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ON-SITE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION INVESTIGATION

CASE NUMBER - IN09028

LOCATION - MISSOURI

VEHICLE - 2008 NISSAN SENTRA S

CRASH DATE - June 2009

Submitted:

January 20, 2010



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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

Technical Report Documentation Page

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16. <i>Abstract</i> This on-site investigation focused on the side impact air bag system of a 2008 Nissan Sentra S, the crash dynamics, and the sources of the injuries for the driver and second row right passenger. The Nissan was occupied by a restrained 17-year-old male driver, a restrained 18-year-old female front passenger, and an unrestrained 21-year-old male second row right passenger. The driver of the Nissan proceeded from a stop sign into an intersection of a divided U.S. highway and the Nissan was impacted on the left side plane by the front plane of a 2002 Hyundai Santa Fe. The force direction on the Nissan was within the 10 o'clock sector and the impact force was sufficient to trigger deployment of the left side impact inflatable curtain (IC) air bag and the driver's seat-mounted side impact air bag. The impact disintegrated the Nissan's left rear window glazing and displaced the unrestrained second row right passenger to the left. He loaded the deployed left IC air bag and was ejected through the left rear window opening. The driver of the Nissan and the second row right passenger were transported by ambulance to a hospital. The front passenger was transported by private conveyance to a hospital. The driver and front passenger sustained minor injuries and were treated in the emergency room and released. The second row right passenger sustained moderate injuries. He was treated in the emergency room and transferred to a level 1 trauma center where he was admitted and released the following day. The driver and two passengers of the Hyundai were uninjured. Both vehicles were towed due to damage.					
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This on-site investigation focused on the side impact air bag system of a 2008 Nissan Sentra S (**Figure 1**), the crash dynamics, and the sources of the injuries for the driver and second row right passenger. This crash was brought to the attention of the National Highway Traffic Safety Administration (NHTSA) on August 12, 2009 by this contractor. The investigation was assigned on August 14, 2009. The crash involved the Nissan and a 2002 Hyundai Santa Fe GLS. The crash occurred in June, 2009, at 2152 hours, in Missouri and was investigated by the Missouri State Highway Patrol. The crash scene and both vehicles were inspected on August 27 and 28, 2009. An in-person interview was conducted with the father of the Nissan's driver on August 27, 2009. This report is based on the police crash report, scene and vehicle inspections, interview information, occupant kinematic principles, and evaluation of the evidence.



Figure 1: The damaged 2008 Nissan Sentra S

CRASH CIRCUMSTANCES

Crash Environment: The trafficway that the Nissan was traveling on was a 2-lane, undivided, rural roadway, traversing in a southwest-northeast direction and approached a 4-leg intersection. On the northeast leg of the intersection, the roadway had one travel lane in each direction and was bordered by grass shoulders. There were no lane markings and the roadway was 11.6 m (38 ft) in width. The roadway pavement markings consisted of a solid white stop bar and the intersection was controlled by a stop sign. The trafficway that the Hyundai was traveling on was an 7-lane, divided, U.S. highway, traversing in a northwest-southeast direction. On the southeast leg of the intersection the northwestbound roadway had two through lanes, a right turn lane and a left turn lane. The southeastbound roadway had three through lanes and the trafficway was divided by a grass median 8.3 m (27.2 ft) in width. Each lane was approximately 3.8 m (12.5 ft) in width. The roadway pavement markings consisted of solid white edge lines, solid yellow median edge lines, broken white lane lines, solid white turn lane lines, and solid white turn arrows. The outside shoulder was 1.6 m (5.2 ft) in width, while the median shoulder was 1.1 m (3.6 ft) in width. The northwestbound roadway was level, curved left, and uncontrolled at the intersection. The roadway was superelevated 6.7% to the northeast. The speed limit for the Nissan was 40 km/h (25 mph). The speed limit for the Hyundai was 105 km/h (65 mph). At the time of the crash the light condition was dark with no artificial lighting and the weather was clear. The roadway surface was dry bituminous. The Crash Diagram is on page 12 of this report.

Pre-Crash: The Nissan was occupied by a restrained 17-year-old male driver, a restrained 18-year-old female front row passenger, and an unrestrained 21-year-old male second row right passenger. The Nissan's driver proceeded southwest from the stop sign into the intersection (**Figure 2**), where he intended to proceed through the median crossover and turn left. The Hyundai's restrained 23-year-old male driver was traveling northwest in the outside through lane

(Figure 3), where he intended to continue straight through the intersection. The Nissan's driver took no actions to avoid the crash. The Hyundai's driver attempted to avoid the crash by initiating a left steering maneuver and applying hard braking. The Hyundai skidded partially into the inside through lane and the crash occurred within the intersection (Figure 3).

Crash: The front plane of the Hyundai (Figure 4) impacted the left side plane of the Nissan (Figure 5). The direction of force on the Nissan was within the 10 o'clock sector and the impact force was sufficient to trigger the deployment of the left IC air bag and driver's seat-mounted side impact air bag. As a result of the impact, the Nissan's left rear window glazing was disintegrated. The unrestrained second row right passenger was displaced to the left by the impact and ejected through the left rear window opening. The Nissan rotated counterclockwise and came to final rest in the median crossover heading northwest. The Hyundai rotated counterclockwise and came to final rest on the median shoulder heading northwest. The rest positions were based on the police crash report narrative. Both vehicles had been moved prior to arrival of the police. There had been several other crashes in this intersection, and many unrelated and conflicting marks were present.



Figure 2: Approach of the Nissan into the intersection; arrow shows the approach of the Hyundai



Figure 3: Approach of the Hyundai to the impact area; arrow on right shows approach of Nissan; arrow on left shows Hyundai's left front skid mark; skid marks in outside lane are unrelated



Figure 4: Damage to the front plane of the Hyundai from the impact with the Nissan's left side plane



Figure 5: Damage to the left side plane of the Nissan

Post-Crash: The police were notified of the crash at 2152 hours and arrived at the crash scene at 2203 hours. The driver of the Nissan and the second row right passenger were transported by ambulance to a hospital. The driver was treated and released and the front passenger was hospitalized. The front row passenger of the Nissan was transported to a hospital by private conveyance where he was treated and released. The driver and two passengers of the Hyundai were uninjured. Both vehicles were towed due to damage.

CASE VEHICLE

The 2008 Nissan Sentra S was a front wheel drive, 4-door sedan (VIN: 3N1AB61E98L-----) that was manufactured in July 2008. The vehicle was equipped with a 2.0-liter, 4-cylinder engine, automatic transmission, 4-wheel anti-lock brakes, and a tire pressure monitoring system. The front row was equipped with bucket seats, adjustable head restraints, lap-and-shoulder belts, driver and passenger frontal air bags, side impact IC air bags, and front seat-mounted side impact air bags. The second row was equipped with a split bench seat with folding backs, lap-and-shoulder safety belts, adjustable head restraints, and Lower Anchors and Tethers for Children (LATCH) in the outboard seating positions. The vehicle’s mileage at the time of the inspection was 12,541 miles (20,183 kilometers). The specified wheelbase was 269 cm (105.9 in).

CASE VEHICLE DAMAGE

Exterior Damage: The impact with the front of the Hyundai involved the left side plane of the Nissan. The left rear door, left rear wheel, and quarter panel were directly damaged. The direct damage began 179 cm (70.5 in) rear of the left front axle and extended 166 cm (65.4 in) rearward along the left side. The crush measurements were taken at the lower door level and the residual maximum crush was 27 cm (10.6 in) occurring 11 cm (4.3 in) rear of C₂ (**Figure6**). The vehicle’s sill height was 32 cm (12.9 in) and the height of the maximum crush was 47 cm (18.5 in). The door sill differential was 3 cm (1.2 in). The induced damage involved the upper C-pillar and quarter panel. The table below shows the left side crush profile.

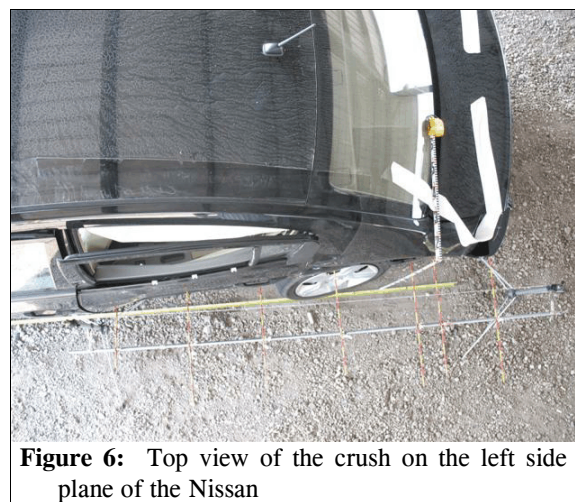


Figure 6: Top view of the crush on the left side plane of the Nissan

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	166	27	187	7	23	20	21	13	0	-124	-115
in		65.4	10.6	73.6	2.8	9.1	7.9	8.3	5.1	0.0	-48.8	-45.3

Damage Classification: The Collision Deformation Classifications (CDC) was **10LZEW3 (290** degrees) for the left side plane impact. The Damage algorithm of the WinSMASH program calculated the Nissan’s total Delta V as 24 km/h (14.9 mph). The longitudinal and lateral velocity changes were -8.2 km/h (-5.1 mph) and 22.6 km/h (14 mph), respectively. Based on the damage sustained by both vehicles, the results appeared reasonable.

The vehicle manufacturer’s recommended tire size was P205/55R16. The Nissan was equipped with the recommended size tires. The vehicle’s tire data are shown in the table below.

Tire	Measured Pressure		Vehicle Manufacturer’s Recommended Cold Tire Pressure		Tread Depth		Damage	Restricted	Deflated
	kPa	psi	kPa	psi	milli-meters	32 nd of an inch			
LF	234	34	228	33	6	7	None	No	No
LR	234	34	228	33	4	5	None	No	No
RR	221	32	228	33	2	3	Sidewall cut	No	No
RF	221	32	228	33	6	7	None	No	No

Vehicle Interior: The inspection of the Nissan’s interior revealed no discernable evidence of occupant contact in the front row. In the second row, the right passenger had contacted the center arm rest and deformed it to the left (**Figure 7**). The left IC air bag was scuffed and there was a small tear on the bottom edge rearward of the scuff (**Figure 8**). A transfer of hair and tissue was located on the glass fragments in the left rear window frame (**Figure 9**) and the window frame was slightly bent. The left rear door panel was also dented and deformed outward (**Figure 10**). This occupant contact evidence supported the left rear window opening as the second row right passenger’s ejection portal.

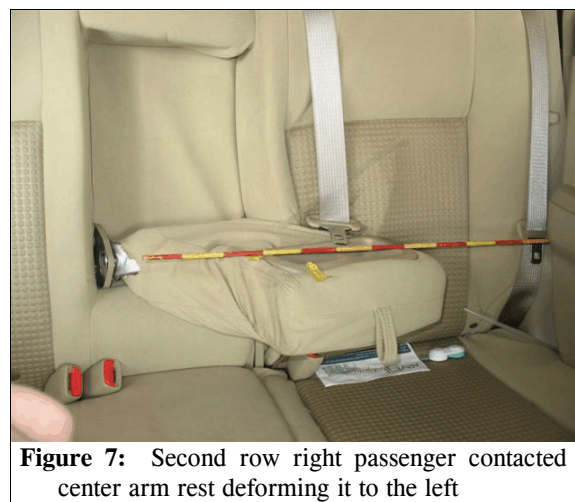


Figure 7: Second row right passenger contacted center arm rest deforming it to the left

The vehicle’s left rear door was jammed shut, while the other doors remained closed and operational. The pre-crash status of all the window glazings was fixed or closed. The left rear window glazing was disintegrated by impact forces. The remaining glazings were undamaged.

The vehicle sustained two passenger compartment intrusions, which occurred in the second row left occupant space. The rear lower quadrant of the left rear door intruded laterally 9 cm (3.5 in) and the seat cushion intruded laterally 5 cm (2 in).



Figure 8: Outline shows area of occupant contact scuff on IC air bag; arrow on left shows location of tear in IC air bag



Figure 9: Hair transfer on left rear window frame

AUTOMATIC RESTRAINT SYSTEM

The Nissan was equipped with a frontal air bag system that was certified by the manufacturer to be compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The frontal air bag system consisted of dual stage driver and front right passenger air bags, driver seat position sensor, safety belt usage sensors, retractor-mounted pretensioners, and a front passenger weight sensor. The frontal air bags did not deploy in this crash.

The Nissan was also equipped with a side air bag system that consisted of roof rail-mounted side impact IC air bags and front seat-mounted side impact air bags. Based on the Holmatro Rescuer's Guide to Vehicle Safety Systems, the side impact sensors were located within the lower B-pillars. The left IC air bag and driver's seat-mounted side impact air bag deployed in this crash.

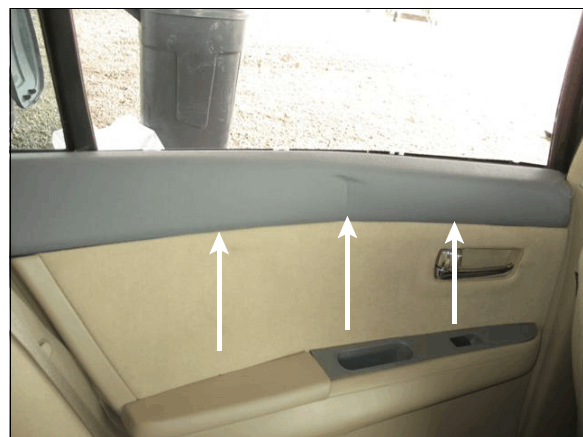


Figure 10: The left rear door panel was dented and deformed outward from occupant contact (arrows)



Figure 11: The Nissan's left IC

The IC air bags were located along the roof side rails inside the headliner and extended from the A-pillar to the C-pillar. The IC air bags were designed with inflation chambers adjacent to the outboard seating positions. There were no external vent ports. The deployed left IC air bag (**Figure 11**) was 145 cm (57.1 in) in width and 44 cm (17.3 in) in height. It was attached to the A-pillar by a 51 cm (20.1 in) nylon rope and at the C-pillar by a 14 cm (5.5 in) nylon rope. The gap between the front of the IC air bag and the A-pillar was 41 cm (16.1 in). There was no gap

between the back of the IC air bag and the C-pillar. The IC air bag extended vertically 9 cm (3.5 in) below the beltline. Inspection of the deployed IC air bag revealed no discernable evidence of occupant contact in the front row. In the second row, an occupant contact scuff was located 23 cm (9 in) forward of the back edge of the IC air bag and 10 cm (2 in) above the bottom of the IC. A 7 cm (2.8 in) tear was located at the bottom of the IC air bag 10 cm (2 in) forward of the back edge. The location of the tear (**Figure 8**) corresponded with the location of the hair and tissue transfer on the back of the left rear window frame (**Figure 9**).

The driver's seat-mounted side impact air bag was located in the outboard side of the seat back and deployed through a tear-seam. The deployed air bag (**Figure 12**) was 53 cm (20.9 in) in height. The upper portion of the air bag was 20 cm (7.9 in) in width, while the middle and lower portions were 17 cm (6.7 in) and 25 cm (9.8 in) wide, respectively. The inspection of the air bag revealed no discernable evidence of occupant contact and no damage.

MANUAL RESTRAINT SYSTEM

The Nissan was equipped with lap-and-shoulder safety belts for all the seating positions. The driver's safety belt consisted of continuous loop belt webbing, an Emergency Locking Retractor (ELR), sliding latch plate, and an adjustable upper anchor that was in the full-up position. The front passenger safety belt was similarly equipped but had an ELR/Automatic Locking Retractor (ALR). The adjustable upper anchor was also located in the full-up position. Both front row safety belts were equipped with retractor-mounted pretensioners, which did not deploy in this crash. The second row safety belts were similarly equipped as the front passenger safety belt but had fixed upper anchors and were not equipped with pretensioners.

The inspection of the driver's safety belt assembly revealed historical usage scratches on the latch plate. The belt webbing was slightly stretched (**Figure 13**) at 103 cm (40.5 in) above the



Figure 12: The front left seat-mounted side impact air bag



Figure 13: Area on driver's safety belt webbing that was slightly stretched

stop button. The driver also sustained contusions during the crash consistent with safety belt usage. Based on this evidence, the driver was restrained by the lap-and-shoulder safety belt.

Inspection of the front passenger’s safety belt assembly revealed some historical usage scratches on the latch plate. The safety belt assembly was otherwise unremarkable. Based on the medical records, the front row passenger was restrained by the lap-and-shoulder safety belt.

Inspection of the second row right safety belt assembly revealed no evidence of loading. The occupant contact evidence on the second row center arm rest, left IC air bag, left rear door, and left rear window frame as described in the vehicle interior section on page 4 of this report indicated that this passenger was not restrained at the time of the crash.

CASE VEHICLE DRIVER KINEMATICS

The Nissan’s driver [17-year-old, male; 185 cm (73 in) and 68 kg (150 lbs)] was seated in an unknown posture. The seat track was adjusted to between the middle and rear positions and the seat back was slightly reclined. The tilt steering column as located between the full-up and center position. The driver was wearing contact lenses at the time of the crash.

The left side plane impact with the front plane of the Hyundai initially displaced the driver to the left and forward opposite the 10 o’clock direction of force and he loaded the safety belt. He sustained contusions on the chest and right hip from loading the safety belt. The driver sustained a contusion and abrasion on the lower left leg, which was probably caused by contact to the forward lower quadrant of the left front door. He also sustained a cervical strain, which was probably caused by impact forces. While there was no discernable evidence of occupant contact on the left IC air bag and seat-mounted side impact air bag, occupant kinematics principles suggest that the driver loaded these air bags. The driver remained restrained in his seat position throughout the crash and was removed from the vehicle by emergency medical responders.

CASE VEHICLE DRIVER INJURIES

The driver of the Nissan sustained minor injuries. He was transported by ambulance to a hospital where he was treated in the emergency room and released. The driver missed five work days due to the crash and received no follow-up medical treatment. The table below presents the driver’s injuries and injury sources.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Strain, acute, cervical with decreased range of motion, pain, and muscle spasm	minor 640278.1,6	Noncontact injury: impact forces	Probable	Emergency room records
2	Contusion chest, not further specified	minor 490402.1,4	Torso portion of safety belt system	Probable	Interviewee (relative)

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
3	Contusion, 10.2-12.7 cm (4-5 in) right hip, not further specified	minor 590402.1,1	Lap portion of safety belt system	Probable	Emergency room records
4	Abrasion left lower extremity below knee	minor 890202.1,2	Left front door panel, forward lower quadrant	Probable	Emergency room records
5	Contusion left lower extremity below knee	minor 890402.1,2	Left front door panel, forward lower quadrant	Probable	EMS treatment record

CASE VEHICLE FRONT ROW PASSENGER KINEMATICS

The front row passenger of the Nissan [18-year-old, female; unknown height and 61 kg (134 lbs)] was seated in an unknown posture. The passenger's seat track was adjusted to between the middle and rear positions and the seat back was slightly reclined.

The impact with the Hyundai initially displaced the passenger forward and left opposite the 10 o'clock direction of force. There was no discernable evidence that the passenger contacted any interior surfaces. She sustained a cervical strain, which was probably caused by impact forces. The front passenger remained restrained in her seat position throughout the crash and exited the vehicle with some assistance from a passerby.

CASE VEHICLE FRONT ROW PASSENGER INJURIES

The front row passenger sustained a minor injury. She was transported by private conveyance to a hospital where she was treated in the emergency room and released. The table below presents the passenger's injury and injury source.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Strain, acute, cervical with decreased range of motion and muscle spasm posterior neck	minor 640278.1,6	Noncontact injury: impact forces	Probable	Emergency room records

CASE VEHICLE SECOND ROW RIGHT PASSENGER KINEMATICS

The second row right passenger of the Nissan [21-year-old, male; 170 cm (67 in) and 100 kg (220 lbs)] was seated in an unknown posture.

The left side plane impact with the front plane of the Hyundai disintegrated the left rear window glazing and displaced the passenger to the left. His left hip contacted the center arm rest and deformed it to the left. His head loaded the deployed IC air bag and his upper torso contacted the left rear door. The passenger's head also contacted the rear portion of the left rear window frame and hair transfer was left on the glass fragments in the window frame. The passenger was fully ejected through the left rear window opening. He came to final rest in the median near the crossover. The head contact on the left rear window frame and the glass fragments caused a nonanatomic brain injury with loss of consciousness and abrasions on the head, respectively. He also probably contacted the left shoulder and left arm on the glass fragments, which caused a long, linear laceration on the left shoulder, left upper arm, and left elbow.

CASE VEHICLE SECOND ROW RIGHT PASSENGER INJURIES

The second row right passenger sustained moderate injuries and was transported by ambulance to a hospital. He was treated in the emergency room and transferred to a level 1 trauma center where he was admitted and released the following day. The table below presents the passenger's injuries and injury sources.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury with loss of consciousness of unknown duration, amnesia for event, repetitive questions from patient, GCS=14	moderate 160606.2,0	Left rear window frame	Certain	Hospitalization records
2	Abrasions head, not further specified, bleeding controlled	minor 190202.1,9	Left rear window's glazing	Certain	Emergency room records
3 4	Lacerations, superficial, left and right cheeks	minor 290602.1,1 290602.1,2	Noncontact injury: flying glass, left rear glazing	Certain	Hospitalization records
5	Contusion right chest wall, not further specified	minor 490402.1,1	Left rear window sill	Probable	Hospitalization records
6	Abrasions, vertically oriented, along left side of back	690202.1,2	Ground	Probable	Hospitalization records
7	Abrasion upper and lower left posterior arm, not further specified	minor 790202.1,2	Ground	Probable	Hospitalization records
8	Lacerations, long, linear, left shoulder, left upper arm, and left elbow	minor 790602.1,2	Left rear window's glazing	Certain	Hospitalization records

The 2002 Hyundai Santa Fe GLS was a front wheel drive, 4-door, sport utility vehicle (VIN: KM8SC13D02U-----) equipped with a 2.7-liter, V6 engine, automatic transmission, and redesigned driver and front passenger frontal air bags.

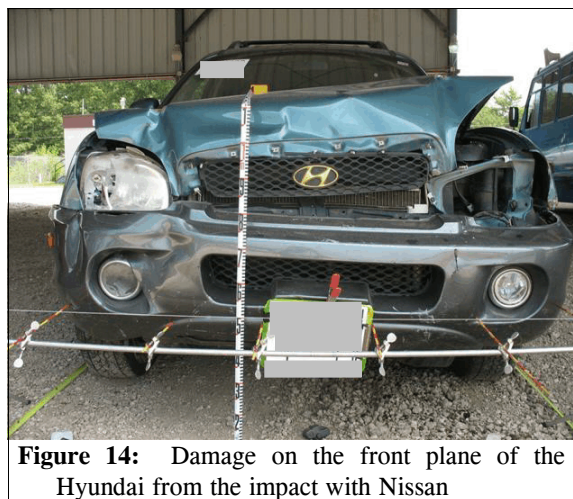


Figure 14: Damage on the front plane of the Hyundai from the impact with Nissan

Exterior Damage: The impact with the Nissan involved the Hyundai’s front plane (**Figure 14**). The front bumper, grille, hood, and both headlamp/turn signal assemblies were directly damaged. The direct damage began at the front right bumper corner and extended 160 cm (63 in) across front plane. The crush measurements were taken at the bumper level and the residual maximum crush was 21 cm (8.3 in) occurring at C₄. The induced damage involved the hood and both fenders. The table below shows the front crush profile.

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	160	21	160	6	14	17	21	7	0	0	0
in		63.0	8.3	63.0	2.4	5.5	6.7	8.3	2.8	0.0	0.0	0.0

Damage Classification: The CDC for the front impact with the Nissan was **01FDEW1** (20 degrees). The Damage algorithm of the WinSMASH program calculated the Hyundai’s total Delta-V as 18 km/h (11.2 mph). The longitudinal and lateral velocity changes were -16.9 km/h (-6.7 mph) and 6.2 km/h (2.4 mph), respectively. Based on the damage on both vehicles, the results appeared reasonable.

The vehicle manufacturer’s recommended tire size was P225/70R16. The Hyundai was equipped with the recommended size tires. The vehicle’s tire data are shown in the table below.

Tire	Measured Pressure		Vehicle Manufacturer’s Recommended Cold Tire Pressure		Tread Depth		Damage	Restricted	Deflated
	kPa	psi	kPa	psi	milli-meters	32 nd of an inch			
LF	214	31	207	30	5	6	None	No	No
LR	207	30	207	30	6	7	None	No	No

Other Vehicle (Continued)

IN09028

<i>Tire</i>	<i>Measured Pressure</i>		<i>Vehicle Manufacturer's Recommended Cold Tire Pressure</i>		<i>Tread Depth</i>		<i>Damage</i>	<i>Restricted</i>	<i>Deflated</i>
	kPa	psi	kPa	psi	milli-meters	32 nd of an inch			
RR	138	20	207	30	10	12	None	No	No
RF	172	25	207	30	6	7	None	No	No

Other Vehicle's Occupants: The police crash report indicated that the driver of the Hyundai (23-year-old, male), the front passenger (28-year-old, male), and second row right passenger (22-year-old, male) were all restrained by their lap-and-shoulder safety belts and sustained no injury. Both frontal air bags deployed as a result of the crash.

