

Sled Impact Test

PR 2101
Product Design Group

**Frontal Impact of an Bentley LTR Wheelchair
Secured by a Surrogate Four-Point, Strap-Type Tiedown
and Loaded with a Hybrid III Midsize-Male ATD
Restrained by a Three-Point Belt with a
Commercial Wheelchair-Anchored Lap Belt**

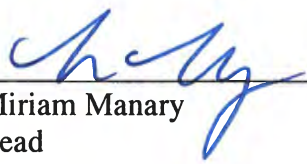
Tested in accordance with Annex A of
ANSI/RESNA WC-4:2017: Section 19, *Wheelchairs Used as Seats in Motor Vehicles*
and ISO 7176-19 (2008): *Wheeled Mobility Devices for Use in Motor Vehicles*


Test Date: October 8, 2021

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ACKNOWLEDGMENT AND DATA USE RESTRICTION

This test was sponsored by Product Design Group of Vancouver, Canada and was conducted in accordance with procedures set forth in Annex A of ANSI/RESNA WC-4:2017, Section 19: *Wheelchairs Used as Seats in Motor Vehicles*, hereafter referred to as WC19, and ISO 7176-19 (2008): *Wheeled Mobility Devices for Use in Motor Vehicles*. The wheelchair's performance has been measured and evaluated according to the performance criteria of 5.3.2 of WC19 and 5.2 of ISO 7176-19. Advertisements and marketing literature should refer to the requirements and provisions of WC19 and ISO 7176-19, 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 in accordance with Annex A of WC19 and ISO 7176-19. 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

The Bentley LTR Wheelchair was placed on the sled platform facing forward and secured using the surrogate four-point, strap-type tiedown specified in Annex D of WC19. The front and rear tiedown straps were hooked to the securement points provided on the wheelchair frame.

The wheelchair was loaded with a Hybrid III midsize-male anthropomorphic test device (ATD) that was restrained by a three-point belt comprised of a commercial, wheelchair-anchored lap belt and surrogate shoulder belt. The ends of the lap belt anchored to bolts on the rear securement brackets. The shoulder-belt upper anchorage was attached to a rigid structure on the sled platform at a position above and behind the ATD's shoulder that simulated a typical vehicle sidewall anchor point. The lower end of the shoulder belt was attached to the pin-bushing anchorage on a metal bracket sewn onto a length of webbing on the right half of the lap belt positioned near the right hip of the ATD. 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 frontal-impact response of the wheelchair and compliance with performance criteria in sections 5.3.2 of WC19 and 5.2 of ISO 7176-19. The following table provides further details about the test equipment and setup.

SUMMARY OF TEST SETUP AND PRE-TEST MEASUREMENTS

<p>GENERAL TEST INFORMATION</p> <p>Test number Test date Wheelchair type Wheelchair tiedown Occupant restraint Anthropomorphic Test Dummy (ATD) Wheelchair orientation Sled platform Desired impact velocity (delta V) Desired average sled deceleration</p>	<p>PR 2101 October 8, 2021 Bentley LTR Wheelchair Surrogate four-point, strap-type tiedown Three-point belt with WC-anchored lap belt Hybrid III midsize-male @ 76 kg (170 lb) Forward facing Rigid steel plate 48 kph (30 mph) 20 g</p>
<p>WHEELCHAIR TIEDOWN</p> <p>Front-to-rear anchor-point distance Rear tiedowns Lateral distance between anchor points Angle wrt horizontal Angle wrt to wheelchair center plane Anchor point to rear-wheel hub Length (anchor point to securement point)</p> <p>Front tiedowns Lateral distance between anchor points Angle wrt horizontal Angle wrt to wheelchair center plane Length (anchor point to securement point)</p>	<p>1283 mm (50.5 in) 356 mm (14.0 in) 38 degrees 0 degrees 191 mm (7.5 in) 495 mm (19.5 in)</p> <p>699 mm (27.5 in) 32 degrees 22 degrees 546 mm (21.5 in)</p>
<p>OCCUPANT RESTRAINT</p> <p>Shoulder belt upper anchor point location Behind ATD shoulder Above ATD shoulder Above sled platform Left of wheelchair centerline Angle of pelvic belt wrt to horizontal Angle of shoulder-belt Projected frontal view wrt horizontal Projected lateral view wrt horizontal</p>	<p>305 mm (12.0 in) 178 mm (7.0 in) 1168 mm (46.0 in) 305 mm (12.0 in) 68 degrees 55 degrees, measured on ATD torso 30 degrees, measured above ATD shoulder</p>
<p>FOOTSTRAP POSITIONING</p> <p>Below ATD knee center In front of ATD knee center</p>	<p>127 mm (5.0 in) 381mm (15.0 in)</p>
<p>ATD POSITIONING</p> <p>Shoulder height above sled platform H-point height above sled platform</p>	<p>991 mm (39.0 in) 508 mm (20.0 in)</p>
<p>WHEELCHAIR</p> <p>Weight Wheelbase Seatback angle wrt vertical Seatback height (with headrest) Seatpan angle wrt horizontal Seat surface height from floor @ SB junction Seatpan length</p>	<p>30.0 kg (66 lb) 483 mm (19.0 in) 15 degrees 508 mm (20.0 in) 5 degrees 406 mm (16.0 in) 483 mm (19.0 in)</p>
<p>POSTURAL SUPPORT DEVICES USED</p>	<p>Foot, arm, and head supports</p>

TEST RESULTS

During the test, the wheelchair sustained impact intact. The wheelchair was in an upright position at the completion of the test with the ATD torso upright. The ATD could be released from the wheelchair and three-point belt without the use of tools.

The maximum forward excursion of point P on the wheelchair seating system was 77 mm, which is below the ISO 7176-19 and WC19 excursion limit of 200 mm. No deformation, failure, or separation of the securement points was observed and the wheelchair could be released from the four tiedown hooks without the use of tools. No hardware weighing over 100 g detached from the wheelchair and no sharp edges were created with potential for occupant contact.

Peak forward excursion of the ATD's head was limited to approximately 445 mm and peak forward knee excursion was about 272 mm, which are below the ISO 7176-19 and WC19 limits of 650 mm and 375 mm, respectively. The post-test height of the ATD's H-point decreased 3% from the pre-test height, which is within the 20% limit. The ATD's head travelled 369 mm rearward from its initial position, which is within the ISO 7176-19 and WC19 limit of 450 mm.

The results of this test show that the Bentley LTR Wheelchair with four securement points and a wheelchair-anchored lap belt *meets* all of the performance criteria for wheelchair dynamic strength specified in 5.3.2 of ANSI/RESNA WC-4:2017, Section 19 or in 5.2 of ISO 7176-19. The following tables summarize the test results and compliance with WC19 and ISO 7176-19.

SUMMARY OF TEST RESULTS

GENERAL TEST INFORMATION Test number Actual impact velocity (delta V) Actual average sled deceleration level Actual peak sled deceleration level Total time of deceleration over 20 g Total time of deceleration over 15 g Deceleration pulse duration	PR 2101 48 kph (29.8 mph) 21.5 g 23.6 g 37.0 ms 65.0 ms 75.8 ms
ATD MEASUREMENTS Peak resultant head acceleration Peak resultant chest acceleration Head Injury Criterion (15 ms) Maximum forward head excursion [†] Maximum forward knee excursion ^{††} Maximum rearward head excursion ^{††} Average post-test H-pt ht above sled platform	54 g 44 g 288 445 mm (17.5 in) 272 mm (10.7 in) 369 mm (14.5 in) 495 mm (19.5 in) 3% change
TIEDOWN LOADS Peak left-rear lower tiedown strap force Peak right-rear lower tiedown strap force	16303 N (3665 lb) 18531 N (4166 lb)
BELT LOADS AND PELVIC BELT ANGLE Peak left pelvic-belt load Peak shoulder-belt load	10395 N (2337 lb) 10013 N (2251 lb)
WHEELCHAIR MEASUREMENTS^{††} Maximum forward wheelchair excursion at Point P* Maximum forward excursion of front-wheel hub Maximum forward excursion of rear-wheel hub	77 mm (3.0 in) 31 mm (1.2 in) 53 mm (2.1 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 PERFORMANCE TO ANSI/RESNA WC-4:2017, SECTION 19
SLED TEST PR 2101

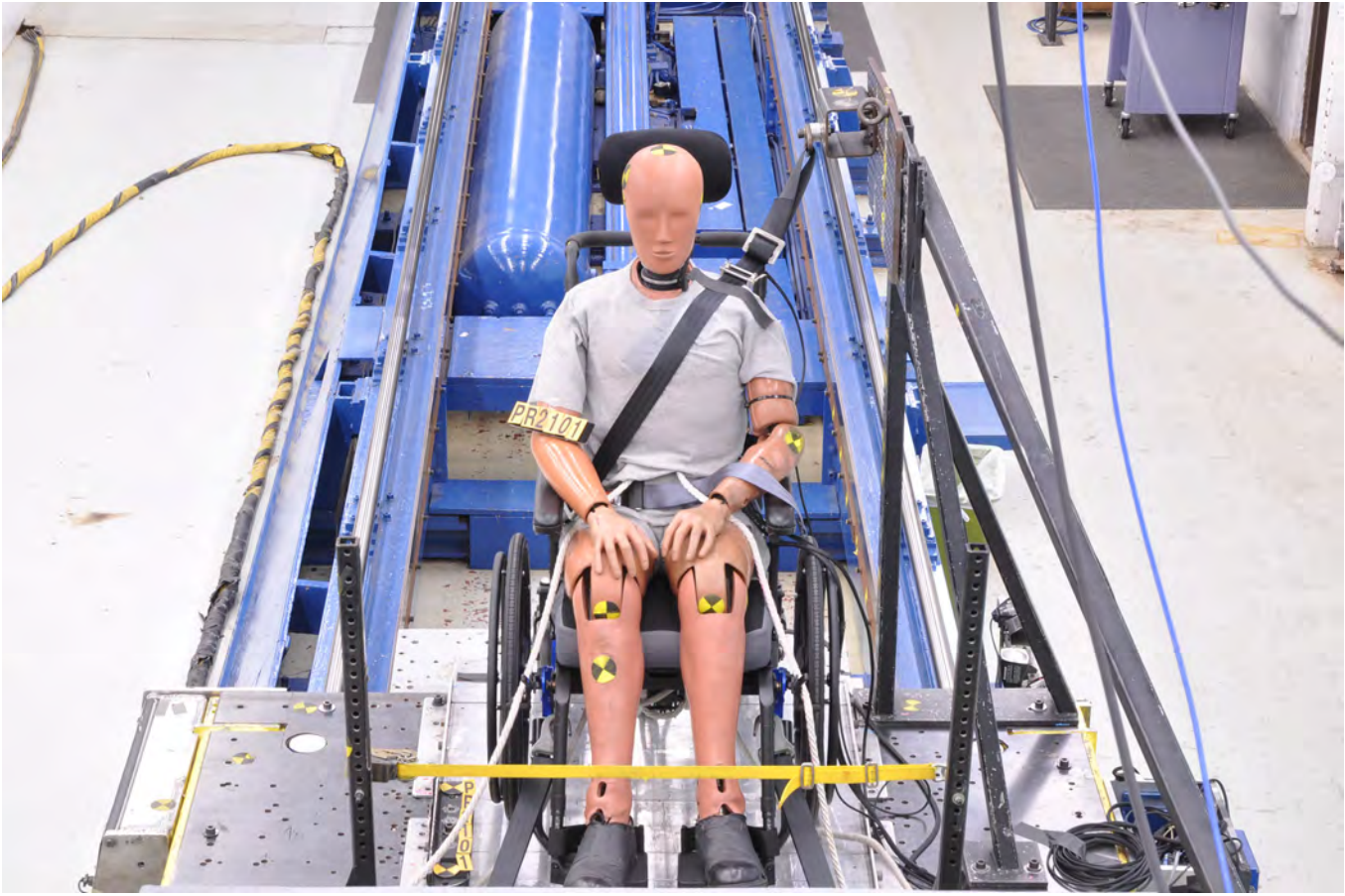
Requirement		Observed Performance	
WC19 Clause	Description	Description	Pass/Fail
5.3.2a	Structural components of the WC securement points shall not completely fail	There were no securement-point failures.	Pass
5.3.2b	Deformation of WC securement points must not prevent disengagement of hook	Hooks could be easily removed from securement points.	Pass
5.3.2c	WC upright and on test platform	The WC was upright on the test platform.	Pass
5.3.2d	ATD must be in WC seat with torso leaning not more than 45°	The ATD was seated in the WC after the test with torso upright.	Pass
5.3.2e	Detached hardware cannot exceed 150 g	No hardware > 150 g detached from the WC.	Pass
5.3.2f	WC must not have sharp edges with potential for occupant contact	There were no sharp edges with potential for occupant contact.	Pass
5.3.2g	Primary load-carrying components cannot completely fail, unless there is a backup mechanism that does not fail	No primary load-carrying parts completely failed.	Pass
5.3.2h	Forward excursion of Point P < 200 mm	77 mm	Pass
	Forward knee excursion < 375 mm	272 mm	Pass
	Forward head excursion < 650 mm	445 mm	Pass
	Rearward head excursion < 450 mm	369 mm	Pass
5.3.2i	Ratio of ATD knee excursion to Point P excursion must exceed 1.1.	N/A – a WC-anchored lap-belt restraint was used.	Pass
5.3.2j	Locking mechanisms of tilt seating cannot release or completely fail.	No locking mechanisms released or failed.	Pass
5.3.2k	Post-test height of ATD H-point shall be \geq 20% of pretest height	Average H-point height decreased 3%.	Pass
5.3.2l	Seating system cannot break free from WC at any attachment point.	The seating system remained attached at all attachment points.	Pass
5.3.2mi	Batteries must be within WC footprint	N/A.	N/A
5.3.2mii	Batteries must remain attached to battery compartment	N/A.	N/A
5.3.2miii	Batteries cannot move into the WC user's space.	N/A.	N/A
5.3.2n	WC cannot cause complete failure of the surrogate WTORS.	No failure of the WTORS occurred.	Pass
5.3.2o	Tiedown hooks of WTORS shall remain engaged with WC securement points.	All tiedown hooks were engaged with the WC securement points at the end of the test.	Pass
5.3.2p	WC-anchored belt restraints shall not detach or completely fail.	The WC-anchored belt restraints did not fail.	Pass

SUMMARY OF WHEELCHAIR PERFORMANCE TO ISO 7176-19 (2008)
SLED TEST PR 2101

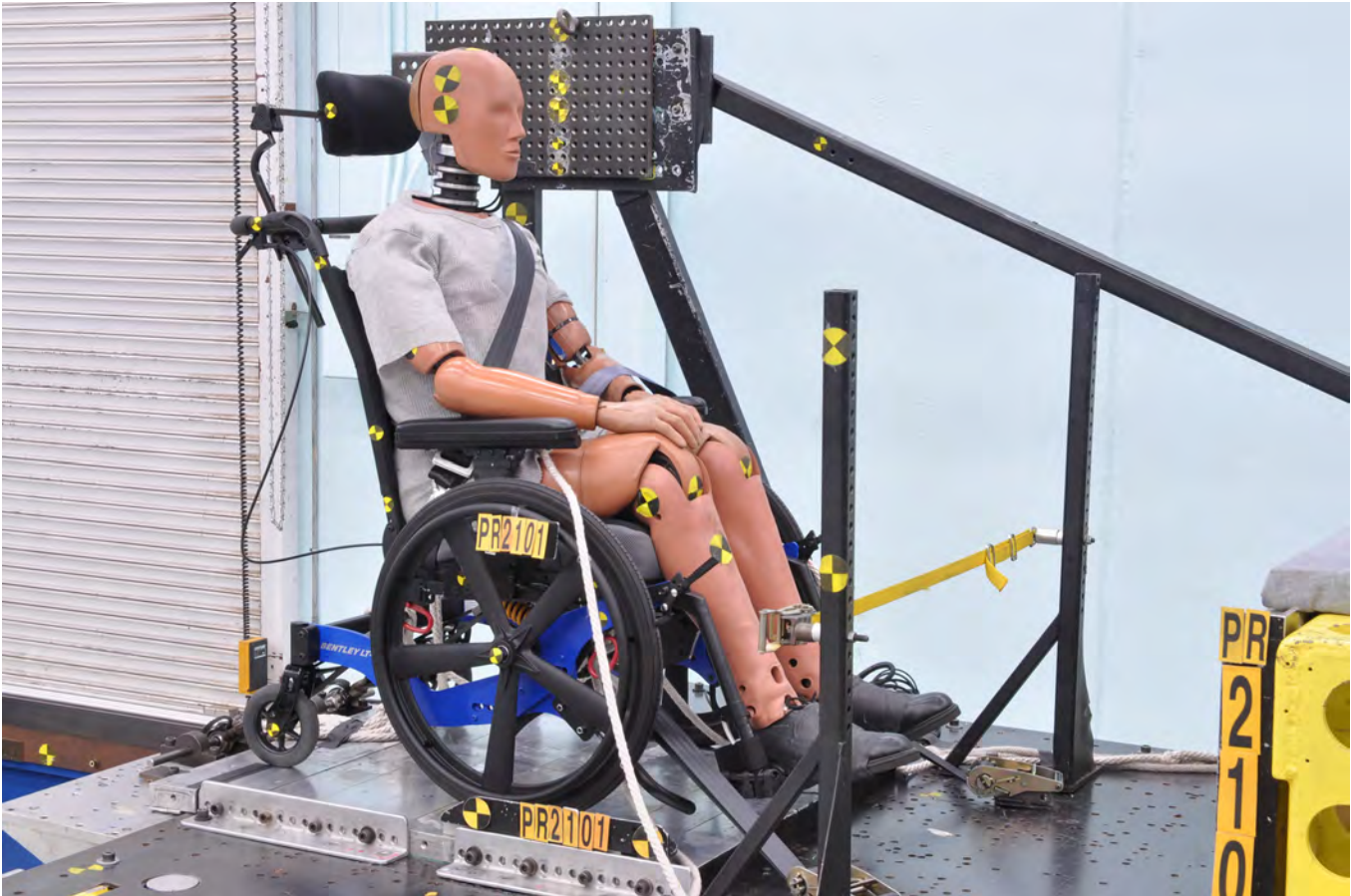
Requirement		Observed Performance	
ISO 7176-19 Clause	Description	Description	Pass/Fail
5.2.1a	Forward excursion of Point P < 200 mm	77 mm	Pass
	Forward knee excursion < 375 mm	272 mm	Pass
	Forward head excursion < 650 mm	445 mm	Pass
	Rearward head excursion < 450 mm	369 mm	Pass
5.2.1b	Ratio of ATD knee excursion to Point P excursion must exceed 1.1.	N/A – a WC-anchored lap-belt restraint was used.	N/A
5.2.1c	Batteries must be within WC footprint	N/A.	N/A
	Batteries cannot move into the WC user's space.	N/A.	N/A
5.2.2a	WC must be upright and on test platform and the ATD must be in WC seat with torso leaning not more than 45° in any direction	The WC was upright on test platform and the ATD was seated with torso upright.	Pass
5.2.2b	WC securement points cannot show signs of material failure	There were no securement-point failures.	Pass
5.2.2c	Rigid components with a mass of >100 g cannot detach from the WC.	No hardware > 100 g detached from the WC.	Pass
5.2.2d	WC must not have sharp edges with potential for occupant contact	There were no sharp edges with potential for occupant contact.	Pass
5.2.2e	Primary load-carrying components shall not show visible signs of structural failure unless there is a backup system to provide support	No primary load-carrying parts showed signs of failure.	Pass
5.2.2f	Locking mechanisms of tilt-in-space seat adjusters shall not show signs of failure	Locking mechanisms of the seating system did not show signs of failure.	Pass
5.2.2g	Removal of ATD from WC shall not require use of tools	No tools were required.	Pass
5.2.2h	Release of WC from tiedown system shall not require use of tools	No tools were required.	Pass
5.2.2i	Post-test height of ATD H-point shall not be more than 20% lower than pretest height	The average post-test H-point height decreased 3%.	Pass
5.2.2j	WC cannot cause partial or complete failure of the webbing of the surrogate WTORS	The SWTORS did not fail.	Pass

Note: WC = wheelchair , N/A = not applicable

PRE-TEST PHOTOS



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PR210102.JPG



PR210103.JPG



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PR210105.JPG



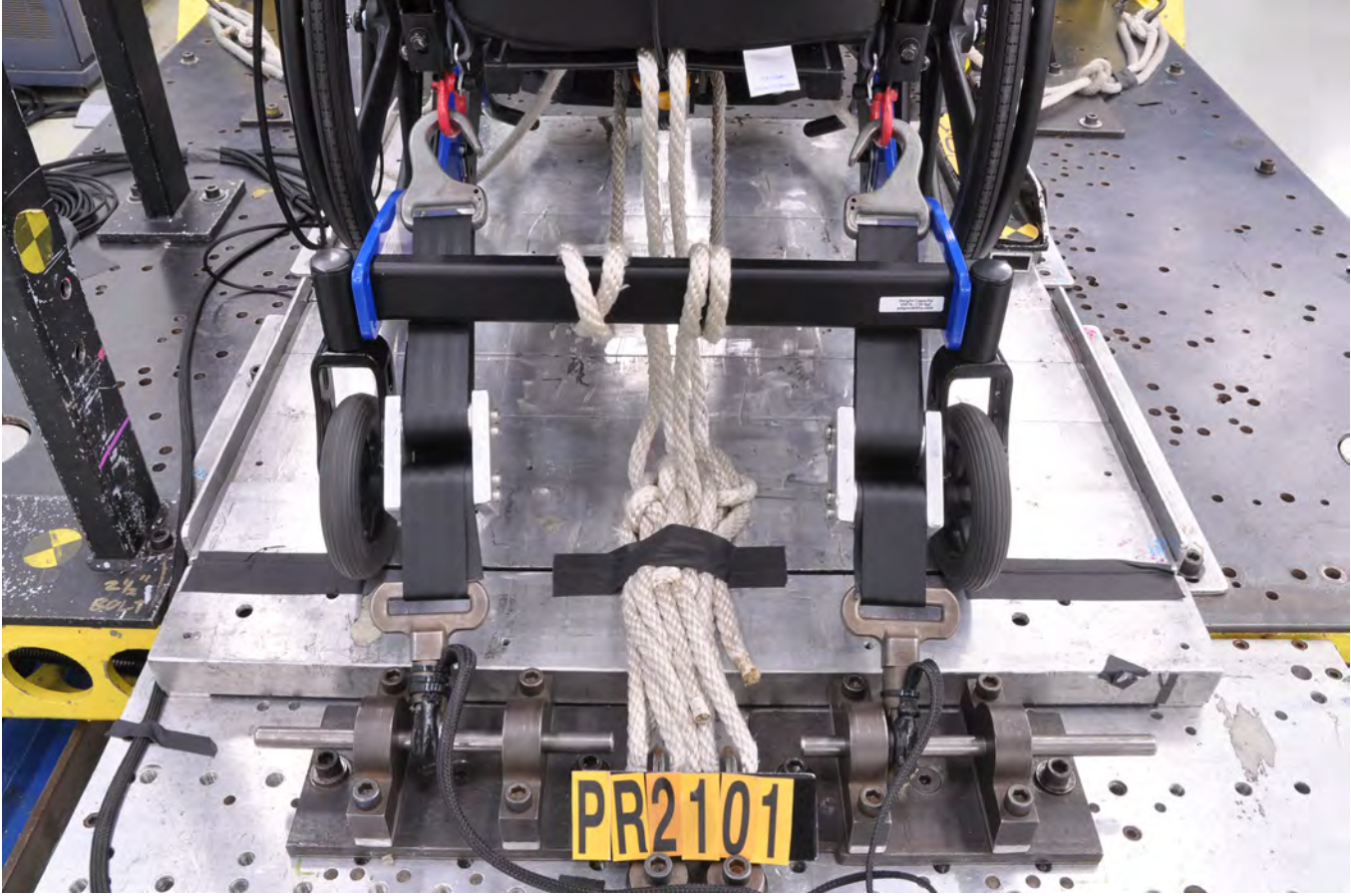
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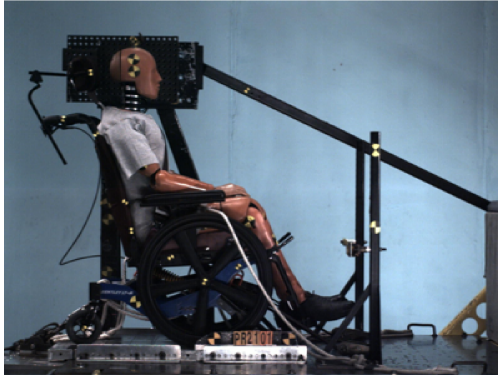


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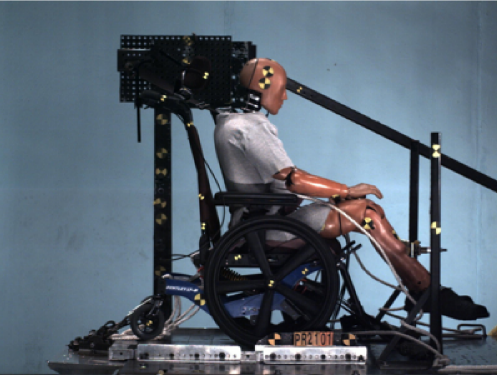
TEST AND POST-TEST PHOTOS

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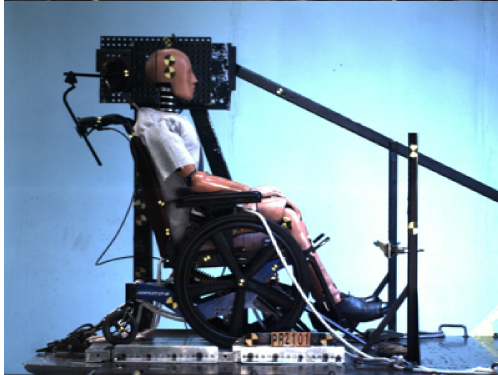
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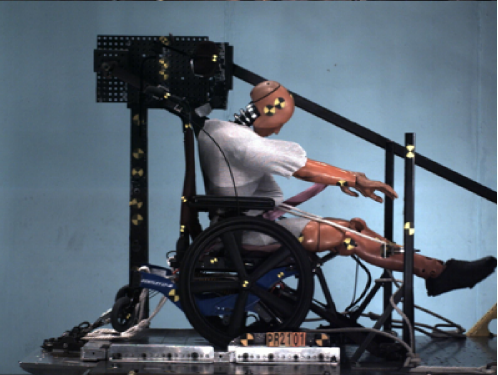
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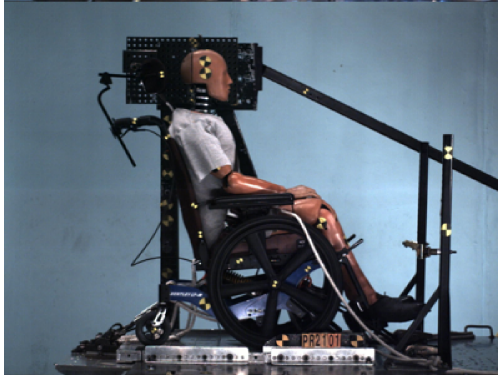
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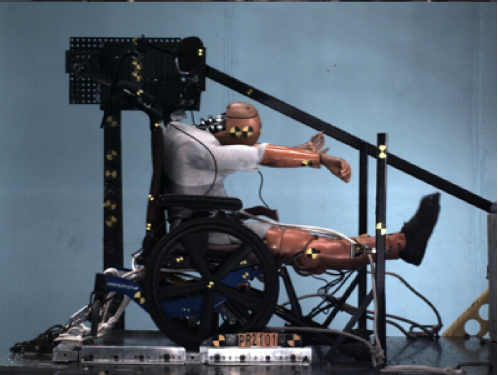
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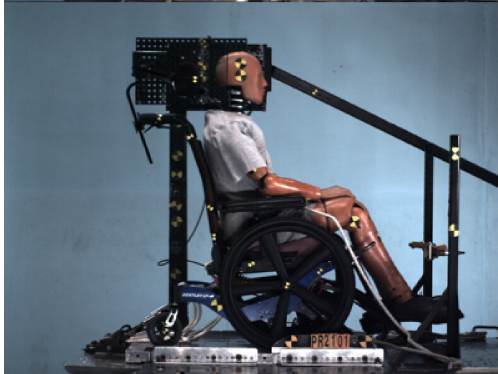
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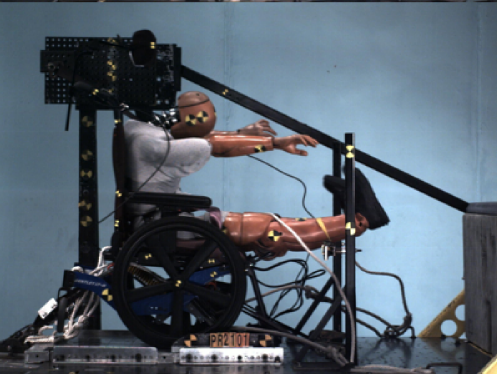
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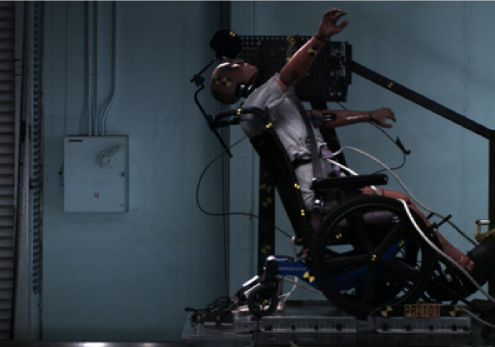


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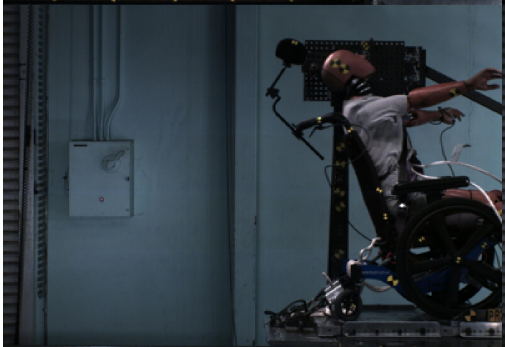
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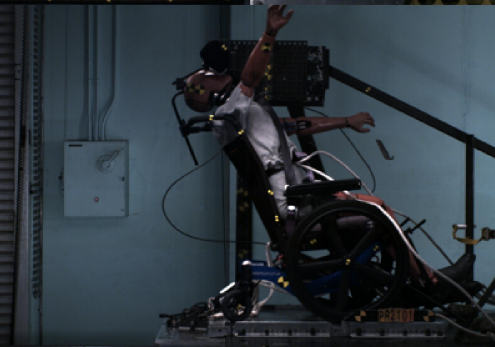
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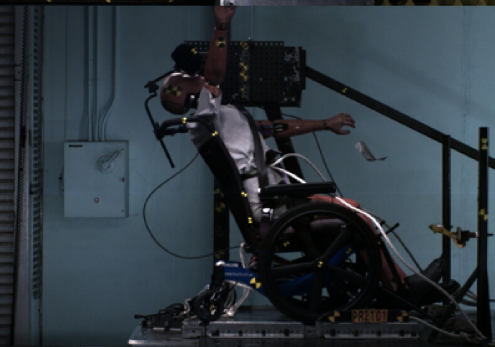
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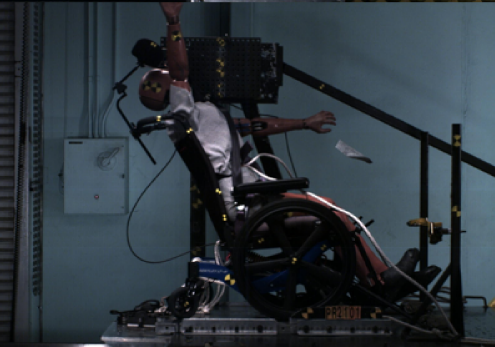
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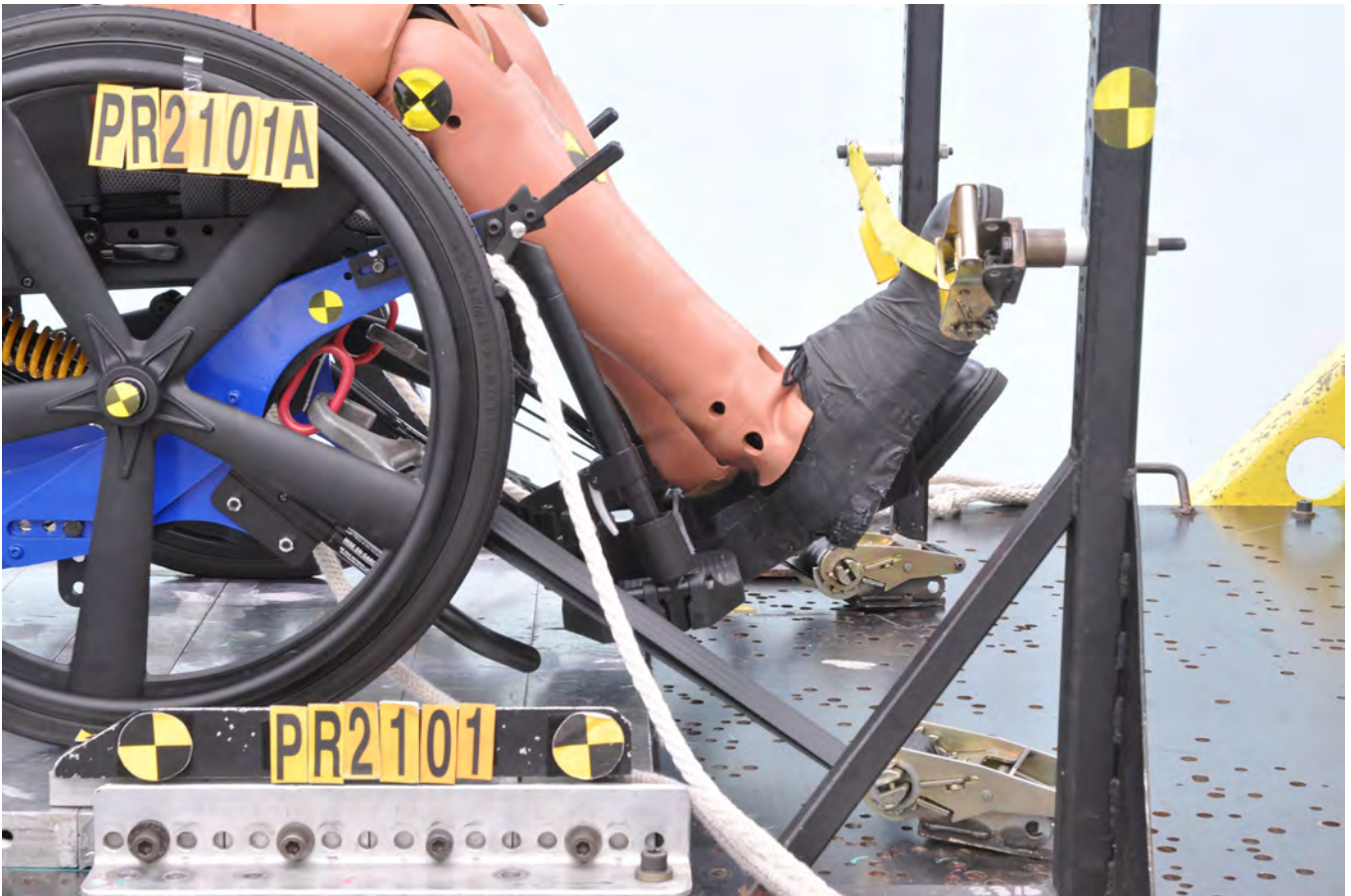
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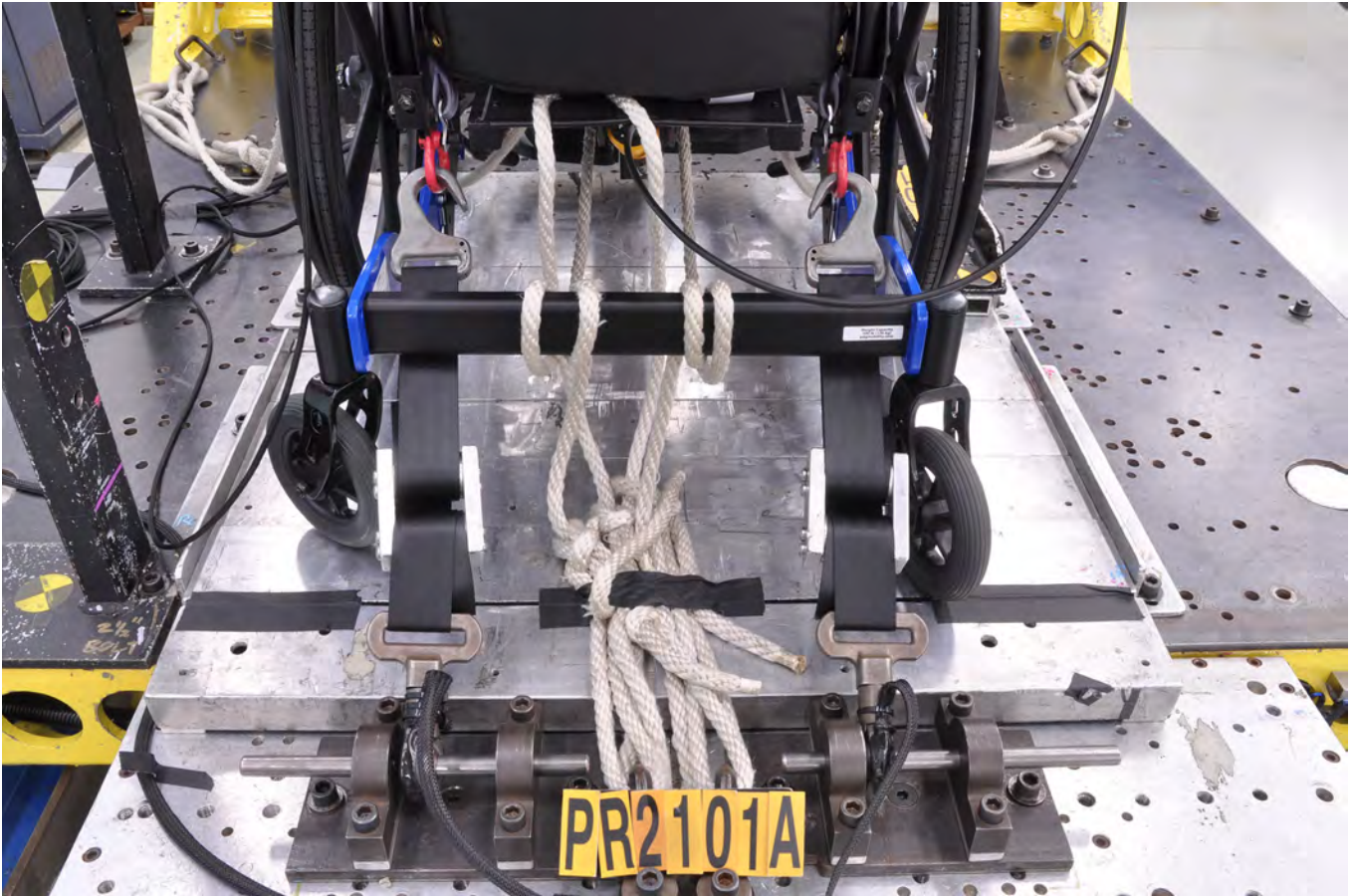
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TEST SIGNALS



Results

PR2101

Nominal = 30 mph / 20 g avg Pressures: 134.5/1174
 Actual[P] = 47.9 km/h (29.8 mph) (74.7%) Plateau Avg.= -21.5 G; Peak = -23.6 G

Dummy: Hybrid III 50th Male (kg) Buck Weight: 2203
 Buck: steel plate, risers, extensions, bolster, shoulder anchor brace

PDG Bentley
 WCA lap, SWTORS

Sled Summary

Sled Pulse Duration = 75.8 ms	Efficiency = $V_{out} / V_{in} = 20.5 / 27.4 = 74.7\%$
Sled Plateau Average Level = -21.5 G	Sled Delta V = 47.9 kph (29.8 mph)
Sled Decel Peak = -23.6 G	Stopping Dist. (est) = .534 m
Total time under -20.0 G was 37.0 ms	
Continuous time under -15.0 G was 65.0 ms	

Head Acceleration

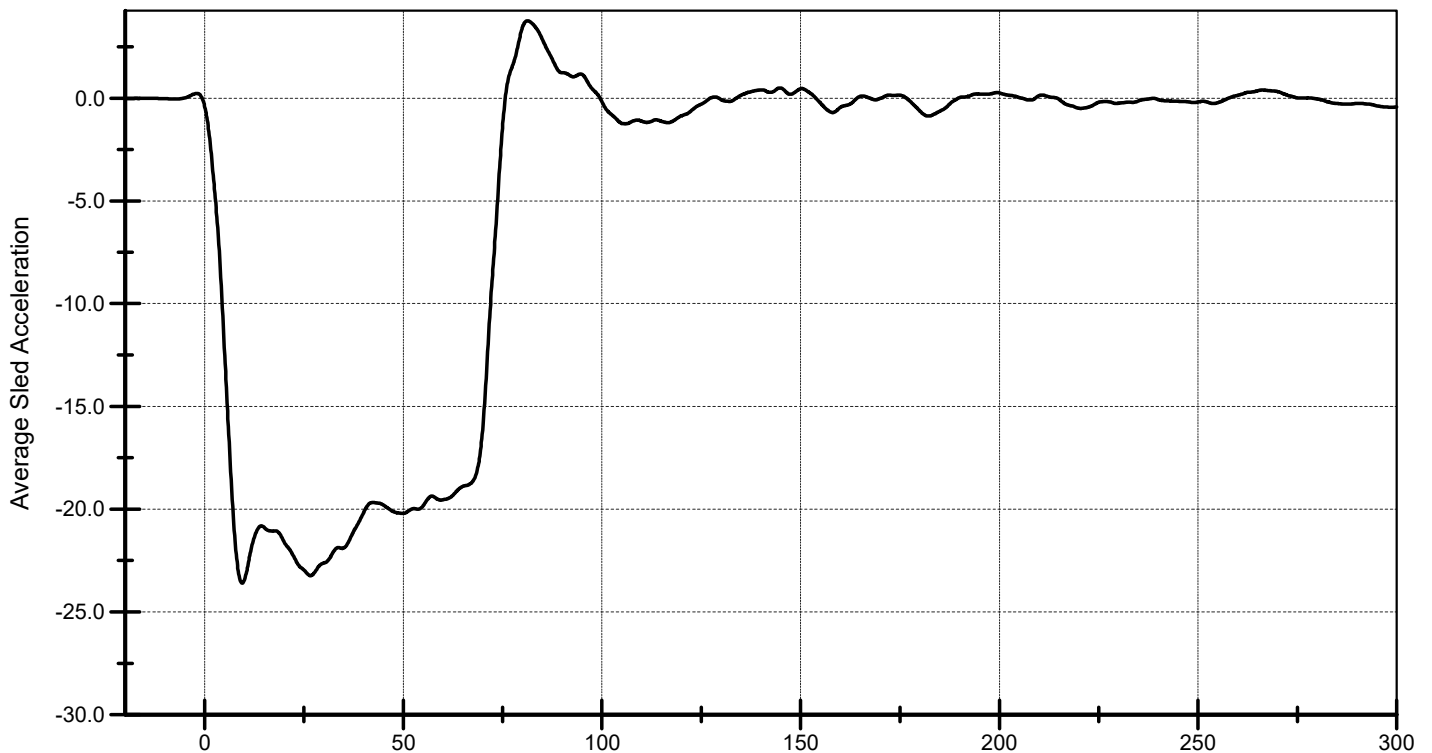
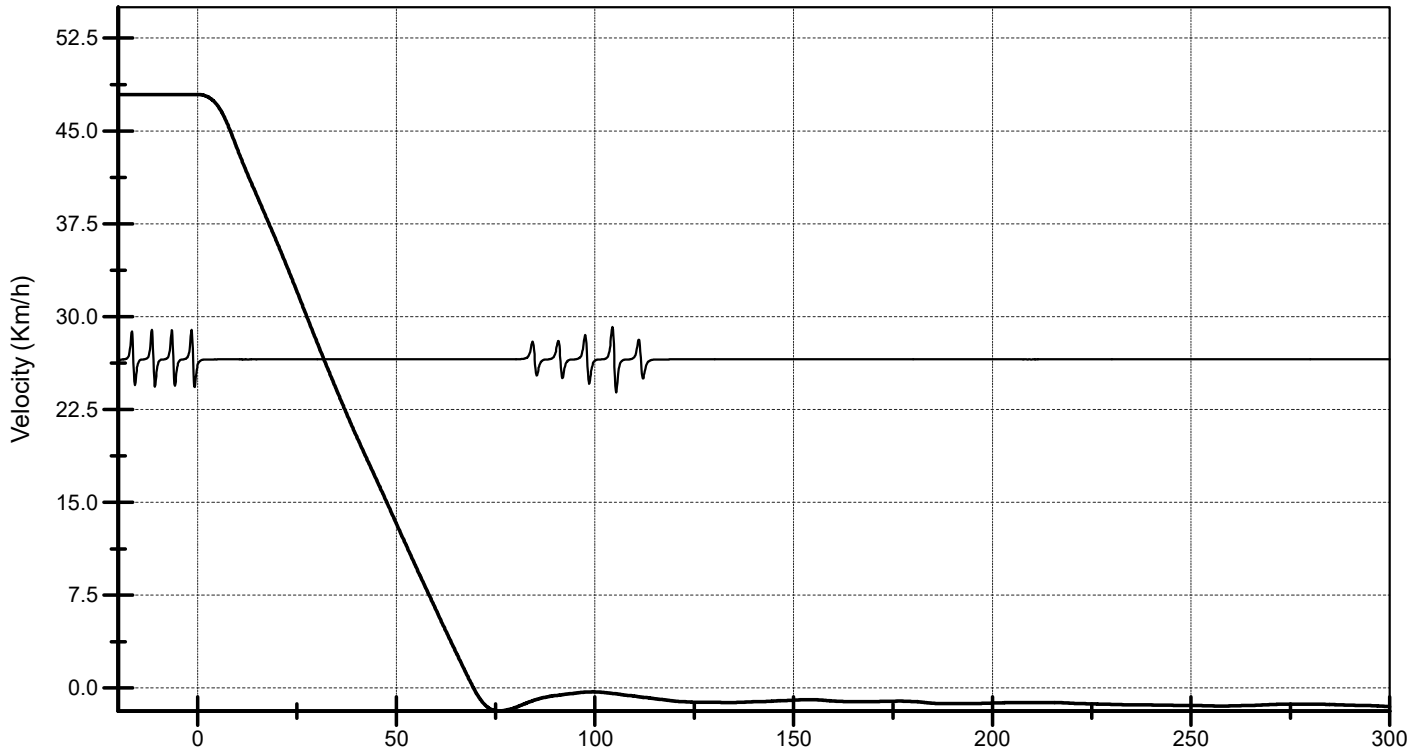
X	-6.3 g @ 286 ms	42.8 g @ 99 ms
Y	-4.0 g @ 15 ms	23.4 g @ 68 ms
Z	-43.7 g @ 74 ms	.5 g @ 109 ms
Resultant	Peak: 53.5 g @ 83 ms	
H.I.C. (UN) = 688.5	From 48.7 to 112.9 ms	
H.I.C. (36) = 568.6	From 66.5 to 102.5 ms	
H.I.C. (15) = 287.6	From 72.6 to 87.6 ms	

Chest Acceleration

X	-8.9 g @ 162 ms	42.8 g @ 66 ms
Y	-8.7 g @ 145 ms	8.9 g @ 160 ms
Z	-6.2 g @ 48 ms	9.6 g @ 102 ms
Resultant	Peak: 43.5 g @ 66 ms	
3.0 ms Clipped Peak = 41.9G	From: 62.3 to 66.3 ms	
Total time over 60 G was 0.0 ms		

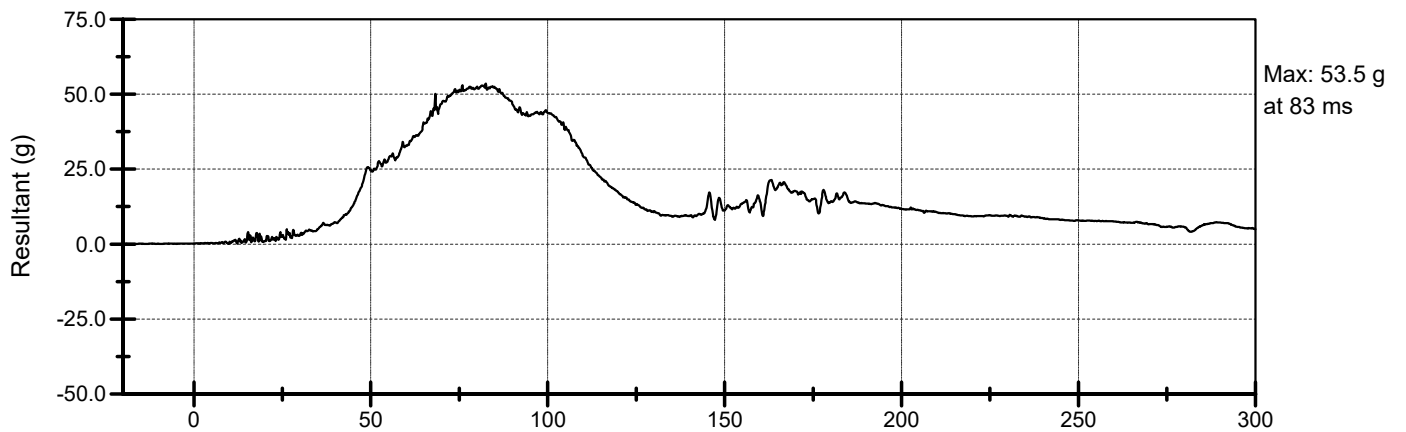
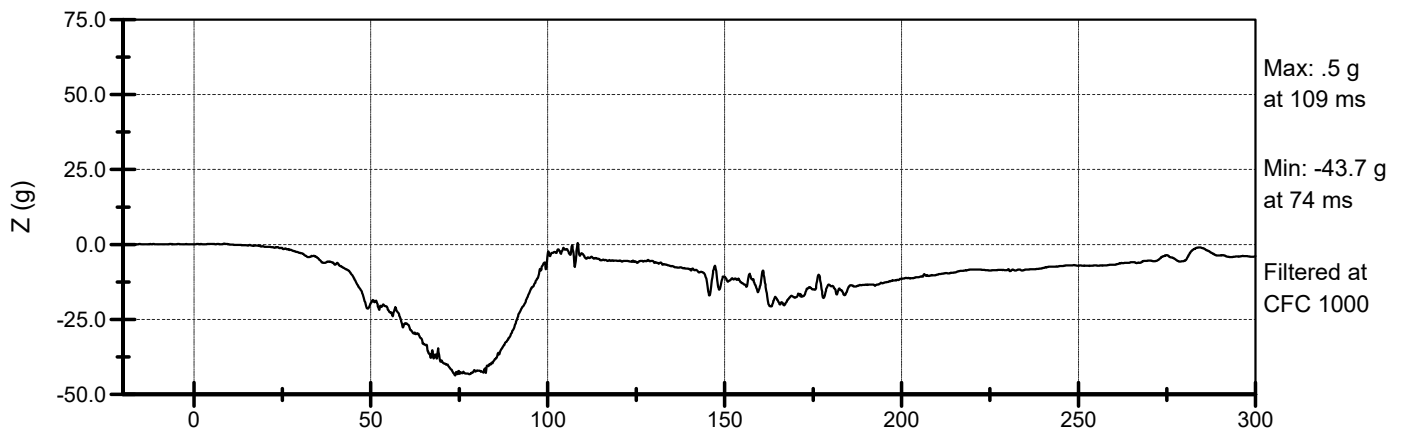
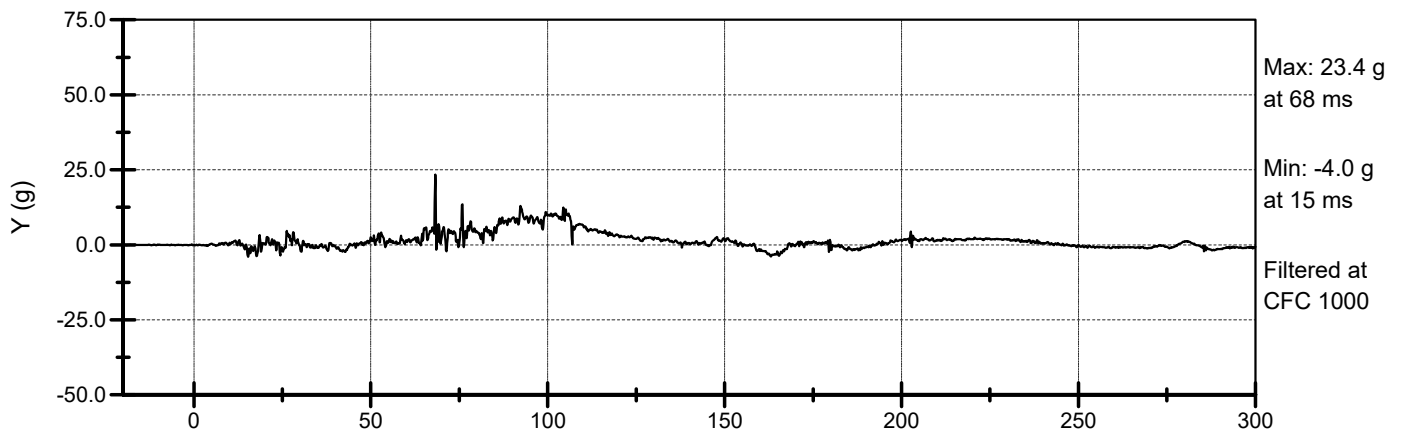
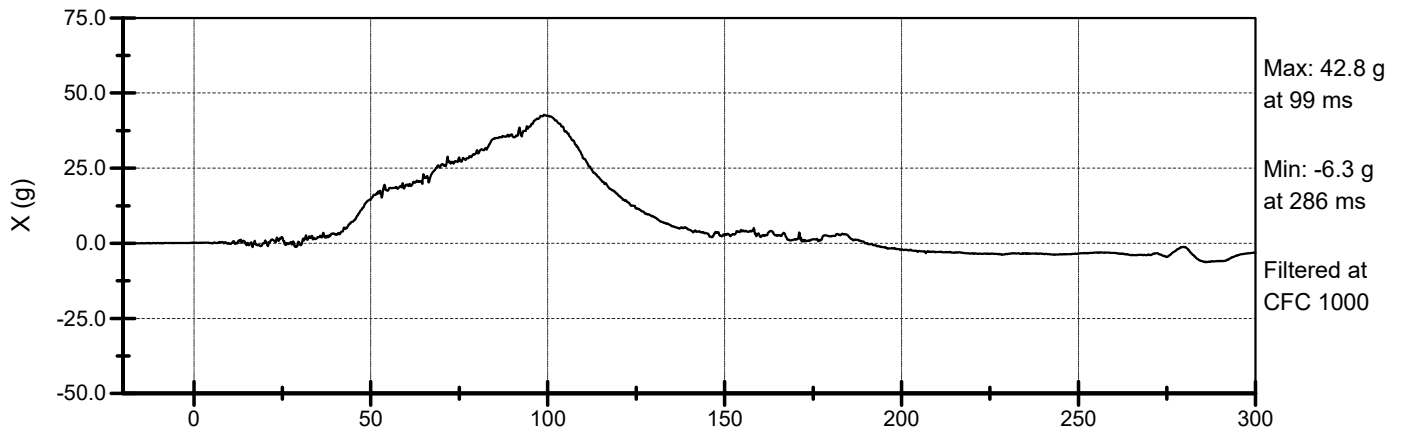
Belt Loads

Lap Belt Load	-4.1 N (-.9 lb) @ 3 ms	10394.2 N (2336.7 lb) @ 66 ms
Shoulder Belt Load	-8.6 N (-1.9 lb) @ 209 ms	10010.9 N (2250.5 lb) @ 74 ms
Left Rear Tiedown Load	-774.0 N (-174.0 lb) @ 157 ms	16301.9 N (3664.8 lb) @ 67 ms
Right Rear Tiedown ...	-882.9 N (-198.5 lb) @ 257 ms	18532.2 N (4166.2 lb) @ 68 ms



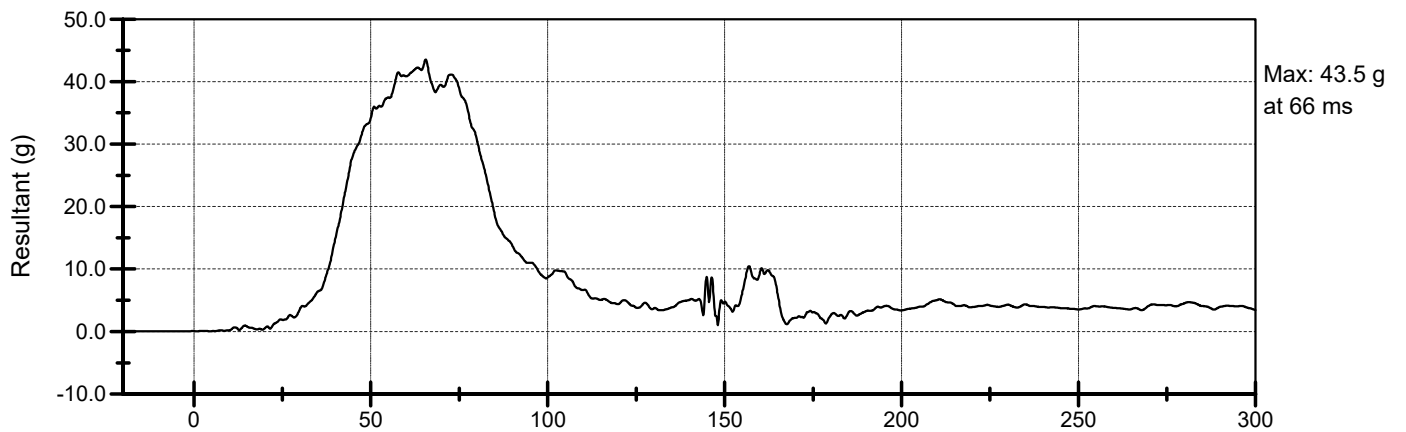
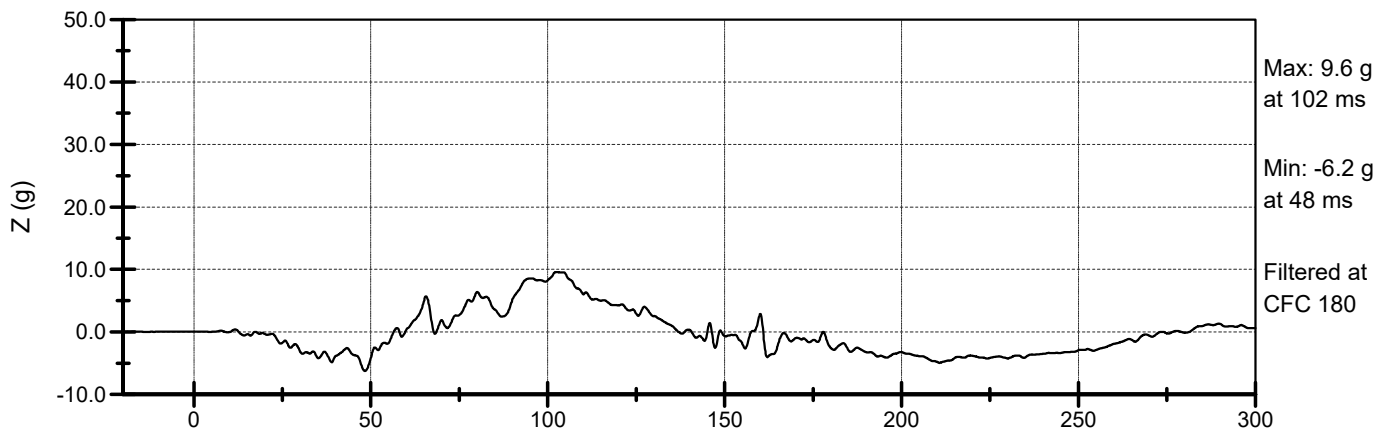
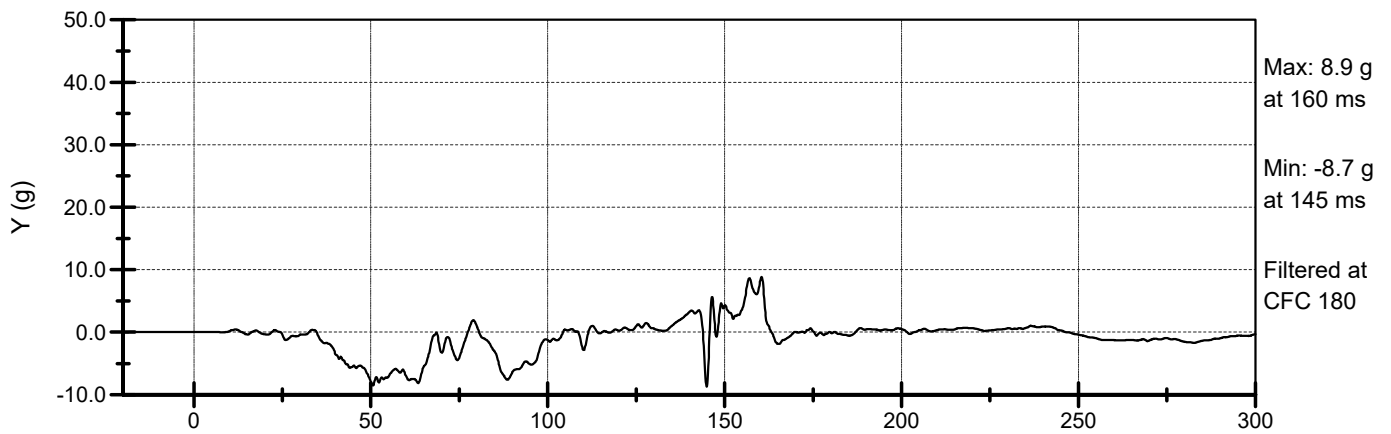
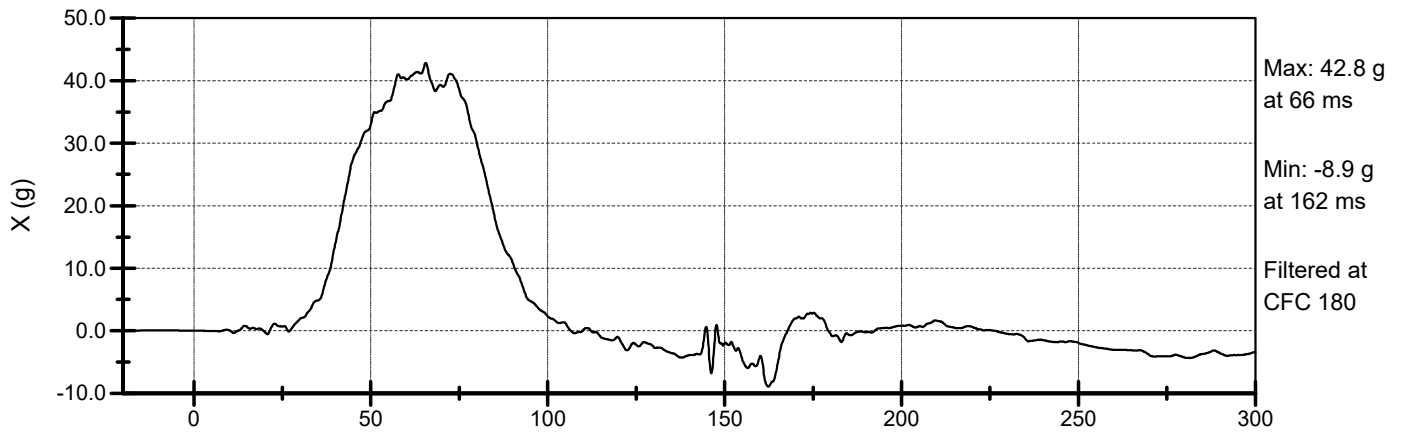
Continuous time under -15.0 G was 65.0 ms
Total time under -20.0 G was 37.0 ms
Sled Decel Peak = -23.6 G
Sled Plateau Average Level = -21.5 G
Sled Pulse Duration = 75.8 ms

Stopping Dist. (est) = .534 m
Sled Delta V = 47.9 kph (29.8 mph)
Efficiency = $V_{out} / V_{in} = 20.5 / 27.4 = 74.7\%$



H.I.C. (15) = 287.6
H.I.C. (36) = 568.6
H.I.C. (UN) = 688.5

From: 72.6 to 87.6 ms
From: 66.5 to 102.5 ms
From: 48.7 to 112.9 ms



Total time over 60 G was 0.0 ms

3.0 ms Clipped Peak = 41.9G

From: 62.3 to 66.3 ms

