Sled Impact Test

SD 2202
Symmetric Designs

Frontal Impact of a Symmetric Designs Free Form Back Support with FA Mounts Installed on the ISO/RESNA Surrogate Wheelchair Frame (SWCF) with a Surrogate Seatpan and Commercial Seat Cushion Secured by a Surrogate Four-Point, Strap-Type Tiedown and Loaded with a Hybrid III Midsize Male ATD Restrained by a Surrogate Three-Point Belt with a SWCF-Anchored Lap Belt

This test was conducted in accordance with standards ANSI/RESNA WC-4:2017, Section 20: *Wheelchair Seating Systems for Use in Motor Vehicles* and ISO 16840-4 (2009): *Wheelchair Seating- Part 4: Seating Systems for Use in Motor Vehicles*

Test Date: December 21, 2022

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ACKNOWLEDGEMENT AND TEST PURPOSE

This test was sponsored by the Symmetric Designs of Salt Spring Island, British Columbia and was conducted in accordance with procedures in Annex A of ANSI/RESNA WC-4:2017, Section 20: *Wheelchair Seating Systems for Use in Motor Vehicles,* hereafter referred to as WC20, and ISO 16840-4, *Wheelchair Seating- Part 4: Seating Systems for Use in Motor Vehicles,* hereafter referred to as ISO 16840-4. These two standards provide a method for evaluating a complete seating system consisting of back support, seat, attachment hardware, and postural support devices, but the purpose of this test was to evaluate only the back support and its attachment hardware. Therefore, a commercial back support and a surrogate seat consisting of a steel plate with a commercial seat cushion was used to comprise a complete wheelchair seating system for testing. The performance of the commercial back support, the postural support devices and the attachment hardware were measured and evaluated according to the applicable performance criteria WC20 and ISO 16840-4.

Advertisements and marketing literature should refer to the requirements and provisions of WC20 and ISO 16840-4, but should not refer to the University of Michigan or the University of Michigan Transportation Research Institute (UMTRI). Requests for copies of this report, test film, and video should be directed to the test sponsor.

TEST METHODS

This frontal impact test was conducted on the UMTRI impact sled. The sled operates on the rebound principle, achieving the desired change in velocity by reversing direction during the impact event. The sled crash pulse is trapezoidal in shape and is reported as an average deceleration level in *g*. The sled velocity is monitored immediately before and after impact.

Data generated during the test were digitized live using a TDAS onboard data acquisition system. All signals were filtered to the requirements of SAE J-211. The photo documentation consisted of high-speed (1000-frames/sec) digital video from right and right-rear side views of the impact event. A strobe flash and simultaneous voltage pulse record and synchronize the onset of impact deceleration on video and transducer signals.

TEST SETUP

A Symmetric Designs Free Form back support with FA mounts was installed on the ISO/RESNA surrogate wheelchair frame (SWCF), which was placed on the sled platform facing forward and secured using the surrogate four-point, strap-type tiedown specified in RESNA WC-4:2017, Section 19: *Wheelchairs Used As Seats in Motor Vehicles*.

The adjustable width of the SWCF was set to 14 inches (measured between the outside edges of the seat rails) prior to installing the seating system. The attachment hardware of the seat was attached to the seat rails and back-support posts, respectively, and the back-support height was adjusted according to the manufacturer's instructions. A generic metal planar seatpan and 50-mm thick dense foam commercial cushion was used to represent a nominal seat. The front and rear tiedown straps were hooked to the securement points provided on the SWCF.

The seating system was loaded with a Hybrid III midsize male anthropomorphic test device (ATD) that was restrained by a surrogate three-point belt with a SWCF-anchored lap belt. The left end of the lap belt was anchored with three-bar clips to a D-ring attached near the rear securement point on the left side of the SWCF, while the right side of the lap belt and the lower portion of the shoulder belt formed a continuous loop through a D-ring that was anchored near the rear securement point on the right side of the SWCF. A heavy-duty three-bar clip held the lap and shoulder belts together near the right hip of the ATD. The shoulder-belt upper anchorage was attached to a rigid structure on the sled platform at a position above and behind the ATD's left shoulder that simulated a typical vehicle sidewall anchor point. The pelvic belt was tightened to fit snugly over the ATD pelvic region. The shoulder belt was tightened snugly across the ATD chest with a 75-mm block between the belt and ATD, and the block was removed prior to the test.

The test was conducted using 48-kph (30-mph) and 20-*g* average impact conditions to determine the response of the Symmetric Designs Free Form back support with FA mounts during frontal-impact loading, and compliance of the seating system to performance criteria in 5.1 of WC20 and 5.1 of ISO 16840-4. The table on the following page provides further details about the test equipment and setup.

SUMMARY OF TEST SETUP AND PRE-TEST MEASUREMENTS

GENERAL TEST INFORMATION	
Test number	SD 2202
Test date	December 21, 2022
Seating System	Symmetric Designs Free Form Back Support with FA Mounts
Wheelchair type	ISO/RESNA surrogate wheelchair frame
Wheelchair tiedown	Surrogate four-point, strap-type tiedown
Occupant restraint	Surrogate 3-point belt with SWCF-anchored lap
Anthropomorphic Test Dummy (ATD)	Hybrid III midsize male @ 78 kg (171 lb)
Wheelchair orientation	Forward facing
Sled platform	Rigid steel plate
Desired impact velocity (delta V)	48 kph (30 mph)
Desired average sled deceleration	20 *g*
WHEELCHAIR TIEDOWN	
Front-to-rear anchor-point distance	1283 mm (50.5 in)
Rear tiedowns	
Lateral distance between anchor points	330 mm (13.0 in)
Angle wrt horizontal	43 degrees
Angle wrt to wheelchair center plane	0 degrees
Anchor point to rear-wheel hub	432 mm (17.0 in)
Length (anchor point to securement point)	495 mm (19.5 in)
Front tiedowns	
Lateral distance between anchor points	686 mm (27.0 in)
Angle wrt horizontal	44 degrees
Angle wrt to wheelchair center plane	15 degrees
Length (anchor point to securement point)	
OCCUPANT RESTRAINT	
Shoulder belt upper anchor point location	
Behind ATD shoulder	305 mm (12.0 in)
Above ATD shoulder	178 mm (7.0 in)
Above sled platform	1257 mm (49.5 in)
Left of wheelchair centerline	305 mm (12.0 in)
Angle of pelvic belt wrt to horizontal	55 degrees
Angle of shoulder-belt	
Projected frontal view wrt horizontal	58 degrees, measured on ATD torso
Projected lateral view wrt horizontal	30 degrees, measured above ATD shoulder
Footstrap location	
In front of ATD knee center	381 mm (15.0 in)
Below ATD knee center	127 mm (5.0 in)
ATD POSITIONING	
Shoulder height above sled platform	1080 mm (42.5 in)
H-point height above sled platform	622 mm (24.5 in)
WHEELCHAIR	
Weight	63.6 kg (140 lb)
Wheelbase	533 mm (21.0 in)
Seatback angle wrt vertical	10 degrees
Seatback height (with headrest)	533 mm (21.0 in)
Seatpan angle wrt horizontal	5 degrees
Seat surface height from floor @ SB junction	546 mm (21.5 in)
Seatpan length	432 mm (17.0 in)

TEST RESULTS

The Symmetric Designs Free Form back support with FA mounts sustained impact intact and remained attached to the SWCF/SWCB. The maximum forward excursion of point P on the wheelchair seating system was 78 mm, which is below the WC20 and ISO 16840-4 excursion limit of 200 mm. After the test, the SWCF was upright on the sled platform and the ATD was seated in the wheelchair seat with the torso leaning forward and left 10 degrees. The ATD could be removed from the belt restraint without the use of tools.

The ATD was effectively restrained from forward and rearward excursions by the surrogate three-point belt with a SWCF-anchored lap belt and the back support, respectively. Peak forward excursion of the ATD's head was limited to approximately 300 mm and peak forward knee excursion was limited to about 180 mm, which are both below the WC20 and ISO 16840-4 limits of 650 mm and 375 mm, respectively. The ATD's head traveled 333 mm rearward of its initial position during the test, which is below the WC20 and ISO 16840-4 limit of 450 mm. The ATD's post-test H-point height did not change from the pre-test height.

The results of this test show that the Symmetric Designs Free Form back support with FA mounts *meets* all performance criteria for wheelchair seating systems in Section 5.1 of WC20 and 5.1 of ISO 16840-4. The following tables summarize the test results and compliance with applicable performance criteria of WC20 and ISO 16840-4.

SUMMARY OF TEST RESULTS

GENERAL TEST INFORMATION	
Test number	SD 2202
Actual impact velocity (delta V)	48 kph (30.3 mph)
Actual average sled deceleration level	21.4 *g*
Actual peak sled deceleration level	23.1 *g*
Total time of deceleration over 20 *g*	30.7 ms
Total time of deceleration over 15 *g*	66.0 ms
Deceleration pulse duration	77.7 ms
ATD MEASUREMENTS	
Peak resultant head acceleration	52 *g*
Peak resultant chest acceleration	46 *g*
Head injury criteria (unlimited)	211
Maximum forward head excursion†	300 mm (11.8 in)
Maximum forward knee excursion††	180 mm (7.1 in)
Maximum rearward head excursion††	333 mm (13.1 in)
Average post-test H-pt ht above sled platform	622 mm (24.5 in) 0% change
TIEDOWN LOADS	
Peak left-rear tiedown strap force	17654 N (3969 lb)
Peak right-rear tiedown strap force	21561 N (4847 lb)
BELT LOADS AND PELVIC BELT ANGLE	
Peak left pelvic-belt load	7522 N (1691 lb)
Peak shoulder-belt load	9189 N (2066 lb)
WHEELCHAIR MEASUREMENTS††	
Maximum forward wheelchair excursion at Point P*	78 mm (3.1 in)
Maximum forward excursion of front-wheel hub	52 mm (2.0 in)
Maximum forward excursion of rear-wheel hub	57 mm (2.2 in)

†The forward head excursion is the total forward change in position of the leading edge of the head, measured at the initial position prior to impact and at the time of maximum forward head travel.

††Excursions reported are the total horizontal change in the position of the affixed targets relative to the sled platform from just prior to impact to the time of maximum forward or rearward excursion.

*Point P is a seating reference point located 50 mm above and 50 mm in front of the junction of the seatback and seat cushion planes.

SUMMARY OF SEATING SYSTEM PERFORMANCE CRITERIA IN RESNA WC-4:2017, SECTION 20

SLED TEST SD 2202

Requirement		Observed Performance	
WC20 Clause	Description	Description	Pass/Fail
5.1a	Forward excursion of Point P<200 mm	78 mm	Pass
	Forward knee excursion <375 mm	180 mm	Pass
	Forward head excursion <650 mm	300 mm	Pass
	Rearward head excursion <450 mm	333 mm	Pass
5.1b	Seating system shall not completely separate from the SWCF at any attachment point.	The seating system remained attached at all attachment points.	Pass
5.1c	ATD must be in WC seat with torso leaning not more than 45˚ from vertical.	The ATD was seated on the WC seat with the torso leaning forward and left 10 degrees.	Pass
5.1d	Primary load-carrying components of the seating system and attachment hardware shall not completely fail.	No primary load-carrying components completely failed.	Pass
5.1e	Rigid components, fragments, or accessories with mass of 150 g or greater shall not completely detach.	No components detached from the seating system.	Pass
5.1f	Seating system components must not have sharp edges with potential for occupant contact.	There were no sharp edges exposed.	Pass
5.1g	The surrogate belt restraint shall not completely fail due to contact with the seating system.	The surrogate belt restraint did not fail.	Pass
5.1h	Average post-test height of ATD H-points shall not be more than 20% lower than the average pretest height.	The average H-point height decreased 0%.	Pass

Note: SWCF = surrogate wheelchair frame.

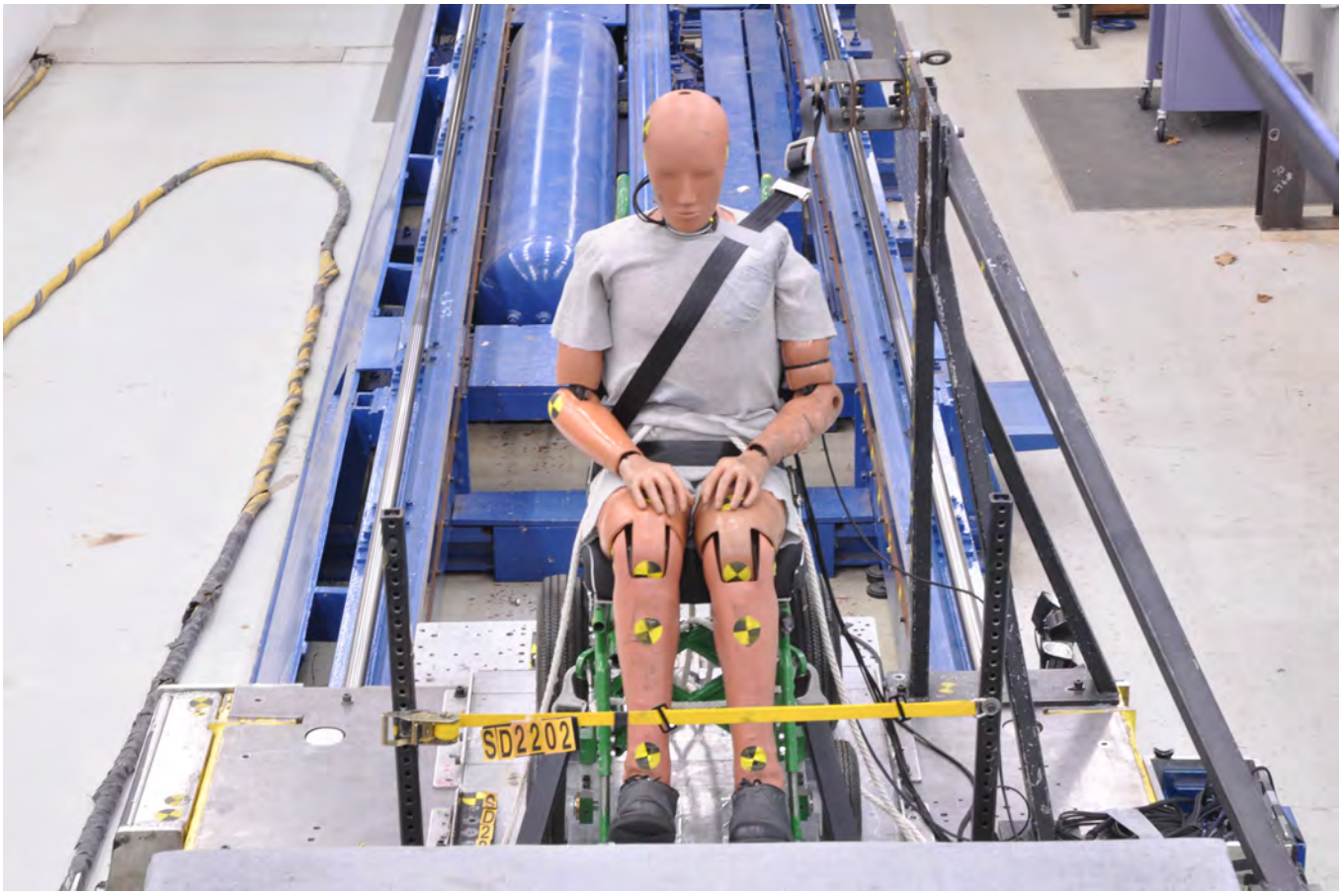
SUMMARY OF SEATING SYSTEM PERFORMANCE PER CRITERIA IN ISO 16840-4

SLED TEST SD 2202

Requirement		Observed Performance	
ISO 16840-4 Clause	Description	Description	Pass/Fail
5.1.2a	Forward excursion of Point P<200 mm	78 mm	Pass
	Forward knee excursion <375 mm	180 mm	Pass
	Forward head excursion <650 mm	300 mm	Pass
	Rearward head excursion <450 mm	333 mm	Pass
5.1.2b	Ratio of ATD knee excursion to Point P excursion must exceed 1.1.	N/A – A SWCB-anchored pelvic belt was used.	N/A
5.1.2d	Seating system shall not separate from the SWCB at any attachment point.	The seating system remained attached at all attachment points.	Pass
5.1.3a	ATD must be in WC seat with torso leaning not more than 45˚ from vertical.	The ATD was seated on the WC seat with the torso leaning forward and left 10 degrees.	Pass
5.1.3b	Primary load-carrying components of the seating system and attachment hardware cannot show visible signs of structural failure.	No primary load-carrying components showed signs of failure.	Pass
5.1.3c	Detached seating hardware cannot exceed 0.1 kg.	No hardware detached from the seating system.	Pass
5.1.3d	Rigid seating system components must not have sharp edges with potential for occupant contact.	There were no sharp edges exposed.	Pass
5.1.3e	Post-test height of ATD H-point shall not be more than 20% lower than pretest height	The average H-point height decreased 0%.	Pass

Note: SWCB = surrogate wheelchair base, N/A = not applicable.

PRE-TEST PHOTOS



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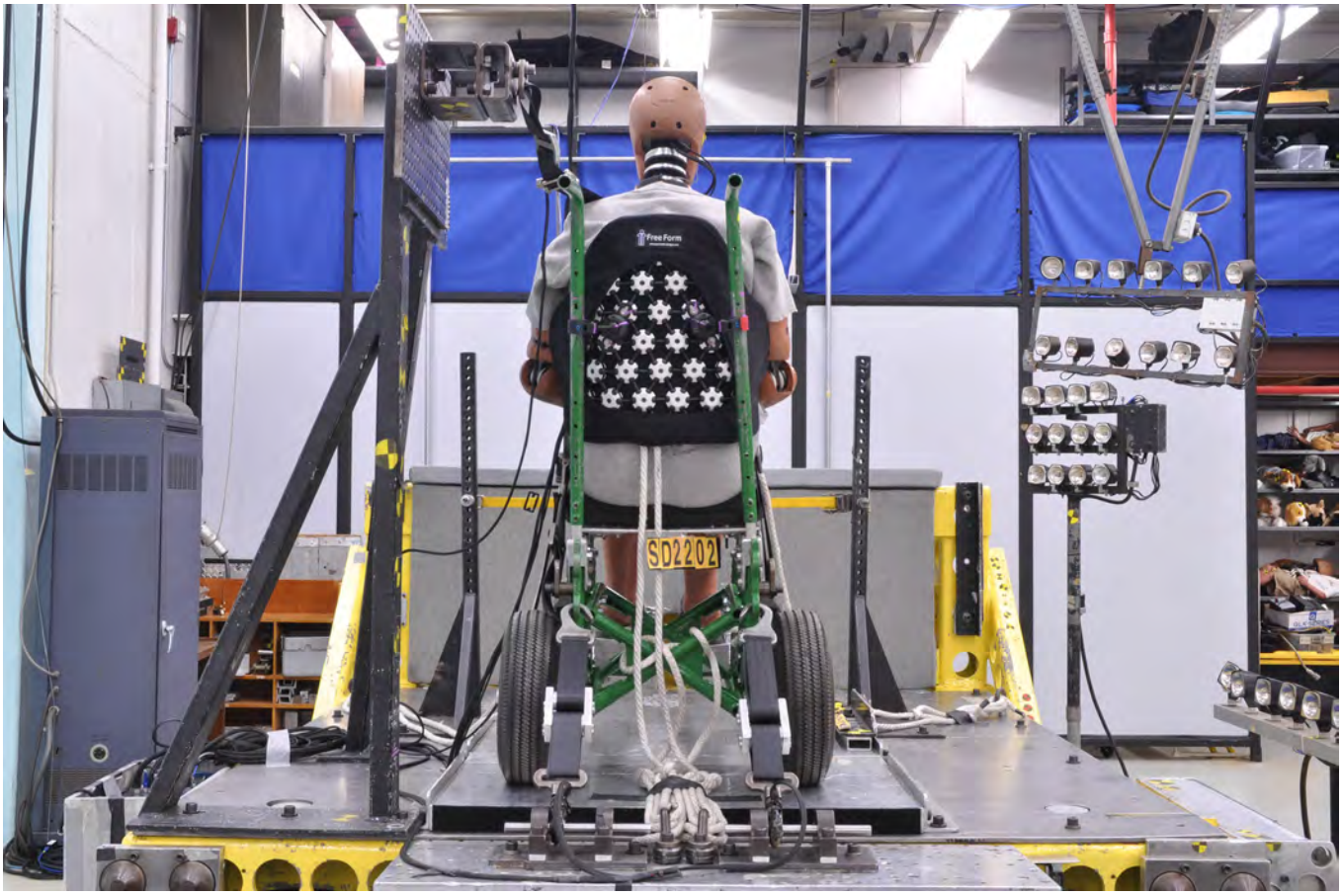

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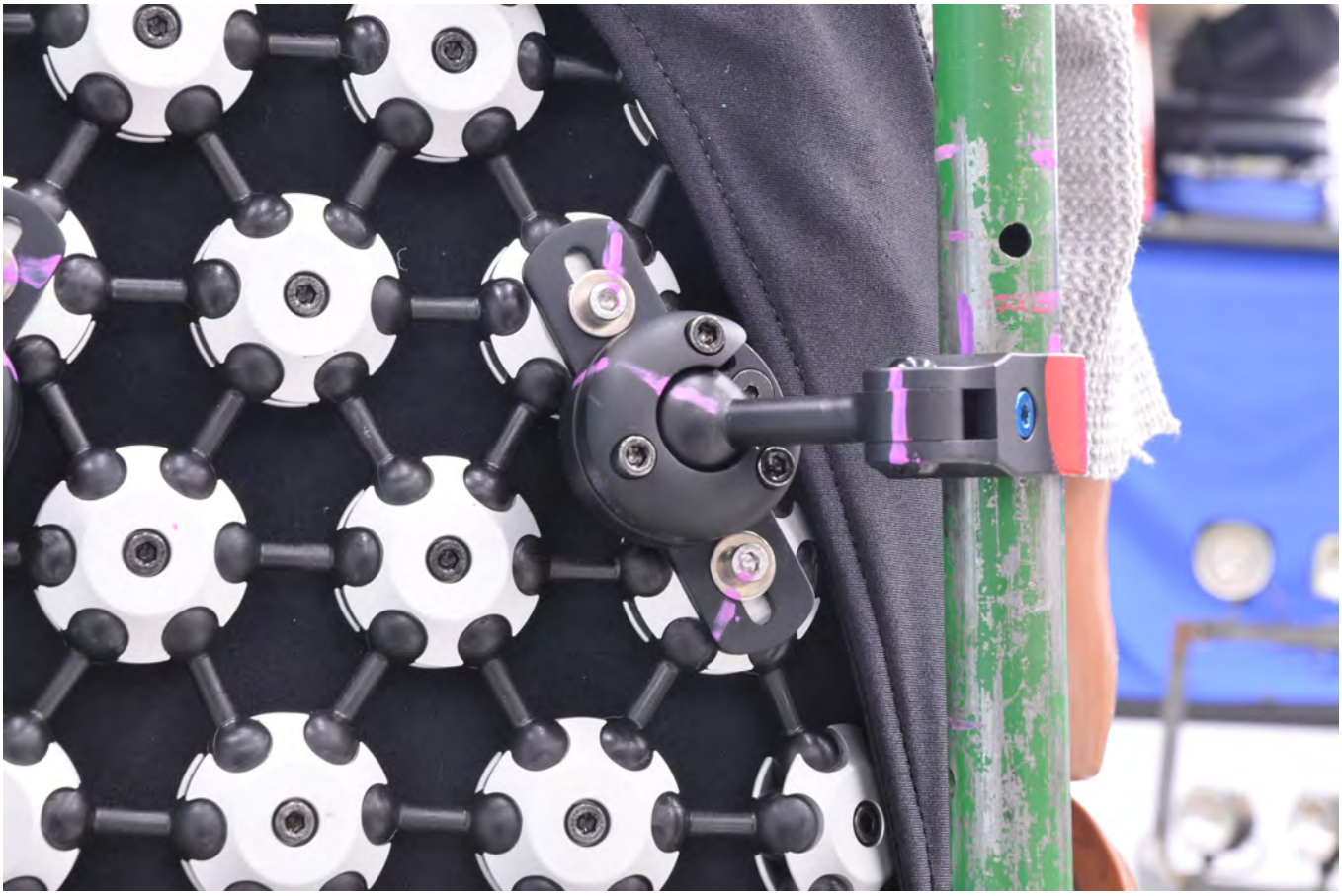

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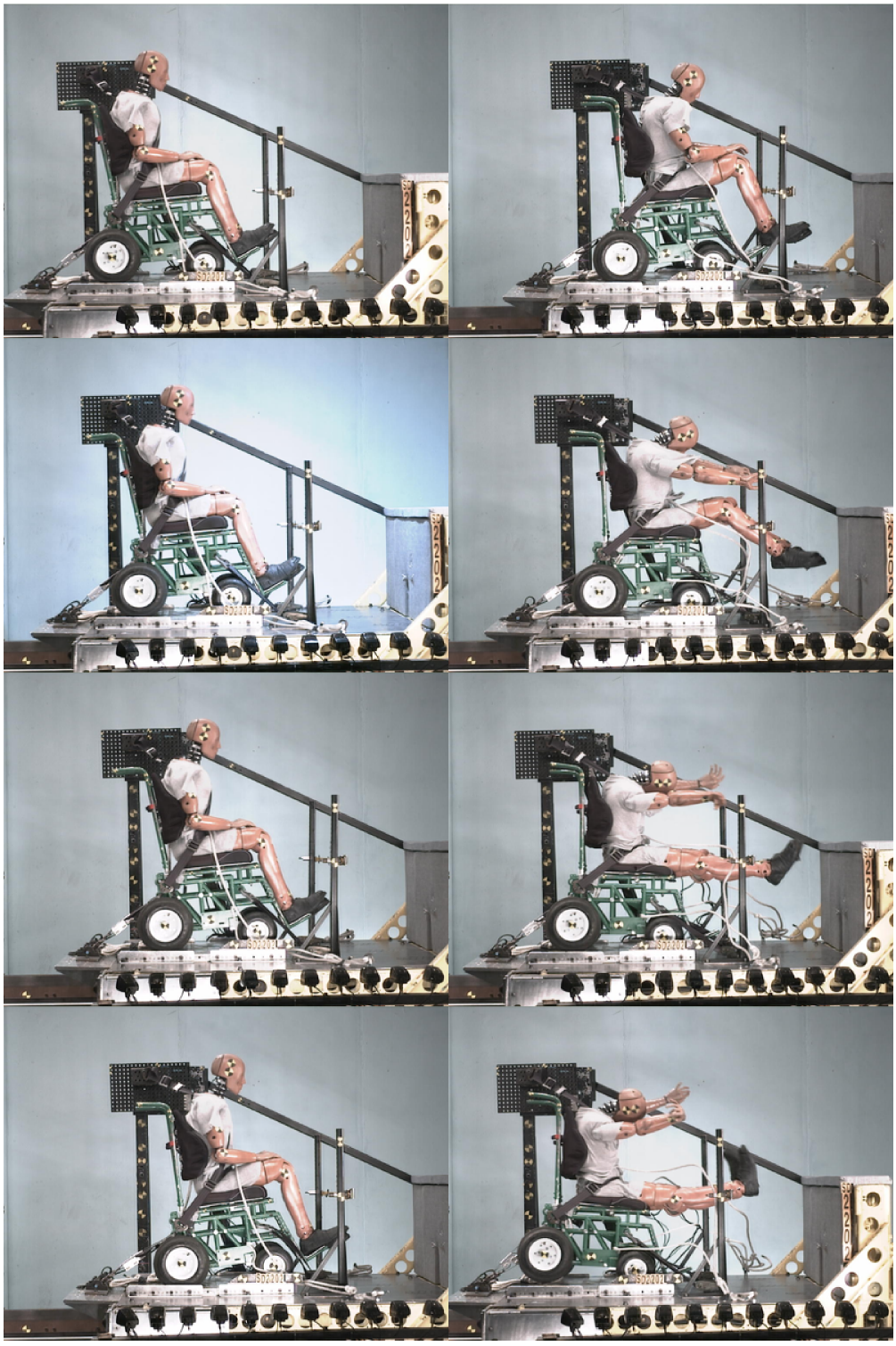
TEST AND POST-TEST PHOTOS

SD2202



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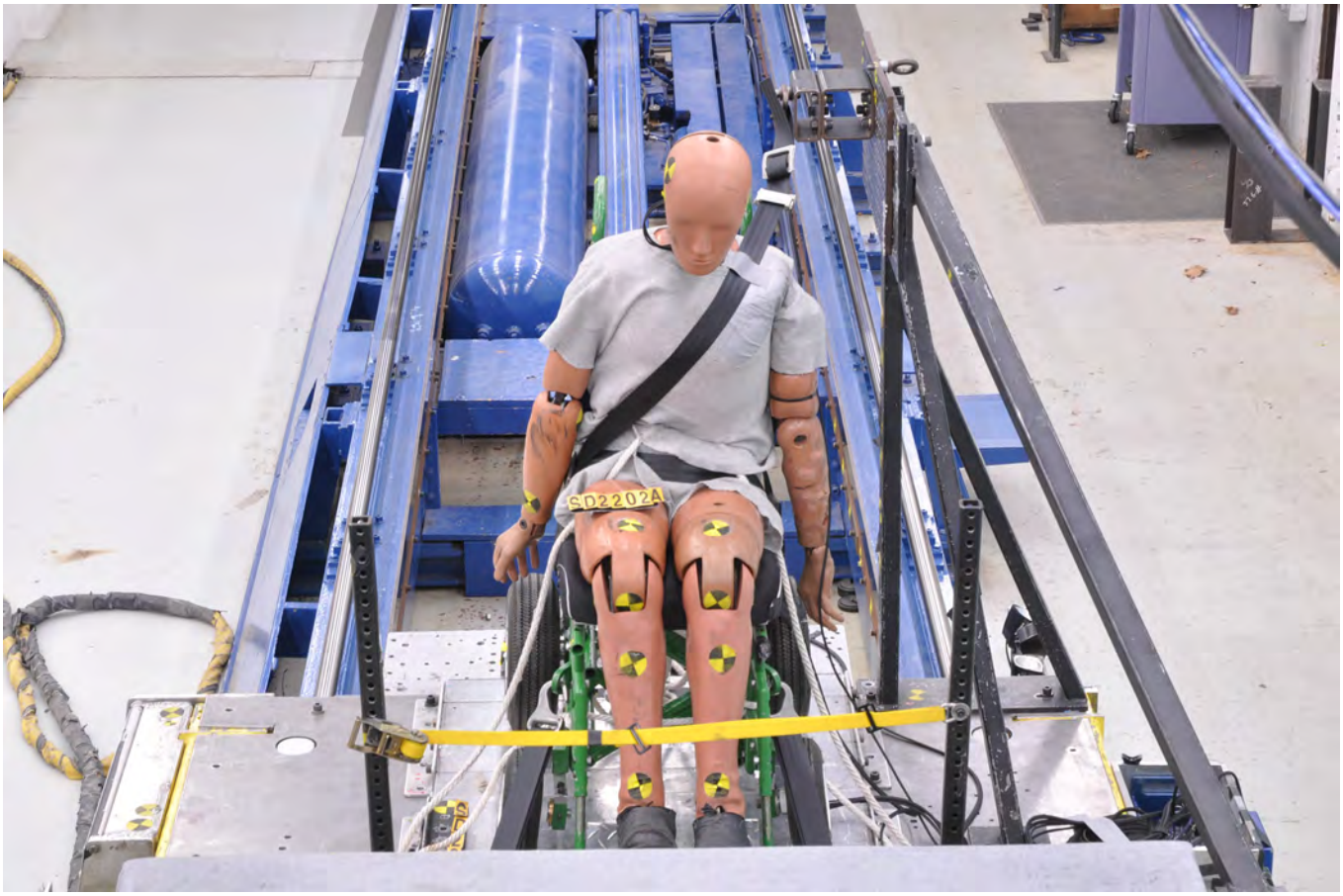

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TEST SIGNALS

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Results

SD2202

Nominal = 30 mph / 20 g avg
Actual[P] = 48.7 km/h (30.3 mph) (75.1%)

Pressures: 139.3/1210
Plateau Avg.= -21.4 G; Peak = -23.1 G

Dummy: Hybrid III 50th Male (77.7 kg)
Buck: steel plate, extensions, bolster,risers, shoulder brace

Buck Weight: 2277

Symmetric Designs Free Form Back Support with Fixed Adjustable Mounts
WC 3pt, 4pt SWTORS

Sled Summary

Sled Pulse Duration = 77.7 ms
Sled Plateau Average Level = -21.4 G
Sled Decel Peak = -23.1 G
Total time under -20.0 G was 30.7 ms
Continuous time under -15.0 G was 66.0 ms

Efficiency = Vout / Vin = 20.9 / 27.8 = 75.1%
Sled Delta V = 48.7 kph (30.3 mph)
Stopping Dist. (est) = .553 m

Head Acceleration

X	-4.3 g @ 212 ms	**29.8 g @ 85 ms**
Y	-4.5 g @ 59 ms	**8.4 g @ 102 ms**
Z	-1.6 g @ 108 ms	**45.1 g @ 54 ms**
Resultant	**Peak: 51.5 g @ 54 ms**	
H.I.C. (UN) = 461.4		From 35.1 to 114.3 ms
H.I.C. (36) = 261.6		From 35.9 to 66.4 ms
H.I.C. (15) = 210.7		From 44.3 to 59.3 ms

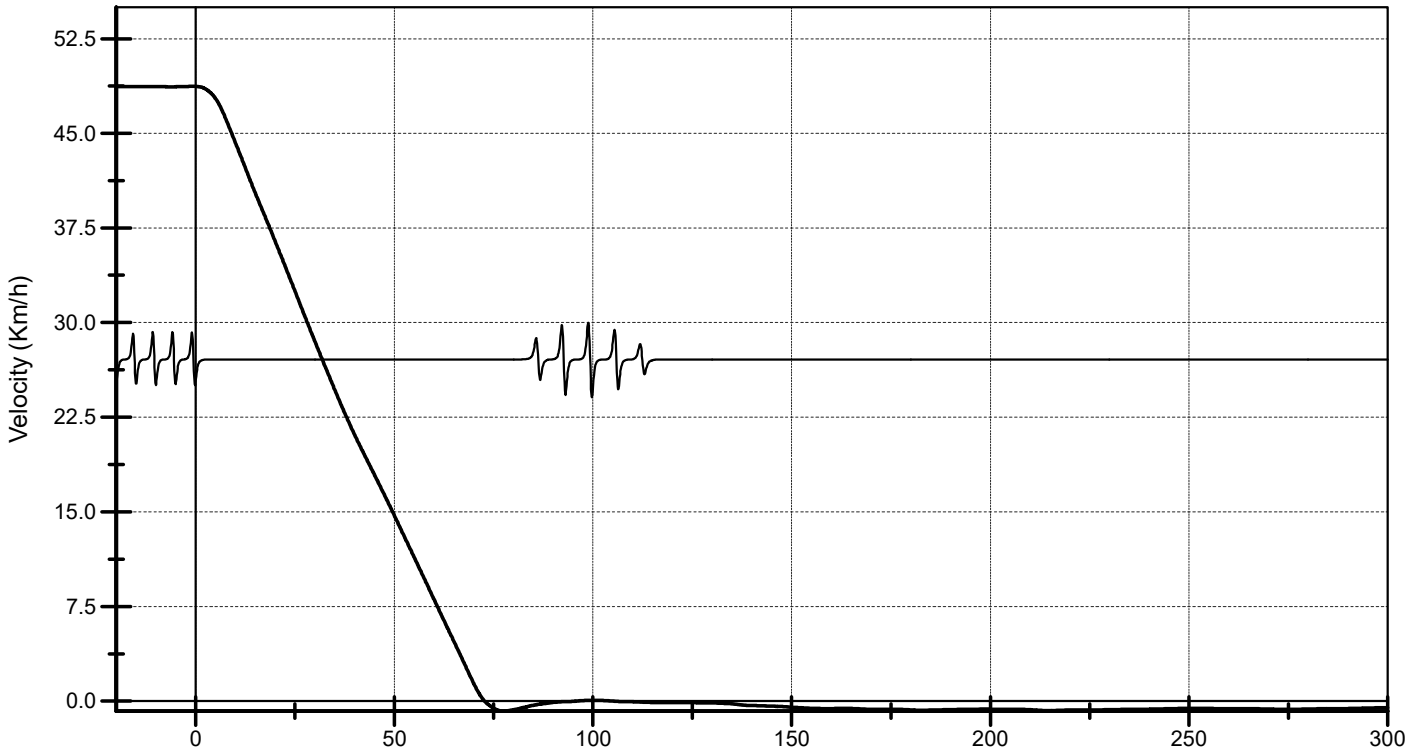
Chest Acceleration

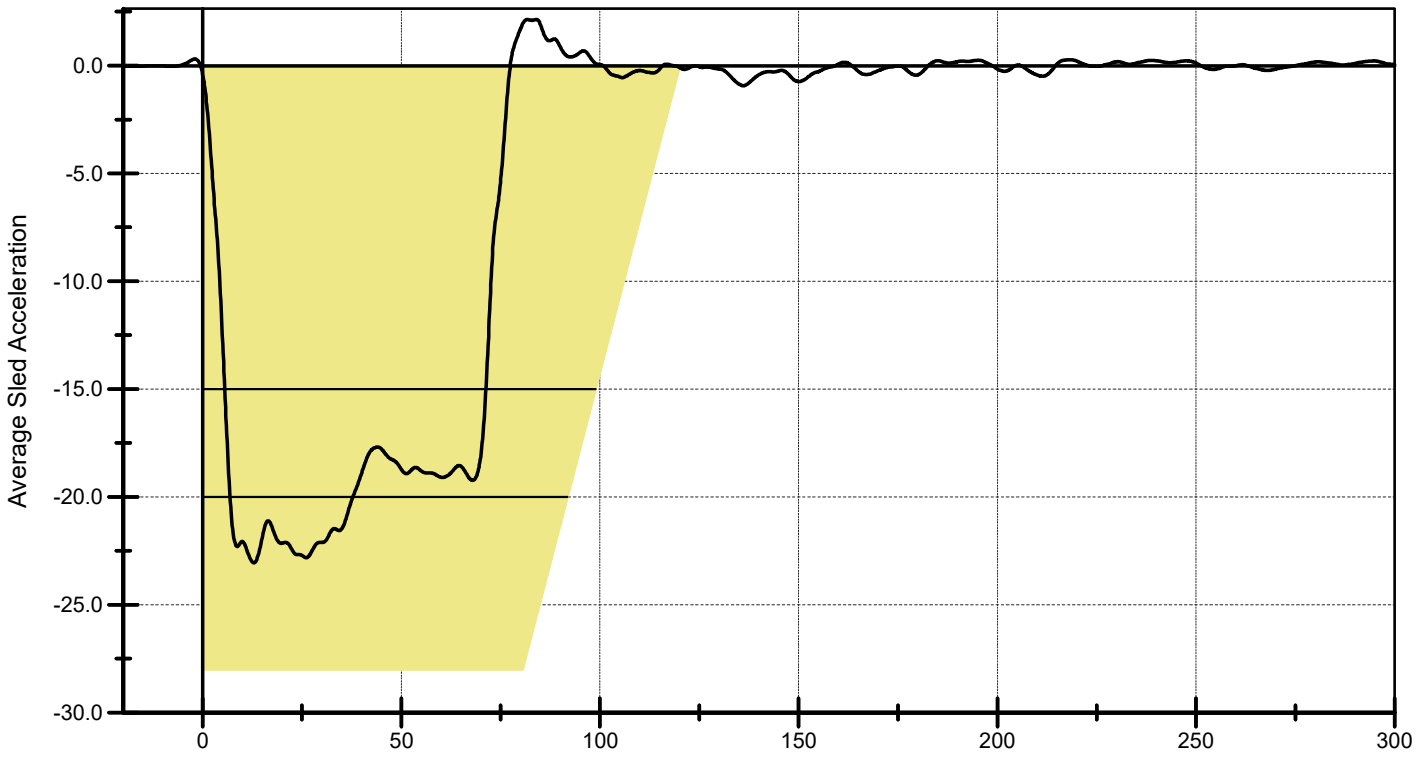
X	-6.7 g @ 202 ms	**41.9 g @ 51 ms**
Y	**-12.7 g @ 89 ms**	4.1 g @ 199 ms
Z	**-18.7 g @ 40 ms**	12.9 g @ 78 ms
Resultant	**Peak: 46.2 g @ 51 ms**	
3.0 ms Clipped Peak = 45.3G		From: 49.7 to 52.7 ms
Total time over 60 G was 0.0 ms		

Belt Loads

Lap Belt Load	-3.6 N (-.8 lb) @ 8 ms	**7521.9 N (1691.0 lb) @ 62 ms**
Shoulder Belt Load	-11.1 N (-2.5 lb) @ 188 ms	**9189.3 N (2065.8 lb) @ 54 ms**
Left Rear Tiedown Load	-458.0 N (-103.0 lb) @ 121 ms	**17654.4 N (3968.9 lb) @ 60 ms**
Right Rear Tiedown ...	-416.3 N (-93.6 lb) @ 277 ms	**21561.0 N (4847.1 lb) @ 59 ms**

Sled Summary SD2202





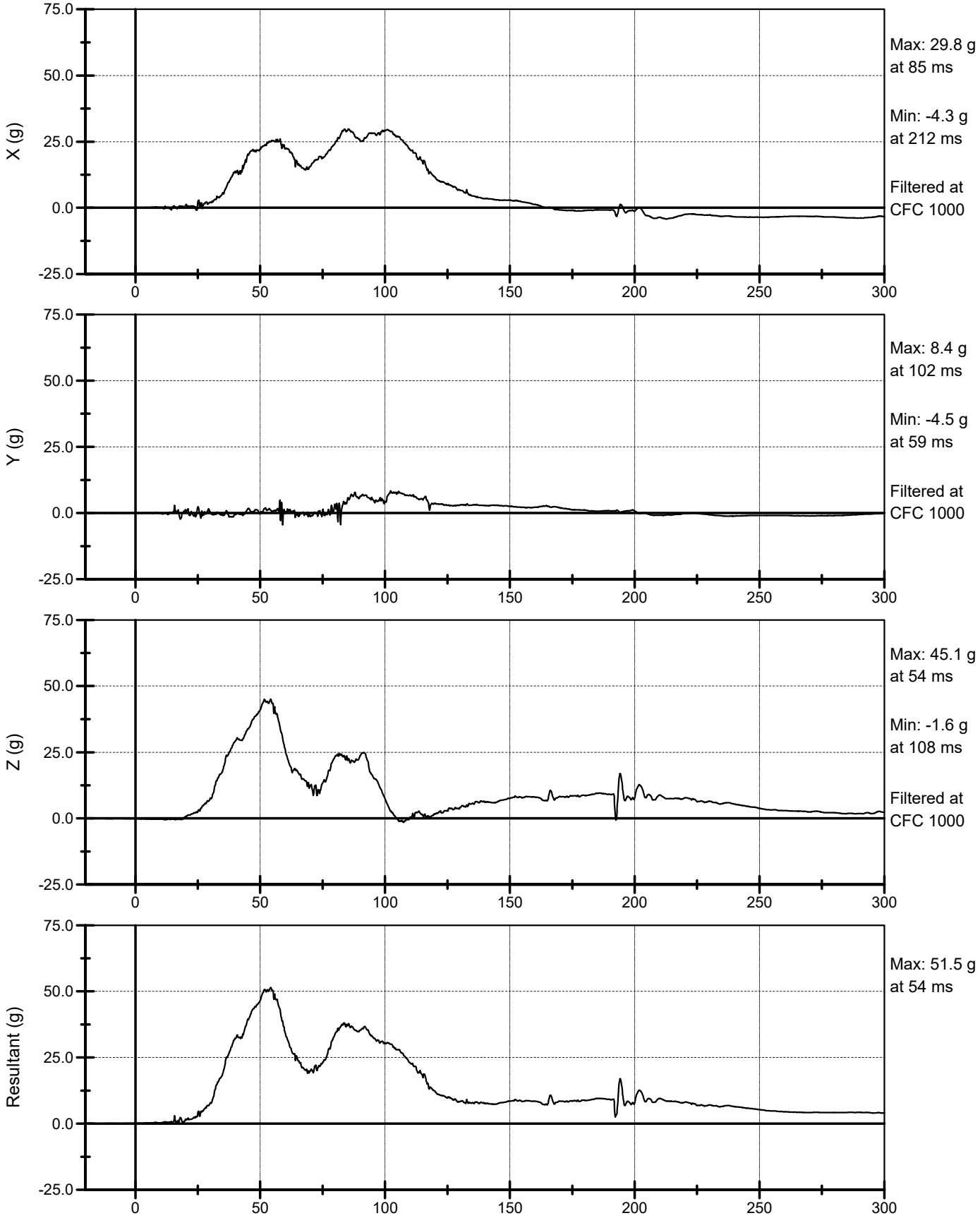
Continuous time under -15.0 G was 66.0 ms
Total time under -20.0 G was 30.7 ms
Sled Decel Peak = -23.1 G
Sled Plateau Average Level = -21.4 G
Sled Pulse Duration = 77.7 ms

Stopping Dist. (est) = .553 m
Sled Delta V = 48.7 kph (30.3 mph)
Efficiency = Vout / Vin = 20.9 / 27.8 = 75.1%

UMTRI

Head Acceleration

SD2202



H.I.C. (15) = 210.7 From: 44.3 to 59.3 ms

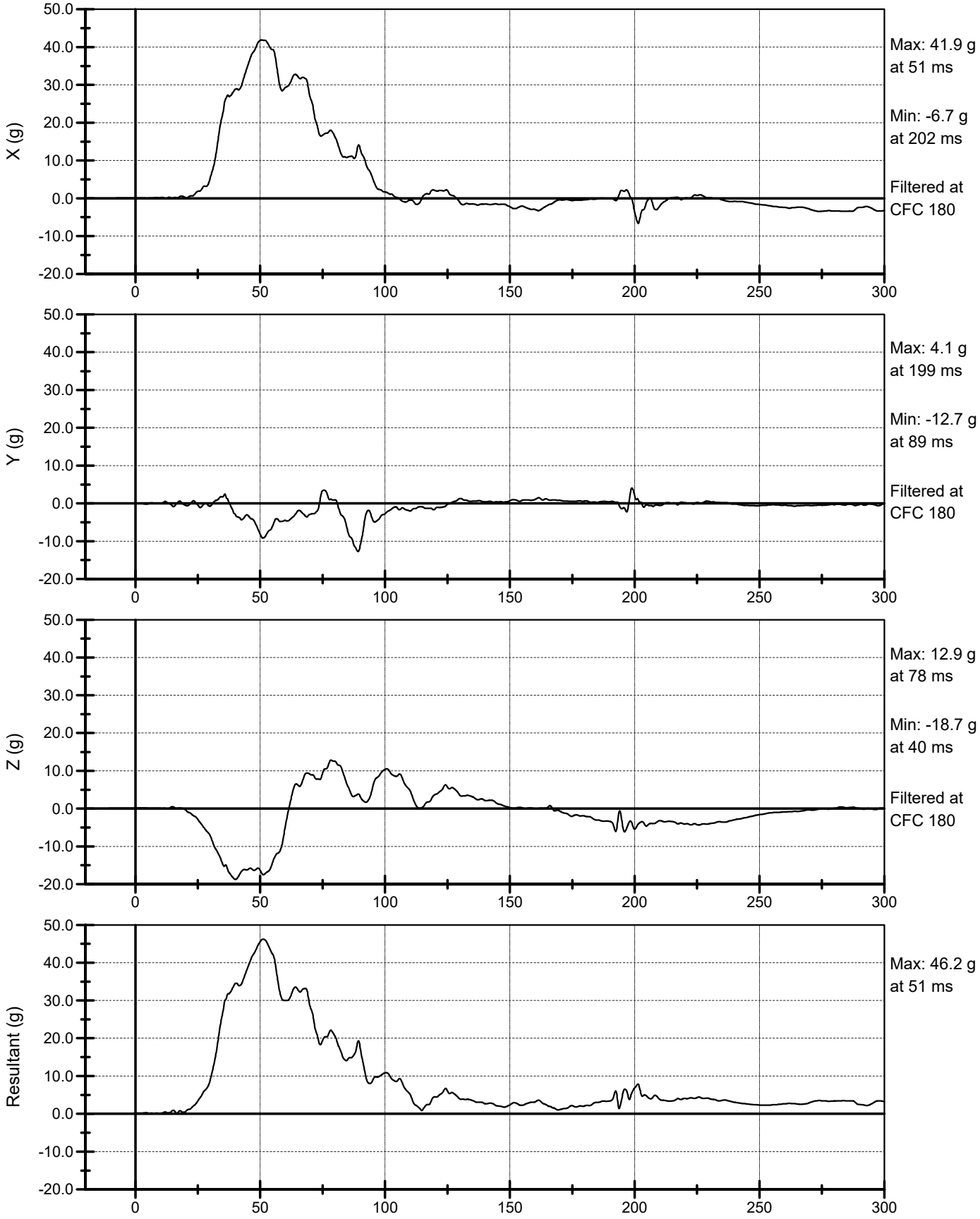
H.I.C. (36) = 261.6 From: 35.9 to 66.4 ms

H.I.C. (UN) = 461.4 From: 35.1 to 114.3 ms

UMTRI

Chest Acceleration

SD2202



Total time over 60 G was 0.0 ms

3.0 ms Clipped Peak = 45.3G

From: 49.7 to 52.7 ms

UMTRI

Belt Loads

SD2202