, it is concluded that any trends in data between Calspan and VRTC can be attributable to factors such as subtleties in difference in the sled acceleration profiles, installation procedures, variability in the ATDs and the foam within the calibration specifications.

In some cases reproducibility is shown to be much greater than the single lab repeatability. This indicates that although the data generated within each lab is repeatable, between the labs it was at slightly different magnitudes.

The notable outlier for the two restraint models used for reproducibility was the chest displacement for the Graco Nautilus harnessed seat. Although repeatability within each lab was under 7%, the reproducibility between the labs was almost 24%.This is in contrast to the much closer chest displacement reproducibility seen with the Graco Affix booster seat, where it is around 5%.

A problem here is that this CV is influenced by the within lab repeatability (i.e. this CV will take on a smaller value if the measurements within the labs are close to each other). The correct way to extract reproducibility is to average response from each lab, and then calculate CV of the averages. This approach would require testing at least 3 labs, which could be part of a future test program.

Table 4 - Reproducibility of the Graco Affix 6yo with 3 pt belt restraint

		Acc. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
CALSPAN	RR04-19-02	23.3	48.6	521	309	54.7	-37.7	51.1	490	580
	RR04-19-03	23.2	48.5	429	254	51.1	-38.8	51.2	476	586
	RR04-19-05	23	47.4	457	293	54.9	-36.6	52.2	497	609
	Mean	23.2	48.2	469.0	285.3	53.6	-37.7	51.5	487.7	591.7
	Std Dev	0.2	0.7	47.2	28.3	2.1	1.1	0.6	10.7	15.3
	% CV	1%	1%	10.1%	9.9%	4.0%	2.9%	1.2%	2.2%	2.6%
VRTC	S150917-1_Right_86	21.75	47.3	479	266	53.3	-38	56.6	466	589
	S150918-1_Right_88	21.7	47.3	573	334	58.2	-37.7	60.1	491	599
	S150921-1_Right_90	21.65	47.3	535	330	58.9	-41.3	59.6	495	598
	Mean	21.7	47.3	529.0	310.0	56.8	-39.0	58.8	484.0	595.3
	Std Dev	0.1	0.0	47.3	38.2	3.1	2.0	1.9	15.7	5.5
	% CV	0%	0%	8.9%	12.3%	5.4%	5.1%	3.2%	3.2%	0.9%
CALSPAN + VRTC	Mean	22.4	47.7	499.0	297.7	55.2	-38.4	55.1	485.8	593.5
	Std Dev	0.81	0.63	53.52	32.94	2.95	1.61	4.17	12.19	10.48
	% CV	4%	3.6%	1.3%	10.7%	11.1%	5.3%	4.2%	2.5%	1.8%

		Nij				Restraint Loads	
		Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shldr (N)	Lap (N)
CALSPAN	RR04-19-02	0.9	1.1	0	0.4	5267	2489
	RR04-19-03	0.873	0.952	0.061	0.017	5571	2475
	RR04-19-05	0.927	1.08	0.002	0.133	4949	2732
	Mean	0.900	1.044	0.021	0.183	5262.3	2565.3
	Std Dev	0.027	0.080	0.035	0.196	311.0	144.5
	% CV	3.0%	7.7%	165.0%	107.1%	5.9%	5.6%
VRTC	S150917-1_Right_86	0.95	1.3	0.04	0.44	5849	3585
	S150918-1_Right_88	0.98	1.5	0.00	0.46	5836	3763
	S150921-1_Right_90	0.85	1.54	0.00	0.59	5930	3836
	Mean	0.927	1.447	0.013	0.497	5871.7	3728.0
	Std Dev	0.068	0.129	0.023	0.081	50.9	129.1
	% CV	7.3%	8.9%	173.2%	16.4%	0.9%	3.5%
CALSPAN + VRTC	Mean	0.9	1.2	0.0	0.3	5567.0	3146.7
	Std Dev	0.05	0.24	0.03	0.22	388.74	648.50
	% CV	5%	19%	155%	64%	7%	21%

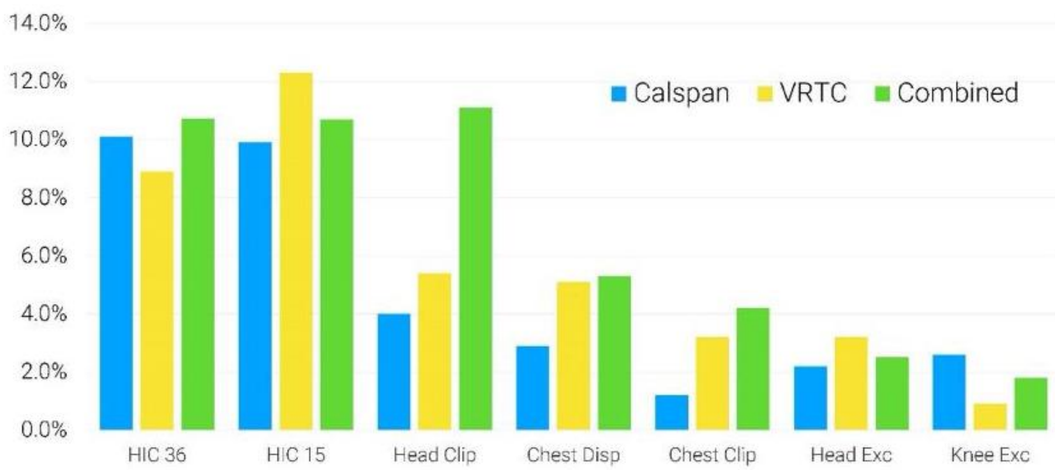


Figure 20 - Reproducibility of the Graco Affix 6yo with 3 pt belt restraint

Table 5 - Reproducibility of the Graco Nautilus 6yo with 3 pt belt

		Acc. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp. (mm)	Chest Clip (g)	Head Exc. (mm)	Knee Exc. (mm)
CALSPAN	RR04-19-01	22.9	47.3	456	285	53.3	-12.5	44.6	670	737
	RR04-19-04	23.3	48.4	490	299	54.2	-13.4	45.6	703	749
	RR04-19-09	23.5	47.9	474	284	53.8	-14.5	45.7	694	752
	Mean	23.2	47.9	473.3	289.3	53.8	-13.5	45.3	689.0	746.0
	Std Dev	0.3	0.6	17.0	8.4	0.5	1.0	0.6	17.1	7.9
	% CV	1%	1%	3.6%	2.9%	0.8%	7.4%	1.3%	2.5%	1.1%
VRTC	S150909-1_Right_76	21.9	47.2	570	405	64.7	-21.7	44.5	664	725
	S150909-1_Right_78	22	47.3	535	358	61.3	-20.2	43.0	656	725
	S150911-1_Right_80	21.85	47.3	535	334	59.2	-20	43.3	676	740
	Mean	21.9	47.3	546.7	365.7	61.7	-20.6	43.6	665.3	730.0
	Std Dev	0.1	0.1	20.2	36.1	2.8	0.9	0.8	10.1	8.7
	% CV	0%	0%	3.7%	9.9%	4.5%	4.5%	1.8%	1.5%	1.2%
CALSPAN + VRTC	Mean	22.6	47.6	510.0	327.5	57.8	-17.1	44.5	677.2	738.0
	Std Dev	0.75	0.48	43.50	47.94	4.71	4.02	1.13	18.03	11.49
	% CV	3.3%	1.0%	8.5%	14.6%	8.2%	23.6%	2.5%	2.7%	1.6%

		Nij				Restraint Loads	
		Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Shldr (N)	Lap (N)
CALSPAN	RR04-19-01	0.674	0.59	0.043	0.029	5393	5211
	RR04-19-04	0.6	0.7	0	0	5480	5586
	RR04-19-09	0.617	0.628	0.002	0.024	4964	5236
	Mean	0.630	0.639	0.015	0.018	5279.0	5344.3
	Std Dev	0.039	0.056	0.024	0.016	276.2	209.7
	% CV	6.1%	8.7%	161.8%	87.8%	5.2%	3.9%
VRTC	S150909-1_Right_76	0.63	1.23	0.04	0.11	cf	cf
	S150909-1_Right_78	0.59	1.18	0.04	0.13	5764	5749
	S150911-1_Right_80	0.57	1.17	0.05	0.13	5641	5711
	Mean	0.597	1.193	0.043	0.123	5702.5	5730.0
	Std Dev	0.031	0.032	0.006	0.012	87.0	26.9
	% CV	5.1%	2.7%	13.3%	9.4%	1.5%	0.5%
CALSPAN + VRTC	Mean	0.6	0.9	0.0	0.1	5448.4	5498.6
	Std Dev	0.04	0.31	0.02	0.06	306.35	258.42
	% CV	6%	33%	76%	84%	6%	5%

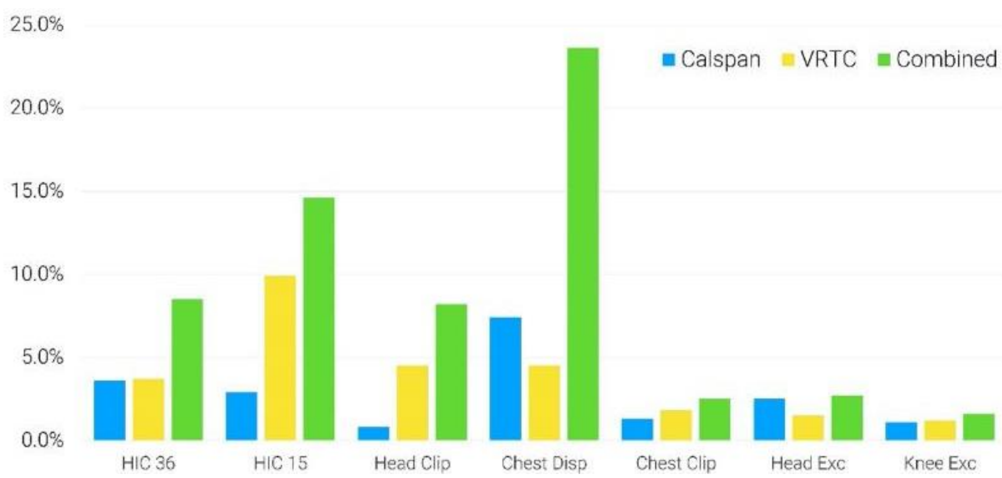


Figure 21 – Reproducibility of the Graco Nautilus 6yo with 3 pt belt

3.2.3 Single Point Data

At the end of the repeatability testing, Calspan performed a series of 6 single tests. The data from these tests is shown below.

3.2.3.1 Britax Marathon – 6yo

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
6/24/2019	RR06-19-38	Britax Marathon	H3-6yo	FF	Lower anchor	N	12	F	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR06-19-38	23.3	47.7	652	547	71.1	-10.9	40.6	772	851

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	TT (N)	Lower Right (N)	Lower Left (N)	Installer	Foam
RR06-19-38	0.748	1.26	0.885	0.006	-	-	-	MB	6

3.2.3.2 Britax Skyline – 10yo

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
6/24/2019	RR06-19-39	Britax Skyline	H3-10yo	FF	Lap/Shoulder	N	-	-	-

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR06-19-39	23.4	48	525	284	61.5	-30.4	47.9	578	716

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	TT (N)	Shoulder Right (N)	Lap Left (N)	Installer	Foam
RR06-19-39	1.127	0.626	0.08	0.009	-	4382	4702	MB	7

3.2.3.3 Chicco GoFit – 10yo

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
6/24/2019	RR06-19-40	Chicco GoFit	H3-10yo	FF	Lap/Shoulder	N	-	-	-

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR06-19-40	23.4	48.1	590	293	64.8	-32.1	47.5	523	670

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	TT (N)	Shoulder Right (N)	Lap Left (N)	Installer	Foam
RR06-19-40	1.081	1.677	0.004	0.036	-	4150	4786	MB	6

3.2.3.4 Chicco KeyFit – 12mo

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
6/14/2019	RR06-19-34	Chicco keyFit	CRABI 12mo	RF	Lower anchor	N	3		1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Pre SB Exc (deg)	Post SB Exc (deg)
RR06-19-34	23.1	47.8	380	180	44.2	-	43.9	39.5	51.6

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	TT (N)	Lower Right (N)	Lower Left (N)	Installer	Foam
RR06-19-34	0.9	1.796	0.19	0.361	-	2979	1949	MB	7

3.2.3.5 Dorel Pria 70 – 3yo

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
6/14/2019	RR06-19-36	Dorel Pria 70	H3-3yo	RF	Lap belt	N	5	M	3

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Pre SB Exc (deg)	Post SB Exc (deg)
RR06-19-36	23.2	47.8	623	499	76.1	-13.6	45.1	33.3	62.6

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	Lower Right (N)	Lower Left (N)	TT (N)	Installer	Foam
RR06-19-36	0.72	0.576	0.232	0.071	3814	2537	-	MB	7

3.2.3.6 Dorel Summit – 3yo

Date	Test#	Test Seat	Dummy	FF or RF	Belt Type	Tether (Y/N)	Shoulder / Headrest	Crotch Position	Recline Position
6/14/2019	RR06-19-37	Dorel Summit	H3-3yo	FF	Lower anchor	Y	3	M	1

	ACC. (g)	Vel. (kph)	HIC 36	HIC 15	Head Clip (g)	Chest Disp (mm)	Chest Clip (g)	Head Exc (mm)	Knee Exc (mm)
RR06-19-37	23.3	47.8	404	227	48.9	-20.8	49.4	719	608

	Ten-Flex	Ten-Ext	Comp-Flex	Comp-Ext	TT (N)	Lower Right (N)	Lower Left (N)	Installer	Foam
RR06-19-37	0.123	1.26	0.048	0.775	1813	3493	2552	BH	6

4 Discussion

We noted several issues during the course of the project that should be mentioned here. These are just suggestions and comments that may help future construction and usage of the bench be more consistent.

The Dimensions in Drawing Package: The current drawing package dimensions are from measurements of the prototype after it was built. It may be better if the final drawing package used the measurements from which the prototype was built.

The Bench Height: The current bench design allows the back of ATD head to impact the hard frame of the bench during rebound in some booster seat tests, potentially leading to damage to the 6yo and 10yo ATDs. A removable head rest mounted to the bench seat back could mitigate this issue.

The Top Tether Routing: The current top tether location routes the webbing across the steel edge of the seat back, which may lead to unrepresentative abrasion of the tether webbing. It may be worth reviewing this and adding a radius to the edge or wrapping some fabric over it to lessen abrasion.

Calculation of head and knee displacement: The method for determining whether or not an ATD body component (usually the head or the knee) exceeds a certain threshold is outlined in the test procedure for FMVSS No. 213 (National Highway Traffic Safety Adminstration 2014). This method is sufficiently accurate for quantifying excursions proximal to the lens axis, but the accuracy degrades for measurements away from the lens axis. VRTC has employed the parallax compensation algorithm in the TEMA software that provides consistent accuracy across the field of view of the lens. Future work should investigate this matter further.

4.1 Future Work

We note in the table below the testing that was conducted as part of this research program in the context of the variety of CRS types and configurations that are possible under FMVSS No. 213. The extensive combinations CRS types, ATD, mode and fixation method necessitate testing for repeatability and reproducibility that extends beyond what was tested herein. Future researchers, should consider the table below, and in particular the empty cells in the rightmost three columns as new test programs are developed.

CRS Type	ATD	Mode	Fixation	Tests Done		
Rear-Facing Only Infant Carrier	CRABI	with Base	Belt			
			LATCH	Re - Embrace 35	1 - Chicco KeyFit	
		without base	Belt			
Rear-Facing Only Infant Carrier	HIII 3yo	with Base	Belt			
			LATCH			
		without base	Belt			
Convertible	CRABI	Rear-Facing	LATCH*			
			Belt*			
		Forward-Facing	LATCH*	Re - Scenera Next - No Tether		
			Belt*			
	HIII 3yo	Rear-facing	LATCH*	1 - Maxi Cosi Pria 70		
			Belt*	Re - My Ride 65 - No Tether		
		Forward Facing	LATCH*	Re - Scenera Next - Tether	1 - Safety 1st Summit HB	
			Belt*			
	HIII 6yo	Forward Facing	LATCH*	Re - Evenflo Sureride - Tether	1 - Britax Marathon - No Tether	
			Belt*	Re/Ru - Graco Nautilius 65LX - No Tether		
	HIII 10yo	Forward Facing	LATCH*			
			Belt*	Re - Britax Frontier - tether		
Booster	HIII 6yo	Forward Facing	Belt	Re/Ru - Graco Affix - No Tether	Re - Harmony Youth - No Tether	Re - Dorel Pronto - NoTeth
	HIII 10yo			Re - Evenflo Amp - NoTeth	1 - Britax Skyline	1 - Chicco GoFit

Notes: * with or without top tether, "Re" = Repeatibility, "Ru" = Reproducibility, "1" = 1 test only

5 References

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Saunders, James, and Daniel Parent. 2013. “Repeatability of a Small Overlap and an Oblique Moving Deformable Barrier Test Procedure.” *SAE International Journal of Transportation Safety* 1 (2): 309–27. https://doi.org/10.4271/2013-01-0762.

Wietholter, Kedryn, Cristina Echemendia, and Allison E. Louden. 2017. “Development of a Representative Seat Assembly for FMVSS No. 213.” In *25th International Technical Conference on the Enhanced Safety of Vehicles (ESV) National Highway Traffic Safety Administration*.

6 Appendix - Bench Dimensional Verification

The dimensions of the bench built for this project were approved by NHTSA. The critical dimensions are shown in the tables in the following sub-sections and the drawings shown in Appendix 8. Dimensional comparison was conducted three times, once by the bench fabricator (Blaimar), and twice by Calspan. Dimensions that exceeded the ±3mm tolerance are highlighted in red. These dimensions, even though out of specification, were approved by the NHTSA COTR for this project.

6.1 Drawing 3021-015, sheet 1

Zone	Dimension APRIL 2018 (mm)	MAX	MIN	BLAIMAR INSPECTION	CALSPAN INSPECTION 02/01/2019	CALSPAN INSPECTION 02/12/2019	CALSPAN Comments 02/12/2019
B15	86.5	89.5	83.5	86	87.5	87.5	
B15	50.8	53.8	47.8	51.4	51	51	
B14	161.9	164.9	158.9	160.5	161.2	161.2	
B13	101.6	104.6	98.6	102.5	103.3	103.3	
B13	161.9	164.9	158.9	160.5	161.6	161.6	
B12	50.8	53.8	47.8	51.4	48.8	48.8	
B12	86.5	89.5	83.5	86	87.4	87.4	
J11	700.0	703.0	697.0	699.5	702.8	702.8	
D13	31.8	34.8	28.8	31.4	33.1	33.1	
D11	661.9	664.9	658.9	662	662.6	662.6	
D11	725.4	728.4	722.4	725	728.8	723.3	Mis-measured
D9	31.8	34.8	28.8	31.4	33.1	33.1	
I7	114.3	117.3	111.3	119	118.4	118.4	
I7	254.7	257.7	251.7	254.4		254.2	
L7	12.5	13.0	12.0	10		10.9	
L7	16.8	19.8	13.8	16.8		16.6	
I7	65.4	68.4	62.4	64	66.7	66.7	

G6	65.9	68.9	62.9	64.5	63.1	63.1	
K5	88.2	91.2	85.2	89	90.2	90.2	
K4	33.9	34.4	33.4	33.6	32.7	35.3	Right & left
F8	15.2000	15.7	14.7	15.3		15.7	
F7	202.2	205.2	199.2	203	169.5	199.7	Mis-measured
E7	61.8	64.8	58.8	62.8	68	61.3	Mis-measured
E7	63.5	66.5	60.5	63.5	78.1	64.7	Mis-measured
E2	80.0	83.0	77.0	80.3		79.6	
D7	12.7	15.7	9.7	12.7	13.2	13.2	
D5	741.7	744.7	738.7	741	744.5	744.5	
D3	120.0	123.0	117.0	120.7		121.7	
F2	420.0	423.0	417.0	418.7	422.8	422.8	
G2	953.2	956.2	950.2	951.7	952	947.5	Right & left
H2	533.2	536.2	530.2	533	524.7	529.2	
J2	89.8	92.8	86.8	91			

6.2 Drawing 3021-015, sheet 2

Zone	Dimension APRIL 2018 (mm)	MAX	MIN	BLAIMAR INSPECTION	CALSPAN INSPECTION 02/01/2019	CALSPAN INSPECTION 02/12/2019	CALSPAN Comments 02/12/2019
C14	19.1	22.1	16.1		20.7	20.7	
C12	623.8	626.8	620.8	622.7	619	622	Mis-measured
C12	661.9	664.9	658.9		660.4	660.4	
C10	19.1	22.1	16.1		20.7	20.7	
D12	44.7						
H13	247.7	250.7	244.7		247.4	247.4	
H12	247.7	250.7	244.7		247.4	247.4	
H10	866.6	869.6	863.6	864	851.9	856.1	Corner of bar cut
I10	400.5	403.5	397.5	397.8	384.7	389.2	Corner of bar cut

H10	127.0	130.0	124.0	127	125.3	125.3	
G9	339.1	342.1	336.1	337	341.9	341.9	
C8	12.7	15.7	9.7		13.2	13.2	
D8	128.8	131.8	125.8		133.4	127.5	Mis-measured
C8	63.5	66.5	60.5		78.1		Capped
D8	204.9	207.9	201.9		169.5		Capped
B8	44.5	47.5	41.5				Capped
B8	38.1	41.1	35.1				Capped
D8	127.0	130.0	124.0		129.2	129.2	
E8	39.8	42.8	36.8				
D8	15.2	15.7	14.7			15.7	
C6	526.6	529.6	523.6		530.2	527.2	Mis-measured
C5	741.7	744.7	738.7		744.5	744.5	
C4	215.1	218.1	212.1		214.3	214.3	
D7	247.7	250.7	244.7	249			Under
D6	247.7	250.7	244.7	249			Under
D6	535.2	538.2	532.2		536	536	
F5	600.2	603.2	597.2	599	599.4	599.4	
F5	574.8	577.8	571.8	572			
H4	25.4	28.4	22.4	24.6			Capped
H4	50.8	53.8	47.8	51.9	77		Capped
F4	254.0	257.0	251.0	253	251.2	251.2	
E5	270.0	273.0	267.0	270	271.2	271.2	
E4	20.0	20.5	19.5	19.6		19.5	
D6	247.7	250.7	244.7	247			Under
D6	247.7	250.7	244.7	247			Under
D6	535.2	538.2	532.2	532.5		532.3	
D3	12.7	15.7	9.7				
E3	368.3	371.3	365.3				
F3	940.5	943.5	937.5		936.9	938.8	Mis-measured

6.3 Drawing 3021-015, sheet 3

Zone	Dimension APRIL 2018 (mm)	MAX	MIN	BLAIMAR INSPECTION	CALSPAN INSPECTION 02/01/2019	CALSPAN INSPECTION 02/12/2019	CALSPAN Comments 02/12/2019
I15	12.7	15.7	9.7	11.9			
G15	57.2	60.2	54.2	57.2	57.1	57.1	
E15	548.8	551.8	545.8	548	549.5	549.5	
C15	54.0	57.0	51.0		51.6	51.6	
C14	54.0	57.0	51.0		51.6	51.6	
C12	661.9	664.9	658.9	662	661.9	661.9	
C10	54.0	57.0	51.0		51.2	51.2	
C10	54.0	57.0	51.0		51.2	51.2	
I15	12.7	15.7	9.7				
I14	83.0	86.0	80.0	82			Capped
I14	76.2	79.2	73.2		75.6	75.6	
I12	725.4	728.4	722.4	725	729.2	726.2	Mis-measured
I12	700.0	703.0	697.0	700			
I12	381.6	384.6	378.6	381.5	381.2	381.2	
I11	76.2	79.2	73.2	76.8	76.6	76.6	
I10	83.0	86.0	80.0	82.5			Capped
I10	12.7	15.7	9.7				
C9	76.2	79.2	73.2	76.5	82.6	73.5	Mis-measured
E9	295.3	298.3	292.3	295	294.6	204.6	
G9	295.3	298.3	292.3	296	288.7	295.1	Mis-measured
H9	741.7	744.7	738.7	741	737.3	741.8	Mis-measured
H9	19.1	22.1	16.1	18.3			
H9	74.9	77.9	71.9	75.5	72.3	72.3	
G8	121.4	124.4	118.4	123	120.3	120.3	
G7	228.6	231.6	225.6	229	227.7	227.7	

G6	698.5	701.5	695.5	699	698.1	698.1	
G6	228.6	231.6	225.6	227	227.9	227.9	
G5	119.9	122.9	116.9	121	122.2	122.2	
D4	336.5	339.5	333.5	342	357.9	335.5	Mis-measured
D4	575.0	578.0	572.0	575	568.3	573.8	Mis-measured
E4	108.0	111.0	105.0	108	103.2	107.8	Mis-measured
H6	121.4	124.4	118.4	123		122.2	
I6	228.6	231.6	225.6	230		228	
I6	700.0	703.0	697.0	700		700.8	
J6	228.6	231.6	225.6	230		228.8	
K6	121.4	124.4	118.4	122		121.7	
L5	108.0	111.0	105.0	108		109.6	
L4	260.3	263.3	257.3	260		260.2	
L4	520.7	523.7	517.7	520		519.6	

6.4 Drawing 3021-750, sheet 1

Zone	Dimension APRIL 2018 (mm)	MAX	MIN	BLAIMAR INSPECTION	CALSPAN INSPECTION 02/01/2019	CALSPAN INSPECTION 02/12/2019	CALSPAN Comments 02/12/2019
E11	167.0	170.0	164.0	166.5		165.7	
D11	85.0	88.0	82.0	86.5		85.8	
E10	50.8	53.8	47.8	51.4		52.5	
E10	163.0	166.0	160.0	164		163.8	
E10	112.2	115.2	109.2	112		110.4	
E10	25.5	26.0	25.0	25.3		25.4	
E8	84.5	87.5	81.5	84.6		87.4	
E7	280.0	283.0	277.0	277		277.8	
E7	449.0	452.0	446.0	448		451.5	
E6	84.5	87.5	81.5	86.3		86.9	

E3	64.5	67.5	61.5	62.7		64.1	
D4	27.0	27.5	26.5	27.3		26.3	
D4	114.0	117.0	111.0	113.7		114.7	
D2	123.6	126.6	120.6	124		121.7	
D2	130.0	133.0	127.0	131.5		129.3	
C2	6.4	9.4	3.4	6.3			
G10	101.6	104.6	98.6	102		101.3	
G9	57.2	60.2	54.2	57		56.2	
G7	534.0	537.0	531.0	533		532.5	
G4	50.8	53.8	47.8	50.3		50.7	
G4	50.8	53.8	47.8	50.3		50.7	

6.5 Drawing 3021-1000, sheet 1

Zone	Dimension APRIL 2018 (mm)	MAX	MIN	BLAIMAR INSPECTION	CALSPAN INSPECTION 02/01/2019	CALSPAN INSPECTION 02/12/2019	CALSPAN Comments 02/12/2019
B3	90.0	93.0	87.0			88	85
B4	877.0	880.0	874.0			876.9	measured in plane with back structure
A4	372.0	375.0	369.0			370.8	
A4	289.0	292.0	286.0				
A4	205.0	208.0	202.0			202.8	
A4	152.0	155.0	149.0			150.6	
A4	80.0	83.0	77.0			79.3	
A3	25.0	28.0	22.0			23.7	
A3	120.0	123.0	117.0			122	
A3	229.0	232.0	226.0			226.8	
A3	249.0	252.0	246.0			249.5	
A3	384.0	384.5	383.5				

7 Appendix – Sled, Tool and ATD Sensor Calibrations

7.1 Sled and Facility Calibrations

Instrument	***Serial Number***	***Calibration Date***	***Due Date***
DTS Unit #736	ESL 400704	12/10/2018	12/10/2019
DTS Unit #737	ESL 400705	12/10/2018	12/10/2019
Temp and Humidity Recorder Onset HOBO	ESL 400632	11/08/2018	11/08/2019
Digital Angle Gauge Digi-Pas	ESL 400482	9/24/2018	9/24/2019
Bosch/Kent Moore Belt Tension Gauge ± 1 lb.	ESL 400415	3/25/2019	9/25/2019
Bosch/Kent Moore Belt Tension Gauge ± 1 lb.	ESL 400943	3/25/2019	9/25/2019
Imada Force Gauge Model DPSH-440R	ESL 400931	3/12/2019	3/12/2020
Imada Force Gauge Model DS2-110	ESL 400368	8/10/2018	8/10/2019
Imada Force Gauge Model ZTS-550	ESL 400474	7/28/2018	7/28/2019
Proto Torque Wrench	ESL 400978	7/19/2018	7/19/2019
Sled Primary x Accelerometer Endevco 7292A	10302	5/6/2019	5/6/2020
Sled Secondary X Endevco 7264	P69794	5/6/2019	5/6/2020
Sled Secondary Y Endevco 7264	P71301	5/6/2019	5/6/2020

7.2 CRABI-12mo Calibrations

Instrument	***Serial Number***	***Certification Test***	***Calibration Date***	***Due Date***
CRABI-12mo	114	ATD	6/10/2019	7/10/2019
Instrument	***Serial Number***	***Full Scale EU***	***Calibration Date***	***Due Date***
Head X Accelerometer Endevco 7264	17600	2000	3/4/2019	9/4/2019
Head Y Accelerometer Endevco 7264	P71305	2000	3/4/2019	9/4/2019
Head Z Accelerometer MS 64M30	MS26699	2000	3/4/2019	9/4/2019
Upper Neck FX Denton 2554A	300 FX	889	5/8/2019	5/8/2020
Upper Neck FY Denton 2554A	300 FY	889	5/8/2019	5/8/2020
Upper Neck FZ Denton 2554A	300 FZ	2224	5/8/2019	5/8/2020
Upper Neck MX Denton 2554A	300 MX	56	5/8/2019	5/8/2020
Upper Neck MY Denton 2554A	300 MY	56	5/8/2019	5/8/2020
Upper Neck MZ Denton 2554A	300 MZ	34	5/8/2019	5/8/2020
Chest X Accelerometer Endevco 7264	17605	2000	3/4/2019	9/4/2019
Chest Y Accelerometer Endevco 7264	P71274	2000	3/4/2019	9/4/2019
Chest Z Accelerometer MS 64M30	MS26710	2000	3/4/2019	9/4/2019
Lumbar FX Denton 2554A	172 FX	889	5/6/2019	5/6/2020
Lumbar FY Denton 2554A	172 FY	889	5/6/2019	5/6/2020
Lumbar FZ Denton 2554A	172 FZ	2224	5/6/2019	5/6/2020

Lumbar MX Denton 2554A	172 MX	56	5/6/2019	5/6/2020
Lumbar MY Denton 2554A	172 MY	56	5/6/2019	5/6/2020
Lumbar MZ Denton 2554A	172 MZ	34	5/6/2019	5/6/2020
Left LATCH belt Load Cell MG Sensor F1B1B11A	G9054	16030	8/29/2018	8/29/2019
Right LATCH belt Load Cell MG Sensor F1B1B11A	H5084	16030	8/29/2018	8/29/2019

7.3 H3-3yo Calibrations

Instrument	***Serial Number***	***Certification Test***	***Calibration Date***	***Due Date***
H3-3YO	136	ATD	6/10/2019	7/10/2019
Instrument	***Serial Number***	***Full Scale EU***	***Calibration Date***	***Due Date***
Head X Accelerometer Endevco 7264	AC-P32204	500	2/13/2019	8/13/2019
Head Y Accelerometer Endevco 7264	MS26711	500	2/13/2019	8/13/2019
Head Z Accelerometer Endevco 7264	AC-P16591	500	2/13/2019	8/13/2019
Upper Neck FX Denton 1716A	126 FX	2400	1/18/2019	1/18/2020
Upper Neck FY Denton 1716A	126 FY	2400	1/18/2019	1/18/2020
Upper Neck FZ Denton 1716A	126 FZ	2400	1/18/2019	1/18/2020
Upper Neck MX Denton 1716A	126 MX	2400	1/18/2019	1/18/2020
Upper Neck MY Denton 1716A	126 MY	2400	1/18/2019	1/18/2020
Upper Neck MZ	126 MZ	2400	1/18/2019	1/18/2020

Denton 1716A				
Chest X Accelerometer Endevco 7264	MS26666	500	3/26/2019	9/26/2019
Chest Y Accelerometer Endevco 7264	A203038	500	2/13/2019	8/13/2019
Chest Z Accelerometer Endevco 7264	MS26647	500	3/26/2019	9/26/2019
Chest Displacement Servo H3CD	DS136	40	4/5/2019	10/5/2019
Pelvis X Accelerometer MS 64CM30	MS26692	2000	11/30/2018	5/30/2019
Pelvis Y Accelerometer MS 64CM30	MS26696	2000	11/30/2018	5/30/2019
Pelvis Z Accelerometer MS 64CM30	MS26689	2000	11/30/2018	5/30/2019
Lumbar FX Denton 2431	98 FX	2400	11/5/2018	11/5/2019
Lumbar FY Denton 2431	98 FY	2400	11/5/2018	11/5/2019
Lumbar FZ Denton 2431	98 FZ	2400	11/5/2018	11/5/2019
Lumbar MX Denton 2431	98 MX	2400	11/5/2018	11/5/2019
Lumbar MY Denton 2431	98 MY	2400	11/5/2018	11/5/2019
Lumbar MZ Denton 2431	98 MZ	2400	11/5/2018	11/5/2019
Not used MG Sensor F1B1B11A	G9054	16030	8/29/2018	8/29/2019
Leftt lower belt Load Cell MG Sensor F1B1B11A	G9055	16030	4/9/2019	4/9/2020
Right lower belt Load Cell MG Sensor F1B1B11A	H5084	16030	8/29/2018	8/29/2019

7.4 H3-6yo Calibrations

Instrument	***Serial Number***	***Certification Test***	***Calibration Date***	***Due Date***
H3-6YO	855	ATD	4/27/2019	5/27/2019
Instrument	***Serial Number***	***Full Scale EU***	***Calibration Date***	***Due Date***
Head X Accelerometer Endevco 7264	AC-17604	500	3/3/2019	9/3/2019
Head Y Accelerometer Endevco 7264	AC-P68050	500	3/3/2019	9/3/2019
Head Z Accelerometer Endevco 7264	AC-P71289	500	3/3/2019	9/3/2019
Upper Neck FX Denton 1716A	576 FX	8896	1/18/2019	1/18/2020
Upper Neck FY Denton 1716A	576 FY	8896	1/18/2019	1/18/2020
Upper Neck FZ Denton 1716A	576 FZ	13344	1/18/2019	1/18/2020
Upper Neck MX Denton 1716A	576 MX	282	1/18/2019	1/18/2020
Upper Neck MY Denton 1716A	576 MY	282	1/18/2019	1/18/2020
Upper Neck MZ Denton 1716A	576 MZ	282	1/18/2019	1/18/2020
Chest X Accelerometer Endevco 7264	AC-P69798	500	3/3/2019	9/3/2019
Chest Y Accelerometer Endevco 7264	AC-17447	500	3/3/2019	9/3/2019
Chest Z Accelerometer Endevco 7264	AC-17583	500	3/3/2019	9/3/2019
Chest Displacement Servo H3CD	855	125	3/4/2019	9/4/2019
Chest Angular Rate DTS PRO-18k 2khz	ARS13828	18000	2/27/2019	2/27/2020
Pelvis X Accelerometer MS 64CM30	MS26692	2000	11/30/2018	5/30/2019

Pelvis Y Accelerometer MS 64CM30	MS26689	2000	11/30/2018	5/30/2019
Pelvis Z Accelerometer MS 64CM30	MS26696	2000	11/30/2018	5/30/2019
Lumbar FX Denton 2431	148 FX	4448	11/5/2018	11/5/2019
Lumbar FY Denton 2431	148 FY	4448	11/5/2018	11/5/2019
Lumbar FZ Denton 2431	148 FZ	7117	11/5/2018	11/5/2019
Lumbar MX Denton 2431	148 MX	266	11/5/2018	11/5/2019
Lumbar MY Denton 2431	148 MY	266	11/5/2018	11/5/2019
Lumbar MZ Denton 2431	148 MZ	141	11/5/2018	11/5/2019
Lap Belt Load Cell MSI EL20-S458-16kn	X150QP	16000	6/14/2018	6/14/2019
Shoulder belt Load Cell MG Sensor F1B1B11A	G9054	16030	8/29/2018	8/29/2019

7.5 H3-10yo Calibrations

Instrument	***Serial Number***	***Certification Test***	***Calibration Date***	***Due Date***
H3-10YO	009	ATD	4/27/2019	5/27/2019
Instrument	***Serial Number***	***Full Scale EU***	***Calibration Date***	***Due Date***
Head X Accelerometer MS 64C 360t	A203046	500	2/28/2019	8/28/2019
Head Y Accelerometer Endevco 7264	AC-P71299	500	2/28/2019	8/28/2019
Head Z Accelerometer Endevco 7264	AC-P16862	500	2/28/2019	8/28/2019
Upper Neck FX Denton 1716A	1629 FX	8896	9/28/2018	9/28/2019

Upper Neck FY Denton 1716A	1629 FY	8896	9/28/2018	9/28/2019
Upper Neck FZ Denton 1716A	1629 FZ	13346	9/28/2018	9/28/2019
Upper Neck MX Denton 1716A	1629 MX	350	9/28/2018	9/28/2019
Upper Neck MY Denton 1716A	1629 MY	350	9/28/2018	9/28/2019
Upper Neck MZ Denton 1716A	1629 MZ	350	9/28/2018	9/28/2019
Lower Neck FX Denton 5124J	83 FX	6672	4/29/2019	4/29/2020
Lower Neck FY Denton 1716A	83 FY	6672	4/29/2019	4/29/2020
Lower Neck FZ Denton 1716A	83 FZ	8896	4/29/2019	4/29/2020
Lower Neck MX Denton 1716A	83 MX	8896	4/29/2019	4/29/2020
Lower Neck MY Denton 1716A	83 MY	8896	4/29/2019	4/29/2020
Lower Neck MZ Denton 1716A	83 MZ	6672	4/29/2019	4/29/2020
Chest X Accelerometer Endevco 7264	AC-P17603	500	2/28/2019	8/28/2019
Chest Y Accelerometer Endevco 7264	AC-71277	500	2/28/2019	8/28/2019
Chest Z Accelerometer MS EGAS-S398A	26721	500	2/28/2019	8/28/2019
Chest Displacement Servo 14CB1	CST-023	46	3/4/2019	9/4/2019
Chest Angular Rate DTS PRO-18k 2khz	ARS13828	18000	2/27/2019	2/27/2020
Pelvis X Accelerometer MS 64CM30	26692	2000	11/30/2018	5/30/2019
Pelvis Y Accelerometer MS 64CM30	26689	2000	11/30/2018	5/30/2019

Pelvis Z Accelerometer MS 64CM30	26696	2000	11/30/2018	5/30/2019
Lumbar FX Humanetics 6251J	78 FX	11120	4/29/2019	4/29/2020
Lumbar FY Humanetics 6251J	78 FY	11120	4/29/2019	4/29/2020
Lumbar FZ Humanetics 6251J	78 FZ	15569	4/29/2019	4/29/2020
Lumbar MX Humanetics 6251J	78 MX	497	4/29/2019	4/29/2020
Lumbar MY Humanetics 6251J	78 MY	497	4/29/2019	4/29/2020
Lumbar MZ Humanetics 6251J	78 MZ	311	4/29/2019	4/29/2020
Lap Left belt Load Cell MG Sensor F1B1B11A	G9054	16030	8/29/2018	8/29/2019
Shoulder belt Load Cell MG Sensor F1B1B11A	H5084	16030	8/29/2018	8/29/2019
Top Tether belt Load Cell MSI EL20-S458-16kn	X150QP	16000	6/14/2018	6/14/2019

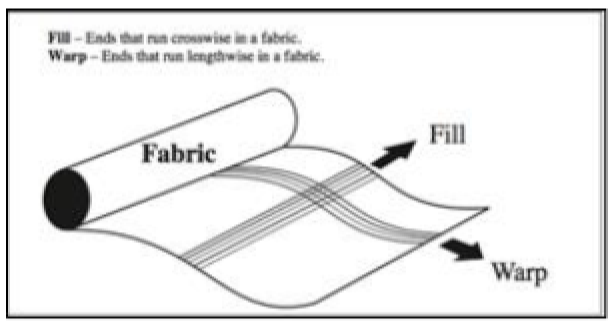
8 Appendix – Seat Cushion Cover Methods (Spring 2018)

8.1 Warp Definition

Warp Definition

- Material: Polyacrylate Fiber (Fabric Weight: 9oz. Break Strength: 285lbs Warp and 180lbs Filling)

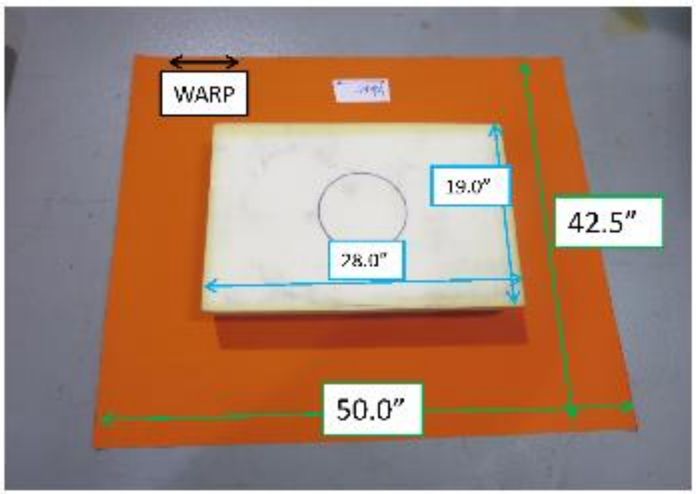
- “Warp is down the length of the roll, fill is across the width” from manufacturer



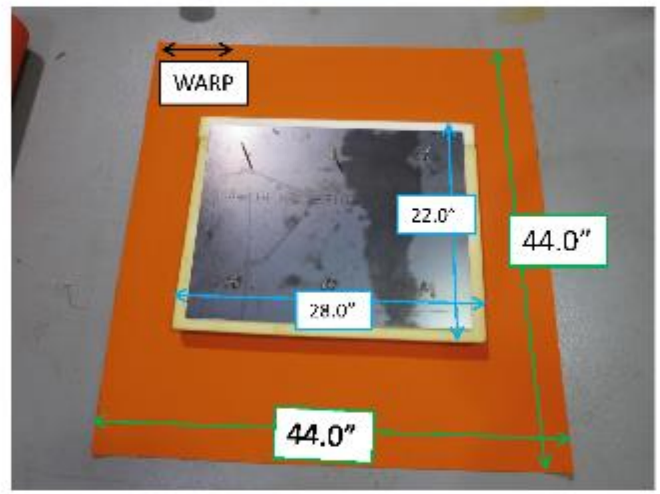
8.2 Grommet Method

Grommet Method: Seat Pan and Back Dimensions

Seat Pan



Seat Back



Metal plate used but not shown in seat pan and sand paper was added to the reverse side for both the seat pan and seat back.

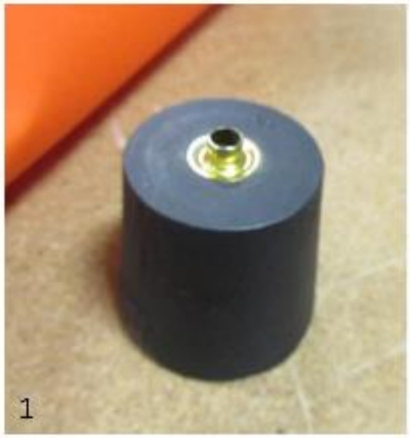
Materials

- Grommets
  - Size 1
- Hammer-Driven Cutting Punches
  - Size 1

How to Install a Grommet

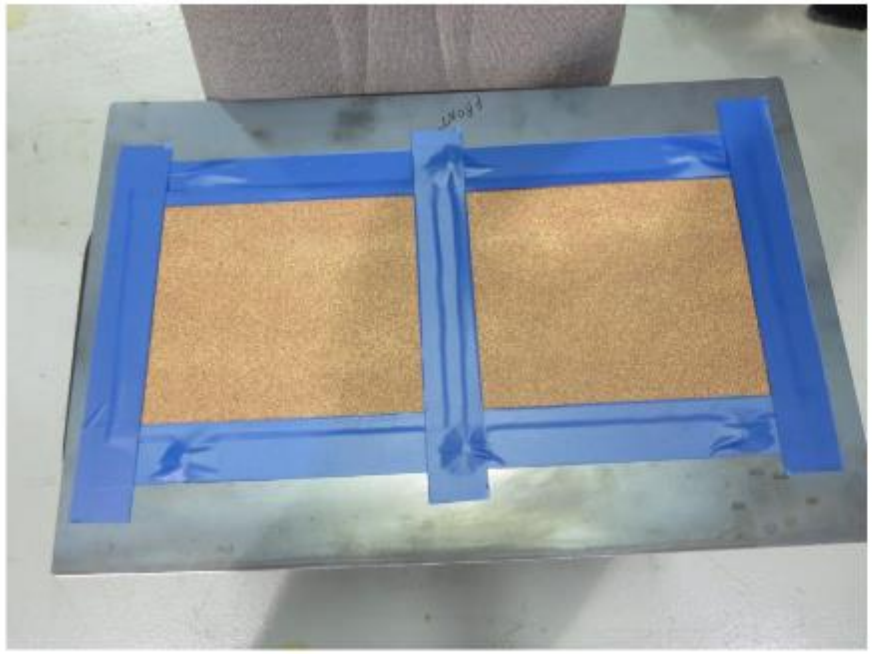
In order to install a grommet:

- Put the end of the grommet with hole up on the base (1)
- Put the washer end curved side up on top of the hole of the base piece (2)
- Put the top tool into the base (3)
- Using a hammer, hit the top of the tool compressing the grommet into the material (4)
- * When installing a grommet, add another layer of material (4) to help secure grommet



8.3 Sand Paper

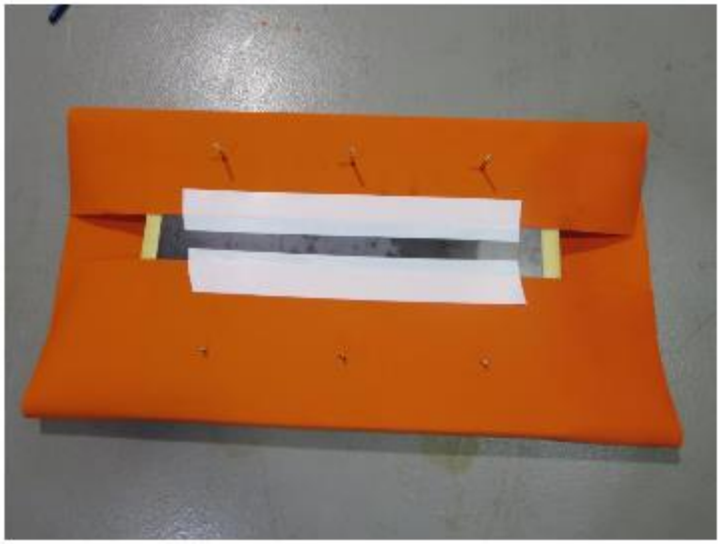
Wrapping Foam



Adhere 50 Garnet Paper to the side of the plate that will be in contact with the foam (without the bolts)

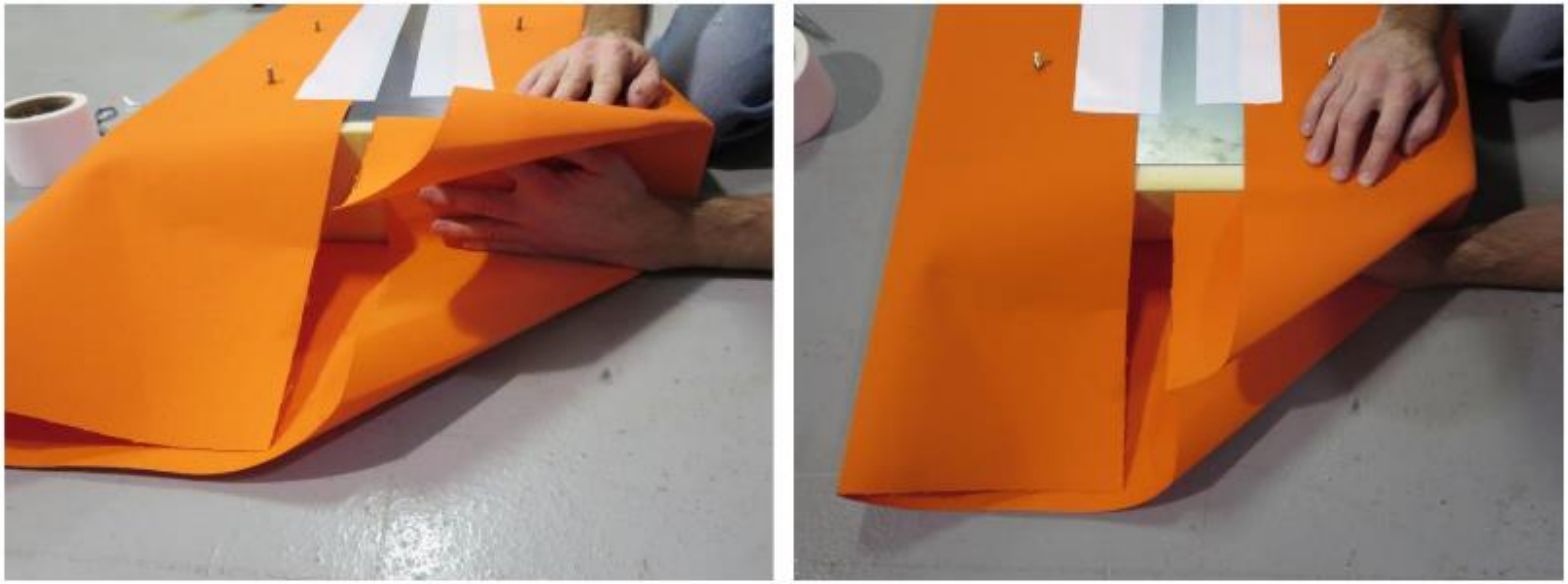
8.4 Foam Wrapping

Folding Center Edge of Foam



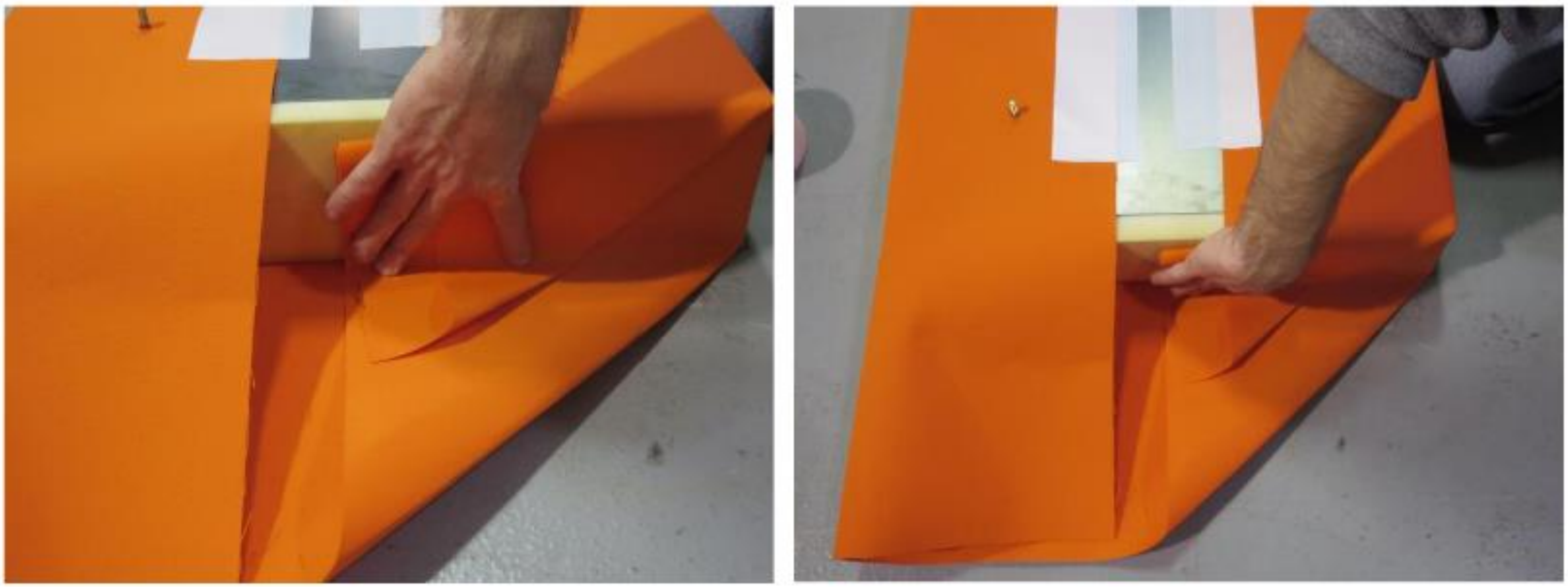
Place plate on foam with 1" on each side and place bolts through holes in fabric; adhere using Dr. Shrink tape

Folding Edge of Foam



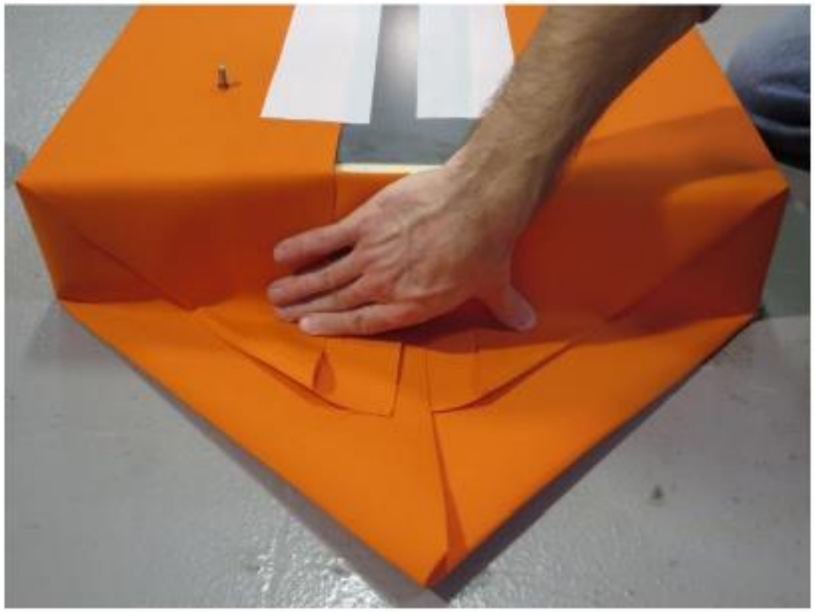
Push fabric into the thickness of the foam

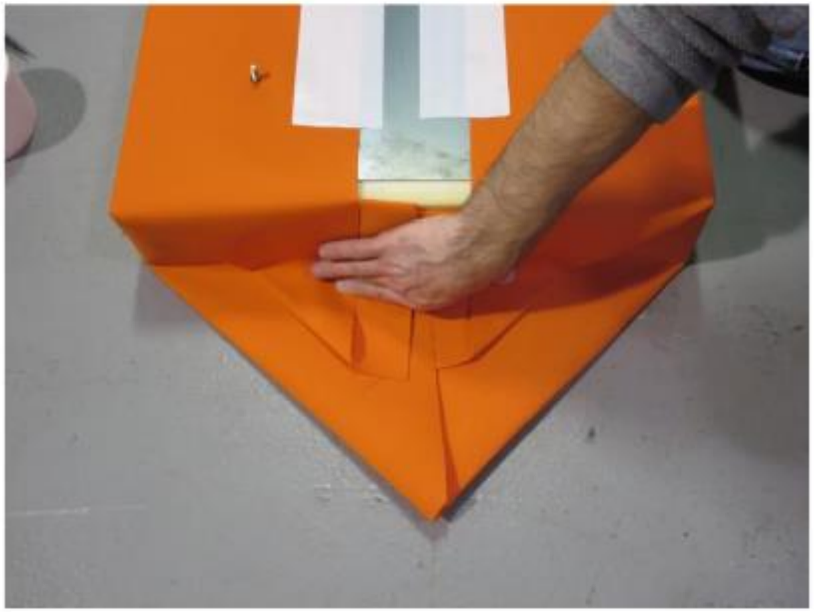
Folding Edge of Foam



Fold top piece downward

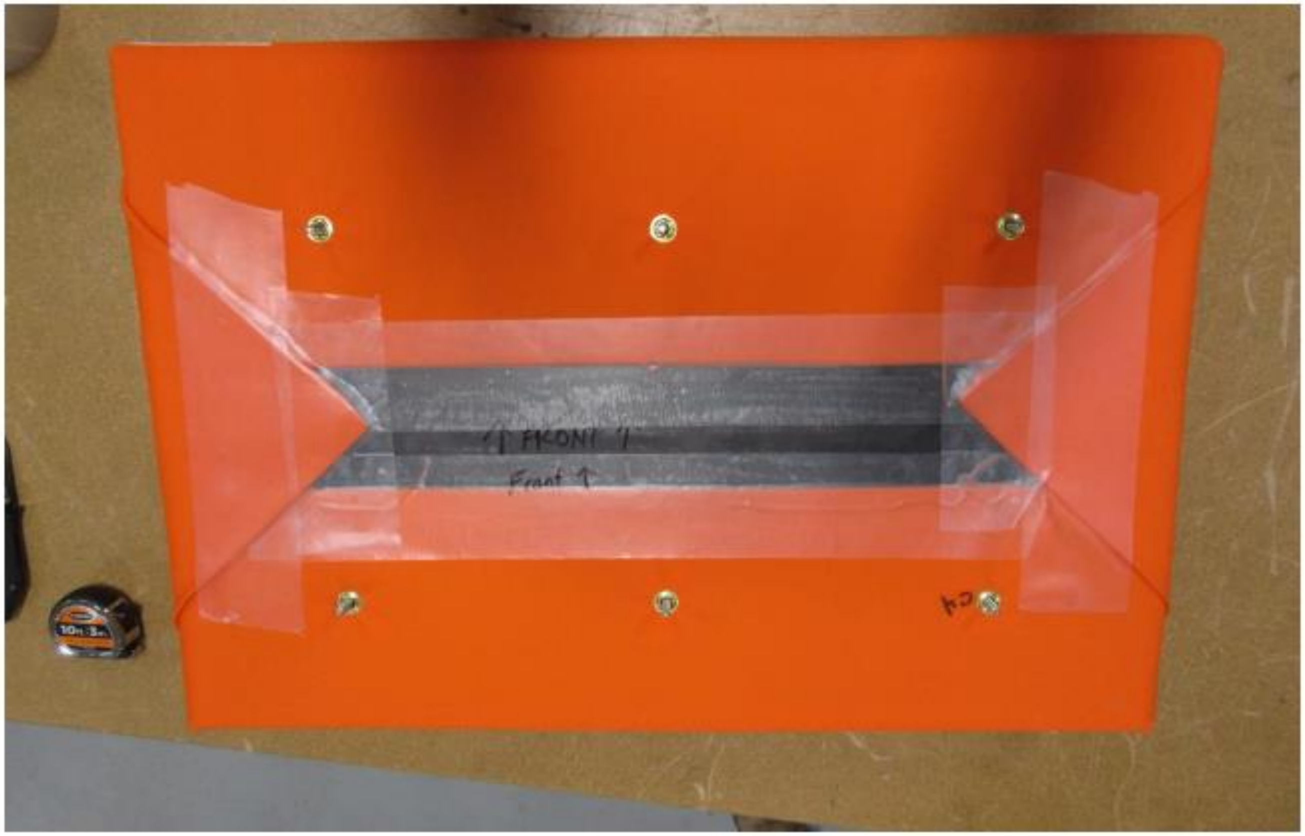
Folding Edge of Foam



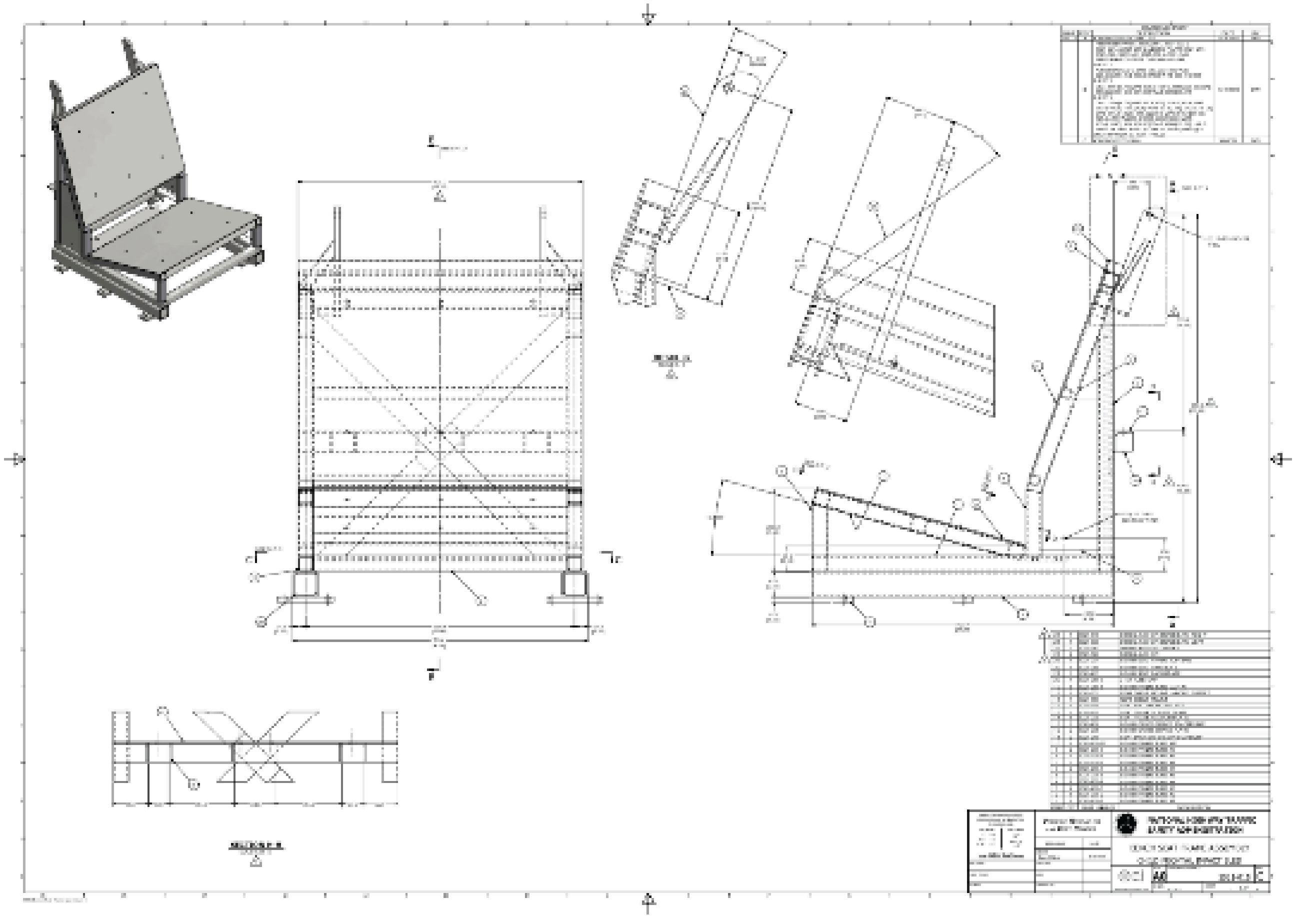


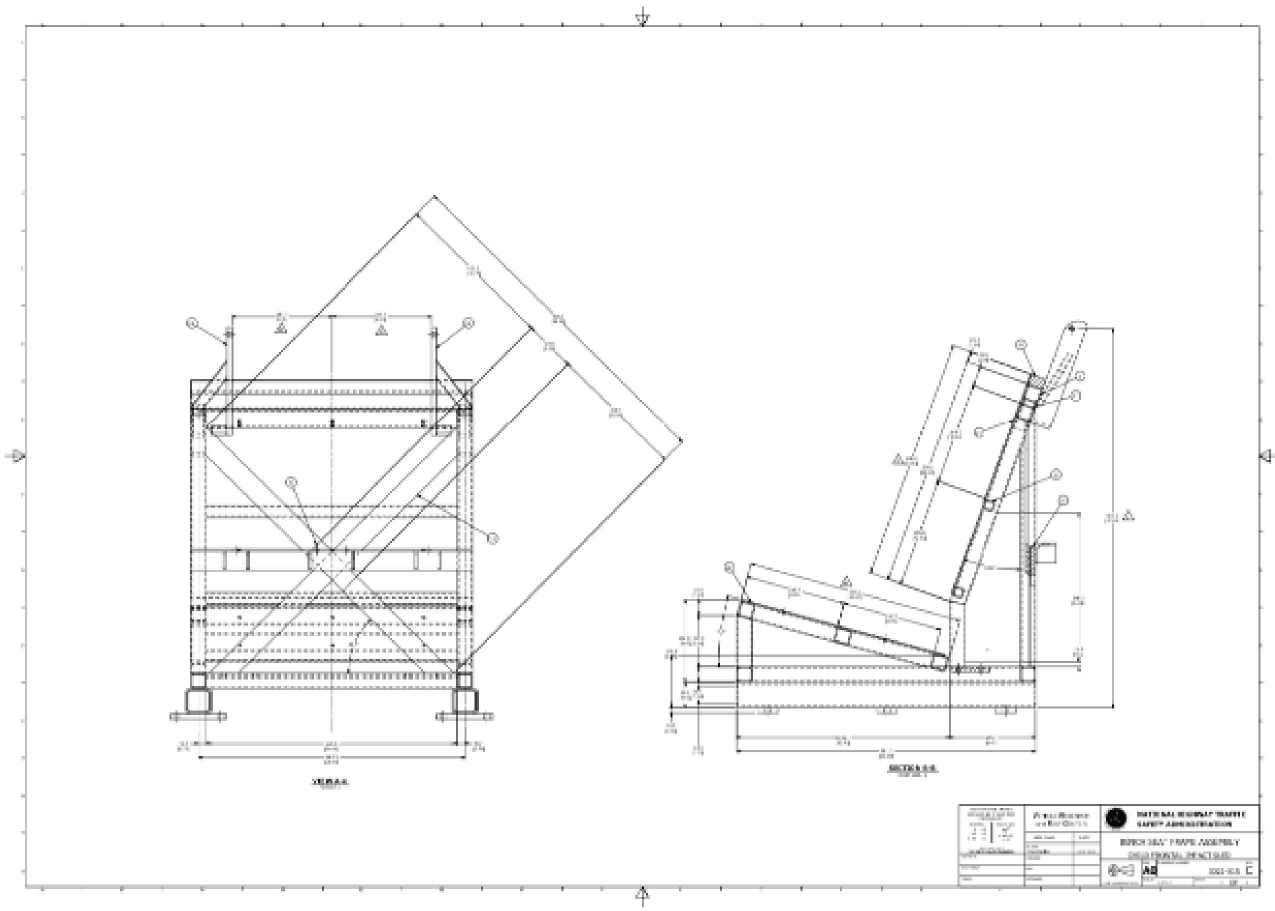
Complete the above 2 steps on both sides
Then, pull upward and secure with Dr. Shrink Tape

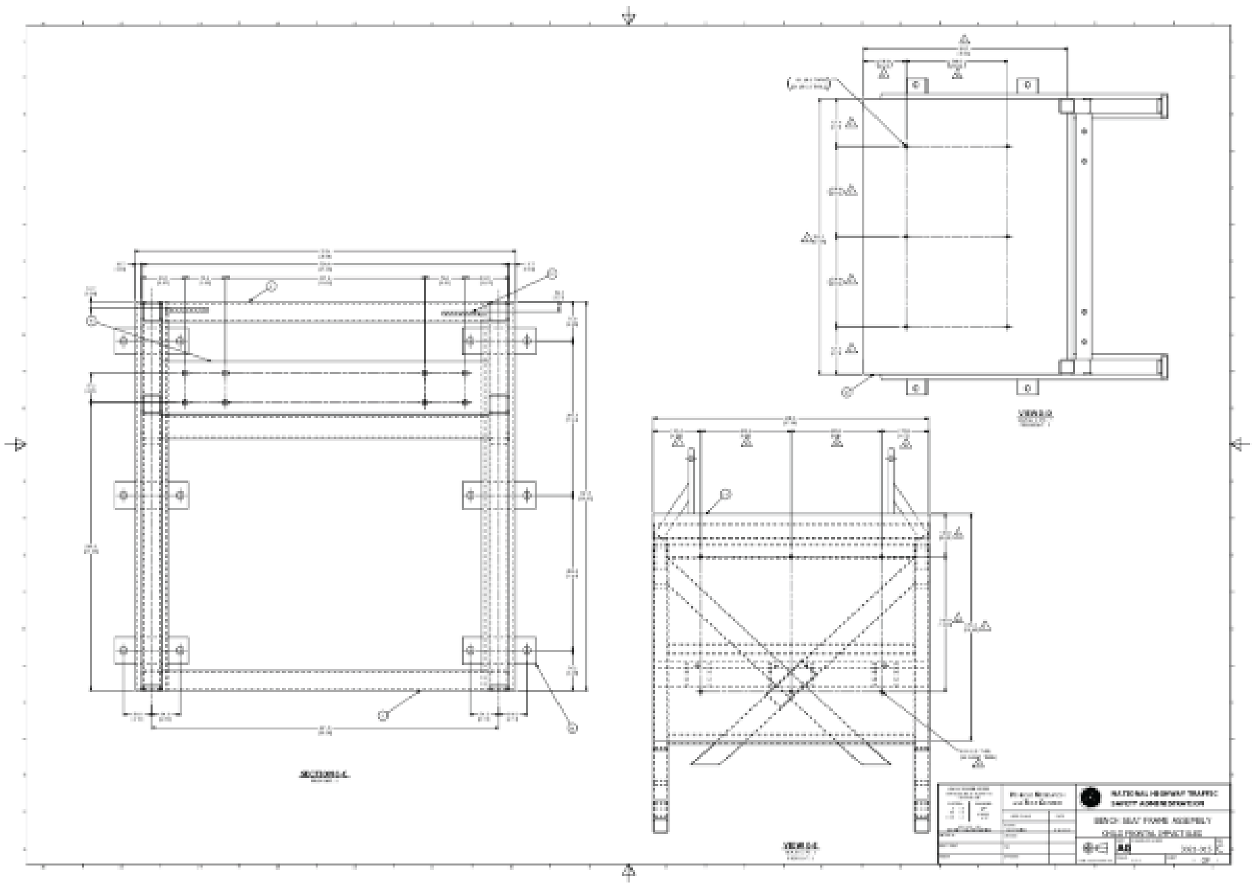
Finished Wrapping

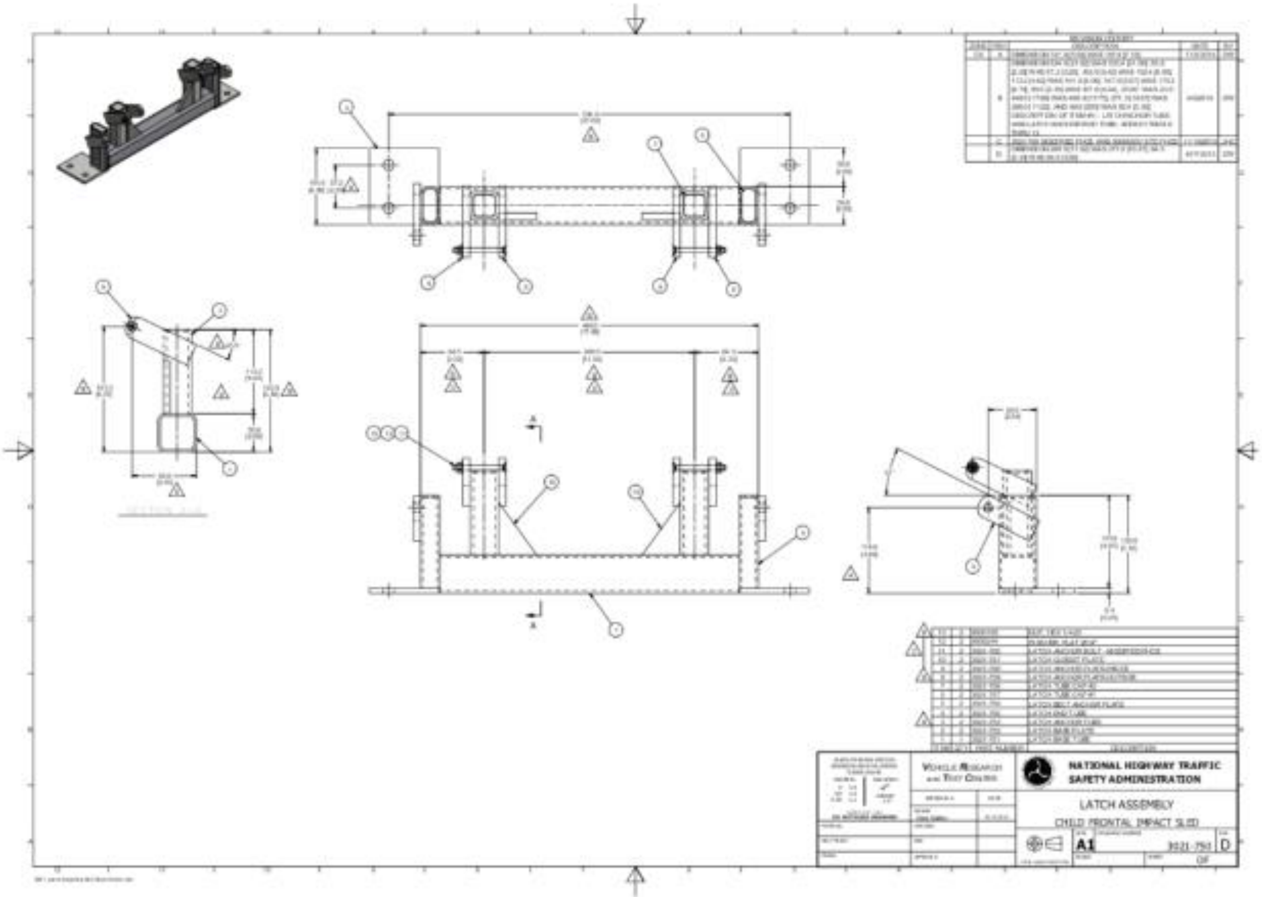


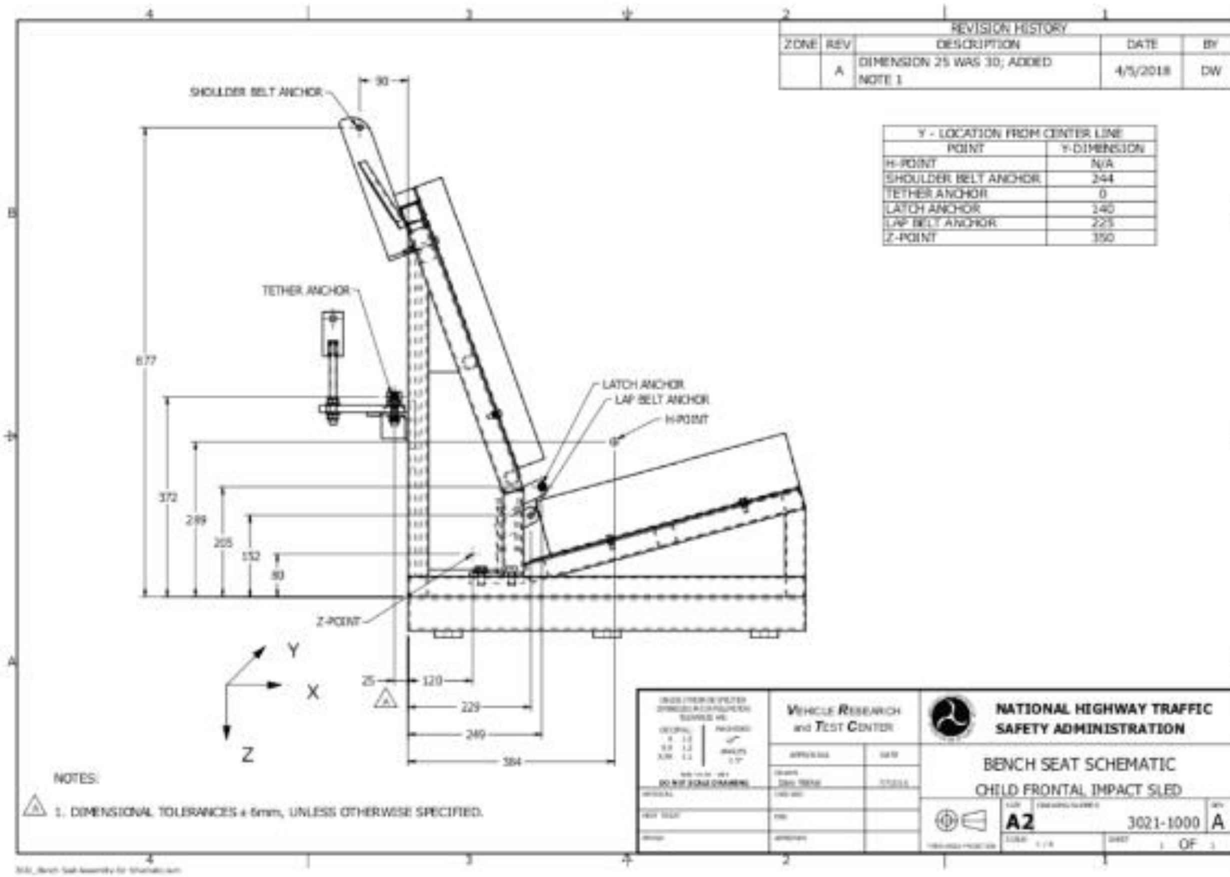
9 Appendix – Bench drawings




NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
BENCH SEAT FRAME ASSEMBLY


NATIONAL HIGHWAY TRAFFIC
SAFETY ADMINISTRATION


NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
LATCH ASSEMBLY
CHILD FRONTAL IMPACT SLED
A1
D


REVISION HISTORY
ZONE | REV | DESCRIPTION | DATE | BY
A | DIMENSION 25 WAS 30; ADDED NOTE 1 | 4/5/2018 | DW
Y - LOCATION FROM CENTER LINE
POINT | Y-DIMENSION
H-POINT | N/A
SHOULDER BELT ANCHOR | 244
TETHER ANCHOR | 0
LATCH ANCHOR | 140
LAP BELT ANCHOR | 225
Z-POINT | 350
SHOULDER BELT ANCHOR
90
TETHER ANCHOR
877
LATCH ANCHOR
LAP BELT ANCHOR
H-POINT
372
289
205
152
80
Z-POINT
Y
X
Z
25
120
229
249
384
NOTES:
1. DIMENSIONAL TOLERANCES ± 6mm, UNLESS OTHERWISE SPECIFIED.
VEHICLE RESEARCH and TEST CENTER
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
BENCH SEAT SCHEMATIC
CHILD FRONTAL IMPACT SLED
A2
3021-1000
A
1 OF 1