DRAFT INTERNAL RESEARCH REPORT

EVALUATION OF INFLATABLE BOOSTER SEATS

A comparison of performance in rear seats of vehicles undergoing crash tests and the CMVSS 213.2 type sled test

Part 2: GoBooster®

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1 Introduction

The evaluation was conducted in response to concerns raised by international members attending GRSP WP.29 (November 2011) regarding the safety of inflatable and partially inflatable child restraints. The regulatory and compliance branches of Transport Canada initiated a review of the situation in Canada to determine if further testing and potential regulatory efforts would be needed to address the safety of inflatable restraints. Six GoBooster® seats were provided to the Crashworthiness Division for evaluative testing.

2 METHODOLOGY:

2.1 TEST MATRIX

To date two in-vehicle crash tests and one CMVSS 213 type sled test have been conducted with the GoBooster® restraint. The two in-vehicle tests were frontal regulatory type (CMVSS 208) frontal rigid barrier tests.

2.1.1 FRONTAL IMPACT CRASH TEST 1

TEST CONFIGURATION

Test vehicle: 2011 Dodge Grand Caravan;
Test mass: 2201 kg
Velocity: 40 km/h

The vehicle was undergoing a full frontal rigid barrier CMVSS 208 type crash test. The driver and right front passenger seats were occupied by Hybrid III 5th percentile anthropometric test devices (ATDs) and placed in the mid seat track position. Pre-test photos of the vehicle alignment with the barrier are shown in Figure 1.

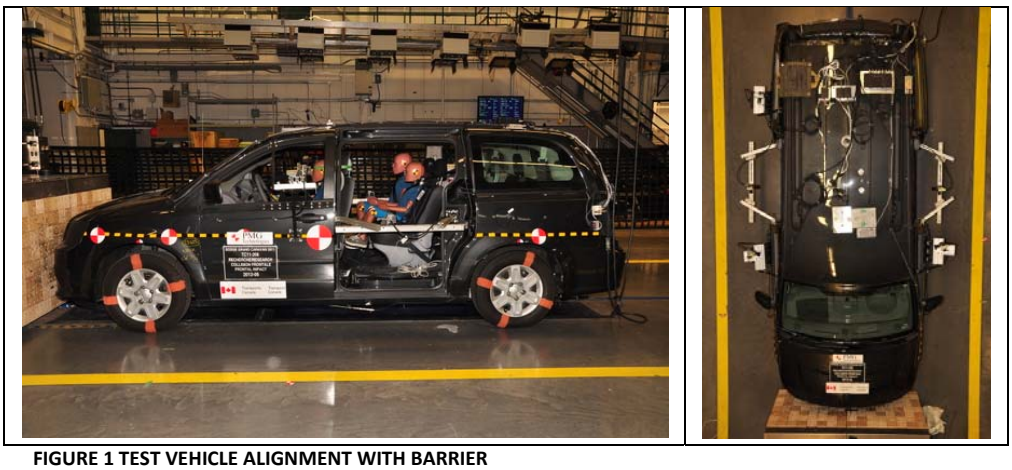

FIGURE 1 TEST VEHICLE ALIGNMENT WITH BARRIER

ATD PLACEMENT IN SECOND ROW SEAT OF TEST VEHICLE

Behind the driver: An instrumented Hybrid III 6 - year-old ATD was placed on a GoBooster® booster seat as per manufacturer instructions[1]. The dummy was seated upright and a shield was positioned over the front region of the pelvis to prevent the lap belt from penetrating the space between the pelvis and upper femurs. Pre-test position of the lap and torso belt displayed good fit though the seatbelt was difficult to route through guides. The centre photo shown in Figure 2 displays the inboard belt routing while the right hand photo displays the outboard routing.

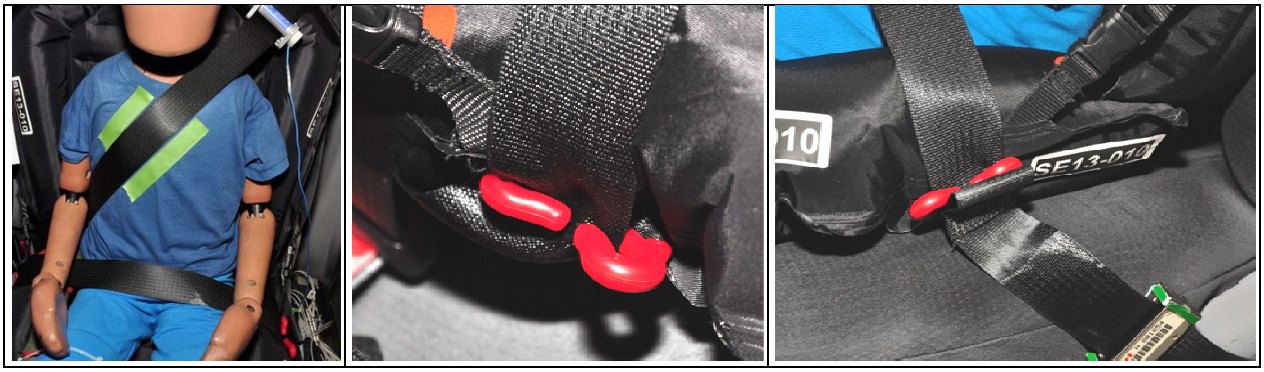

FIGURE 2 PRE-TEST POSITION OF HYBRID III 6 - YEAR-OLD PLACED ON THE GOBOOSTER® IN DODGE GRAND CARAVAN

Behind the right front passenger: An instrumented Hybrid III 10 - year-old ATD was placed on a GoBooster® booster seat as per manufacturer instructions[1]. The lower spine of the ATD was set to 0 degrees, which represents a relaxed. Pre-test position of the lap and torso belt displayed good fit though the seatbelt was difficult to route through guides. The centre photo of Figure 3 displays the inboard belt routing. Note how the lap portion of the belt must be brought forward to be routed through the guide. The right most photo displays the outboard routing.

FIGURE 3 PRE-TEST POSITION OF HYBRID III 10 - YEAR-OLD PLACED ON THE GOBOOSTER® IN DODGE GRAND CARAVAN

[1] PICTOGRAM INSTRUCTING THAT THE SHOULDER PORTION OF THE SEAT BELT BE TUCKED BETWEEN THE SEATBACK AND CUSHION OF THE BOOSTER SEAT WAS NOT CORRECTLY INTERPRETED BY THE TECHNICIAN. IN BOTH INSTALLATIONS THE SHOULDER BELT PATH WAS FORWARD OF THE BOOSTER SEAT CUSHION/BACK JUNCTION BUT INBOARD OF CONNECTING STRAP.

INSTRUMENTATION

Test vehicle: Tri-axial accelerometers at the base of the left B-pillar
Tri-axial accelerometers at the base of the right B-pillar
Tri-axial accelerometers at approximate location of vehicle center of gravity
Lap and torso belt load measurements for all seating positions

HIII 10 and 6-year-olds:
Tri-axial accelerometers in head, chest, pelvis
Uni- axial accelerometers in the sternum and lower spine
Load sensing in upper and lower neck
Chest deflection

All data were processed as per the Society of Automotive Engineers (SAE J-211). High-speed videos were used to record a frontal view of both seats and a lateral view of each seat at a rate of 1000 frames/second. The rear passenger car doors were removed in order to obtain an enhanced camera view of the dummy and booster cushion motion during the crash event.

2.1.2 FRONTAL IMPACT CRASH TEST 2

TEST CONFIGURATION

Test vehicle: 2011 Ford Fiesta 4-door sedan; automatic transmission
Test mass: 2047.60 kg
Velocity: 40 km/h

The vehicle was undergoing a full frontal rigid barrier CMVSS 208 type test. The driver and right front passenger seats were occupied by Hybrid III 5th percentile anthropometric test devices (ATDs) placed in the mid seat track position. Pre-test photos of the vehicle alignment with the barrier are shown in Figure 4.

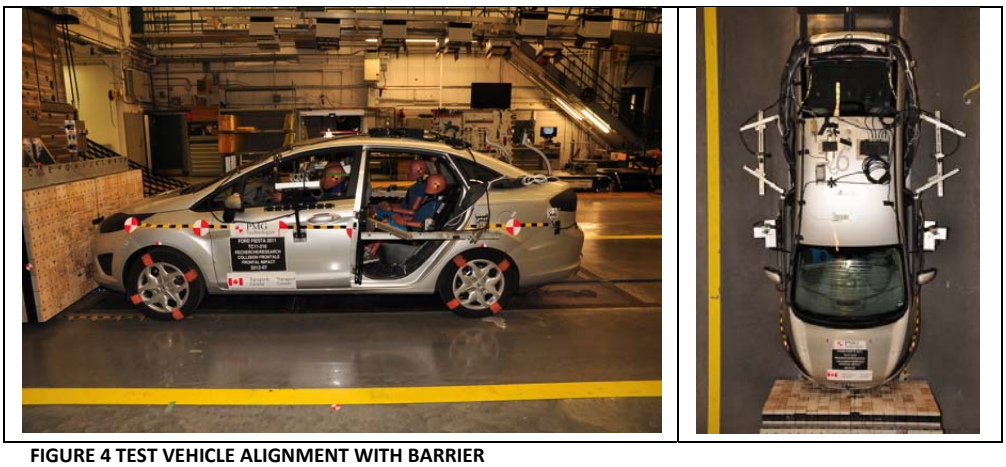

FIGURE 4 TEST VEHICLE ALIGNMENT WITH BARRIER

ATD PLACEMENT IN SECOND ROW SEAT OF TEST VEHICLE

Behind the driver: An instrumented Hybrid III 6 - year-old ATD was placed on a GoBooster® booster seat as per manufacturer instructions. The dummy was seated upright and a shield was positioned over the front region of the pelvis to prevent the lap belt from penetrating the space between the pelvis and upper femurs. Pre-test position of the lap displayed good fit though the seatbelt was difficult to route through the guides shown in Figure 5.

FIGURE 5 PRE-TEST POSITION OF HYBRID III 6- YEAR-OLD PLACED ON THE GOBOOSTER® IN THE FORD FIESTA

Behind the right front passenger: An instrumented Hybrid III 10-year-old ATD was placed on a GoBooster® booster seat as per manufacturer instructions. The lower spine of the ATD was set to 0 degrees, which represents a relaxed position. Pre-test position of the lap belt displayed good fit though the seatbelt was difficult to route through the guides shown in Figure 6.

FIGURE 6 PRE-TEST POSITION OF HYBRID III 10 - YEAR-OLD PLACED ON THE GOBOOSTER® IN THE FORD FIESTA

INSTRUMENTATION

The instrumentation for the vehicle and ATDs was as described for frontal impact crash test 1 on page 7.

All data were processed as per the Society of Automotive Engineers (SAE J-211). High-speed videos were used to record a frontal view of both seats and a lateral view of each seat at a rate of 1000 frames/second. The rear passenger car doors were removed in order to obtain an enhanced camera view of the dummy and booster cushion motion during the crash event.

2.1.3 CMVSS 213.2 SLED TEST

TEST CONFIGURATION

A Hybrid III 6-year-old was placed on the GoBooster® booster seat and on the CMVSS 213 sled bench as per manufacturer instructions. The lap and torso belt was applied and tightened as per the CMVSS 213.2 test protocol. Pre-test photos are presented in Figure 7 below. Two CMVSS 213 tests were conducted.

FIGURE 7 PRE-TEST POSITION OF HYBRID III 6-YEAR OLD ON COMPLIANCE TEST BENCH

TEST PULSE

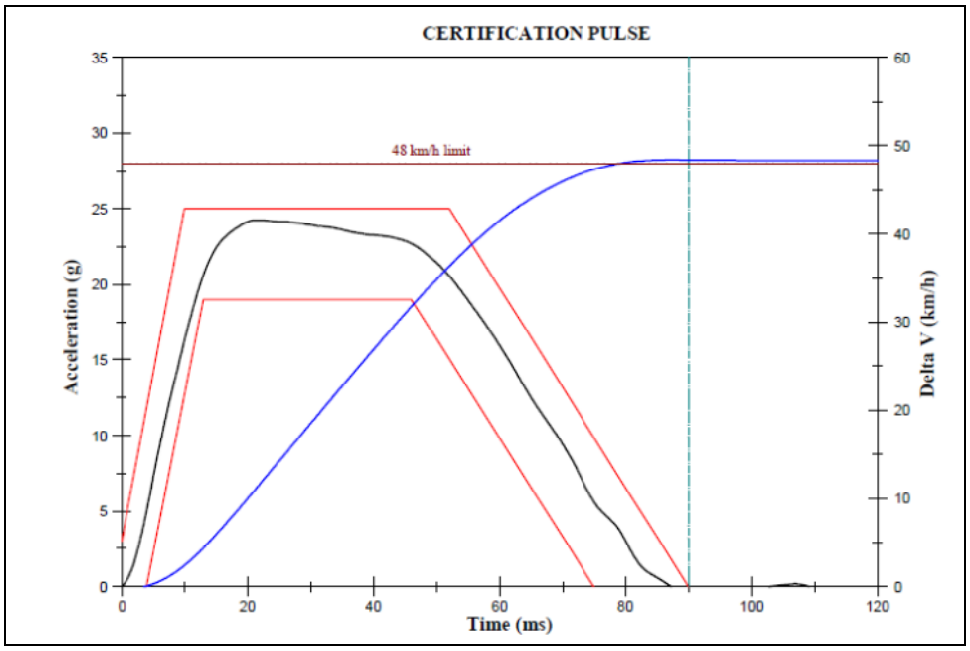

FIGURE 8 ACCELERATION PULSE AND DELTA V

The compliance pulse for test one produced a peak change in velocity of 48.4 km/h at 87.3 ms and peak acceleration of 24.3 g at 21.6 ms; test two produced a peak change in velocity of 49.1 km/h at 90 ms and peak acceleration of 24.3 g at 21.8 ms.

3 RESULTS

3.1 FRONTAL IMPACT TEST 1

The Dodge Grand Caravan impacted the rigid wall at 39.88 km/h. The peak vehicle resultant acceleration recorded at the center of gravity of the vehicle was 32 g.

3.1.1 OCCUPANT KINEMATICS & INJURY MEASURES

The left views of Figure 9 illustrate the position of each dummy as the vehicle is accelerated down the ramp towards the barrier. In the top right image the 6-year old has slid off the front edge of the vehicle seat cushion together with the booster seat. The lap belt has penetrated the abdomen and the dummy is suspended by the rib cage. In the bottom right image the 10-year-old has slid to the front edge of the seat. The lap belt has penetrated the abdominal region.

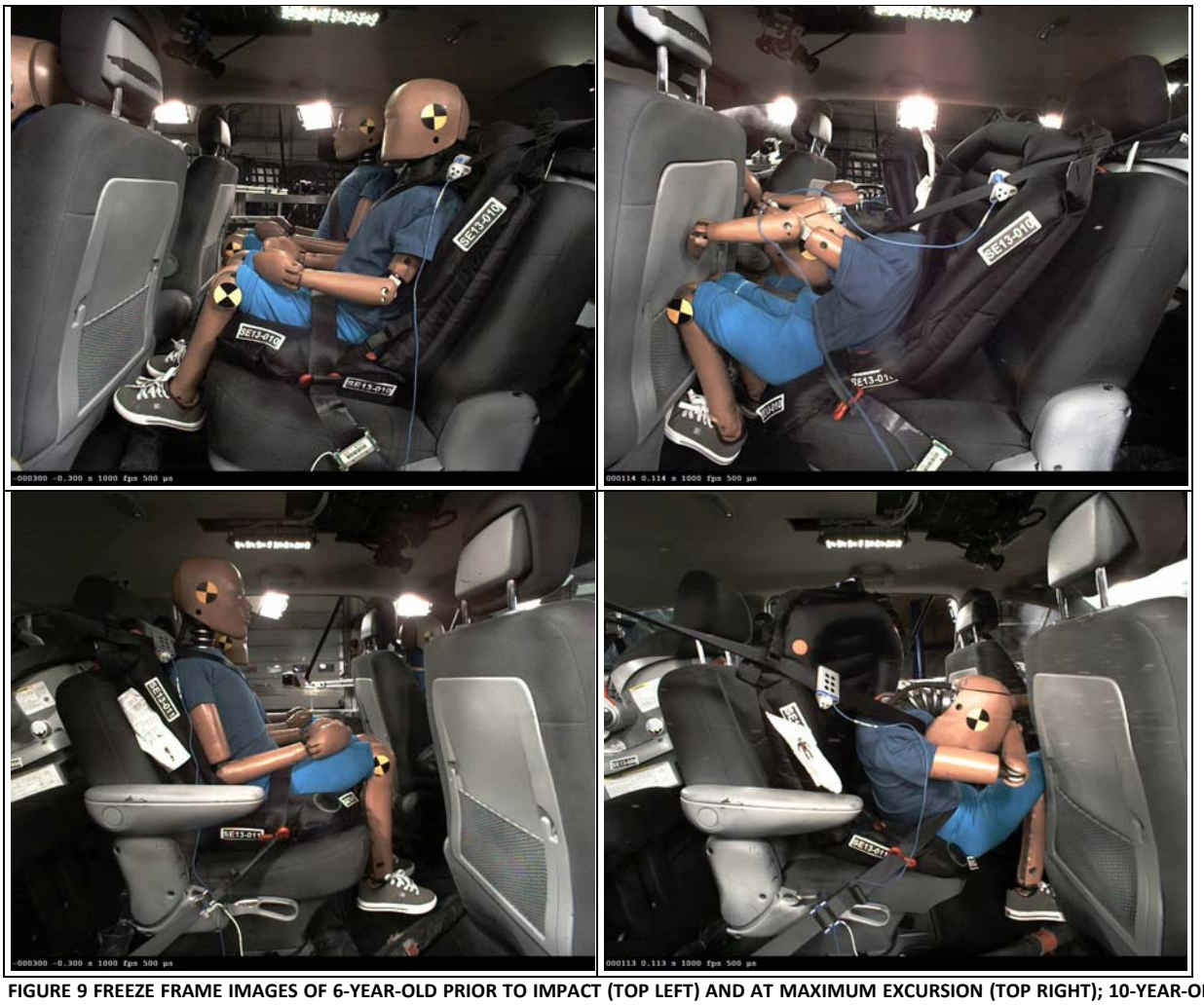

FIGURE 9 FREEZE FRAME IMAGES OF 6-YEAR-OLD PRIOR TO IMPACT (TOP LEFT) AND AT MAXIMUM EXCURSION (TOP RIGHT); 10-YEAR-OLD PRIOR TO IMPACT (BOTTOM LEFT) AND AT MAXIMUM EXCURSION (BOTTOM RIGHT) DURING FFRB TEST AT 40 KM/H.

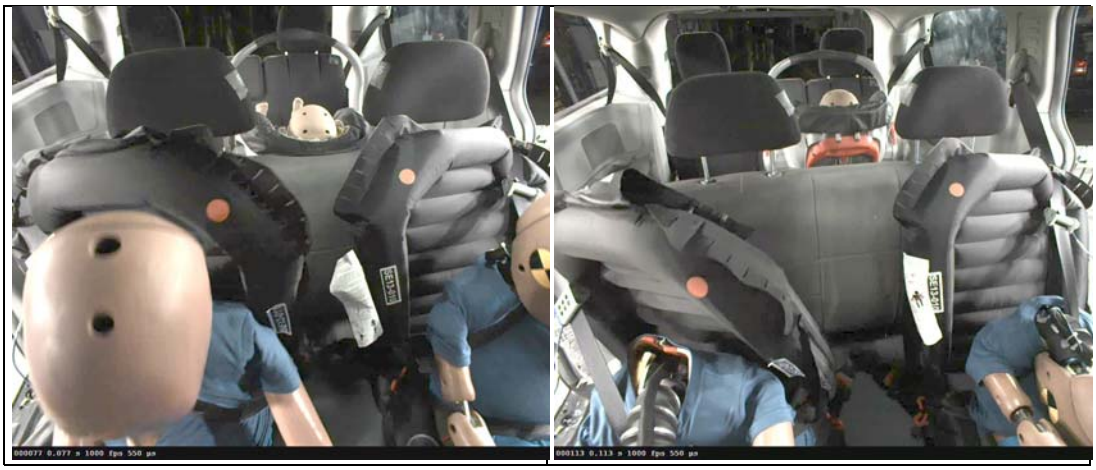

FIGURE 10 FRONTAL VIEWS OBTAINED DURING FORWARD EXCURSION SHOWING SHOULDER BELT LOADING OF THE NECK AND INBOARD AXILLAE FOR BOTH THE 6 AND 10-YEAR-OLD ATDS.

Figure 10 displays the position of the shoulder belt with respect to the neck as the dummies slid towards the front edge of the seat and slipped underneath the lap belts. Both shoulder belts loaded the neck and inboard axilla of each ATD.

TABLE 1 ATD RESPONSES RECORDED IN THE DODGE GRAND CARAVAN 40 KM/H FFRB TEST

	HIC_{36}	Head 3ms clip g	Chest 3ms clip g	Chest Deflection mm
Hybrid III 6-yr-old No head impact	483	65.6	68.1	28.5
Hybrid III 10-yr-old No head impact	636	83.5	50.4	46.3

3.2 FRONTAL IMPACT TEST 2

The Ford Fiesta impacted the rigid wall at 39.71 km/h. The peak vehicle resultant acceleration recorded at the center of gravity of the vehicle was 28.9 g.

3.2.1 OCCUPANT KINEMATICS & INJURY MEASURES

The left side of Figure 11 illustrates the position of the 6 and 10-year-old ATDs as the vehicle is accelerated down the ramp towards the barrier. The top and bottom right hand images show the 6 and 10-year old ATD respectively, at peak excursion. Both dummies have slid off the front edge of the vehicle seat cushion together with the booster seat. The lap belt has penetrated the

abdomen and the dummies are suspended by the rib cage. Note how each booster cushion opens out almost acting as a shoot to dump the ATDs out of their seats.

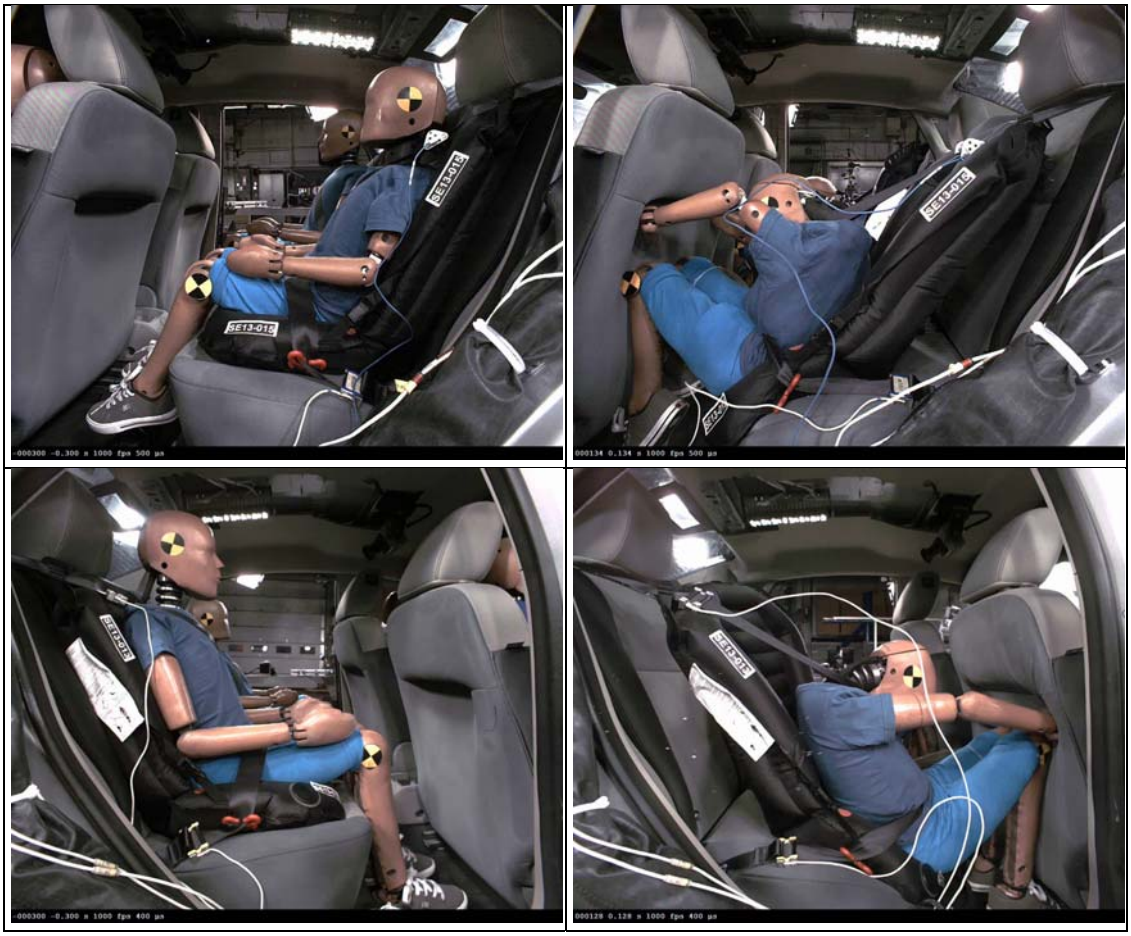

FIGURE 11 FREEZE FRAME IMAGES OF 6-YEAR-OLD PRIOR TO IMPACT (TOP LEFT) AND AT MAXIMUM EXCURSION (TOP RIGHT); FREEZE FRAME IMAGES OF 10-YEAR-OLD PRIOR TO IMPACT (BOTTOM LEFT) AND AT MAXIMUM EXCURSION (BOTTOM RIGHT) DURING FFRB TEST AT 40 KM/H.

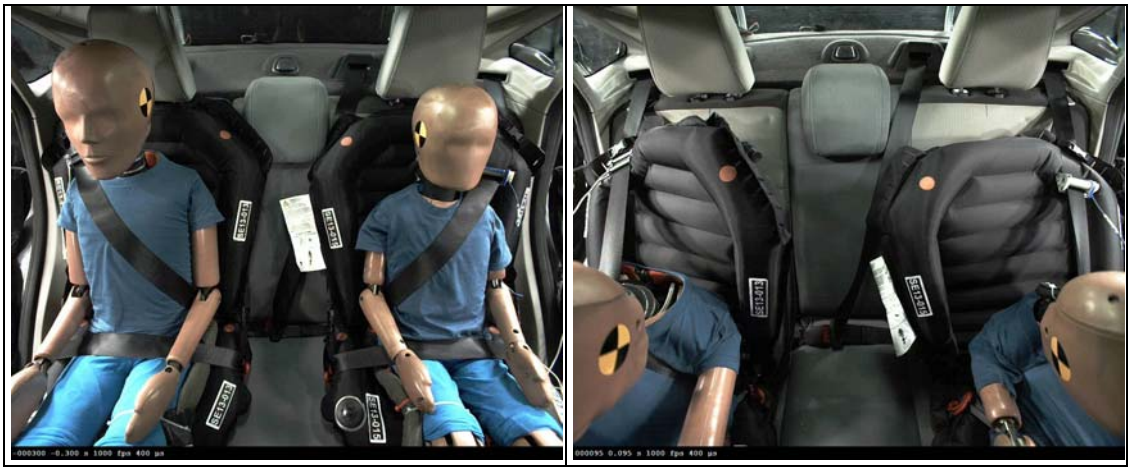

FIGURE 12 FRONT VIEW OF SHOULDER BELT LOADING DURING FORWARD EXCURSION OF TEST 2.

Figure 12 displays the position of the shoulder belt with respect to the neck as the dummies slid towards the front edge of the seat and slipped underneath the lap belts. Both shoulder belts loaded the neck and inboard axilla of each ATD.

TABLE 2 ATD RESPONSES RECORDED IN THE FORD FIESTA 40 KM/H FFRB TEST

	HIC_{36}	Head 3ms clip g	Chest 3ms clip g	Chest Deflection mm
Hybrid III 6-yr-old No head impact	518	58.7	75.6	24.3
Hybrid III 10-yr-old No head impact	443	59.7	72.0	30.2

3.3 CMVSS 213.2 SLED TEST

Kinematic response for the Hybrid III 6-year-old was significantly different when evaluated on the CMVSS 213 bench. As can be seen from left and right side images obtained at peak excursion and shown in Figure 13, the ATD remained upright and there was very little forward displacement of the ATD or booster cushion with respect to the bench.

FIGURE 13 MOTION OF HYBRID III 6-YEAR-OLD AND THE GOBOOSTER DURING THE CMVSS 213 COMPLIANCE TEST.

The GoBooster met all excursion requirements but failed to meet the peak chest acceleration clip requirement of 60 g in both compliance tests.

TABLE 3 ATD RESPONSES RECORDED IN THE FORD CMVSS 213 COMPLIANCE TEST

	HIC_{36}	Head 3ms clip g	Chest 3ms clip g	Chest Deflection mm
SLED TEST 1 Hybrid III 6-yr-old	502	61	**63.5**	41.6
SLED TEST 2 Hybrid III 6-yr-old	566	68.4	**61.7**	41.3

4 CONCLUSION

The combined effects of the inflatable/compressible cushion, the slippery material, ribbed contours and routing of the lap belt all appear to contribute to the forward excursion and ejection of the dummy occupant from the vehicle seat when tested in the rear seats of two passenger vehicles. The belt routing introduces slack into the belt system and causes the occupant to move further forward relative to the seat of the vehicle. By the time the seatbelt locks and begins to decelerate the ATD, the accelerating dummy is already sufficiently forward to compress the booster and slide underneath the seatbelt and off the front edge of the vehicle seat. Even though the compliance tests are conducted at a greater velocity than the vehicle crash tests (48km/h vs 40km/h) this interaction cannot be observed on the compliance bench because the seatbelt is locked. The ATD is prevented from moving forward relative to the bench and cannot be ejected from the seat as is observed in the rear seat of a motor vehicle.

Given the portability of this product there is concern that Canadian consumers could acquire this product in the U.S. and expose their children to undue risk of injury in the event of a collision.