Insurance Institute for Highway Safety
Crashworthiness Evaluation

Crash Test Report
1998 Nissan Sentra (CF97021)

Vehicle identification number: 1N4AB41D2WC709761
Body style: Four-door sedan
Engine/transmission: Transverse 1.6-liter 4-cylinder, 4-speed automatic, front-wheel drive

Standard crashworthiness features:

Driver and right front passenger front airbags
Dual-locking shoulder belts (front and rear outboard seating positions)
Shoulder belt upper anchorage height adjusters (front seating positions only)
Shoulder belt webbing grabbers (front seating positions only)
Right front and both rear shoulder belt retractors are convertible from emergency to automatic locking for ease of child restraint use

Optional safety features:

Four-wheel antilock brakes

Vehicle specifications (provided by manufacturer):

Wheelbase:	254 cm
Overall length:	434 cm
Overall width:	169 cm
Curb weight:	1,061 kg

Vehicle specifications (measured):

Front bumper to firewall:	103 cm
Curb weight:	1,134 kg
Test weight:	1,281 kg
Overall width:	169 cm

Nominal test parameters:

40.0 mi/h (64.4 km/h), 40 percent overlap, deformable barrier face with slotted bumper

Crash test date:

October 8, 1997

Precrash — 1998 Nissan Sentra

Postcrash — 1998 Nissan Sentra

Summary

A 1998 Nissan Sentra was crash tested on October 8, 1997 into a fixed deformable barrier at 40.0 mi/h (64.3 km/h) and a 40 percent overlap on the driver side. A Hybrid III 50th percentile male dummy was positioned in the driver seat with the lap/shoulder belt fastened.

Measures of intrusion taken after the crash indicated the lower instrument panel in front of the dummy moved rearward 4-8 cm. Resultant intrusion in the driver footwell measured 15 cm in the area where a footrest typically would be located and 18-28 cm at other places on the toepan. The upper end of the steering column moved upward 6 cm and rearward 5 cm. All doors remained closed during the crash. The driver door required tools to open, and the left rear door required additional effort to open after the crash. The right front and right rear doors opened with ease after the crash. The dummy's right foot was found trapped between a metal bracket of the center console and the accelerator pedal.

The driver dummy was restrained by a three point lap/shoulder belt and an airbag. During the crash, 2 cm of webbing spooled off the retractor. The dummy's head contacted the airbag at the time the airbag appeared to be fully inflated. As the dummy continued forward into the airbag, its head, neck, and shoulders moved leftward, and then its head turned to the right. The dummy's head then began to move rearward, passing through the open driver door window. The back of the dummy's head contacted the B-pillar and re-entered the vehicle. The dummy then rocked back and forth right to left, and the back of the dummy's head contacted the B-pillar, again, and the shoulder belt adjustment mechanism. The dummy then settled into the seat.

The maximum resultant head acceleration (85 g) was recorded when the dummy's head first contacted the B-pillar. The left tibia-femur had a maximum displacement of 16 mm. The left upper tibia reached a maximum index of 1.00.

Test Conditions

This vehicle had been tested previously in the Institute's Low-Speed Crash Test Program and subjected to an impact on the front corner of the passenger side at 5 mi/h (8 km/h) into a 30 degree angle barrier and a rear impact at 5 mi/h (8 km/h) into a flat barrier. All structural damage on the front was repaired prior to this test (see Appendix, Low-Speed Crash Test Damage Repair Estimate).

This test was conducted according to the procedures specified in the IIHS Offset Barrier Crash Test Protocol (Version IV). The Hybrid III dummy positioned in the driver seat was equipped with instrumented lower legs that included feet modified to include two accelerometers and to have a 45 degree dorsiflexion range with soft stops at all extremes of foot-ankle motion. All dummy seating parameters were set according to the procedures specified for Federal Motor Vehicle Safety Standard 208 compliance testing (49 *CFR* Part 571.208 § 11). The dummy's left foot was placed in the area where a footrest typically would be located.

Seat back, shoulder belt upper anchorage, and steering column adjustments were set according to the manufacturer's specifications for government crash testing. Other adjustments were set according to the procedure specified for Federal Motor Vehicle Safety Standard 208 compliance testing (49 *CFR* Part 571.208 § 7 and 8). After final positioning of the dummy, measurements from various parts of the dummy to a number of vehicle interior points were made. These measurements and the seat back, shoulder belt upper anchorage, and steering column adjustments are described in the Appendix, Dummy Clearance Measurements.

Vehicle acceleration measurements were made by a triaxial arrangement of accelerometers mounted on the vehicle's longitudinal centerline and 54 cm behind its center of gravity (163 cm behind the front axle). The vehicle speed recorded just prior to impact was 40.0 mi/h (64.3 km/h), and the actual overlap was 40 percent.

Structural Performance

All doors remained closed during the crash. The driver door aperture shortened 11 cm as measured at the lower edge of the window. The driver door required tools to open, and the left rear door required additional effort to open after the crash. The right front and right rear doors opened with ease after the crash.

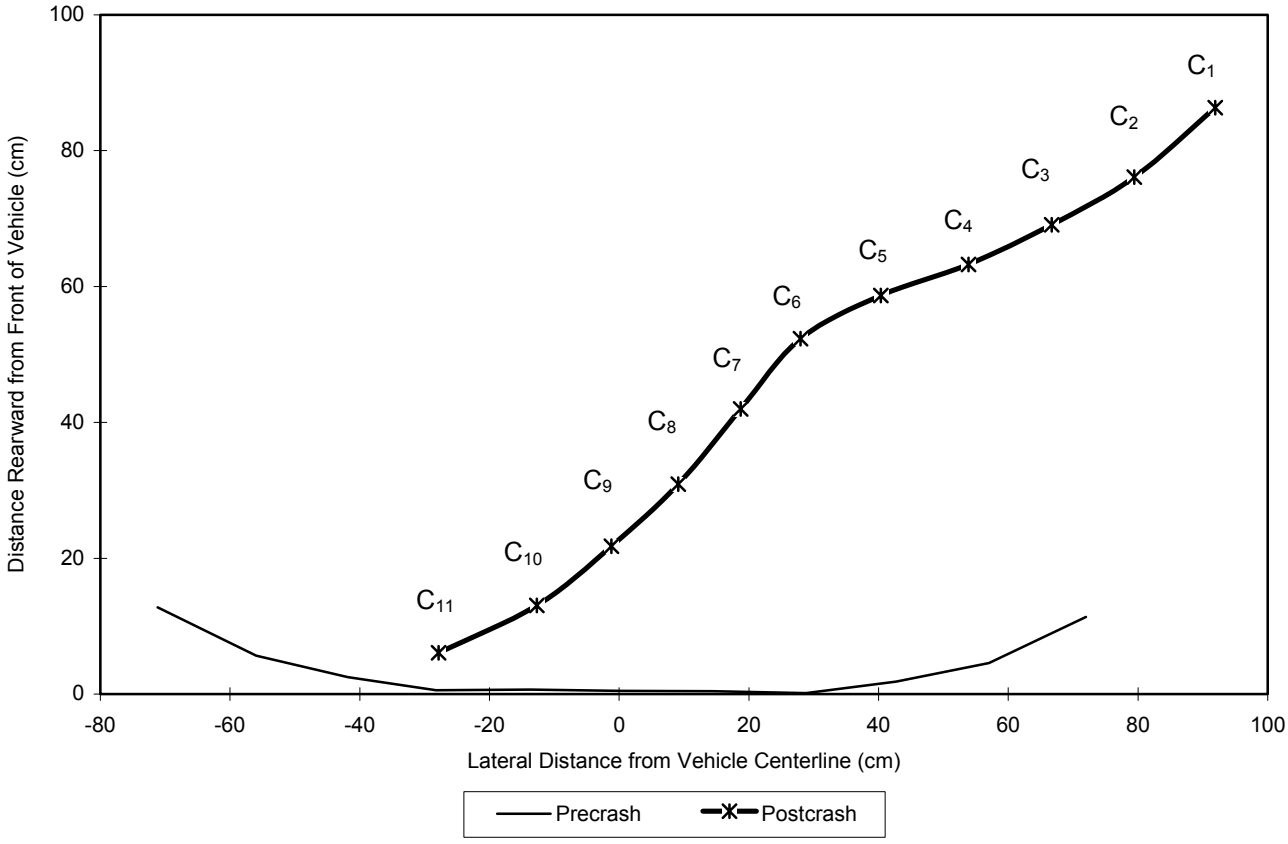
No fuel system leaks were observed after the crash. In addition, no fuel system leaks were observed when the vehicle was rotated onto its right side to allow postcrash photography.

Figure 1 shows the overhead view of the crash deformation. Figure 2A illustrates the precrash and postcrash contour measures of the front bumper cover profile and the resulting permanent crush. Figure 2B illustrates the corresponding measures of both the front bumper reinforcement bar and the upper crossmember of the radiator support. Figure 3 shows the precrash and postcrash views from below. Figure 4 illustrates the deformation of the side rails, floor rails, and engine support members, which are visible in Figure 3.

Figure 1
Overhead View of Crash Deformation — 1998 Nissan Sentra

Figure 2
Crush Contour Measurements — 1998 Nissan Sentra

a) Exterior Crush Contour at Bumper Height



	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
Postcrash Contour (cm)	86	76	69	63	59	52	42	31	22	13	6
Precrash Contour (cm)	11	5	2	0	0	0	1	1	2	6	13
Resulting Crush (cm)	75	71	67	63	59	52	41	30	20	7	-7

The bumper cover was torn completely off the vehicle during the crash. The postcrash contour represents the best attempt to fit the cover back onto the vehicle. The length of the reference line was 143 cm precrash and 120 cm postcrash.

b) Front Bumper Bar and Upper Radiator Support Crossmember Crush Contour

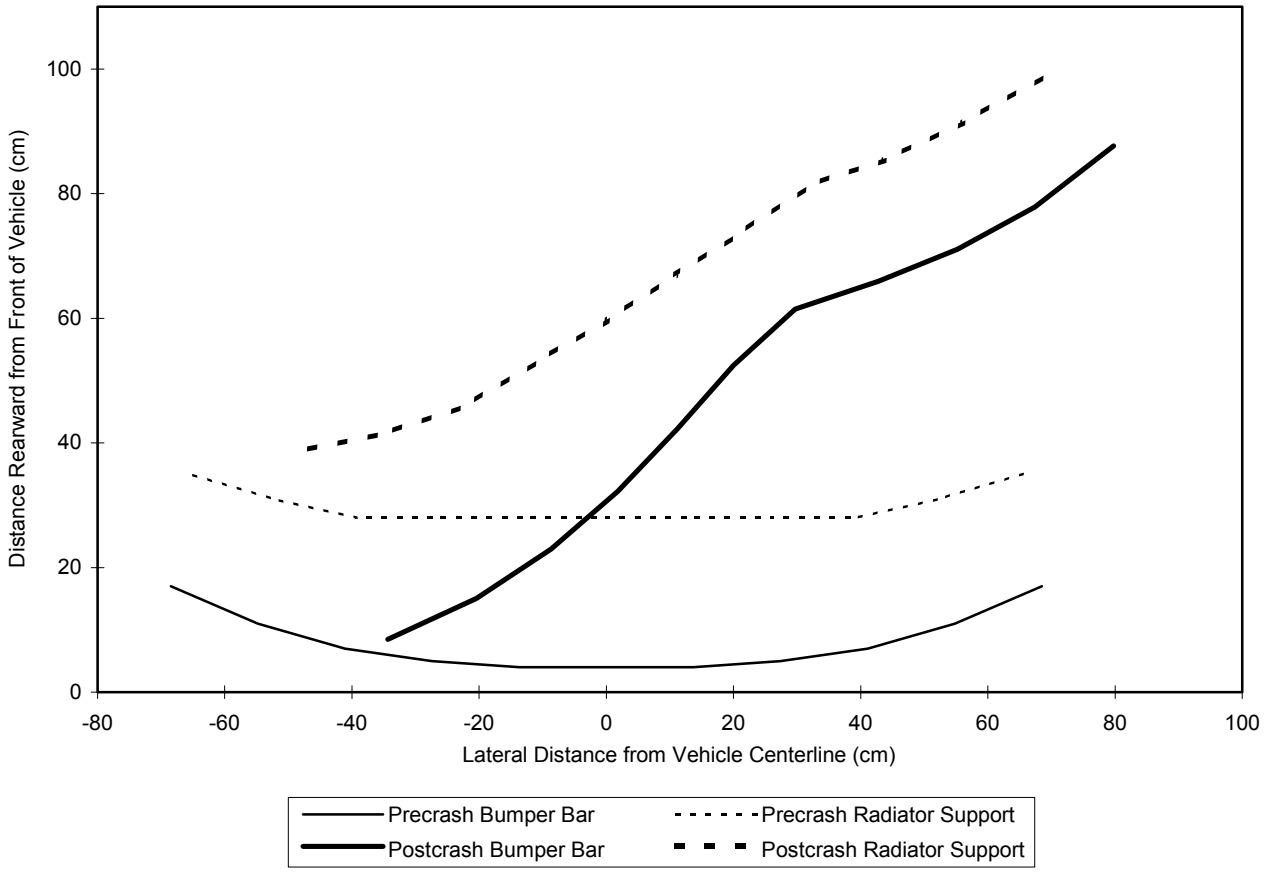
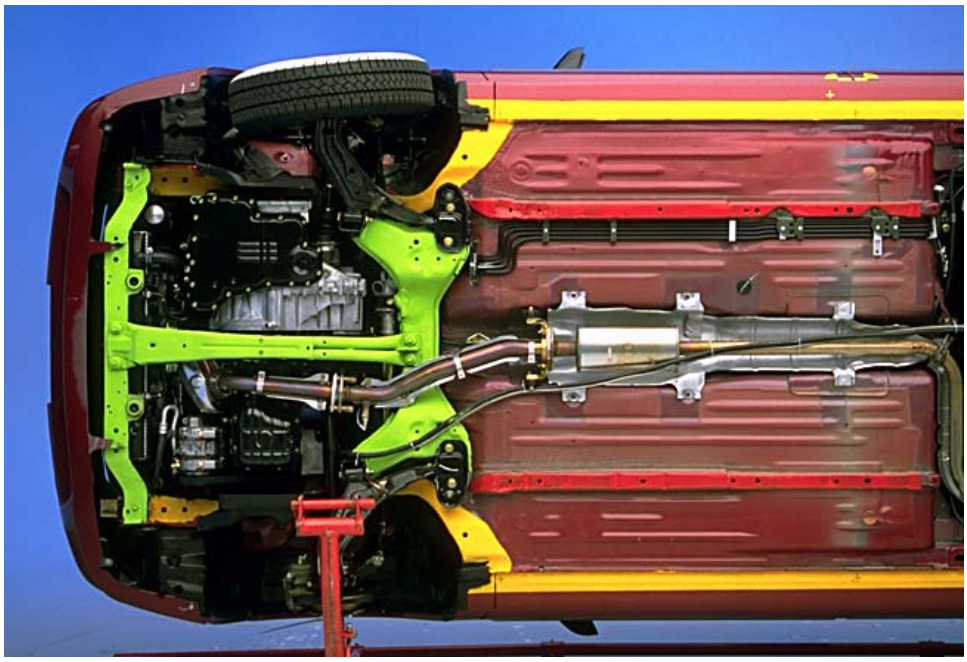


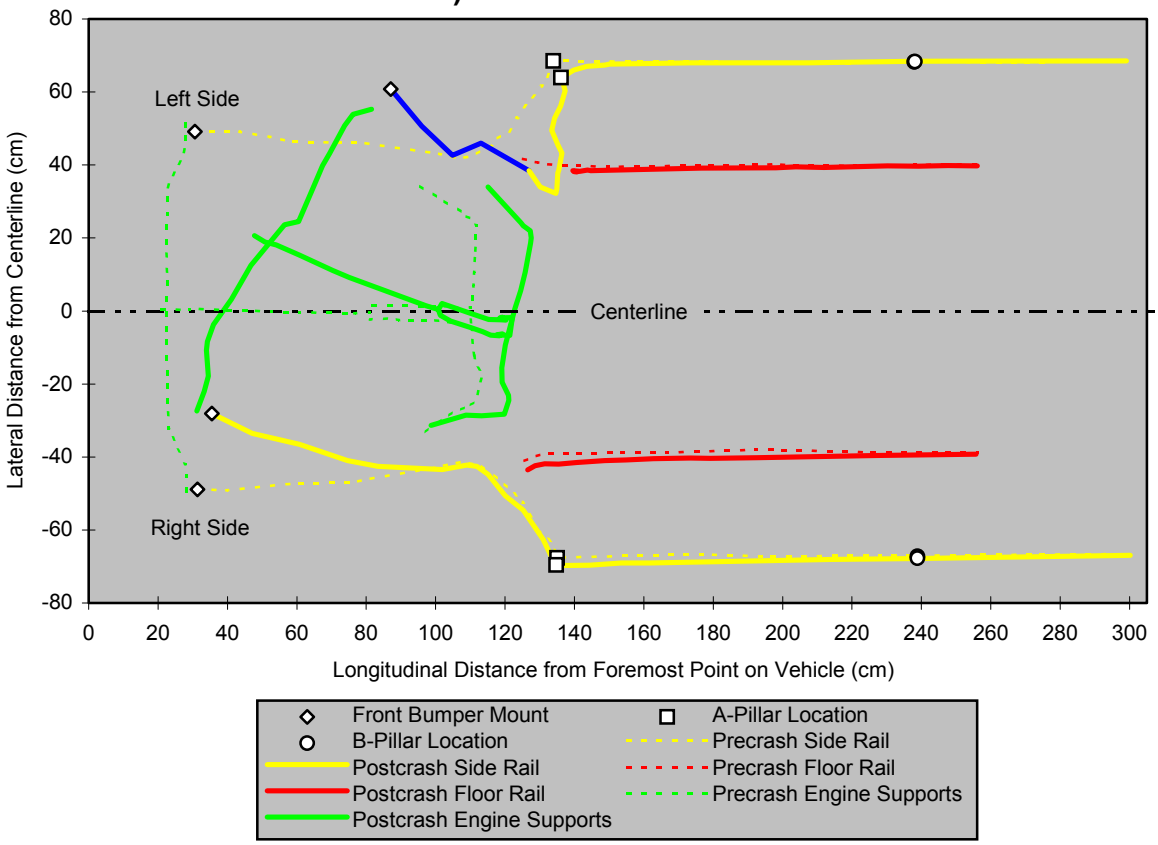
Figure 3
Precrash View from Below — 1998 Nissan Sentra



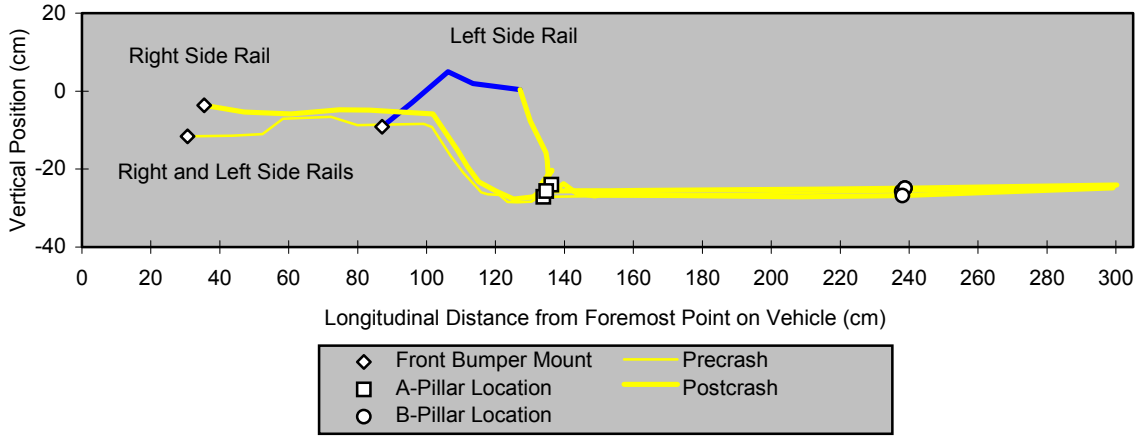
Postcrash View from Below — 1998 Nissan Sentra

Figure 4
Frame Rail Deformation — 1998 Nissan Sentra

a) View from Below*



b) Side View*



* After the crash, the position of the leading segment of the left side rail (indicated by ——) was approximated because this segment could not be adequately accessed due to the crush.

Various measures of intrusion were made after the crash. These residual measures of intrusion typically are less than the maximum deformation that occurs during the crash. The primary coordinate reference system for these measures is described in the IIHS Offset Barrier Crash Test Protocol (Version IV). The measures of deformation shown in Table 1 have been adjusted to better reflect the displacement of the various target locations relative to the driver. This was done by subtracting the average component displacements of the four seat-attachment bolts, which also were measured relative to the primary coordinate system, from the respective components of displacement for each of the target locations. The average displacement of the four seat-attachment bolts relative to the primary reference system also is shown in Table 1.

Table 1
Residual Measurements of Intrusion Relative to Driver Seat — 1998 Nissan Sentra

Selected Locations*	Longitudinal	Lateral	Vertical	Resultant
Steering column (cm)	-5	0	6	8
Left lower instrument panel (cm)	-8	-2	1	9
Right lower instrument panel (cm)	-4	-1	-1	4
Brake pedal (cm)	-20	-2	6	21
Left toepan (cm)	-27	-4	7	28
Center toepan (cm)	-25	-2	6	26
Right toepan (cm)	-17	0	4	18
Footrest (cm)	-14	-3	4	15
Average displacement of the four seat attachment bolts from primary reference system (cm)	-2	2	-3	—

* All measurements taken on driver side. From the driver's position, positive is forward, left, and up.

Restraint System Performance

Airbags

Driver: The uninflated driver airbag was 66 cm in diameter, and the excursion of its center when inflated was limited by two 21 cm-long tethers. The airbag was vented by two 33 mm-diameter holes at positions corresponding to 10 and 2 o'clock on the forward-facing surface of the airbag. Analysis of the high-speed film taken from camera position D indicated the airbag deployed at
28 ms into the crash and appeared to be fully inflated at 64 ms.

Passenger: The top-mounted passenger airbag deployed vertically and was untethered. The cylinder-shaped airbag was vented by two 40 mm-diameter holes located at the lateral ends. The airbag did not appear to contribute to windshield damage during deployment.

Seat Belts

This vehicle is equipped with dual-locking lap/shoulder belts with sliding latch plates at the outboard seating positions and adjustable upper anchorage points at both front seating positions. The front inboard lower anchorage points are attached to and move with the seats. The front outboard lower anchorage points are bolted to the B-pillars. During the crash, 2 cm of webbing was pulled from the retractor through the D-ring as measured by a pull-string mounted between the retractor housing and the webbing just beyond the retractor.

Seat

Postcrash examination of the driver seat rails indicated no discernible movement of the seat in its tracks during the crash. Analysis of the high-speed film taken from camera position D indicated the driver seat back movement was minimal. Deformation of the floor under the driver seat caused the seat to tip outboard slightly.

Steering Column

The upper end of the steering column moved upward 6 cm and rearward 5 cm relative to the driver seat. The lower portion of the steering column inside the occupant compartment uses a tube-in-tube design, and a residual collapse of approximately 10 cm was measured. An additional 1 cm of collapse of the steering column was attributed to the forward bending of the U-shaped bracket attached to the upper tube. The upper portion of the column does not have shear modules; instead, bolts mounted in elongated slots are used. Movement was approximately 1 mm forward on the left side and zero on the right side.

Dummy Kinematics

Head, Neck, and Torso

Analysis of the high-speed film taken from camera position D indicated the dummy's face began to load the airbag at the time the airbag appeared to be fully inflated (64 ms into the crash). Paint transferred from the dummy's face onto the airbag indicated the dummy's nose loaded the airbag 8 cm above and 3 cm to the right of its center. As the dummy continued forward, its head, neck, and shoulders moved leftward, and then its head began to turn to the right. As the dummy's head moved rearward, its left side passed through the open driver door window and close to the top of the driver door. The back of its head contacted the B-pillar at 228 ms, as indicated by head acceleration measures and confirmed by paint transfer and the bent metal underneath the weather stripping. The dummy then shifted to the right and back to the left, and the left rear side of the dummy's head contacted the B-pillar, again, and the shoulder belt height adjustment mechanism at about 504 ms; contact was confirmed by paint transfer. The dummy then shifted to the right and back to the left again, and the dummy's head neared, but did not contact, the B-pillar. The dummy then settled into the seat. Table 2 provides the timing and duration of these events.

Table 2
Analysis of Restraint System Performance and Dummy Kinematics — 1998 Nissan Sentra

Event	Time (ms)
Deployment of airbag	28
Airbag fully inflated	64
Head begins to load airbag	64
Head contacts B-pillar*	228
Head contacts B-pillar again and shoulder belt height adjuster	≅504

*Time determined from head acceleration measurements.

Legs and Feet

Left leg and foot: Paint transferred from the dummy's left knee indicated the knee contacted the middle section of the instrument panel, outboard of the steering column and above the knee bolster (8 cm above the left instrument panel intrusion measurement point). The left knee also contacted the steering column adjustment lever and the lower left corner of the steering column trim. Paint transferred from the dummy's left shin indicated the shin contacted the knee bolster 4 cm below the left instrument panel intrusion measurement point and then moved rightward to the steering column bulge. The left foot was found with the back of its heel pressed into a downward buckle of floormat and carpeting. The right side of the sole (from toe to heel) was pressed against the intruded toepan. The foot was fully dorsiflexed and slightly everted.

Right leg and foot: Paint transferred from the dummy's right knee indicated the knee contacted the lower right corner of the steering column trim just below the ignition switch and key. The right knee also contacted the middle section of the instrument panel slightly to the right of the steering column. Paint transferred from the dummy's right shin indicated the shin contacted and broke the knee bolster trim in the area of the right instrument panel intrusion measurement point. The right foot was found wedged between the center console trim bracket and the accelerator pedal. The back of the heel was pressed into a downward buckle of the floormat and carpeting. The sole of the heel and instep were pressed against the accelerator pedal, which was pressed against the toepan. The top of the foot was pressed against a metal bracket on the left side of the center console. The small clearance between these components and the dummy's foot made it difficult to free the foot after the crash.

Dummy Injury Measures

Head

The HICs were calculated during an interval that corresponds with the dummy's head excursion into the airbag. The maximum vector resultant head accelerations were recorded during an interval that corresponds with the dummy's first head contact against the B-pillar. The dummy's second head contact against the B-pillar at 512 ms occurred after data collection ended. Table 3 provides a summary of the maximum head injury measurements recorded during the crash.

Table 3
Head Injury Measurements — 1998 Nissan Sentra

Measure	Published Tolerance Threshold	Result	Time (ms)
Vector resultant acceleration (g)	80	85	230
Vector resultant acceleration — 3 ms clip (g)	80	71	230-233
Head Injury Criterion (HIC)*	1000	454	78-114
Head Injury Criterion — 15 ms interval (HIC-15)**	700	280	90-105

* A damaged wire connecting the head X-accelerometer to the data recorder caused data to be recorded intermittently. The X-acceleration was estimated so that approximate HIC values could be calculated. The estimate of the X-acceleration was derived by reconstructing a continuous data stream from the recorded head acceleration. The data in the following time periods was unchanged: -63.1-80.2 ms, 141.9-175.2 ms, 187.2-188.2 ms, 191.5-248.0 ms, 251.9-268.1 ms, and 298.3 ms to the end of data collection. Accelerations recorded at 81.4-140.6 ms were offset from the preceding data by -96.47 g, so the data were adjusted accordingly. Similarly, accelerations recorded at 176.7-186.2 ms were adjusted by -82.52 g to align it with the preceding data segment. Accelerations recorded at 188.8-190.5 ms were offset -81.43 g and those recorded at 269.8-296.5 were offset -83.22 g. Each offset was estimated by linear extrapolation from several data points at the end of the preceding intact or reconstructed data segments. Data recorded at 80.3-81.3 ms, 140.7-141.8 ms, 175.3-176.6 ms, 186.3-187.1 ms, 188.3-188.7 ms, 190.6-191.4 ms, 248.1-251.8 ms, 268.2-269.7, and 296.6-298.2 ms did not appear to represent the head acceleration. They were discarded and replaced with linear interpolations between the last data point of the preceding segment and the first data point in the following segment. The reconstructed X-acceleration and resultant acceleration are shown in Figures A-5b and A-8b.

** A proposed amendment to the Canadian Motor Vehicle Safety Regulations suggests calculating HIC during a 15 ms interval rather than the 36 ms interval specified by the U.S. standard. The Canadian proposal includes an injury threshold of 700 for front-seat occupants protected by airbags.

Neck

Table 4 provides a summary of the maximum neck injury measurements recorded during the crash.

Table 4
Neck Injury Measurements — 1998 Nissan Sentra

Measure	Published Tolerance Threshold	Result	Time (ms)
A-P shear force (kN)	±3.1*	0.4	232
Axial compression force (kN)	4.0*	0.1	142
Axial tension force (kN)	3.3*	1.8	102
Flexion bending moment (Nm)	190**	22	95
Extension bending moment (Nm)	57**	19	240

* These values are for instantaneous loading. Neck loads are compared with magnitude-duration injury criteria in Figures A-12 to A-15.

** These published thresholds are recommended injury assessment reference values from Backaitis and Mertz (1994), but significant neck injury may occur at lower bending moments. Mertz and Patrick (1971) report that bending moments of 47 Nm in extension and 88 Nm in flexion would be non-injurious for occupants represented by the Hybrid III 50th percentile adult male dummy.

Chest

Table 5 provides a summary of the maximum chest injury measurements recorded during the crash.

Table 5
Chest Injury Measurements — 1998 Nissan Sentra

Measure	Published Tolerance Threshold	Result	Time (ms)
Vector resultant spine acceleration — 3 ms clip (g)	60	43	100
Rib compression (mm)	50	38	105
Viscous criterion (m/s)	1.0	0.2	63

Legs and Feet

Left leg and foot: The left knee reached a maximum displacement of 16 mm. The maximum left upper tibia index was 1.00.

Right leg and foot: None of the injury measures approached the reference values.

Table 6 provides a summary of the maximum leg and foot injury measurements recorded during the crash.

Table 6
Leg and Foot Measurements — 1998 Nissan Sentra

Measure	Published Tolerance Threshold	Left Leg		Right Leg	
		Result	Time (ms)	Result	Time (ms)
Axial femur force (kN)	9.1*	3.3	104	2.0	69
Tibia-femur displacement (mm)	15	16	98	7	101
Upper Tibia					
L-M moment (Nm)	±225	-56	100	-111	103
A-P moment (Nm)	±225	-219	97	101	59
Vector resultant moment (Nm)	225	224	97	127	101
Index	1.00	1.00	97	0.60	60
Lower Tibia					
L-M moment (Nm)	±225**	23	87	-63	104
A-P moment (Nm)	±225**	156	94	62	95
Vector resultant moment (Nm)	225**	156	93	80	104
Axial force (kN)	8.0**	1.5	62	2.9	58
Index	1.00	0.71	93	0.37	105
Foot					
A-P foot acceleration (g)	±150	-54	64	-78	60
I-S foot acceleration (g)	±150	87	62	101	56
Vector resultant foot acceleration (g)	150	95	62	111	56

* This critical value is for instantaneous loading. Femur loads are compared with magnitude-duration injury criteria in Figures A-23 and A-34.

** These published thresholds are for fractures of the tibia. Ankle and foot injuries have been associated with bending moments as low as 50-100 Nm, and heel fractures have been associated with axial forces as low as 6.0 kN.

References

Backaitis, S.H. and Mertz, H.J. (eds). 1994. *Hybrid III: The First Human-Like Crash Test Dummy.* Warrendale, PA: Society of Automotive Engineers.

Begeman, P.C. and Prasad, P. 1990. Human ankle impact response in dorsiflexion (SAE 902308). *Thirty-fourth Stapp Car Crash Conference Proceedings,* 39-53. Warrendale, PA: Society of Automotive Engineers.

Begeman, P.; Balakrishnan, P.; Levine, R.; and King, A. 1993. Dynamic human ankle response to inversion and eversion (SAE 933115). *Thirty-seventh Stapp Car Crash Conference Proceedings,* 83-93. Warrendale, PA: Society of Automotive Engineers.

Part 1 Amendments to Motor Vehicle Safety Regulations 208 & 210. December 2, 1995. Canada Gazette, pp. 4131-60.

Mertz, H.J. and Patrick, L.M. 1971. Strength and response of the human neck (SAE 710855). *Biomechanics of Impact Injury and Injury Tolerances of the Head-Neck Complex*, 821-46. Warrendale, PA: Society of Automobile Engineers.

Parenteau, C.S. 1995. Foot-ankle injury: epidemiology and method to investigate joint biomechanics. Gothenburg, Sweden: Chalmers University of Technology.

Prasad, P. and Mertz, H.J. 1985. The position of the United States delegation to the ISO Working Group 6 on the use of HIC in the automotive environment (SAE 851246). *Biomechanics of Impact Injury and Injury Tolerances of the Head-Neck Complex*, 373-83. Warrendale, PA: Society of Automotive Engineers.

Welbourne, E.R. 1994. Vehicle performance requirements for head injury protection: a comparison of the head injury criterion with an 80 g limit on resultant acceleration. Technical Memorandum. Ottawa, Ontario: Transport Canada, Vehicle System Division.

Zeidler, F. 1984. The significance of lower limb injuries of belted drivers. *Journal of Orthopedics* [German].

Appendix

Low-Speed Crash Test Damage Repair Estimate

Dummy Clearance Measurements

Graph Index — index to graphs of time plots of dummy and vehicle data

Manufacturer's window sticker

Low-Speed Crash Test Damage Repair Estimate

1998 Nissan Sentra Four-Door Sedan: 5 mi/h Front into Angle Barrier

Test number: LA97015
VIN: 1N4AB41D2WC709761
Mileage: 117
Features: Driver and passenger airbags, air conditioning, automatic transmission, power steering, power mirrors, power door locks, power windows, heated back glass, tilt steering wheel, cruise control, two-stage paint.

	Part		Labor	
Description	**Mfg. No**	**Price**	**Operation**	**Hours**
Bumper reinforcement, front			Remove/reinstall	1.2
Bumper cover, front	F2022-1M225	$132.28	Replace	0.8
Bumper cover, front			Refinish	3.6
Bumper mounting bracket, left front			Remove/reinstall	0.2
Bumper mounting bracket, left front			Repair/align*	0.1
Bumper mounting bracket, right front	62210-1M200	11.25	Replace*	0.2
Headlamps			Aim	0.5
Lamp assembly, parking/turn signal, right			Remove/reinstall	0.2
Vertical lock support, hood			Repair/align	0.3
Fender, left front			Repair/align*	1.0
Fender, left front			Refinish	2.4
Fender, right front			Repair/align*	0.5
Fender skirt, right front			Repair/align	0.5
Sidemember, left front			Repair/align*	0.3
Sidemember, left front			Refinish	0.1
Sidemember, right front			Repair/align*	0.3
Sidemember, right front			Refinish	0.1
Paint and materials		99.20		
Total Parts		$242.73		
Total Labor		381.30		12.3
Grand Total		$624.03		

* This item was repaired or replaced as indicated before the 40 mi/h frontal offset barrier test.

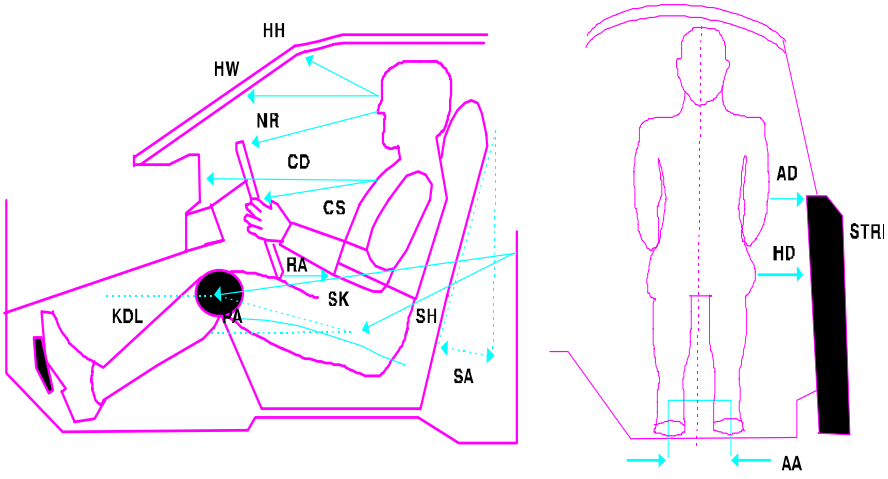
Dummy Clearance Measurements

Test Number: CF97021
Vehicle Make: Nissan Sentra
Vehicle Model Year: 1998
Seat Type: Manual adjustment

Manufacturer's Specifications
Seat Back Information: Reclined rearward to eighth locking position (first locking position is most upright)
Upper Belt Anchorage: Adjusted to uppermost position
Steering Column Adjustment: Midpoint

Location	Code	Measurement	Location	Code	Measurement
Head to header	HH	340	Torso angle	TA	23.8°
Head to windshield	HW	575	Striker to knee**	SK	600
Nose to rim	NR	415	Striker to knee angle**	SKA	0.7°
Chest to dash	CD	600	Striker to H-point horizontal	SHH	210
Chest to steering wheel	CS	385	Striker to H-point vertical	SHV	126
Rim to abdomen	RA	200	Arm to door	AD	20
Pelvic angle	PA	24.5°	H-point to door	HD	130
Knee to dash left	KDL	190	Seat back angle	SA	14.8°
Knee to dash right	KDR	195	Ankle to ankle	AA	295
Chest to airbag module*	ABM	280	Knee to knee	KK	285

All distance measurements are in mm.
* Center of airbag module to front point of chest level.
** These measurements are made in a vertical plane containing the striker and parallel to the driver door sill.



Graph Index