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Side Impact Test
Evaluation and Revision

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16. Abstract

On January 28, 2014, the National Highway Traffic Safety Administration published a notice of proposed rulemaking (NPRM) that would require all child restraint systems (CRSs) designed to seat children weighing up to 18 kg (~40 lb) to provide protection in side impact crashes. The proposed sled test simulates the two-vehicle side crash replicated by the Federal Motor Vehicle Safety Standard (FMVSS) No. 214, “Side impact protection,” moving deformable barrier test of a small passenger car. Since the release of the NPRM, additional research was conducted to assess the comments and other research questions that were presented in the NPRM. This report addresses the changes incorporated in the test buck and test methodology from those that were originally released with the NPRM. The modified test buck minimized variability in installation, made equipment more durable, and better matched the proposed frontal FMVSS No. 213 seat assembly. An updated test procedure is included for full test set-up details. The final sled test buck and equipment, following revisions detailed in this report, were described including final honeycomb specifications, anchorage locations and design, and accelerometer type and placement. All the testing with the final configuration sled test buck and procedures were analyzed and were within the sliding seat acceleration corridor and relative velocity tolerance. Paired tests using four forward-facing and three rear-facing CRSs of comparable make/model in the final configuration test buck and that proposed in the NPRM produced similar results. However, testing of CRS models with a variety of advertised side impact protection features in the final configuration test buck using the Q3s dummy showed elevated injury responses (greater than HIC15 limit of 570 and chest deflection limit of 23 mm).

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Table of Contents

List of Figures

List of Tables

Executive Summary

On January 28, 2014, the National Highway Traffic Safety Administration published a notice of proposed rulemaking (NPRM) that proposed a side impact test that simulates the two-vehicle side crash replicated by the FMVSS No. 214 moving deformable barrier (MDB) test of a small passenger car.[1] The proposal would require all child restraint systems (CRSs) designed to seat children weighing up to 18 kg (~40 lb)[2] to meet specific performance criteria in a dynamic sled test that simulates the MDB test (striking vehicle traveling at 48.3 kilometers per hour (30 mph) striking the side of a small passenger car traveling at 24 kph (15 mph)). The test procedure simulates a near-side crash environment experienced by a child restrained in a CRS with an internal harness in the rear seat of a passenger car.[3]

A final rule adopting the proposed requirements in the 2014 NPRM would satisfy §31501(a) of the Moving Ahead for Progress in the 21st Century Act (MAP-21), which requires NHTSA to issue a final rule amending FMVSS No. 213 to improve the protection of children seated in child restraint systems during side impact crashes.

Since the release of the NPRM, a repeatability and reproducibility study was completed[4] and additional research was conducted to assess the comments and other research questions that were raised by the NPRM. NHTSA published an NPRM (85 FR 69388, November 2, 2020) updating the frontal FMVSS No. 213 sled assembly and sought to incorporate the updates that were included for the side impact test assembly.

This report addresses modifications to the FMVSS No. 213a side impact test buck and test methodology from those that were originally released with the NPRM. The modified test buck minimized variability in installation, made test equipment more durable, and better matched the proposed frontal FMVSS No. 213 seat assembly. This report addresses the changes incorporated in the test buck and test methodology from those that were originally released with the NPRM and provides an updated research test procedure. The research test procedure is not the official test procedure of the standard. The official test procedure is published in the final rule and is set forth in the Code of Federal Regulations.

The final sled test buck and equipment, following revisions detailed in this report, were described including final honeycomb specifications, anchorage locations and design, and accelerometer type and placement. All the testing with the final configuration sled test buck and procedures were analyzed and were within the sliding seat acceleration corridor and relative velocity tolerance. Overall, the dummies were durable and had minimal issues during numerous test series. Paired tests using four forward-facing and three rear-facing CRSs of comparable make/model in the final configuration test buck and that proposed in the NPRM produced similar results. However, testing of CRS models with a variety of advertised side impact protection features in the final configuration test buck using the Q3s dummy showed elevated injury responses (greater than HIC15 limit of 570 and chest deflection limit of 23 mm).

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[1] 79 FR 4570. Available at www.regulations.gov/document?D=NHTSA-2014-0012-0001

[2] FMVSS No. 213 also includes children in a height range up to 1100 millimeters (43.3 inches) regardless of weight.

[3] Obtained from an analysis of the National Automotive Sampling System—Crashworthiness Data System (NASS-CDS) data files for the years 1995-2009 for restrained children 0 to 12 years old in all restraint environments including seat belts and CRS. Details of the analysis are provided in the technical report in the docket for the NPRM.

[4] Wietholter, K., & Louden, A. E. (in press). *Repeatability and reproducibility of the FMVSS No. 213 side impact test.* National Highway Traffic Safety Administration.

1 Introduction

On January 28, 2014, NHTSA published an NPRM proposing a side impact test that simulates a two-vehicle side crash replicated by the FMVSS No. 214 moving deformable barrier test of a small passenger car.[5] The proposal would require all CRSs designed to seat children weighing up to 18 kg (~40 lb)[6] to meet specific performance criteria in a dynamic sled test that simulates the MDB test (striking vehicle traveling at 48.3 kph (30 mph) striking the side of a small passenger car traveling at 24 kph (15 mph)). The test procedure simulates a near-side crash environment experienced by a child restrained in a CRS with an internal harness in the rear seat of a passenger car. Approximately 92 percent of side crashes involving restrained children are of equivalent or lower crash severity than the FMVSS No. 214 MDB crash test of a small passenger car.[7]

A final rule adopting the proposed requirements in the 2014 NPRM would satisfy §31501(a) of the MAP-21 Act, which requires NHTSA to issue a final rule amending FMVSS No. 213 to improve the protection of children seated in child restraint systems during side impact crashes. Since the release of the NPRM, a repeatability and reproducibility study was completed[8] and additional research was conducted to assess the comments and other research questions that were raised by the NPRM. This report addresses the changes incorporated in the test buck and test methodology from those that were originally released with the NPRM and provides an updated research test procedure. The research test procedure is not the official test procedure of the standard. The official test procedure is set forth in the final rule and is published in the Code of Federal Regulations.

1.1 Test Buck and Overall Pulse

The "sled-on-sled" was based upon a test buck created by TK Holding, Inc. (Takata) and then further developed by NHTSA to have a representative sled pulse, impact direction, door and armrest response.[9] NHTSA's Vehicle Research and Test Center (VRTC) completed the test development on a HYGE acceleration sled at Transportation Research Center Inc. (TRC). The HYGE acceleration side impact sled set-up is shown in Figure 1. The acceleration sled test uses pressures to propel the sled buck, where impact is represented at the start of the test.

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[5] 79 FR 4570.

[6] FMVSS No. 213 also includes children in a height range up to 1100 millimeters (43.3 inches) regardless of weight.

[7] Obtained from an analysis of the National Automotive Sampling System—Crashworthiness Data System (NASS-CDS) data files for the years 1995-2009 for restrained children 0 to 12 years old in all restraint environments including seat belts and CRS. Details of the analysis are provided in the technical report in the docket for the NPRM.

[8] Wietholter & Louden (in press).

[9] Sullivan, L. K., Louden, A. E., & Echemendia, C. G. (2013, December). *Child restraint side impact test procedure development.* National Highway Traffic Safety Administration. Available at https://downloads.regulations.gov/NHTSA-2014-0012-0002/attachment_2.docx

Figure 1. Acceleration Sled Set-up

Sled tests were conducted using the proposed specifications for a sliding seat acceleration corridor with the coordinates listed in Table 1. Figure 2 shows the sliding seat acceleration corridor in graphical form. An additional requirement was the test speed of the sliding seat; this was determined using the calculation of the relative velocity between the sliding seat and the door/armrest, with the specification of 31.4 ± 0.8 kph (19.5 ± 0.4 mph).

Table 1. Sliding Seat Acceleration Corridor Coordinates

Upper		**Lower**	
Time (ms)	**Acceleration (g)**	**Time (ms)**	**Acceleration (g)**
0	0.5	2	0
6	25.5	13	18.5
44	25.5	40	18.5
58	0	48	0

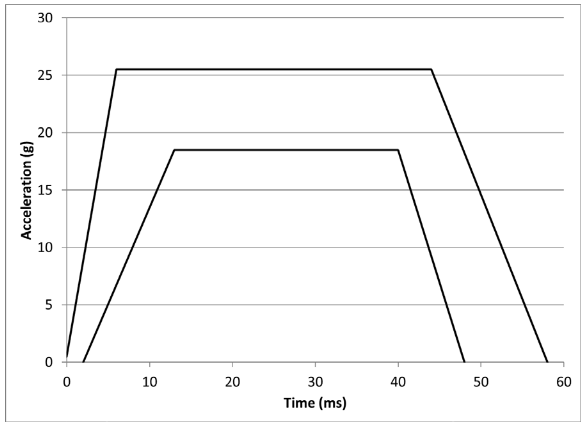

Figure 2. Sliding Seat Acceleration Corridor

1.2 Injury Criteria

To assess CRS performance, testing included the CRABI 12-month-old (CRABI 12 MO) and Q series side impact 3-year-old (Q3s) anthropomorphic test devices (ATDs). The CRABI 12 MO was used in the rear-facing (RF) configuration with infant and convertible CRSs, as well as forward-facing (FF) with convertible CRSs. A list of instrumentation used for the CRABI 12 MO ATD can be found in Table 2.

Table 2. CRABI 12MO Instrumentation

Location	Measurement	Instrument	Channels
Head	Head C.G. Acceleration	Tri-Axial Accelerometer	3
Neck	Upper Neck Forces & Moments	Six-Channel Load Cell	6
Thorax	Chest Acceleration	Tri-Axial Accelerometer	3
Pelvis	Pelvis Acceleration	Tri-Axial Accelerometer	3
Total			15

The Q3s ATD was tested in both RF and FF configurations with convertible CRSs and FF in combination CRSs. Table 3 contains the list of instrumentation used in the Q3s ATD.

Table 3. Q3s Instrumentation

Location	Measurement	Instrument	Channels
Head	Head C.G. Acceleration	Tri-Axial Accelerometer	3
Neck	Upper Neck Forces & Moments	Six-Channel Load Cell	6
Shoulder	Shoulder Displacement	String Potentiometer	1
Upper Spine	Upper Spine Acceleration	Tri-Axial Accelerometer	3
Thorax	Chest Displacement	IR-TRACC	1
Lumbar Spine	Lumbar Spine Forces & Moments	Six-Channel Load Cell	6
Pelvis	Pelvis Acceleration	Tri-Axial Accelerometer	3
Pubic	Pubic Force	One-Channel Load Cell	1
Total			24

All the above data was collected. However, analysis was only performed for injury criteria proposed in the FMVSS No. 213 NPRM: HIC15 and chest displacement for the Q3s ATD. Additionally, head contact with the armrest/door structure was analyzed for proposed containment criteria for the CRABI 12 MO ATD, as well as HIC15 for comparison purposes.

2 Sled Test Buck Modifications

Since the NPRM was released, NHTSA has modified the sled-on-sled test buck to minimize variability in installation, be more durable, and better match the proposed frontal FMVSS No. 213 seat assembly. The modifications, illustrated in Figure 3, included additional stiffening framework, an updated D-ring location, increased seat back height, simplified door and armrest shapes, modified lower anchor bracket and tether anchor location, and incorporation of a seat cushion assembly representative of current vehicles.[10] Section 3 of this report details testing and further revision to the modified sled test buck; the final configuration of the test buck is specified in Section 4.

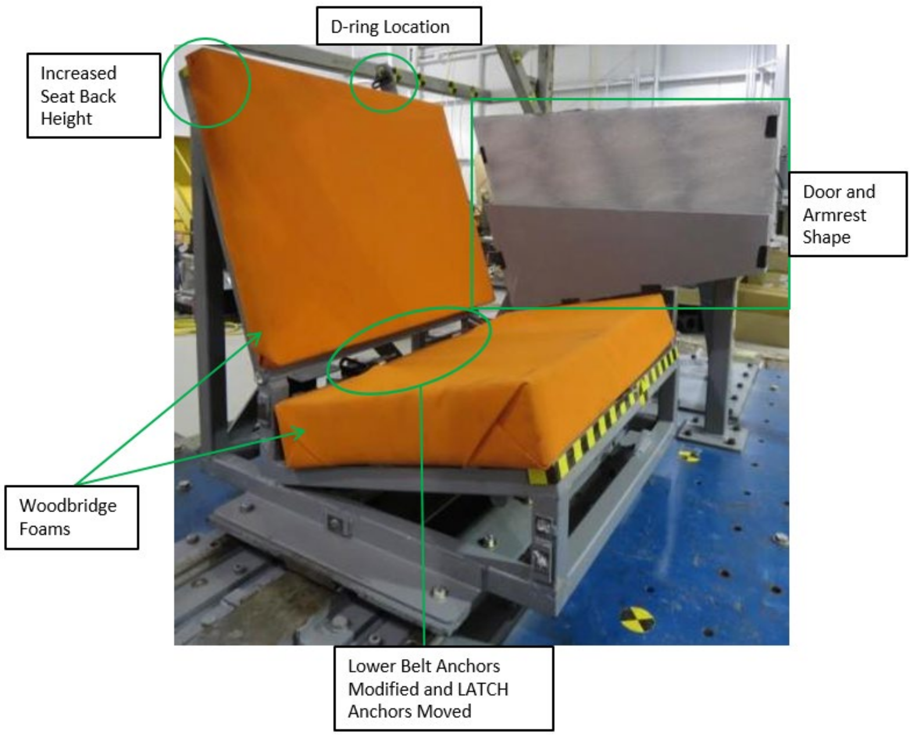

Figure 3. Sliding Seat Modifications

The testing conducted for the NPRM used foam that was specified in the Economic Commission for Europe (ECE) R.44 and was included in the drawing package submitted with the NPRM.[11] It was determined that the foam proposed for the FMVSS No. 213 frontal bench should also be used on the side impact bench for simplicity. The ECE foam has a thickness of 135 mm (5.31 in.) for the seat pan and 70 mm (2.75 in.) for the seat back. The new proposed foam has a thickness of 102 mm (4 in.) for the seat pan and 51 mm (2 in.) for the seat back. To keep the same proposed test condition, the impact wall was adjusted to impact the CRSs as it had with the original ECE proposed foam cushion. This required the wall to be lowered and shifted rearward to maintain the height of the windowsill and armrest relative to the seat pan. In addition to this

[10] Child Side Impact Sled – December 2021 drawing package.
[11] Child Side Impact Sled – December 2013 drawing numbers 2921-372 and 2921-392.

adjustment, the shape of the door and armrest foam was simplified[12] but the material was kept the same.[13]

The newly proposed seat cushion foam is a polyurethane foam with a density of 47 kg per cubic meter and compression force deflection (CFD) of 6.6 kiloPascals and proposed indentation force deflection (IFD) certification based on ASTM D3574-11 Test B1standards.[14] Full foam specifications for the seat pan cushion are detailed in Table 4 below and testing protocols can be found in the NHTSA report "Evaluation of Foam Specifications for Use on the Proposed FMVSS No. 213 Test Bench."[15]

Table 4. Seat Cushion Foam Specifications
Procurement Specifications

	Density kg/m^3 (lb/ft^3)	50% CFD kPa (lb/in^2)	IFD 25% N (lb)	IFD 50% N (lb)	IFD 65% N (lb)
Seat Pan (102 mm)	47 (2.9) ±10%	6.6 (0.96) ±10%	237 (53.3) ± 15% For reference	440 (98.9) ±10% [396-484]	725 (162.9) ±15% For reference
Seat Back (51 mm)	47 (2.9) ±10%	6.6 (0.96) ±10%	157 (35.3) For reference	300 (67.4) ±15% [255-345]	480 (107.9) For reference

Test Specifications During Sled Testing

	IFD 25% N (lb)	IFD 50% N (lb)	IFD 65% N (lb)
Seat Pan (102 mm)	237 (53.3) ± 15% For reference	440 (98.9) ±15% [374-506]	725 (162.9) ±15% For reference
Seat Back (51 mm)	157 (35.3) For reference	300 (67.4) ±15% [255-345]	480 (107.9) For reference

NHTSA sled testing used foams that were manufactured by the Woodbridge Group of Troy, Michigan, and were wrapped in a Sunbrella acrylic awning product with a surface density of 34 g/m^2, a lengthwise breaking strength of 129 kilogram-force (kg_f), and a breadthwise breaking strength of 82 kg_f. Additional specifications and wrapping of the foams can be found in the drawing package and in Appendix E.

An additional update to the sliding seat was the location of the accelerometers that are used to verify that the sliding seat acceleration is in the proposed corridor and to calculate the relative velocity of the sliding seat. Many accelerometer locations on the sliding seat were tested and detailed throughout this report. It was determined that the final placement of the accelerometers would be on the right rear leg at pre-determined locations; with the primary accelerometer to be

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[12] Child Side Impact Sled – December 2021 drawing numbers 2921-501 and 2921-502.
[13] NHTSA purchased the wall and armrest foams from Custom Foam Products, Inc., Fort Loramie, OH.
[14] Per ASTM D3574-11 Test B1 (Indentation Force Deflection)
[15] Louden, A. E., & Wetli, A. E. (2021, June). *Evaluation of foam specifications for the proposed FMVSS No. 213 test bench* (Report No. DOT HS 813 129). National Highway Traffic Safety Administration.

mounted on top and the redundant to be mounted 31 mm below (Figure 4). The final location is specified in the drawing package.

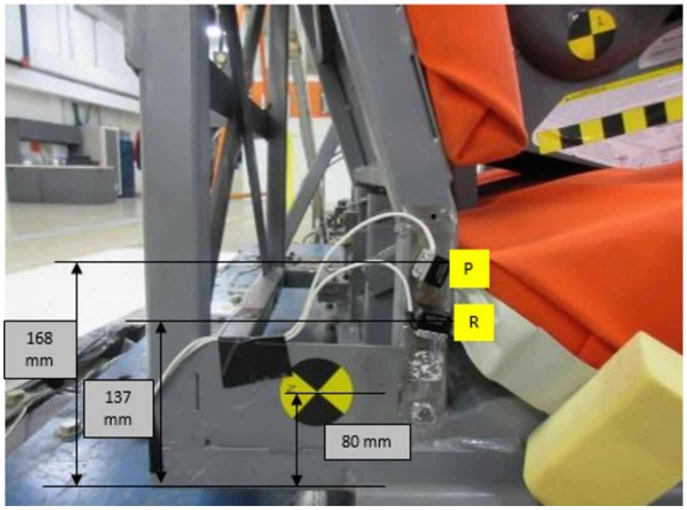

Figure 4. Updated Accelerometer Placement

Originally, the sliding seat weight was 124.7 kg (275 lb) based on the NPRM drawings. After rebuilding with all modifications, the sliding seat weight increased to 137.4 kg (303 lb). Additionally, unnecessary pieces were removed from the sliding seat assembly, including the anti-rebound mechanism. The anti-rebound mechanism is shown in Figure 5; this fixture was developed prior to the NPRM to control the rebound motion of the sliding seat and prevent damage to the seat or rails. Based on numerous tests, it was determined that the device was unnecessary for the acceleration sled and could add additional friction and therefore variability into system.

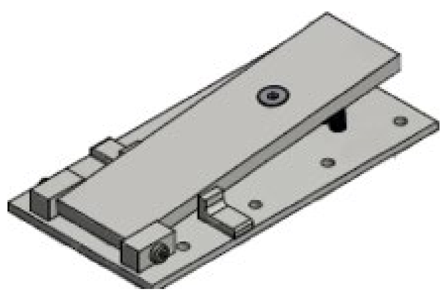

Figure 5. Anti-rebound Mechanism

Furthermore, there was an error reported in the NPRM in regards to the the gap measurement spacing between the wall foams and honeycomb. It was determined that each of the wall foams have tolerances associated with it's manufacturing process that were not taken into consideration when developing the final measurents for the sled setup. Therefore, the gap measurement was adjusted to 38 ± 6 mm (increased from 32 mm) as shown in the schematic in Figure 6.

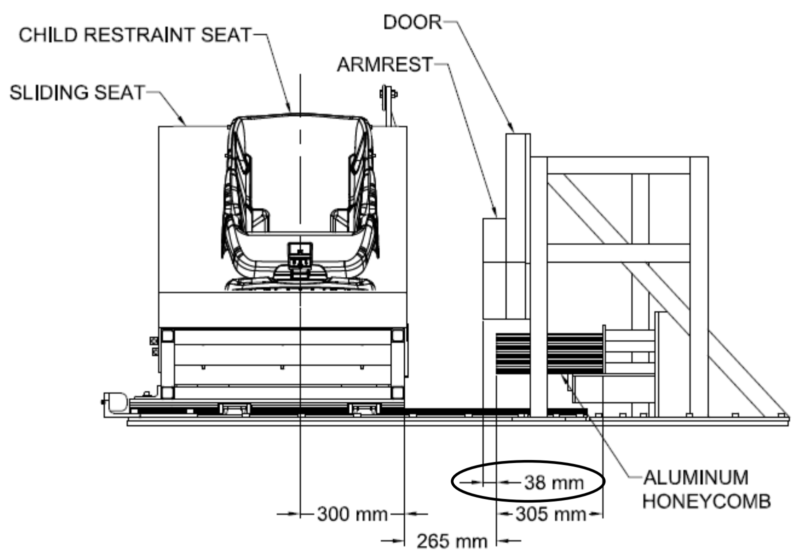

Figure 6. Side Impact Buck Setup Measurements

3 Evaluation and Comparison Testing

3.1 Response to Comments Evaluation

To evaluate comments received on the NPRM, several additional series of sled tests were conducted from November 2014 to November 2017. Specifically, evaluations of honeycomb pre-crush, accelerometer types and location, damped accelerometer filtering, head motion, arm placement with the Q3s, and restraint type installation comparisons were completed.

3.1.1 Honeycomb Pre-crush

Comments on the NPRM included that NHTSA should specify whether the honeycomb is pre-crushed, since the acceleration response can differ depending whether honeycomb is pre-crushed or not.

NHTSA completed testing with pre-crushed honeycomb[16] (Appendix A, Table A-1) to evaluate the effect the pre-crushed honeycomb causes to the acceleration response of the sliding seat. This test series was completed with damped Endevco 7290E accelerometers on the right rear leg. As shown in Figure 7 for a RF infant CRS and Figure 8 for a FF convertible CRS, it was found the pre-crushed honeycomb (dashed lines) lowered the magnitude of the acceleration response within the corridor and extended the duration when compared to tests conducted with non pre-crushed honeycomb. However, the pre-crushed honeycomb did not reduce the oscillations. Based on this testing, the agency decided to continue with the non pre-crushed honeycomb, since it produced a sliding seat acceleration which better fit the corridor and was used during previous testing.

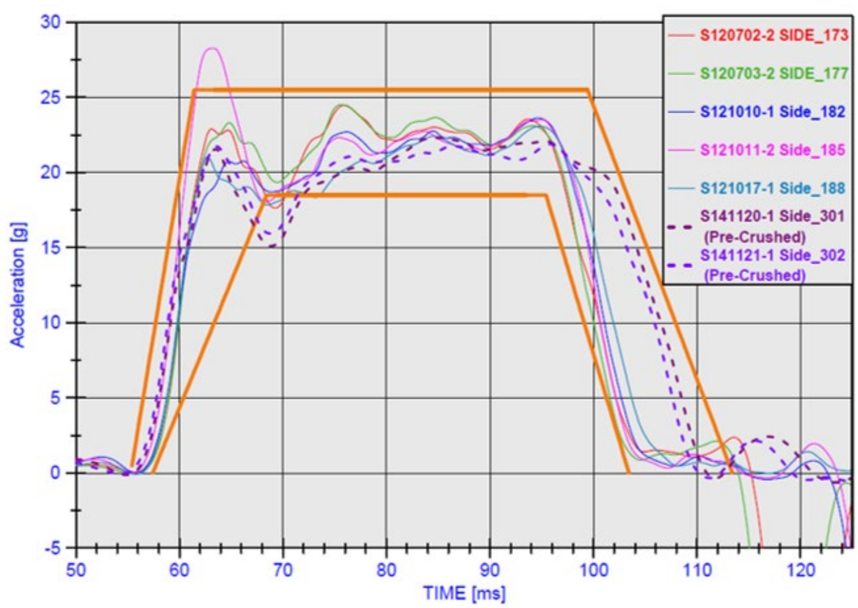

Figure 7. Pre-Crushed Honeycomb Evaluation for RF Infant CRS (Filter: SAE CFC 60)

[16] Plascore Crushlite product: PACL-XR1-2.3-3/8-0015-P-5052-F06; www.plascore.com/download/datasheets/energy_absorption_documentation/Plascore_CrushLite-Sheet-Metric-2021_2.pdf

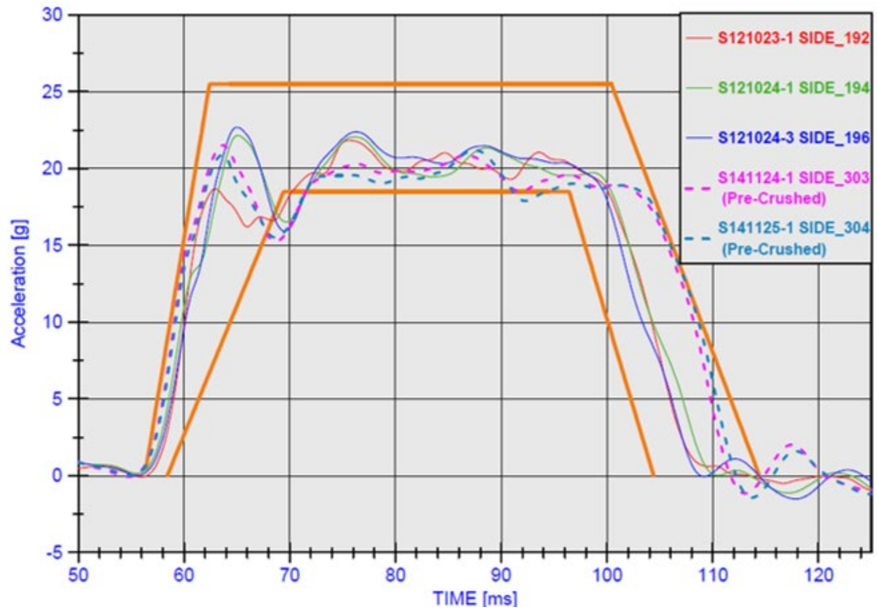

Figure 8. Pre-Crushed Honeycomb Evaluation FF Convertible CRS (Filter: SAE CFC 60)

Further honeycomb analysis will be detailed later in this report. Final honeycomb characteristics are presented in Section 3.3.

3.1.2 Accelerometer Types and Placement

During an initial test series (Appendix A, Table A-2) to evaluate accelerometers, several non-damped (Endevco 7264C) accelerometers were used on the front leg and rear leg of the inboard side of the sliding seat assembly. Damped (Endevco 7290E and 7290A) accelerometers were used on the front leg, rear leg, middle (between the front and rear legs), and at the approximate seat assembly center of gravity. Figure 9 shows the accelerometer locations.

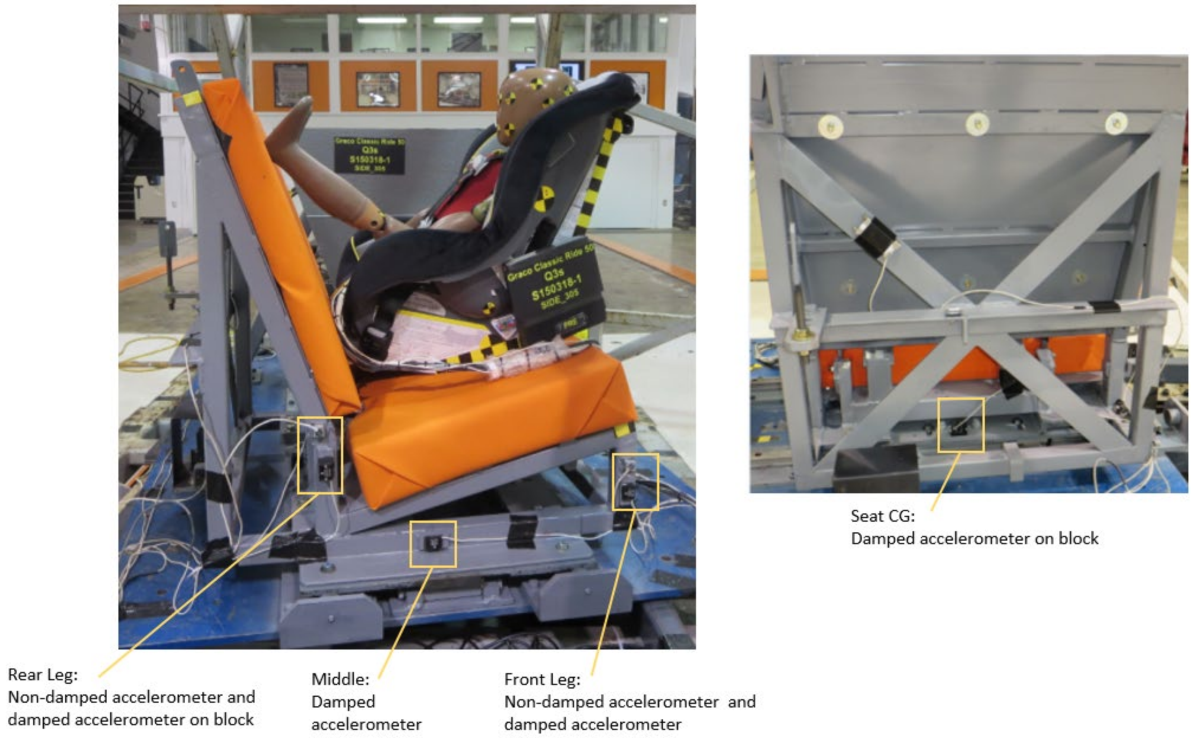

Figure 9. Damped and Non-Damped Accelerometer Placement

The most consistent acceleration results were recorded on the rear leg and middle accelerometer placements shown in Figure 10 below. Additionally, buck modifications appeared to have strengthened the sliding seat and reduced noise in the acceleration data. The right rear leg was consistently used in all prior research testing and is most in-line with the sliding seat rail. It was determined that this location would continue to be used for future work.

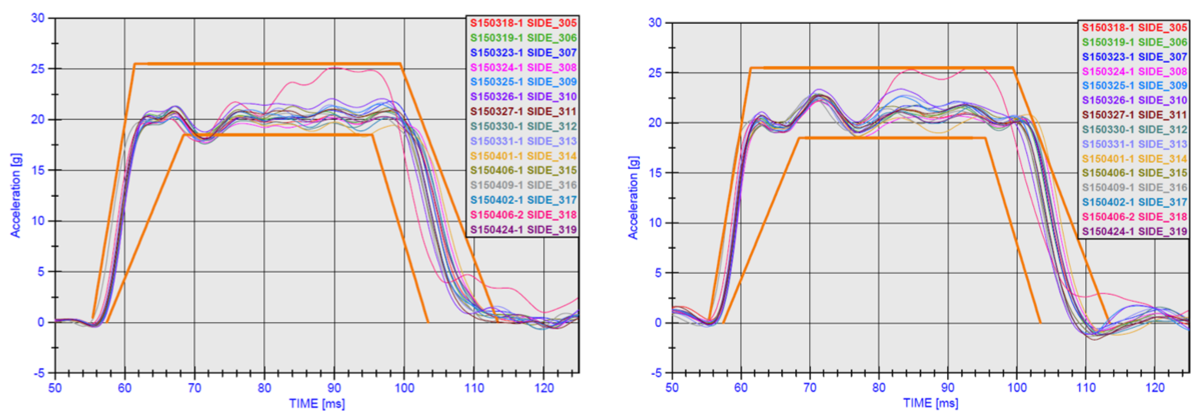

Figure 10. Accelerometer Placement Results for Rear Leg (left) and Middle (right) (Filter: SAE CFC 60)

In the NPRM, it was stated to use the damped 7290E and 7290A accelerometers because they showed the most consistent results; however, comments were received about the filtering within the damped accelerometers. Data from the accelerometers was filtered to CFC 60 based on SAE J211 for sled acceleration.

The damped accelerometers were further researched and used in testing, however the damped accelerometers were being phased out by the manufacturer and had some issues during testing. An additional non-damped accelerometer was hence evaluated (Endevco 7231C), a more ruggedized accelerometer than the others tested.[17] This accelerometer is mounted on a specified mount welded to the frame of the right rear leg and was ultimately utilized exclusively in the final series of tests (Appendix D, Section 1.2.1).

3.1.3 Head Nodding

Head motion was quantified during testing using image analysis software to address a comment regarding head nodding during the run-up to impact with the simulated door structure. Image analysis proved that the head moved an average 44 mm forward relative to the initial head position prior to impact for 6 tests[18] with different restraint types. Whereas the maximum X-direction excursion was 116 mm on average. This was attributed to the sled-on-sled set-up as it was observed consistently throughout testing.

3.1.4 Q3s Arm Placement

The arm placement is part of the seating procedure for the Q3s. Commenters had suggested that the arm being placed in different positions could have an effect on the overall ATD responses, especially in the chest response. In the NHTSA tests the arm was consistently placed in the arm detent by following the seating procedure. (Appendix D).

The Q3s shoulder has a detent in the rotator cup that allows the arm to be placed consistently in same position relative to the ATD; there is a ball plunger screw on the back of the Q3s shoulder that should be installed per the Q3s PADI[19] (Figure 11). In addition, the joints of the arms should be inspected prior to every test and set to the "1G" torque setting requirement as described in the PADI by adjusting the screws on the side of the arm (Figure 12). For every test, the arms were placed in the detent and then the lower portion of the arm segment straightened during the ATD seating.

[17] Endevco 7231C: https://buy.endevco.com/7231c-accelerometer-24.html
[18] Forward Facing CRS Tests From the Response to Comments test series (Appendix A, Table A-2)
[19] NHTSA Docket No. NHTSA-2020-0088-0002; Q3s PADI, May 2016.

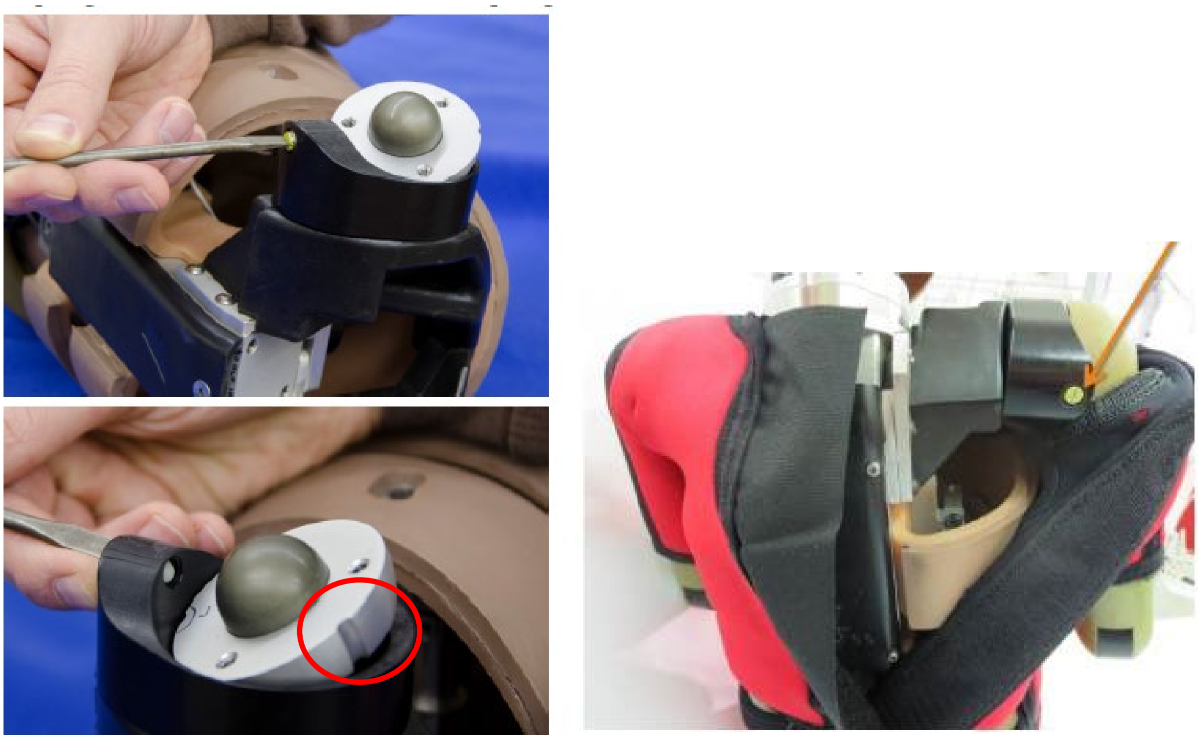

Figure 11. Shoulder Screw and Arm Detent

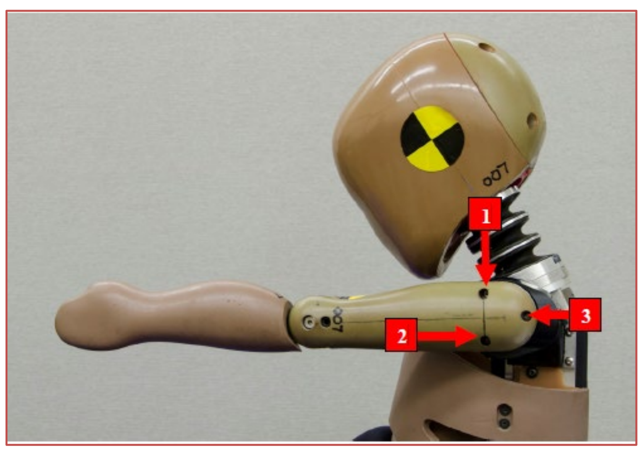

Figure 12. Arm Adjustment

Overall ATD responses can be observed in Appendix B. The results were overall consistent between comparable make/models of CRSs, specifically within 4 mm when using the same CRS. (Refer to Appendix A for the different test matrix configurations).

3.1.5 Installation Method

A series of tests was conducted to assess the installation of the CRS on the bench to address any issues using the lower anchors (LA only), lower anchors and top tether (LATCH), 3-point seat belt (SB3PT), and 3-point seat belt and tether (SB3PT&T).

All four installation types were completed with a FF convertible seat (Graco Comfort Sport). Injury results were analyzed and occupant kinematics observed. There were no noticeable differences in kinematics for the different methods of CRS installation. Results from the four tests are reported in Table 5; no major differences were observed.

Table 5. CRS Installation Type Comparisons

VDB No.	VRTC Test No.	ATD	Restraint Type	HIC 15	Chest Deflection [mm]	Contact?	2D X Displacement at Impact [mm]
V09630	SIDE_314	Q3s	LATCH	640	21.1	Yes	46
V09633	SIDE_317	Q3s	LA Only	579	23.0	Yes	41
V09631	SIDE_315	Q3s	SB3PT&T	580	18.6	Yes	43
V09632	SIDE_316	Q3s	SB3PT	649	19.1	Yes	42

3.2 Lower Anchor Design Evaluation

Along with the other buck modifications discussed in the previous section, the lower anchor design was updated to make the lower anchorages easily removeable in case they were damaged during testing and had to be replaced. Previous testing did show deformation to the lower anchors with the Q3s in a heavy CRS; an example is shown in Figure 13.

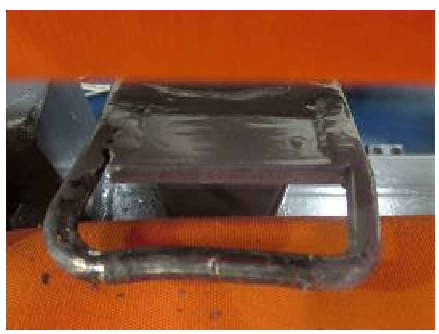

Figure 13. Lower Anchor Deformation

Prior to the modification, if an anchor was damaged, the whole anchorage system would have to be removed. The updated lower anchor bracket with the removable lower anchor pieces is shown below in Figure 14.

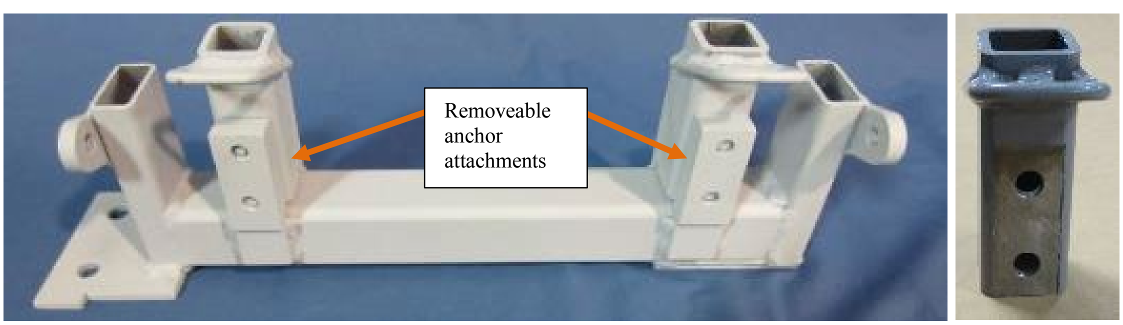

Figure 14. Removable Lower Anchor Brackets

To test that the updated anchorage bracketry was durable and did not affect results, the test matrix contained various lower anchor connector types. The specific aim of this test series was to see if the larger CRS attachments (i.e. non-clips) would work on the new anchor bracket. Photos of each of the LATCH attachment designs tested are shown in Figure 15.

Figure 15. CRS Attachments Evaluated With Removable Lower Anchor Design

Testing with the three different lower anchor connectors in sled tests (Appendix A, Table A-3) found no issues with the design and durability of the new lower anchor brackets. Thus, the new design was used in future testing and is included in the final configuration of the sliding seat assembly.[20]

3.3 Honeycomb Specifications

Honeycomb that met the size and crush strength specifications released in the NPRM was used initially in the testing to evaluate comments on the NPRM with minor issues. As additional tests were conducted, many of the tests were unable to meet the sliding seat acceleration and relative velocity requirements, with the acceleration coming out the lower bound of the corridor. Many considerations were evaluated, and it was noted that the post-test honeycomb thickness was less (more crush) than in previous testing.

After finding that the sliding seat acceleration falling out of the lower bound of the corridor was in some part related to the honeycomb, the honeycomb manufacturer (Plascore) was contacted. After static testing by the manufacturer, it was found that the honeycomb used was within the crush strength specification (552 kPa [80 psi] ± 10%) but at the low end of the tolerance. It was concluded that the acceleration falling out of the lower bound of the corridor was due to a combination of the increased weight of the sliding seat from the buck modifications, the honeycomb being at the low end of the crush strength tolerance, and some variation in honeycomb surface area.

As detailed in Appendix C by Plascore, the final honeycomb specification crush strength was increased to 620 kPa (90 psi) and a tolerance of 5 percent[21] implemented to better control the variation between batches.

After initial use with the 620 kPa (90 psi) crush strength honeycomb, the area needed to be reduced for the sliding seat acceleration to be within the acceleration corridor. The final specification of the honeycomb was 620 kPa (90 psi) ± 5% with dimensions of 342 mm (13.5 in.) by 112 mm (4.4 in.) with a 305-mm (12-in.) standard thickness, as shown in Figure 16. This honeycomb specification was used in the final configuration testing discussed in Section 5.

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[20] In the December 2021 drawing package it has an optional lower anchor attachment if there is still interference with the larger CRS attachment. The re-inforcement around the anchor has been removed and the remaining design remains the same.
[21] The 5 percent tolerance on the honeycomb specification is certified per ASTM D7336 standards and the manufacturer guidelines.

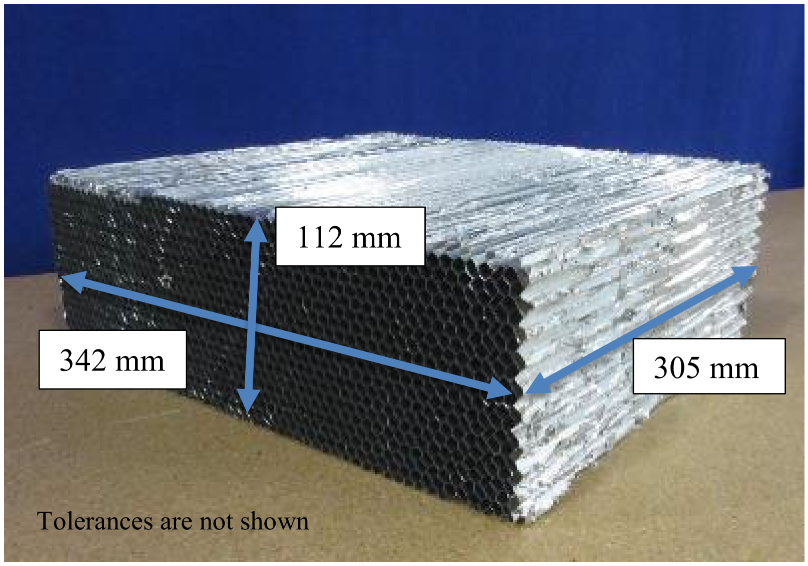

Figure 16. Final Honeycomb Specification

NHTSA procured the honeycomb from the supplier in large quantities and each piece had to be cut prior to sled testing. To cut the honeycomb to the desired measurements, a large piece of honeycomb is cut down to a manageable size using a hand saw. Then, a bandsaw with a new set of blades was used to cut the honeycomb to the required length and width measurements.

4 Final Configuration Details

Details and specifications for the final sled test buck and equipment can be found in a drawing package titled "Child Side Impact Sled – December 2021" that includes all the updates discussed throughout this report, including anchorage locations and design. All details for test set-up and procedures can be found in Appendix D.

The final accelerometer type and location determined for use on the sliding seat assembly were two non-damped Endevco 7231C accelerometers. The accelerometer on top was labeled as primary, and the lower accelerometer the redundant. Figure 17 below shows the final placement of the accelerometers on the inboard rear leg of the sliding seat assembly.

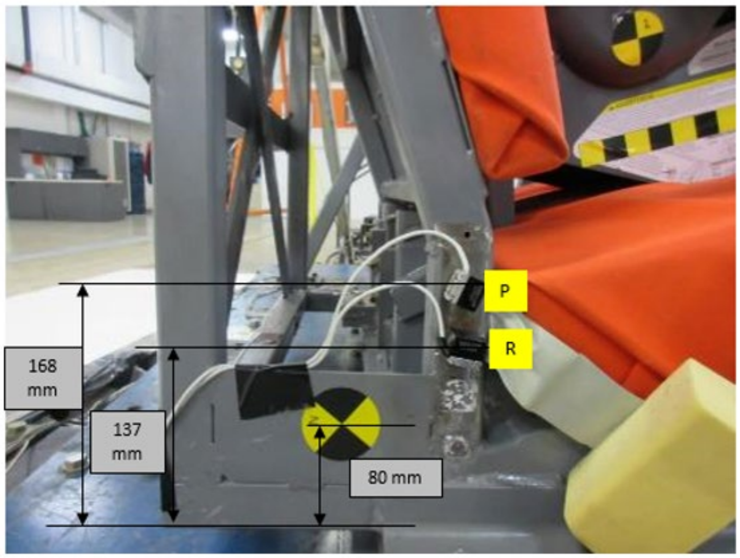

Figure 17. Final Accelerometer Placement

Additionally, switches were used to consistently measure the time of impact between the honeycomb and the sliding seat to calculate the relative velocity. Two copper contact switches were placed on the front face of the honeycomb (Figure 18) and impact plate (Figure 19) for every test.

Figure 18. Switch Placement on Honeycomb

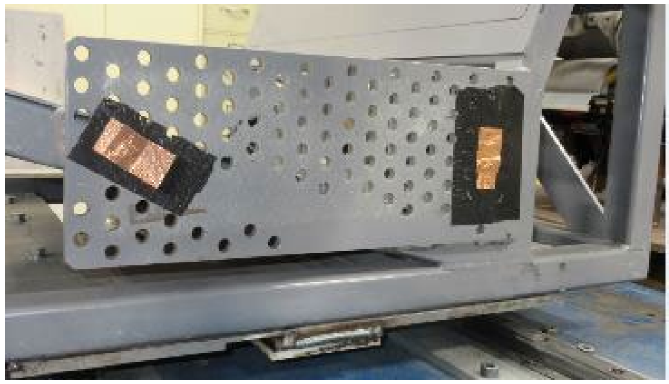

Figure 19. Switch Placement on Impact Plate

Throughout testing, the push and pull forces were monitored to evaluate the friction and status of the four bearings on the rail system. Normally, the push and pull forces for the VRTC sliding seat assembly were 36 to 67 N (8 to 15 lb). If higher forces were observed, the bearings were greased and tested again. If the push and pull forces were still high, additional troubleshooting occurred or the bearings were replaced. The bearings lasted for approximately 80 tests.

The seat cushion foams used on the sliding seat were also monitored throughout testing. Indentation Force Deflection[22] (IFD) testing was used to certify the foams to the specifications pre-test as well as throughout testing to monitor degradation.

[22] Louden & Wetli, 2021 June, Appendix B.

5 Final Configuration Testing

To evaluate the final configuration of the child side impact test buck, two sled test series were completed in April and May and in November 2017 (Appendix A, Table A-4 and A-5). In April (Table A-4), CRSs that were described as having side impact technologies or having been tested for side impact protection by the manufacturer were tested. In the November series (Table A-5), CRSs were tested for comparisons to testing completed with the proposed buck, including sled buck configurations, relative velocity tolerance, and gap measurement between armrest and honeycomb tolerance.

All the sled tests analyzed were within the sliding seat acceleration corridor, as shown in Figures 20 and 21, and relative velocity tolerance.

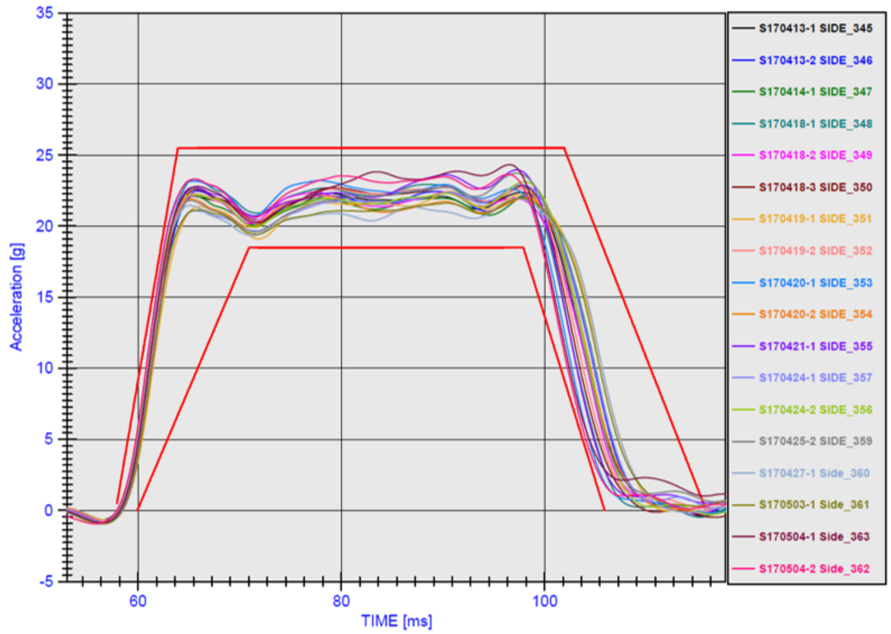

Figure 20. Final Configuration Acceleration Results – Side Impact Technologies Matrix A4 (Filter: SAE CFC 60)

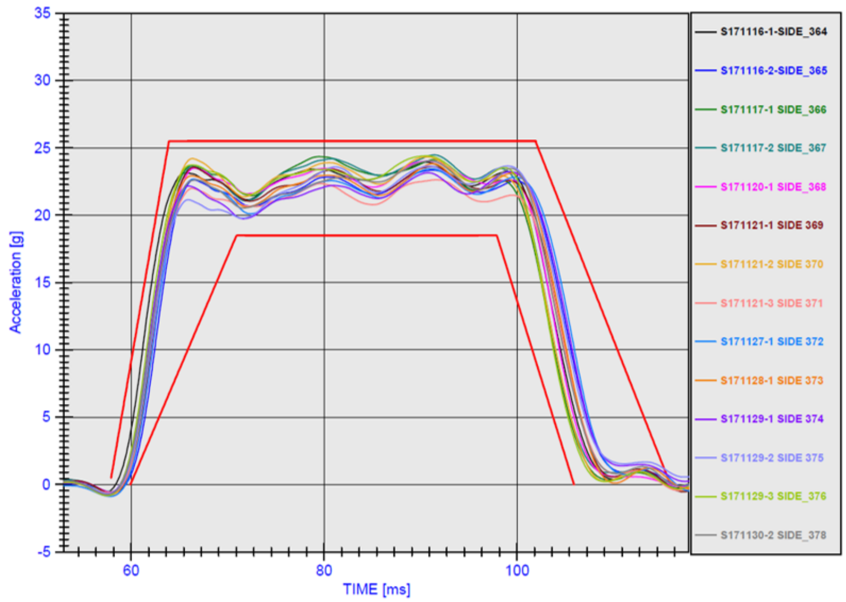

Figure 21. Final Configuration Acceleration Results– Comparisons Matrix A5 (Filter: SAE CFC 60)

Results from both test series showed elevated injury response[23] for both HIC and chest deflection for the Q3s. For the side impact technologies series, 11 of 14 tests had elevated HIC15 results (570 or above) and 6 of 14 tests had elevated chest deflection results (23 mm or above) with the Q3s. For the comparison series, noting some tests were repeats, 10 of 13 tests had elevated HIC15 results and 4 of 13 tests had elevated chest deflection results with the Q3s. The results for all the tests are in Appendix B.

Specific comparisons with the final configuration of the side impact sled test buck were analyzed. First, comparisons were made between testing conducted with the sled buck configuration proposed in the NPRM to tests conducted with the final buck configuration, using similar CRSs. The CRSs selected were visually similar although the models or names differ throughout time; it is possible that there were internal changes to a CRS that were unable to be noted. Table 6 details the comparisons, with previous testing conducted with the NPRM buck configuration marked in grey. There were no substantial differences in results with testing from the final configuration of the child side impact test buck compared to the NPRM buck.

[23] Q3s Injury Assement Values are HIC15 limit of 570 and chest deflection limit of 23 mm.

Table 6. Sled Buck Configuration Comparison

VDB No.	VRTC Test No.	CRS	Orientation	HIC15	Chest Deflection [mm]
V7547	SIDE_150	Evenflo Tribute	FF Conv.	788	20
V10101	SIDE_346	Evenflo Tribute	FF Conv.	760	21
V10277	SIDE_369	Evenflo Tribute	FF Conv.	712	21
V10278	SIDE_370	Evenflo Tribute	FF Conv.	732	22
V8296	SIDE_191	Graco Classic Ride 50	FF Conv.	742	19
V8278	SIDE_193	Graco Classic Ride 50	FF Conv.	679	22
V8280	SIDE_195	Graco Classic Ride 50	FF Conv.	675	20
V10272	SIDE_364	Graco Ready Ride	FF Conv.	771	22
V10273	SIDE_365	Graco Ready Ride	FF Conv.	723	20
V10279	SIDE_371	Graco Ready Ride	FF Conv.	587	20
V8277	SIDE_192	Graco Nautilus	FF Conv.	654	18
V8279	SIDE_194	Graco Nautilus	FF Conv.	597	20
V8281	SIDE_196	Graco Nautilus	FF Conv.	625	17
V10108	SIDE_353	Graco Nautilus 65	FF Conv.	609	14
V7561	SIDE_164	Evenflo Triumph Advantage DLX	FF Conv.	464	15
V8252	SIDE_166	Evenflo Triumph Advantage DLX	FF Conv.	446	16
V8254	SIDE_168	Evenflo Triumph Advantage DLX	FF Conv.	469	13
V10274	SIDE_366	Evenflo Triumph	FF Conv.	499	11
V10275	SIDE_367	Evenflo Triumph	FF Conv.	498	7
V7553	SIDE_156	Safety 1st Alpha Omega	RF Conv.	407	26
V10283	SIDE_375	Safety 1st Alpha Omega	RF Conv.	396	26
V7554	SIDE_157	Evenflo Tribute	RF Conv.	763	22
V10282	SIDE_374	Evenflo Tribute	RF Conv.	611	23
V8260	SIDE_174	Graco My Ride 65	RF Conv.	751	25
V8264	SIDE_179	Graco My Ride 65	RF Conv.	681	31
V10284	SIDE_376	Graco My Ride 65	RF Conv.	778	22

Additionally, a comparison study was completed to determine the effect of the relative velocity tolerance. Tests previously conducted with a FF convertible CRS installed via LATCH and tested at approximately 31.4 kph (19.5 mph) were repeated at the approximate lower and upper bounds of the tolerance of 30.7 and 32.0 kph (19.1 and 19.9 mph). The actual measured relative velocities were 30.3 kph (18.8 mph) and 32.0 kph (19.9 mph). Table 7 below shows the Q3s injury results with the same CRS at different relative velocities. Overall, the HIC15 results showed an increasing trend and the chest deflection results were similar.

Table 7. Relative Velocity Tolerance Comparison (Graco Ready Ride)

VDB No.	VRTC Test No.	Relative Velocity [km/h]	Relative Velocity [mph]	HIC15	Chest Deflection [mm]
V10279	SIDE_371	30.3	18.8	587	20
V10273	SIDE_365	31.1	19.3	723	20
V10100	SIDE_345	31.7	19.7	724	22
V10272	SIDE_364	32.0	19.9	771	21

The gap distance between the armrest and honeycomb was also compared to determine its effect. As noted in the introduction of this report, the revised gap distance is 38 ± 6 mm. To evaluate possible affect of the gap measurements, additional tests were conducted with two CRSs in both forward-facing (Evenflo Tribute) and rear-facing (Graco Size4Me 65) ranging the gap measurements from 33 to 47 mm. Table 8 shows the Q3s injury responses with the FF and RF CRSs at different gap distances. Results were similar for each CRS. Occupant kinematics were observed with no visual differences in kinematic response.

Table 8. Gap Tolerance Comparisons

VDB No.	VRTC Test No.	Orientation	Gap Distance [mm]	HIC15	Chest Deflection [mm]
V10277	SIDE_369	FF Convertible	34	712	21
V10101	SIDE_346	FF Convertible	42	760	21
V10278	SIDE_370	FF Convertible	46	732	22

TRC Test No.	VRTC Test No.	Orientation	Gap Distance [mm]	HIC15	Chest Deflection [mm]
V10285	SIDE_377	RF Convertible	33	751	21
V10116	SIDE_361	RF Convertible	42	778	24
V10286	SIDE_378	RF Convertible	47	754	23

Finally, two CRSs were tested with a CRABI 12 MO in an infant seat without a base, and installed with 3-point seat belt, to compare to results of the same CRS with the base. For one infant seat (Evenflo Discovery – SIDE_183, 186, and 189 with base and SIDE_372 without base), there was no head contact with or without a base.

In the second CRS set-up (Combi Shuttle – SIDE_182, 185, and 188 with base and SIDE_373 without base), there was a difference in head contact with and without a base. Occupant kinematics were explored to better understand the difference in response. Figure 22 shows that without a base, the CRS was lower and interacted primarily with the armrest. With a base, the CRS rotated about the armrest and the head contacted the door structure.

Figure 22. Kinematics With Base (Left) and Without Base (Right)

6 Dummy Durability

The two dummies that were used throughout sled testing were the CRABI 12 MO and the Q3s. Overall, the dummies were durable and had minimal issues during numerous test series. The CRABI 12 MO dummy was designed for frontal impacts. However, it was tested in 17 tests, in both infant and convertible style seats, in the side impact configuration. There were some instances where the outboard arm was broken above the elbow and the outboard leg broke above the knee, as shown in Figure 23; the damage was to plastic parts used as the bone.

Figure 23. CRABI 12 MO Dummy Damage

The Q3s was designed for side impact testing and was used in both FF and RF convertible CRSs and only minimal damage was observed. The outboard leg below the knee was slightly bent after numerous tests. In addition, during this testing, the ball plunger screw was sometimes adjusted to set the arm in the detent. By doing this adjustment, the nylon on the spring screw wore down and caused damage on the edge of the rotator cup and skin of the arm, as shown in Figure 24. It was further determined to avoid adjusting this spring loaded screw because it should be set in its proper location during the ATD build. In order to adjust the arm, use set screws on the outside of the arm as discussed in Section 3.

Figure 24. Q3s Minor Dummy Damage

7 Summary

This report addressed modifications to the FMVSS No. 213a side impact test buck and test methodology from those that were originally released with the NPRM. The modified test buck minimized variability in installation, made test equipment more durable, and better matched the proposed frontal FMVSS No. 213 seat assembly. An updated test procedure was included for full test set-up details. The final sled test buck and equipment were described including final honeycomb specifications, anchorage locations and design, and accelerometer type and placement. All the testing with the final configuration sled test buck and procedures were analyzed and were within the sliding seat acceleration corridor and relative velocity tolerance. Overall, the dummies were durable and had minimal issues during numerous test series. Results in the final configuration showed elevated injury response (greater than HIC15 limit of 570 and chest deflection limit of 23 millimeter) for both HIC and chest deflection for the Q3s. However, there were no substantial differences in results when compared to those from similar tests conducted on the buck configuration proposed in the NPRM.

Appendix A: Test Parameters

Table A-1. November-December 2014 Child Restraint Side Impact Sled Tests

VDB Test No.	Test Reference No.	VRTC Test No.	CRS Model	Dummy Type	CRS Orientation	Honeycomb Config.	Foam Set	Test Velocity (km/h)	Restraint Type	New Anti-Rebound
V09597	S141120-1	SIDE_301	Combi Shuttle	CRABI 12MO	Rear-facing	Pre-Crushed (Facing Sliding Seat)	ECE #6	32.2	LA Only	Yes
V09598	S141121-1	SIDE_302	Combi Shuttle	CRABI 12MO	Rear-facing	Pre-Crushed (Facing Back Plate)	ECE #7	32.2	LA Only	Yes
V09599	S141124-1	SIDE_303	Graco Nautilus	Q3s	Fwd-facing	Pre-Crushed (Facing Back Plate)	ECE #7	32.2	LATCH	Yes
V09600	S141125-1	SIDE_304	Graco Nautilus	Q3s	Fwd-facing	Pre-Crushed (Facing Sliding Seat)	ECE #6	32.2	LATCH	Yes

Honeycomb used for this testing: Plascore Crushlite product: PACL-XR1-2.3-3/8-0015-P-5052-F06 Crush =80%+/-10% PreCrushed
www.plascore.com/download/datasheets/energy_absorption_documentation/Plascore_CrushLite-Sheet-Metric-2021_2.pdf

Table A-2. March 2015 Sled Tests for Response to Comments

VDB Test No.	Test Reference No.	VRTC Test No.	CRS Model	Dummy Type	CRS Orientation	Honeycomb Config.	Foam Set	Test Velocity (km/h)/[mph]	Restraint Type	New Anti-Rebound
V09621	S150318-1	SIDE_305	Graco Classic Ride 50	Q3s	RF Convertible	Non-Crushed 80 psi ± 10%	WB #5	32.77/20.36	LA Only	Yes
V09622	S150319-1	SIDE_306	Graco Comfort Sport	Q3s	RF Convertible	Non-Crushed 80 psi ± 10%	WB #6	32.83/20.4	SB3PT	Yes
V09623	S150323-1	SIDE_307	Sunshine Kids Radian 65	Q3s	RF Convertible	Non-Crushed 80 psi ± 10%	WB #5	32.89/20.44	LA Only	Yes
V09624	S150324-1	SIDE_308	Graco Comfort Sport	Q3s	RF Convertible	Non-Crushed 80 psi ± 10%	WB #6	32.85/20.41	LA Only	Yes
V09625	S150325-1	SIDE_309	Combi Shuttle 33	CRABI 12MO	RF Infant	Non-Crushed 80 psi ± 10%	WB #5	32.73/20.34	SB3PT	Yes
V09626	S150326-1	SIDE_310	Combi Shuttle	CRABI 12MO	RF Infant	Non-Crushed 80 psi ± 10%	WB #6	32.80/20.38	LA Only	Yes
V09627	S150327-1	SIDE_311	Safety 1st OnBoard 35	CRABI 12MO	RF Infant	Non-Crushed 80 psi ± 10%	WB #5	32.77/20.36	SB3PT	Yes
V09628	S150330-1	SIDE_312	Safety 1st OnBoard 35	CRABI 12MO	RF Infant	Non-Crushed 80 psi ± 10%	WB #6	32.89/20.44	LA Only	Yes
V09629	S150331-1	SIDE_313	Baby Trend Inertia	CRABI 12MO	RF Infant	Non-Crushed 80 psi ± 10%	WB #5	32.77/20.36	Rigid LATCH	Yes
V09630	S150401-1	SIDE_314	Graco Comfort Sport	Q3s	FF Convertible	Non-Crushed 80 psi ± 10%	WB #6	32.86/20.42	LATCH	Yes
V09631	S150406-1	SIDE_315	Graco Comfort Sport	Q3s	FF Convertible	Non-Crushed 80 psi ± 10%	WB #6	32.81/20.39	SB3PT&T	Yes
V09632	S150409-1	SIDE_316	Graco Comfort Sport	Q3s	FF Convertible	Non-Crushed 80 psi ± 10%	WB #6	32.94/20.47	SB3PT	Yes
V09633	S150402-1	SIDE_317	Graco Comfort Sport	Q3s	FF Convertible	Non-Crushed 80 psi ± 10%	WB #5	32.81/20.39	LA Only	Yes
V09634	S150406-2	SIDE_318	Baby Trend Trenz FastBack	Q3s	FF Convertible	Non-Crushed 80 psi ± 10%	WB #5	32.86/20.42	Rigid LATCH	Yes
V09635	S150424-1	SIDE_319	Graco Comfort Sport	Q3s	FF Convertible	Non-Crushed 80 psi ± 10%	WB #5	32.91/20.45	SB3PT	Yes

Table A-3. December 2015 Sled Tests for Lower Anchor Evaluation

VDB Test No.	Test Reference No.	VRTC Test No.	CRS Model	Dummy Type	CRS Orientation	Honeycomb Config.	Foam Set	Test Velocity (km/h)/[mph]	Restraint Type	New Anti-Rebound
V09636	S151211-1	SIDE_320	Combi Shuttle	CRABI	RF Infant	Non-Crushed 80 psi ± 10%	WB #5	33.01/20.51	LA Only	Yes
V09637	S151214-1	SIDE_321	Baby Trend EZ Flex-Loc	CRABI	RF Infant	Non-Crushed 80 psi ± 10%	WB #6	32.89/20.44	LA Only	Yes
V09638	S151214-2	SIDE_322	Baby Trend Inertia	CRABI	RF Infant	Non-Crushed 80 psi ± 10%	WB #5	32.86/20.42	Rigid LATCH	Yes
V09639	S151216-1	SIDE_324	Diono Olympia	Q3s	RF Convertible	Non-Crushed 80 psi ± 10%	WB #6	33.07/20.55	LA Only	Yes
V09640	S151217-1	SIDE_323	Evenflo Symphony	Q3s	RF Convertible	Non-Crushed 80 psi ± 10%	WB #5	33.07/20.55	LA Only	No
V09641	S151221-1	SIDE_325	Evenflo Symphony	Q3s	FF Convertible	Non-Crushed 80 psi ± 10%	WB #5	31.99/19.88	LATCH	No
V09642	S151222-1	SIDE_326	Diono Radian RXT	Q3s	FF Convertible	Non-Crushed 80 psi ± 10%	WB #6	32.07/19.93	LATCH	No

Table A-4. April 2017 Side Impact Technologies Testing

VDB Test No.	Test Reference No.	VRTC Test No.	CRS Model	ATD	CRS Orientation	Restraint Type	Honeycomb Spec	WB Foam Set	Test Velocity (km/h)/[mph]	New Anti-Rebound
V10100	S170413-1	SIDE_345	Chicco NextFit	Q3s	FF Convertible	LATCH	90 psi ± 5%	#7	31.77/19.74	No
V10101	S170413-2	SIDE_346	Evenflo Tribute	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	31.73/19.72	No
V10102	S170414-1	SIDE_347	Cosco Scenera Next	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	31.68/19.69	No
V10103	S170418-1	SIDE_348	Maxi-Cosi Pria 70	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	31.67/19.68	No
V10104	S170418-2	SIDE_349	Evenflo Chase	Q3s	FF Convertible	LATCH	90 psi ± 5%	#7	31.75/19.73	No
V10105	S170418-3	SIDE_350	Britax Boulevard	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	31.67/19.68	No
V10106	S170419-1	SIDE_351	Britax Advocate	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	31.74/19.72	No
V10107	S170419-2	SIDE_352	Safety 1st Advance SE Air+	Q3s	FF Convertible	LATCH	90 psi ± 5%	#7	31.8/19.76	No
V10108	S170420-1	SIDE_353	Graco Nautilus 65	Q3s	FF Convertible	LATCH	90 psi ± 5%	#7	31.76/19.73	No
V10109	S170420-2	SIDE_354	Graco Nautilus Safety Surround	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	31.86/19.80	No
V10110	S170421-1	SIDE_355	Britax B-Safe 35	CRABI 12MO	RF Infant	LA Only	90 psi ± 5%	#8	31.98/19.87	No
V10111	S170424-1	SIDE_357	Evenflo Embrace LX	CRABI 12MO	RF Infant	LA Only	90 psi ± 5%	#8	31.83/19.78	No
V10112	S170424-2	SIDE_356	Cybex Aton 2 using telescopic side arm	CRABI 12MO	RF Infant	LA Only	90 psi ± 5%	#7	31.78/19.75	No
V10114	S170425-2	SIDE_359	Maxi-Cosi Mico AP	CRABI 12MO	RF Infant	LA Only	90 psi ± 5%	#8	31.92/19.83	No
V10115	S170427-1	SIDE_360	Cosco Scenera Next	Q3s	RF Convertible	LA Only	90 psi ± 5%	#8	31.97/19.87	No
V10116	S170503-1	SIDE_361	Graco Size4Me 65	Q3s	RF Convertible	LA Only	90 psi ± 5%	#7	31.64/19.66	No
V10117	S170504-1	SIDE_363	Baby Trend PROtect	Q3s	RF Convertible	LA Only	90 psi ± 5%	#7	31.55/19.60	No
V10118	S170504-2	SIDE_362	Evenflo Triumph	Q3s	RF Convertible	LA Only	90 psi ± 5%	#8	31.64/19.66	No

Table A-5. November 2017 Sled Testing for Comparisons

VDB Test No.	Test Reference No.	VRTC Test No.	CRS Model	ATD	CRS Orientation	Restraint Type	Honeycomb Spec	WB Foam Set	Test Velocity (km/h)/[mph]	New Anti-Rebound
V10272	S171116-1	SIDE_364	Graco Ready Ride	Q3s	FF Convertible	LATCH	90 psi ± 5%	#7	33.23/20.65	No
V10273	S171116-2	SIDE_365	Graco Ready Ride	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	32.24/20.03	No
V10274	S171117-1	SIDE_366	Evenflo Triumph	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	32.65/20.29	No
V10275	S171117-2	SIDE_367	Evenflo Triumph	Q3s	FF Convertible	LATCH	90 psi ± 5%	#7	32.57/20.24	No
V10276	S171120-1	SIDE_368	Evenflo Titan	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	32.46/20.17	No
V10277	S171121-1	SIDE_369	Evenflo Tribute	Q3s	FF Convertible	LATCH	90 psi ± 5%	#7	32.48/20.18	No
V10278	S171121-2	SIDE_370	Evenflo Tribute	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	32.49/20.19	No
V10279	S171121-3	SIDE_371	Graco Ready Ride	Q3s	FF Convertible	LATCH	90 psi ± 5%	#8	31.27/19.43	No
V10280	S171127-1	SIDE_372	Evenflo Discovery	CRABI 12MO	RF Infant	SB3PT	90 psi ± 5%	#8	32.56/20.23	No
V10281	S171128-1	SIDE_373	Combi Shuttle	CRABI 12MO	RF Infant	SB3PT	90 psi ± 5%	#7	32.56/20.23	No
V10282	S171129-1	SIDE_374	Evenflo Tribute	Q3s	RF Convertible	LA Only	90 psi ± 5%	#7	32.67/20.30	No
V10283	S171129-2	SIDE_375	Safety 1st Alpha Omega	Q3s	RF Convertible	LA Only	90 psi ± 5%	#8	32.57/20.24	No
V10284	S171129-3	SIDE_376	Graco My Ride 65	Q3s	RF Convertible	LA Only	90 psi ± 5%	#7	38.38/23.85	No
V10285	S171130-1	SIDE_377	Graco Size4Me 65	Q3s	RF Convertible	LA Only	90 psi ± 5%	#7	32.62/20.27	No
V10286	S171130-2	SIDE_378	Graco Size4Me 65	Q3s	RF Convertible	LA Only	90 psi ± 5%	#8	32.59/20.25	No

Appendix B: Test Results

Table B-1. Summary of Injury Results From All Evaluation and Comparison Sled Testing

VDB Test No.	Test Number	VRTC Number	CRS Model	ATD	CRS Orientation	Restraint Type	HIC15	Chest Deflection (mm)	Head Contact?
V09597	S141120-1	SIDE_301	Combi Shuttle	CRABI 12MO	RF Infant	LA Only	552	N/A	Yes
V09598	S141121-1	SIDE_302	Combi Shuttle	CRABI 12MO	RF Infant	LA Only	631	N/A	Yes
V09599	S141124-1	SIDE_303	Graco Nautilus	Q3s	FF Convertible	LATCH	787	19	N/A
V09600	S141125-1	SIDE_304	Graco Nautilus	Q3s	FF Convertible	LATCH	743	21	N/A
V09621	S150318-1	SIDE_305	Graco Classic Ride 50	Q3s	RF Convertible	LA Only	686	26	N/A
V09622	S150319-1	SIDE_306	Graco Comfort Sport	Q3s	RF Convertible	SB3PT	793	23	N/A
V09623	S150323-1	SIDE_307	Sunshine Kids Radian 65	Q3s	RF Convertible	LA Only	731	26	N/A
V09624	S150324-1	SIDE_308	Graco Comfort Sport	Q3s	RF Convertible	LA Only	729	27	N/A
V09625	S150325-1	SIDE_309	Combi Shuttle 33	CRABI 12MO	RF Infant	SB3PT	438	N/A	Yes
V09626	S150326-1	SIDE_310	Combi Shuttle	CRABI 12MO	RF Infant	LA Only	478	N/A	Yes
V09627	S150327-1	SIDE_311	Safety 1st OnBoard 35	CRABI 12MO	RF Infant	SB3PT	614	N/A	No
V09628	S150330-1	SIDE_312	Safety 1st OnBoard 35	CRABI 12MO	RF Infant	LA Only	625	N/A	No
V09629	S150331-1	SIDE_313	Baby Trend Inertia	CRABI 12MO	RF Infant	Rigid LATCH	491	N/A	Yes
V09630	S150401-1	SIDE_314	Graco Comfort Sport	Q3s	FF Convertible	LATCH	640	21	N/A
V09631	S150406-1	SIDE_315	Graco Comfort Sport	Q3s	FF Convertible	SB3PT&T	580	19	N/A
V09632	S150409-1	SIDE_316	Graco Comfort Sport	Q3s	FF Convertible	SB3PT	649	19	N/A
V09633	S150402-1	SIDE_317	Graco Comfort Sport	Q3s	FF Convertible	LA Only	579	23	N/A
V09634	S150406-2	SIDE_318	Baby Trend Trenz FastBack	Q3s	FF Convertible	Rigid LATCH	464	14	N/A
V09635	S150424-1	SIDE_319	Graco Comfort Sport	Q3s	FF Convertible	SB3PT	588	22	N/A
V09636	S151211-1	SIDE_320	Combi Shuttle	CRABI 12MO	RF Infant	LA Only	524	N/A	Yes
V09637	S151214-1	SIDE_321	Baby Trend EZ Flex-Loc	CRABI 12MO	RF Infant	LA Only	332	N/A	No
V09638	S151214-2	SIDE_322	Baby Trend Inertia	CRABI 12MO	RF Infant	Rigid LATCH	450	N/A	Yes
V09639	S151216-1	SIDE_324	Diono Olympia	Q3s	RF Convertible	LA Only	1001	1(QD)	N/A

VDB Test No.	Test Number	VRTC Number	CRS Model	ATD	CRS Orientation	Restraint Type	HIC15	Chest Deflection (mm)	Head Contact?
V09640	S151217-1	SIDE_323	Evenflo Symphony	Q3s	RF Convertible	LA Only	435	22	N/A
V09641	S151221-1	SIDE_325	Evenflo Symphony	Q3s	FF Convertible	LATCH	539	18	N/A
V09642	S151222-1	SIDE_326	Diono Radian RXT	Q3s	FF Convertible	LATCH	674	30	N/A
V10100	S170413-1	SIDE_345	Chicco NextFit	Q3s	FF Convertible	LATCH	582	19	N/A
V10101	S170413-2	SIDE_346	Evenflo Tribute	Q3s	FF Convertible	LATCH	760	21	N/A
V10102	S170414-1	SIDE_347	Cosco Scenera Next	Q3s	FF Convertible	LATCH	980	27	N/A
V10103	S170418-1	SIDE_348	Maxi-Cosi Pria 70	Q3s	FF Convertible	LATCH	513	18	N/A
V10104	S170418-2	SIDE_349	Evenflo Chase	Q3s	FF Convertible	LATCH	937	24	N/A
V10105	S170418-3	SIDE_350	Britax Boulevard	Q3s	FF Convertible	LATCH	522	7(QD)	N/A
V10106	S170419-1	SIDE_351	Britax Advocate	Q3s	FF Convertible	LATCH	665	18	N/A
V10107	S170419-2	SIDE_352	Safety 1st Advance SE Air+	Q3s	FF Convertible	LATCH	616	28	N/A
V10108	S170420-1	SIDE_353	Graco Nautilus 65	Q3s	FF Convertible	LATCH	609	14	N/A
V10109	S170420-2	SIDE_354	Graco Nautilus Safety Surround	Q3s	FF Convertible	LATCH	839	18	N/A
V10110	S170421-1	SIDE_355	Britax B-Safe 35	CRABI 12MO	RF Infant	LA Only	726	N/A	No
V10111	S170424-1	SIDE_357	Evenflo Embrace LX	CRABI 12MO	RF Infant	LA Only	296	N/A	No
V10112	S170424-2	SIDE_356	Cybex Aton 2 using telescopic side arm	CRABI 12MO	RF Infant	LA Only	435	N/A	No
V10114	S170425-2	SIDE_359	Maxi-Cosi Mico AP	CRABI 12MO	RF Infant	LA Only	326	N/A	No
V10115	S170427-1	SIDE_360	Cosco Scenera Next	Q3s	RF Convertible	LA Only	678	26	N/A
V10116	S170503-1	SIDE_361	Graco Size4Me 65	Q3s	RF Convertible	LA Only	778	24	N/A
V10117	S170504-1	SIDE_363	Baby Trend PROtect	Q3s	RF Convertible	LA Only	488	12	N/A
V10118	S170504-2	SIDE_362	Evenflo Triumph	Q3s	RF Convertible	LA Only	964	26	N/A
V10272	S171116-1	SIDE_364	Graco Ready Ride	Q3s	FF Convertible	LATCH	771	21	N/A
V10273	S171116-2	SIDE_365	Graco Ready Ride	Q3s	FF Convertible	LATCH	723	20	N/A
V10274	S171117-1	SIDE_366	Evenflo Triumph	Q3s	FF Convertible	LATCH	499	11	N/A
V10275	S171117-2	SIDE_367	Evenflo Triumph	Q3s	FF Convertible	LATCH	498	7	N/A
V10276	S171120-1	SIDE_368	Evenflo Titan	Q3s	FF Convertible	LATCH	1029	28	N/A

VDB Test No.	Test Number	VRTC Number	CRS Model	ATD	CRS Orientation	Restraint Type	HIC15	Chest Deflection (mm)	Head Contact?
V10277	S171121-1	SIDE_369	Evenflo Tribute	Q3s	FF Convertible	LATCH	712	21	N/A
V10278	S171121-2	SIDE_370	Evenflo Tribute	Q3s	FF Convertible	LATCH	732	22	N/A
V10279	S171121-3	SIDE_371	Graco Ready Ride	Q3s	FF Convertible	LATCH	587	20	N/A
V10280	S171127-1	SIDE_372	Evenflo Discovery	CRABI 12MO	RF Infant	SB3PT	364	N/A	No
V10281	S171128-1	SIDE_373	Combi Shuttle	CRABI 12MO	RF Infant	SB3PT	692	N/A	No
V10282	S171129-1	SIDE_374	Evenflo Tribute	Q3s	RF Convertible	LA Only	611	23	N/A
V10283	S171129-2	SIDE_375	Safety 1st Alpha Omega	Q3s	RF Convertible	LA Only	396	26	N/A
V10284	S171129-3	SIDE_376	Graco My Ride 65	Q3s	RF Convertible	LA Only	778	22	N/A
V10285	S171130-1	SIDE_377	Graco Size4Me 65	Q3s	RF Convertible	LA Only	751	21	N/A
V10286	S171130-2	SIDE_378	Graco Size4Me 65	Q3s	RF Convertible	LA Only	754	23	N/A
Cells marked with “QD” had questionable data results.									

Appendix C: Honeycomb Details

PLASCORE®

In 2016 NHTSA had approached Plascore with regard to the honeycomb being used in the development of Federal Motor Vehicle Safety Standard 213 (FMVSS 213), as it pertains to side impact testing. Through discussions with NHTSA Representatives, it became apparent that the G-force managing Apparatus, in this case, aluminum honeycomb, needed to be better controlled for crush strength of the material. This was due to potential inconsistencies within batches of honeycomb being used. To reduce potential differences in crush strength, which can result in lower, or higher than expected resultant G-forces, it was suggested by Plascore that the standard ASTM D7336 be used to certify the honeycomb. This method is used to quantify the crush strength of honeycomb, as a function of cross sectional area. The crush strength of current samples being used by NHTSA were provided to Plascore. The honeycomb material was tested to understand the strength of the current aluminum honeycomb being used. Through employment of a modified ASTM D7336 (in that longer samples were tested then what is considered normal), it was determined that the crush strength of the honeycomb in NHTSA's possession was approximately 80 PSI. Due to the relationship of crush strength, crush stroke, kinetic energy and resulting acceleration, which is present in the following two equations,

$$G = \frac{V^2}{2gS} \quad \text{and} \quad \frac{1}{2}mV^2 = F * a * S$$

Where:

Symbol	meaning
G	Factor, defined as x amount of times earth's gravity
V	Velocity of the moving part
g	9.81 m/s^2
M	Mass
F	Crush force, defined as pascals or PSI, contrary to standard engineering forces
a	Cross sectional area
S	Crush Stroke, in this case, how far the honeycomb crushes

Assuming that kinetic energy is maintained the same, if could be theorized that either increasing the crush force, or increasing the cross sectional area of the honeycomb being used, would decrease the resulting stroke. Decreasing the resulting stroke would increase the resulting acceleration. Within the fixture which was in NHTSA's possession, the size of the honeycomb could not be increased without modification to the current structure. As such it was decided to increase the crush strength of the honeycomb. The next available material was 90PSI. on this material, it was noticed that Plascore could control this material's nominal crush strength, within a range +/-5% .

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Honeycomb: PACL-XR1-2.3-1/4-10-P-5052 Crush Strength 90 PSI ± 5%

www.plascore.com/download/datasheets/energy_absorption_documentation/Plascore_CrushLite-Sheet-Metric-2021_2.pdf

Appendix D: NHTSA Vehicle Safety Research CRS Side Impact Test Procedure

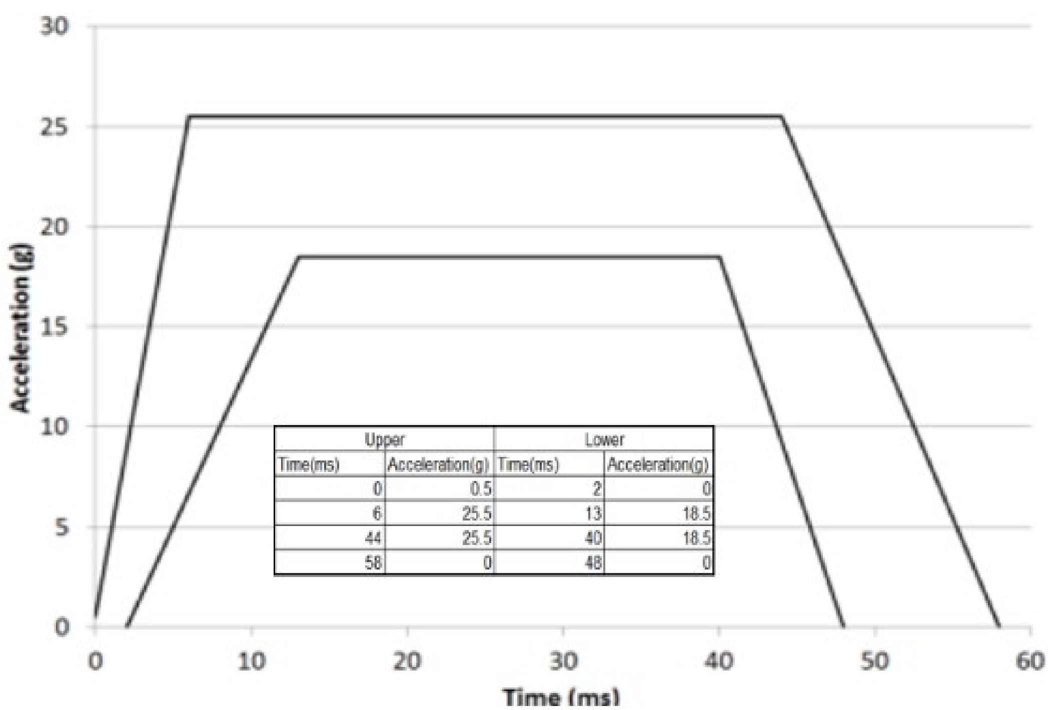
1. TEST EQUIPMENT

1. The test device is a side impact seat assembly (SISA) consisting of a simulated vehicle rear seat, with one seating position, and a simulated door assembly as described in Drawing Package, "NHTSA Child Side Impact Sled," dated September 2018. The simulated door assembly is rigidly attached to the floor of the SISA and the simulated vehicle rear seat is mounted on rails to allow it to move relative to the floor of the SISA in the direction perpendicular to the seat orientation reference line (SORL). The SISA is mounted on a dynamic test platform so that the SORL of the seat is 10 degrees from the perpendicular direction of the test platform travel. The SISA is rotated to replicate a side impact on a near-side child restraint system (CRS). The overall set-up of the FMVSS No. 213 side impact test is shown in Figure D-1.
2. A CRS is attached to the SISA by lower anchor attachments or a 3-point seat belt system.

Figure D-1. Overall FMVSS No. 213 Side Impact Test Set-up

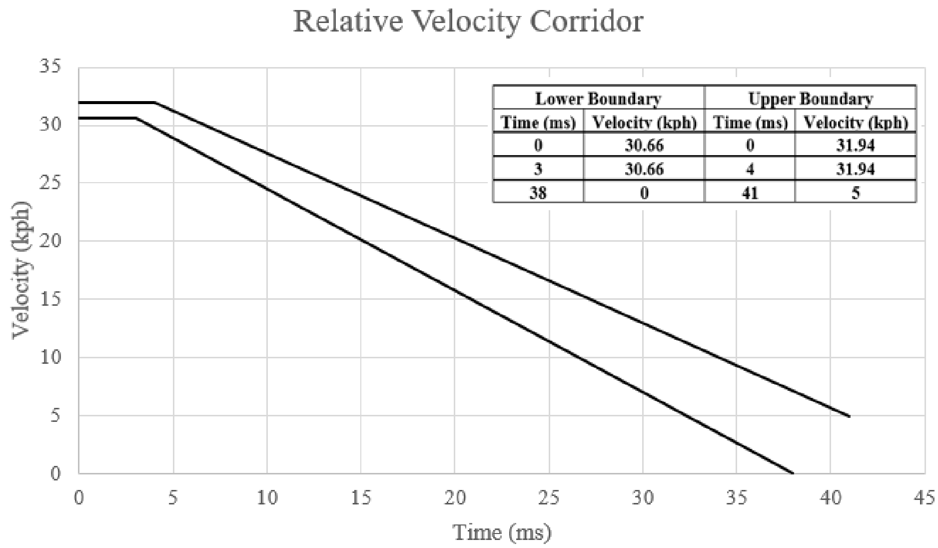
1.1. Test Conditions and Devices Used

1. The seat acceleration must be within the corridor shown in Figure D-2. This is measured by the accelerometers mounted on the rear leg of the sliding seat of the SISA.
2. Accelerate the test platform to achieve a relative velocity (V0) of 31.4 +/- 0.64 km/h (19.5 +/- 0.4 mph) and within the relative velocity corridor shown in Figure D-3 in the direction perpendicular to the SORL between the SISA seat and the door assembly at the time they come in contact (time=T).
3. The test platform in the direction perpendicular to the SORL is not greater than V0 and not less than V0 – 2.5 km/h during the time of interaction of the door with the child restraint system.
4. Test devices used in the CRSs will be the 12-month-old CRABI (CRABI 12 MO) and the Q series side impact 3-year-old (Q3s) anthropomorphic test devices (ATDs) in both forward-facing (FF) and rear-facing (RF) configurations.



Upper		Lower	
Time(ms)	Acceleration(g)	Time(ms)	Acceleration(g)
0	0.5	2	0
6	25.5	13	18.5
44	25.5	40	18.5
58	0	48	0

Figure D-2. Sliding Seat Acceleration Corridor



Lower Boundary		Upper Boundary	
Time (ms)	Velocity (kph)	Time (ms)	Velocity (kph)
0	30.66	0	31.94
3	30.66	4	31.94
38	0	41	5

Figure D-3. Relative Velocity Corridor

1.2. Instrumentation

1.2.1. Instrumentation of SISA

1. Two 7231C-750[24] non-damped accelerometers are mounted on the rear leg of the sliding seat at the location specified in Figure D-4. The top accelerometer is specified as the primary, marked as "P," and the bottom accelerometer as the redundant, marked as "R."

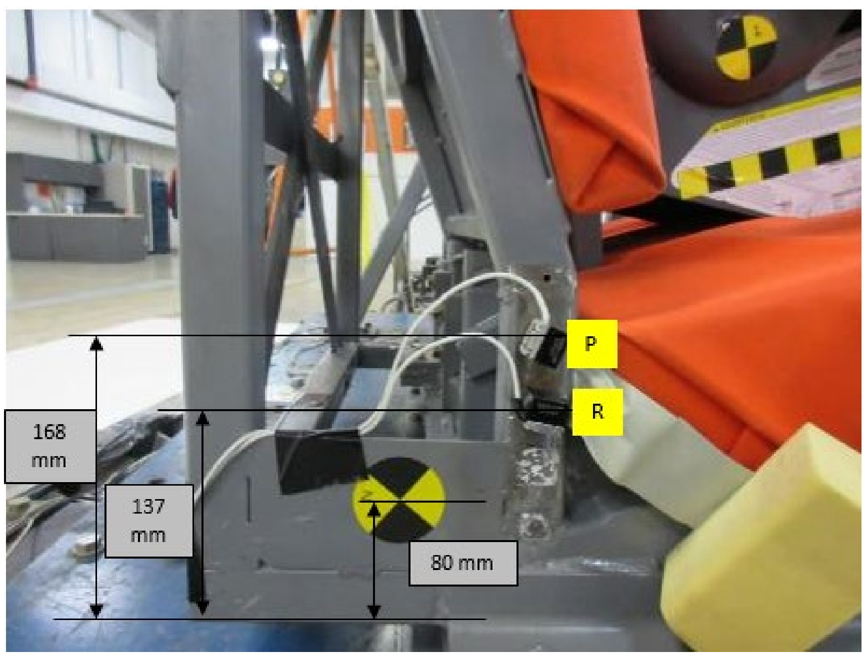


Figure D-4. Sliding Seat Accelerometer Locations

[24] https://buy.endevco.com/amfile/file/download/file_id/2305/product_id/2266/

2. The accelerometers should be protected from light by a foam cover to prevent drifting and/or offset in the data caused by light sensitivity of the accelerometer type (Figure D-5).

Figure D-5. Sliding Seat Accelerometers With Cover

3. Two 7264C[25] accelerometers are mounted on the door structure in the x and y-axis directions of the SISA (Figure D-6).

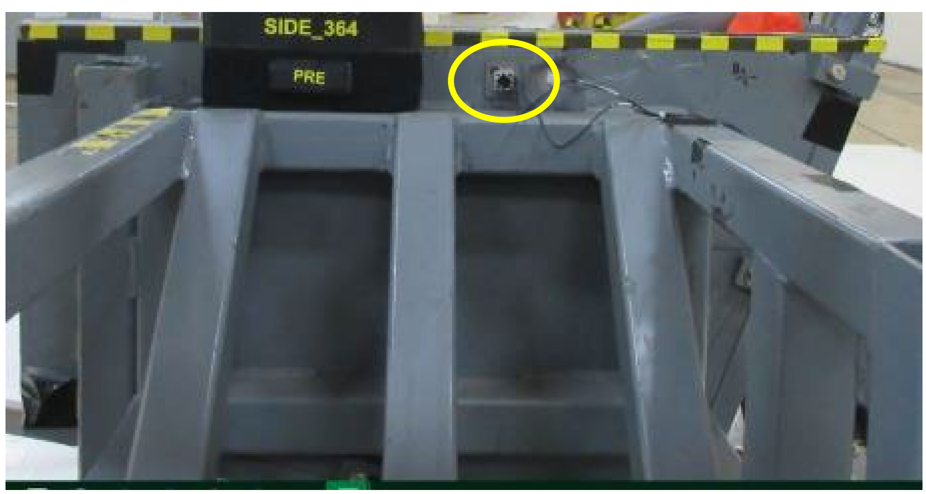


Figure D-6. Door Accelerometers

[25] https://buy.endevco.com/amfile/file/download/file_id/2411/product_id/2377/

4. Contact switches should be added to the sliding seat and honeycomb for all tests.
    a. The contact switches are used to determine the exact timing of the sliding seat impact with the honeycomb (time=T). Figures D-7 and D-8 show the switch placement on the honeycomb and impact plate, respectively.

Figure D-7. Switch Placement on Honeycomb

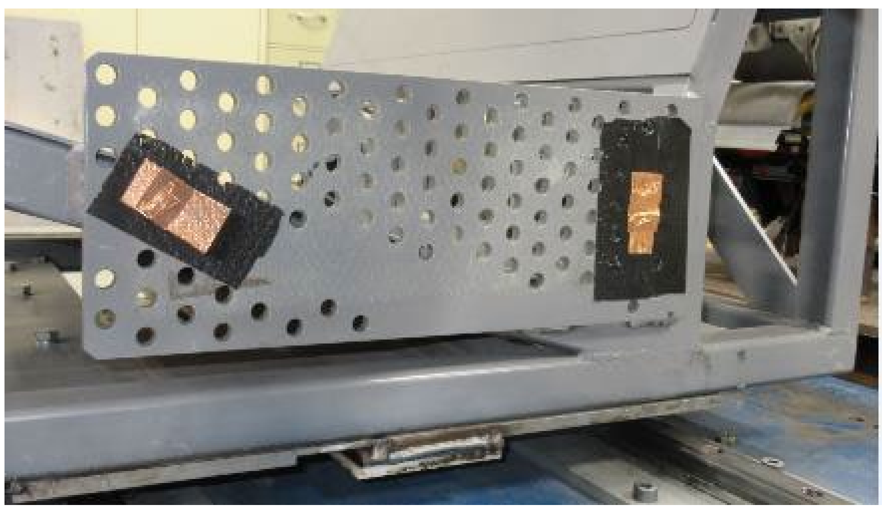


Figure D-8. Switch Placement on Impact Plate

    b. Both FF and RF CRS testing with the CRABI 12 MO requires contact tape and copper wire mesh on both the door and the ATD's head (Figure D-9).

Figure D-9. Contact Tape and Copper Wire Mesh Example

1.2.2. Instrumentation of Sled Buck Platform

1. Two 7231C-750[26] non-damped accelerometers are mounted on the sled buck platform, in line with the direction of the test platform travel. One accelerometer is specified as the primary and another accelerometer as the redundant.

1.2.3. Instrumentation of ATDs

1. ATDs must be certified to specifications: CRABI 12 MO per CFR Title 49, Part 572, Subpart R and Q3s per CFR Title 49, Part 572, Subpart W.

2. The following tables list the instrumentation used during testing:

Table D-1. Instrumentation for CRABI 12 MO

Location	Measurement	Instrument	Channels
Head	Head C.G. Acceleration	Tri-Axial Accelerometer	3
Neck	Upper Neck Forces & Moments	Six-Channel Load Cell	6
Thorax	Chest Acceleration	Tri-Axial Accelerometer	3
Pelvis	Pelvis Acceleration	Tri-Axial Accelerometer	3
Total			15

[26] https://buy.endevco.com/amfile/file/download/file_id/2305/product_id/2266/

Table D-2. Instrumentation for Q3s

Location	Measurement	Instrument	Channels
Head	Head C.G. Acceleration	Tri-Axial Accelerometer	3
Neck	Upper Neck Forces & Moments	Six-Channel Load Cell	6
Shoulder	Shoulder Displacement	String Potentiometer	1
Upper Spine	Upper Spine Acceleration	Tri-Axial Accelerometer	3
Thorax	Chest Displacement	IR-TRACC	1
Lumbar Spine	Lumbar Spine Forces & Moments	Six-Channel Load Cell	6
Pelvis	Pelvis Acceleration	Tri-Axial Accelerometer	3
Pubic	Pubic Force	One-Channel Load Cell	1
Total			24

1.2.4. Additional Instrumentation

1. A seat belt load cell[27] is used for testing with 3-point seat belt systems, top tethers, and if possible on lower anchor attachments.

1.3. Camera Set-Up

1. Five to six high-speed imagers (minimum 1,000 fps) will be set-up in the following locations to record occupant and CRS kinematics during the sled test (Figure D-10)[28]:

(1) Overhead Wide: This view should include the entire sliding seat, CRS, and wall. The impact of the seat into the wall should be in focus and the entire event visible.

(2) Overhead Tight: This view should be focused on the point of impact between the door (armrest foam) and the sliding seat. The view should be focused at the point when the seat contacts the door.

(3) Front View of Dummy: This view should include the entire sliding seat, front view of the CRS, and the door (armrest foam, door foam, and honeycomb). The area of seat and wall contact should be focused to clearly see the event.

(4) Oblique View of Dummy: This view should include the entire sliding seat, CRS, and the wall (armrest foam, wall foam, and entire honeycomb). The area of seat and wall contact should be focused to clearly see the event.

(5) Wall View for RF: This view should include the entire top of the wall. The camera should look from the rear to the front in line with the wall, so that if head contact occurs to the door, the event is clear.

[27] VRTC used EL20-S458 from Measurement Specialties. www.ttiinc.com/content/dam/ttiinc/manufacturers/te-sensor-solutions/Force/PDF/EL20-S458.pdf

[28] In some test series, cameras #3 and #4 were combined into one camera view.

(6) Lateral View for FF: This view should include the wall and CRS. The camera should look straight onto the wall have the entire ATD in view as it contacts the wall.

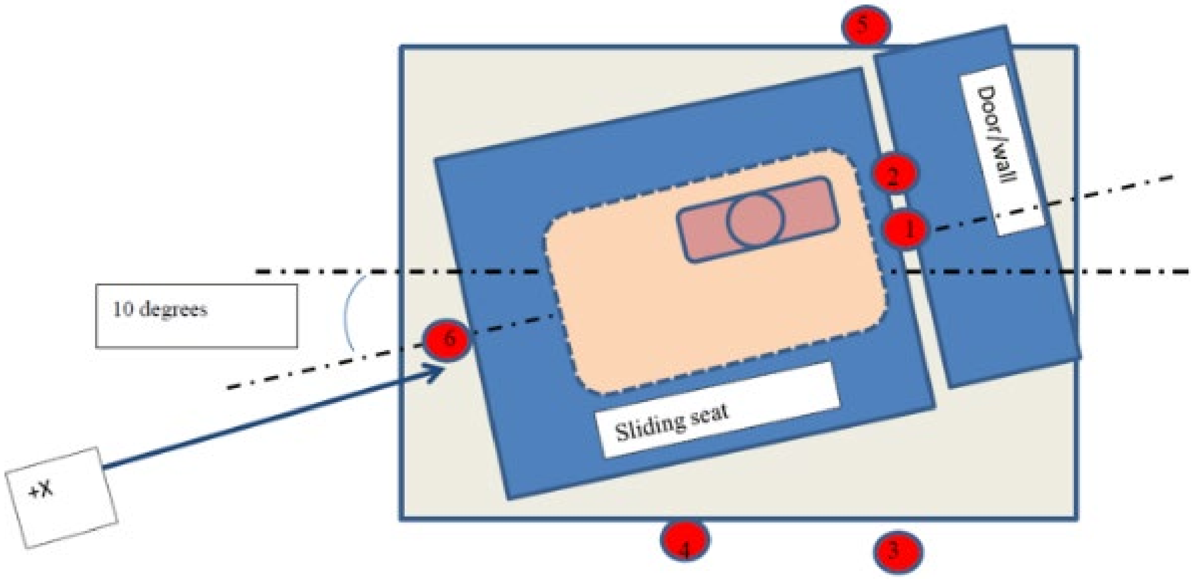


Figure D-10. Camera Locations

1.4. ATD and CRS Targets

1. Each CRS and ATD should be targeted in specific locations. Table D-3 and the schematics below in Figure D-11 list the locations of targets for both the CRS and ATD. These targets are measured with a 3D coordinate measurement system (such as a FARO arm) and recorded. Appendix F shows the targets on the ATD and the CRSs.

Table D-3. Target Locations

Point	Target Description: Infant	Target Description: Rear-Facing CRS	Target Description: Convertible
1	Z-Point (should be 0,0,0)	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)	Center of Seat Frame Back (on buck)
3	Top of CRS	Top of CRS	Top of CRS
4	CRS Bottom Center (near strap adjuster)	CRS Bottom Center (near strap adjuster)	NA
5	NA	CRS Top of Headrest (if applicable)	CRS Top of Headrest (if applicable)
6	CRS Top of the Base (on base - if it has a base)	NA	NA
7	CRS Handle Center (if applicable)	NA	NA
8	Top of Head at CG	Top of Head at CG	Top of Head at CG

Point	Target Description: Infant	Target Description: Rear-Facing CRS	Target Description: Convertible
9	Bridge of Nose	Bridge of Nose	Bridge of Nose
10	Head CG Outboard	Head CG Outboard	Head CG Outboard
11	NA	Neck Center (center mark on neck if applicable)	Neck Center (center mark on neck if applicable)
12	NA	NA	NA
13	NA	NA	NA
14	NA	NA	NA
15	NA	NA	NA
16	Chest Clip	Chest Clip	Chest Clip
17	Buckle	Buckle	Buckle
18	Knee Pivot Center	Knee Pivot Center & Top of Knee	Knee Pivot Center & Top of Knee
19	NA	Ankle Pivot	Ankle Pivot
20	CRS Mid Height (on back of CRS)	NA	NA
21	CRS Base Center or bottom of CRS at centerline	CRS Base Center or bottom of CRS at centerline	CRS Base Center (on front of seat)
22	Center of Seat Frame Bottom (on seat buck)	Center of Seat Frame Bottom (on seat buck)	Center of Seat Frame Bottom (on seat buck)
23	CRS Side Handle (if applicable)	NA	NA
24	Target 1 - Seat Side Upper (see schematic (FIG D-11))	Target 1 - Seat Side Upper (see schematic (FIG D-11))	Target 1 - Seat Side Upper (see schematic (FIG D-11))
25	Target 2 - Seat Base H-Point (see schematic (FIG D-11))	Target 2 - Seat Base H-Point (see schematic (FIG D-11))	Target 2 - Seat Base H-Point (see schematic (FIG D-11))
26	Target 3 - Seat Base Side (see schematic (FIG D-11))	Target 3 - Seat Base Side (see schematic (FIG D-11))	Target 3 - Seat Base Side (see schematic (FIG D-11))
27	Target 4 - Seat Side Lower (see schematic (FIG D-11))	Target 4 - Seat Side Lower (see schematic (FIG D-11))	Target 4 - Seat Side Lower (see schematic (FIG D-11))
28	Seat Release Handle at Centerline	NA	NA
29	Anti-Rebound Bar (if applicable)	NA	NA
30	ATD Shoulder (impact side if accessible)	ATD Shoulder (impact side if accessible)	ATD Shoulder (impact side)

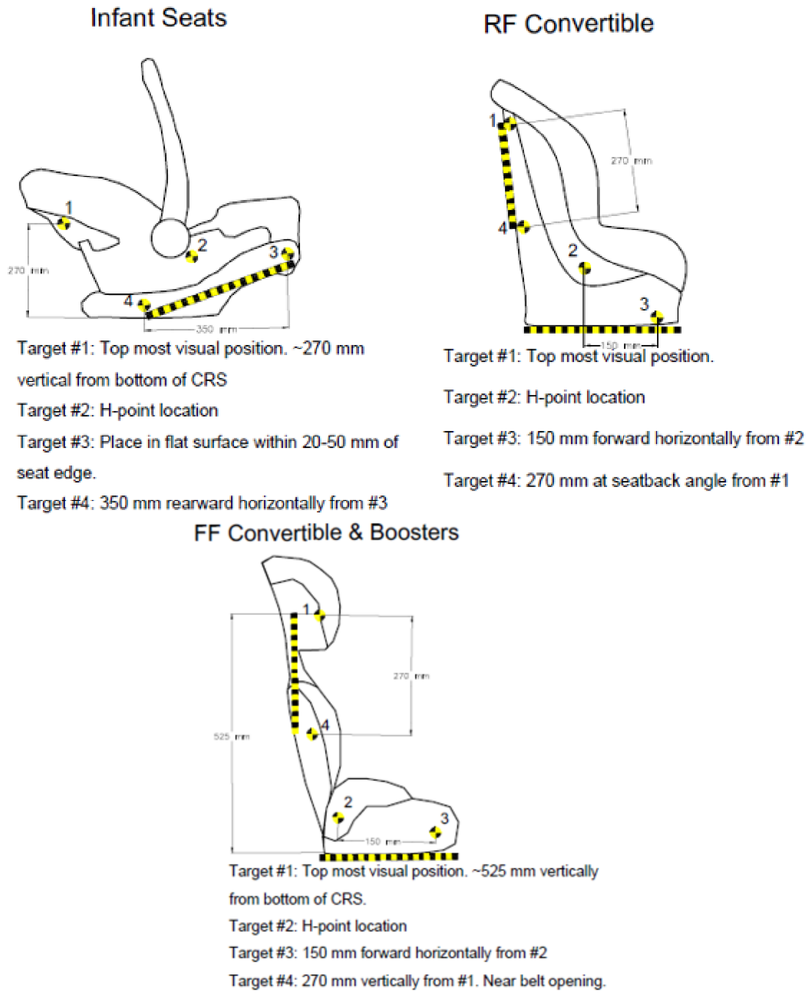


Figure D-11. Schematic of CRS Target Locations

2. TEST SET-UP STEPS

2.1. Evaluate Friction of SISA

1. Using a force gauge, conduct a push and pull test on the sliding seat before the CRS is installed.
2. Record the values
3. Grease the tracks with high performance grease[29] to lube the bearings prior to any test series being conducted.
4. Run another push/pull test on the sliding seat after the tracks are greased.
5. Record the values and if the value is above 67 N (15 lbs); reapply grease and/or change the bearings.

[29] Molykote BR plus High Performance Grease

6. Determine the appropriate range of the forces to push/pull the sliding seat for a given SISA and maintain. This should be checked on average about every 10 tests. Note: The force values for the SISA used by NHTSA VSR ranged from 8 to 15 lbf throughout testing.

2.2. Door Foams, Honeycomb, and Seat Cushions Set-Up

1. A new set of door foams should be cut per the drawing package:
   a. Impactor Door Foam for Child Side Impact Sled Drawing 2921-501
   b. Impactor Armrest Foam for Child Side Impact Sled Drawing 2921-502
2. The wall foams should be attached to the steel plate and to each other per the assembly drawing (Figure D-12).[30]
   a. Impactor Door Foam Assembly for Child Side Impact Sled Drawing 2921-500

Figure D-12. Door and Armrest Foam Assembly

3. For every test, install a new piece of certified honeycomb (Child Side Impact Sled Drawing 2921-600) to the honeycomb shelf under the door structure with a single piece of duct tape. The duct tape should cover the smallest amount of honeycomb cells possible and maintain the honeycomb in a level position (Figure D-13).

[30] The VRTC testing used a 3M double coated polyethylene foam tape (1/16 inch thick) to adhere to steel plate and additional duct tape on <u>only</u> the sides of the wall foams. The armrest foam was adhered to wall foam by spray adhesive or tape.

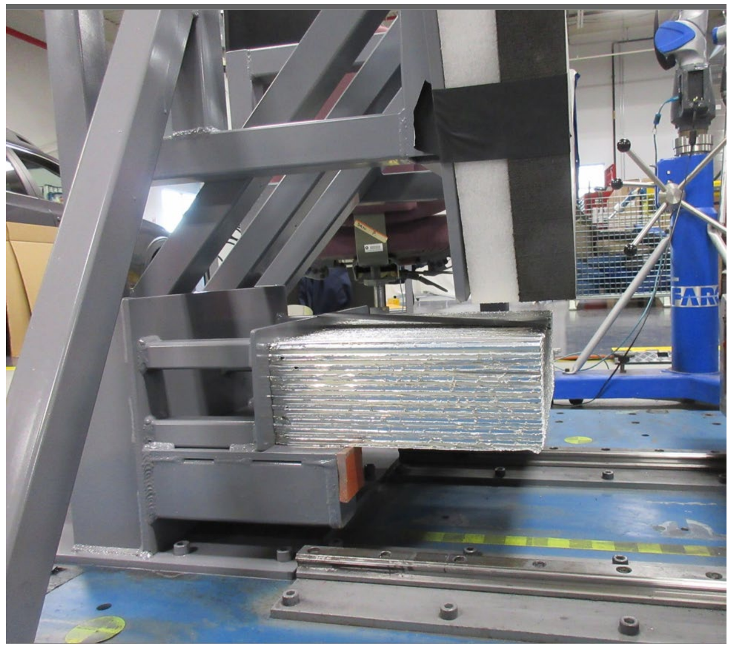


Figure D-13. Honeycomb Set-up

4. Seat Cushions (Drawings 2921-370, 2921-372, 2921-390, 2921-392): The seat cushions used shall be certified per the requirements for foam in the drawing package and IFD procedures.[31] The seat foams will be wrapped in fabric (Drawing 2921-373) and installed on both the seat back and seat pan (Appendix E). Maintain a gap measurement of 69 mm ± 5 mm. Tighten nuts on the bolts.

5. The schematic in Figure D-14 illustrates the critical dimensions that need to be maintained for each side impact test. Dimensions should be checked before every test to make sure that neither the sliding seat nor CRS has moved during the installation of the CRS and restraints. The armrest to honeycomb gap measurement is dependent on the wall foam tolerances and honeycomb tolerance. The spacing that should be maintained is 38 ± 6mm. The other dimensions shown should be setup with a tolerance of ± 1mm.

6. During the initial test buck setup all of the anhorages and attachments should be installed per the anchorage setup drawing no. 2921-900. This drawing provides measurements from the corner of the sliding seat including the z-point. Throughout the series the anchorages and attachment should be checked to make sure they are not deformed or twisted.

[31] Louden & Wetli, 2021 June.Appendix B.

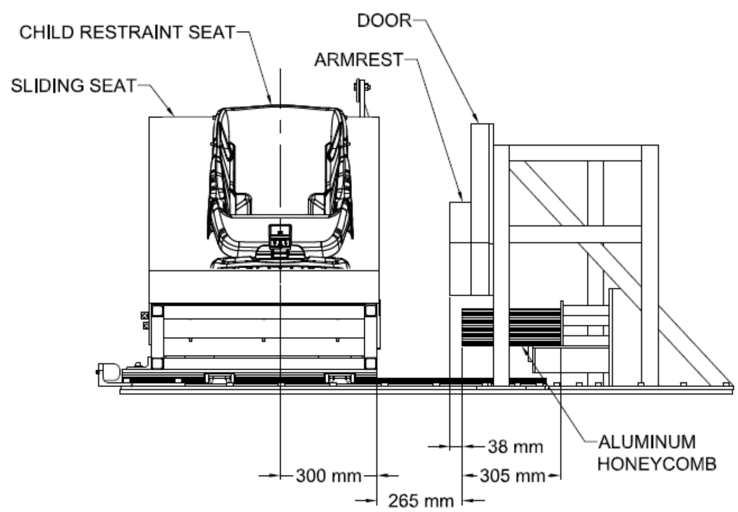


Figure D-14. Schematic of Sled Set-up

2.3. Installation of CRS

1. Each CRS is structurally different and should be installed per manufacturer instructions throughout the installation process.
2. Before installing the CRS on the sliding seat, weigh the CRS and record the value.
3. Lightly set the CRS on the seat cushion of the sliding seat and push the CRS back until the seat back of the CRS contacts the seat back of the sliding seat. Be sure that the footprint of the CRS is in full contact with the seat cushion.
4. Check that the center of the seat is 300 ±1 mm from the edge of the seat on the honeycomb side (Figure D-14).
5. Attach lower anchors of the CRS to the sliding seat attachments. If there is interference with the larger CRS anchor attachments after fully installed (less than 1 mm of clearance), use the optional lower anchor attachements as described in the assembly drawing(drawing no. 2921-350).
6. Tighten the anchors making sure that the CRS does not move or tilt from tightening.
7. Place weight (body weight) with hand onto the inside bottom seat back of the CRS to help tighten the restraints.
8. Attach and tighten the top tether (for FF).
9. Always have the CRS in contact with the seat pan and back while tightening and centering the CRS. If the CRS can be moved forward, then it needs to be retightened.
10. If using a 3-point belt[32]:

[32] VRTC testing used seven-panel seatbelt webbing from Seatbelt Plus; www.seatbeltsplus.com/product/7Panel_Webbing.html

a. Connect the hardware (Drawings 3201-120 to 3201-123) to the sliding seat assembly to where the seat belt anchors are located. Be sure the anchors are installed on the correct side of the attachments (Figures D-15 - D-16).

Figure D-15. Seat Belt Anchor Attachments

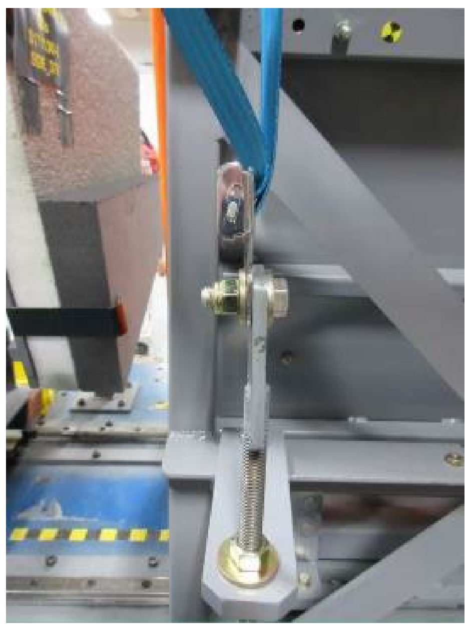


Figure D-16. Rear Locking Anchor Attachments

b. Route the seat belt webbing as shown in Figure D-17.

Figure D-17. Seat Belt Webbing Routing

11. Measure the tensions of the seat belt webbing and/or LATCH system with the CRS installed.
12. Using a 3-prong belt tensioning gauge, verify the tensions match the following ranges.
    a. If the tension gauge cannot be placed on the seat belt, use this method to verify the tension on the CRS is correct. Check at the belt path that the CRS cannot move more than 25 mm (1 in.) in either the fore/aft or lateral directions. Make this measurement using the following steps:

Figure D-18. Reference Point on Base of CRS

        i. Mark a reference point on the base of the CRS in line with the belt path. Mark another reference point on the seat bench cushion in the same lateral plane as the CRS target. This is the starting reference point location (Figure D-18).

ii. Stand, facing the seat, grab the CRS at the belt path, and firmly pull laterally on the CRS left and right two times. Pull first on the side opposite the reference target and then on the same side as the reference target. Mark the seat reference point on the lateral tape.

iii. While in the same position, grab the CRS at the belt path, and firmly pull the CRS forward, away from the seat bench back, and then push it back. This is performed twice. Mark the final location of the reference point on the CRS in the for-aft direction.

iv. The reference point should not have moved more than 25 mm (1 in.) from the starting location in the fore-aft or lateral direction when moving the CRS. If it exceeds 25 mm in either direction, tighten the belts and repeat steps i through iv.

Table D-4. Belt Webbing Tension Specifications

	Lower Anchor Tethers	**Top Tether**	**Internal Harness**	**3PT Seat Belt With CRS**
Tension Requirements	54-67 N (12-15 lb)	45-54 N (10-12 lb)	9-18 N (2-4 lb)	54-67 N (12-15 lb)

13. When initially tightening, the tension gauge can read above the recommended amount because when the ATD gets placed in the CRS, the tension will loosen. Check tension after placing the ATD in the CRS to make sure it still falls within the range recommended.

2.4. Install ATD in CRS

2.4.1. CRABI 12 MO (Figure D-19)

1. Place the ATD in the CRS with the back of the torso and pelvis in contact with the back of the support surface and the bottom of the pelvis in contact with the bottom of the support surface of the CRS.
    a. Place harness straps at or below the shoulder of the ATD in accordance with the manufacturer’s instructions.
    b. Position the ATD in accordance with the manufacturer’s instructions provided with the system, as applicable.
2. If applicable, position CRS handle per manufacturer’s instructions.
    a. If nothing is noted or multiple locations are provided, place the handle in the first locked position rearward on the seat, as shown in Figure D-19.
3. Raise the arms of the ATD vertically above the head.
4. Make sure all the cable routing is gathered and routed under the harness and out the side towards the separating wall of the frontal sled buck assembly.
5. Push the knees of the ATD to ensure contact with the back of the CRS.

6. Fasten the harness on the ATD per manufacturer's instructions and tighten the belt to the recommended tension range shown in Table D-4.
7. Verify the chest clip is placed at armpit level.
8. Slowly lower the arms, without bending, until the arms contact a CRS surface.
9. Verify that the arms are not restrained from any movement other than in the downward direction.
10. Straighten the legs out from the body without bending.

Figure D-19. CRABI 12 MO Installed

11. Re-check that the centerline of the CRS is matched up with the 300-mm mark on the top and bottom of the sliding seat.
12. Re-check the tensions of the lower anchors, seat belt, and/or harness.
13. In order to observe contact of the ATD with the wall, the following parameters can be used:
    a. Copper head mesh (Figure D-9)
    b. High-speed imager along the line of the wall (per Section 1.3)
    c. Lightly grease paint the head of the ATD with contrasting colors, to be able to visually observe any contact with the seat, CRS, or wall.

2.4.2. Forward Facing Installation:

1. Place the ATD in the CRS while holding the ATD torso upright.
   a. Position the ATD in accordance with the manufacturer's instructions provided with the system, as applicable.
2. Gently push the ATD rearward along the CRS seat bottom until the back of the ATD contacts the CRS seat back.
   a. Confirm that the ATD's clothing is not gathered into joints prior to positioning it.
3. Verify the ATD is centered, aligning the midsagittal plane of the dummy's head with the centerline of the seat bench.
4. Raise the arms of the ATD vertically above the head as far as possible.
5. Straighten the legs of the ATD outward from body without bending.
6. Using a flat surface with an area of 2,580 square mm (4 in^2), apply a force of 178 N (40 lb) perpendicular to the plane of the seat bench back.
   a. First, apply the force against the ATD crotch.
   b. Second, apply the force to the ATD thorax in the midsagittal plane of the ATD.
7. Verify the harness straps on the ATD are positioned at or above the shoulder, in accordance with the manufacturer's instructions.
8. Make sure all the cable routing is gathered and routed under the harness and out the side towards the separating wall of the frontal sled buck assembly.
9. Fasten the harness on the ATD per manufacturer's instructions and tighten the belt to the recommended tension range shown in Table D-4.
10. Verify the chest clip is placed at armpit level.
11. Slowly lower the arms, without bending, until the arms contact a CRS surface.
    a. Verify that the arms are not restrained from any movement other than in the downward direction.
12. Verify ankles, knees, and legs are in line.
13. Re-check that the centerline of the CRS is matched up with the 300-mm mark on the top and bottom of the sliding seat.
14. Verify the belt tensions are within specifications.
15. In order to observe contact of the ATD with the wall, the following parameters can be used:
    a. Copper head mesh (per Figure D-9)
    b. High-speed imager along the line of the wall (per Section 1.3)
    c. Lightly grease paint the head of the ATD with contrasting colors, to be able to visually observe any contact with the seat, CRS, or wall.

2.4.3. Q3s Installation

1. Follow the manufacturers' instructions on installing a child into the respective CRS.
    a. Place harness straps at or above the shoulders for forward-facing CRS.
    b. Place harness straps at or below the shoulder for rear-facing CRS.
2. Before every test, check the ATD abdomen and make sure it is untucked and in the correct place. Adjust ATD appendages to the "1G" setting per the Q3s PADI Appendix B "Joint Torque Adjustments."[33]
3. Place the ATD in the CRS and make sure the pelvis of the ATD is touching the back of the CRS.
4. Be sure that ATD suit is not gathered into joints prior to fastening the harness.
5. Make sure all the cable routing is gathered on the opposite side of impact during the test.
6. Push the knees of the ATD to ensure contact with the back of the CRS.
7. Fasten the harness on the ATD per manufacturer's instructions and to the above table recommended range; place the chest clip at armpit level.
8. Raise the arms above the head and slowly lower the arms into detent (Figure D-20). Make sure the suit is not pulled under the arm of the ATD.
    a. Once the arms are in the detent, straighten with no more bend at the elbows until it makes contact with the CRS surface.

Figure D-20. Q3s Arm Placement

[33] NHTSA Docket# NHTSA-2020-0088-0002; Q3s PADI, May 2016.

9. Straighten the ATD legs.
    a. Position the legs such that there is approximately 152.4 mm (6 in.) from center of knee to center of knee for forward-facing CRS.
    b. For rear-facing CRS, position the legs such that the knee to knee spacing is minimized and place the feet on the seat back cushion in line with the knees (or as close as possible) (Figure D-21).

Figure D-21. RF Q3s Leg Positioning

10. Re-check that the centerline of the CRS is matched up with the 300-mm mark on the top and bottom of the sliding seat.
11. Re-check the tensions of the lower anchors, tether, seat belt, and/or harness.
12. Paint the head of the ATD with contrasting grease paint to be able to visually observe any contact with the seat, CRS, or wall. (Figure D-22).

Figure D-22. Q3s Head Painting

2.5. FARO Measurements

1. Confirm that the origin reads (0,0,0). This is located at the upper, outboard corner, back side of the wall (Figure D-23).

Figure D-23. Origin Point on SISA

2. Measure the z-point, the anchor attachmnts, accelerometer locations and camera locations.
3. Center the ATD and CRS at 300 mm from the edge of the sliding seat. Confirm the lateral distances of the centerline targets are aligned by using the FARO arm, and confirm they are within 5 mm of each other (Figure D-24). Adjust where necessary.

Figure D-24. Lateral Alignment of ATD

4. When conducting repeat testing, all measurements for the ATD and CRS should be within tolerance.[34]

3. TESTING

1. Conduct test with the CRS and ATD installed, making sure the sliding seat acceleration is within the corridor and the relative velocity is 19.5 ± 0.4 mph.
2. Calculate the relative velocity as follows:
    a. Remove offset from the sliding seat rear leg X acceleration using the mean of the first 200 points (removes offset from the 7231C accelerometer light sensitivity).
    b. Apply a CFC 180 filter to the sled buck platform X acceleration (accelerometer located on the sled and sliding seat rear leg X (offset removed from step a) accelerations.
    c. Integrate the CFC 180 filtered (step b) sled buck platform X acceleration and sliding seat rear leg (step b) accelerations and multiply each result by 35.3024 to obtain km/h (convert).
    d. Multiply the converted sled buck platform X velocity (step c) by .9848 (Cos(10 degrees)) and output as a channel to be used in final calculation.
    e. Subtract the converted sliding seat rear leg (step c) velocity from the sled buck platform X velocity multiplied by cos(10) (step d). The output is the inverted relative velocity channel.
    f. Multiply the inverted relative velocity channel by -1 and output as the relative velocity channel.

[34] On all repeat measurements, a tolerance of ± 10 mm was targeted.

3. To find relative velocity value at impact from the contact switch, if available:
   a. Find the point at which the relative velocity channel is less than 0 after it has reached the maximum velocity.
   b. Then, subtract 1 point and save that value as variable XZero.
   c. Find point when trigger channel equals zero and save value as variable XZeroTrigger.
   d. Find the velocity value at the XZeroTrigger point on the relative velocity channel and save that value as variable Start Velocity.
   e. Find the velocity value at the XZero point of the sliding seat rear leg velocity channel and save that value as variable End Velocity.
   f. The final relative velocity is the Start Velocity value + End Velocity value.
4. To find relative velocity value at impact if the contact switch is unavailable:
   a. Find the point at which the relative velocity channel is less than 0 after it has reached the maximum velocity.
   b. Then, subtract 1 point and save that value as variable XZero.
   c. Find the maximum velocity value of the relative velocity channel and save that value as variable Start Velocity.
   d. Find the velocity value at the XZero point of the sliding seat rear leg velocity channel and save that value as variable End Velocity.
   e. The final relative velocity is the Start Velocity value + End Velocity value.
5. Disconnect and remove the CRS from the sliding seat, recording any damage to the structure or foam.
6. Remove the honeycomb from the shelf, disconnecting the switches that were installed before testing. Measure the width of the honeycomb (at the middle of the piece).
7. If the foam cushions are used consecutively, make sure there is ample time (minimum of 1 hour) for the seat foam cushion to rest between tests. In most instances the foam cushions were alternated and stored in the temperature chamber when not in use.
8. Assess the anchorages that were used for this test (seat belt anchorages, top tether anchorages, lower anchor attachments) for damage or twisting. Make sure the replaceable lower anchor still meets its required measurements per drawings (2921-375 and 2921-350)
   a. Use the anchor gap gauge to check the clearance of the openings on the inboard latch seat anchor and the d-ring attachment (drawing 2921-950) (Figure D-25).

b. If the tool fits inside of these anchorage openings, then replace the the anchorages (3021-121, 3021-123).

Figure D-25. Anchor Gap Gauge

4. PHOTOGRAPHY

1. Add appropriate signage with CRS, ATD, test number and date, and pre-or post-information to the test apparatus and sign boards.
2. Take photographs of the set-up, CRS, ATD, and wall. The following pictures should be taken before and after testing.
    a. Accelerometers (on first test)
    b. Overall sled buck and seat assembly
    c. Wide front view of seat assembly with the dummy
    d. Tight front view on seat assembly with the dummy
    e. Side view of seat assembly with the dummy
    f. Rear view of seat assembly with the dummy
    g. Up close of ATD installed in CRS
    h. Overhead view of seat assembly with the dummy
    i. View over wall of seat assembly with the dummy
    j. Inclinometer showing RF angle, if applicable
    k. Restraint connections of CRS and seat assembly
3. Post-test photos:
    a. If the ATD head contacted either the CRS or wall, take a picture capturing the mark left behind.
    b. Document with permanent marker the test date, test number, and manufacturer on the CRS. Take a photograph of the information written on the CRS along with the manufacturing label.

c. Place a piece of tape on the honeycomb with the width recorded on the tape, and take a photograph of the honeycomb and tape (Figure D-26).

Figure D-26. Post-Test Honeycomb

Appendix E: Foam Wrapping Procedure for the FMVSS 213 Sled Buck Assembly

1. Wrap each foam and metal plate for the seat bench pan and seat bench back with the appropriate fabric (Drawings 3021-234 and 3021-249).[35]
    a. Dimensions of the seat bench back and seat bench pan foam and plate assemblies are in the FVMSS No. 213a side drawing package.[36]
2. Adhere 120-grit sandpaper to the side of the plate that contacts the foam (side without the bolts). Adhere the sandpaper by spraying the reverse side of the paper with spray adhesive. Use two pieces of sandpaper (Figure E-1).

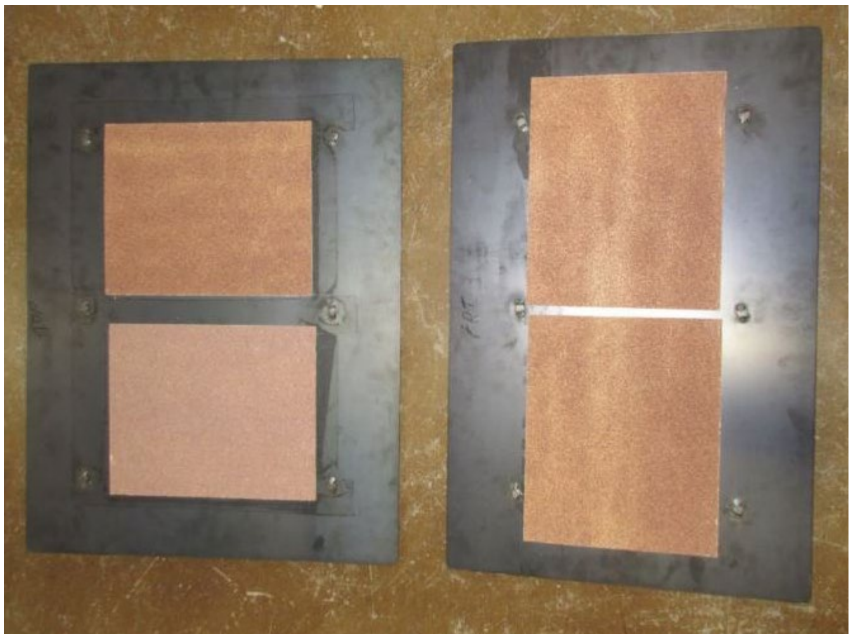


Figure E-1. Two Pieces of Sandpaper Adhered to the Back of Metal Plate

3. Cut two fabric[37] pieces of the following dimensions[38] to wrap around the foams.
    a. Seat bench pan: 1,080 mm x 1,270 mm (42.5 in. x 50 in).
    b. Seat bench back: 1,118 mm x 1,118 mm (44 in. x 44 in).
4. Place the plate on the foam with approximately 25 mm (1 in.) on each side (Figure E-2).

[35] Polyacrylate Fiber, Weight: 90z/yd, Break Strength: 285 lb Warp, 180 lb Filling
[36] Assembly Drawings Numbers: Dated December 2021.
[37] Woven fabric is anisotropic; warp is the stronger direction of the threads.
[38] Second dimension refers to the warp of the material, while the first refers to the filling

Figure E-2. Foam Placed on Plate With 25 mm of Foam on Each Side

5. Stretch the material over the bolts, and mark on the fabric the location of the bolts. Use a soldering iron to burn through the material at those marked locations (for first use).
    a. Install size 1 grommets at each of the hole locations created in step 4.
6. Place the bolts through the grommet holes in the fabric and adhere the edge of the fabric to the plate using 3-in. preservation tape. (Figure E-3).[39]

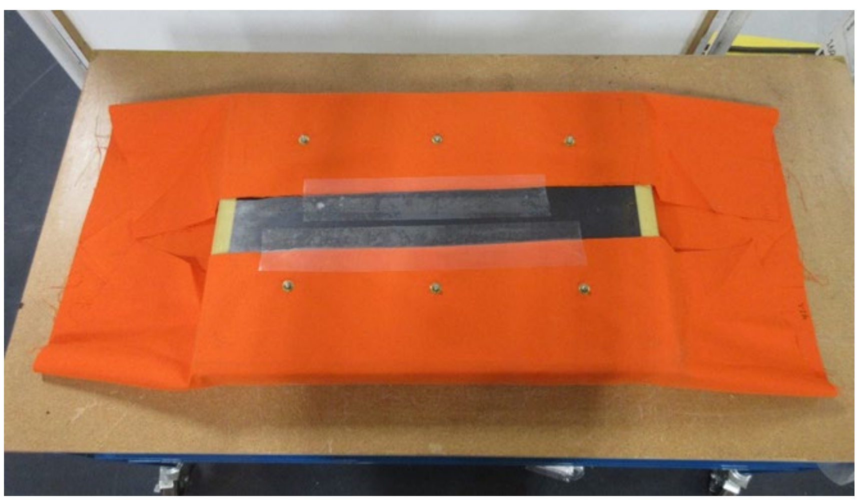


Figure E-3. Material Wrapped Around Foam With Bolts Going Through Grommet Holes

[39] Dr. Shrink brand preservation tape was used throughout the research testing and was determined to be the best product to stick to the Sunbrella fabric, due to its adhesive bond that sticks to most surfaces and leaves little residue. https://dr-shrink.com/wp-content/uploads/2019/04/tape-specs.pdf

7. Push fabric into the thickness of the foam (Figure E-4), and then fold the top piece of the fabric down in a triangular method (Figure E-5). Repeat step 6 for both ends of the fabric.

Figure E-4. Fabric Pushed Into Thickness of Foam

Figure E-5. Top Piece of Fabric Folded Down

8. Pull the fabric upwards and secure the edge of the fabric with the preservation tape (Figure E-6).

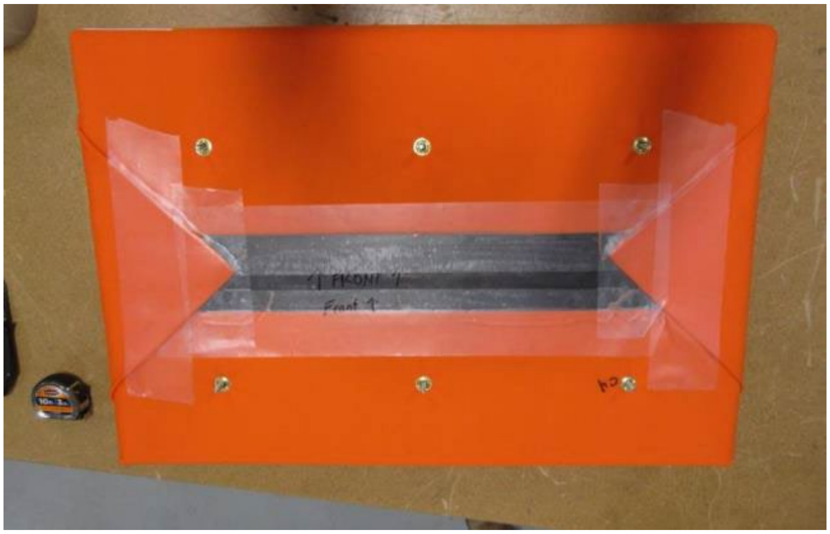


Figure E-6. Finished Final Foam Wrapped Foam Set

Appendix F: CRS/ATD Target Locations

Figure F-1. Infant Seat Target Locations

Figure F-2. Rear Facing CRS Target Locations

Figure F-3. Forward Facing CRS Target Locations

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