Side Impact Crashworthiness Evaluation 2.0 Crash Test Protocol

Version II

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CONTENTS

DOCUMENT REVISION HISTORY

Revisions to Version II of this protocol compared with Version I:

- Added tolerances for the moving deformable barrier's moments of inertia.
- Updated how the impact speed of the moving deformable barrier is determined.
- Updated the weight of and the design details for the antiroll device.
- Clarified that for the manufacturer-specific parts listed in this protocol (e.g., Endevco, Humanetics), an alternative that meets performance specifications can be used.

OVERVIEW

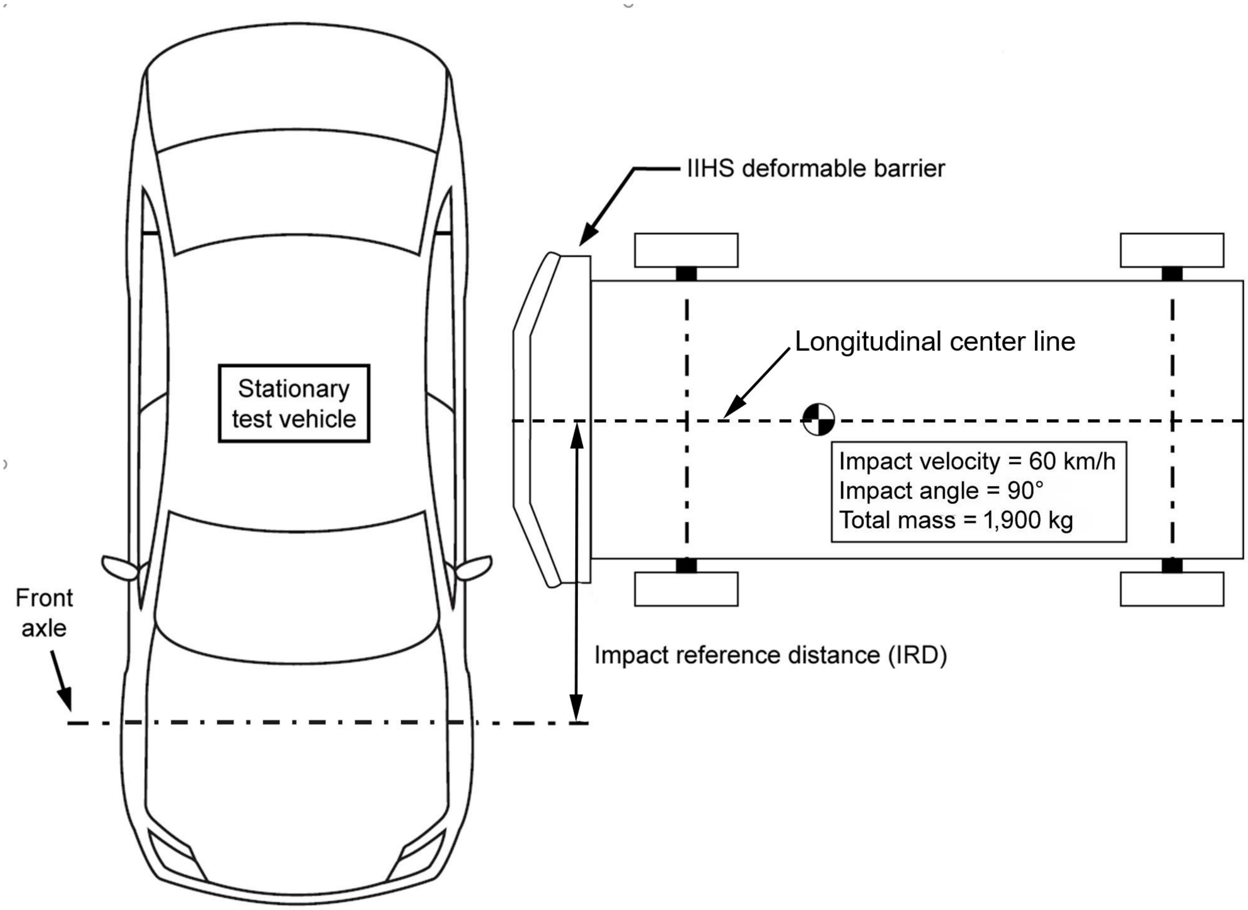
Testing procedures outlined in this document are largely similar to those in the previous side impact testing protocol, *Side Impact 1.0 Crash Test Protocol (Version X),* with changes to the test speed and moving deformable barrier.

Supporting documents for the Insurance Institute for Highway Safety (IIHS) side impact crash test program are available from the *Test protocols and technical information* section of the IIHS website.

IMPACT CONFIGURATION

Side impact crash tests consist of a stationary test vehicle struck on the driver side by a crash cart fitted with a deformable element on the striking face. The 1,900-kg moving deformable barrier (MDB) has an impact velocity of 60 km/h and strikes the vehicle on the driver side at a 90-degree angle. The longitudinal impact point of the barrier on the side of the test vehicle is dependent on the vehicle wheelbase. The impact reference distance (IRD) is defined as the distance rearward from the test vehicle front axle to the centerline of the striking barrier when it first contacts the vehicle (Figure 1).

Figure 1
Moving Deformable Barrier Alignment with Test Vehicle



The MDB alignment calculation was configured to maximize loading to the occupant compartment. If the alignment calculation allows the flat portion of the MDB face to overlap either the front or rear tires, the impact alignment may be modified to prevent direct loading to these structures early in the crash. Currently, there is no set alignment rule for vehicles that fall into this category, therefore impact alignment is determined on a case-by-case basis. Manufacturers may contact IIHS for impact point determination and/or confirmation of the impact point during the vehicle development process.

IRD calculation:

If wheelbase < 250 cm, then IRD = 144.8 cm

If 250 cm ≤ wheelbase ≤ 290 cm, then IRD = (wheelbase ÷ 2) + 19.8 cm

If wheelbase > 290 cm, then IRD = 164.8 cm

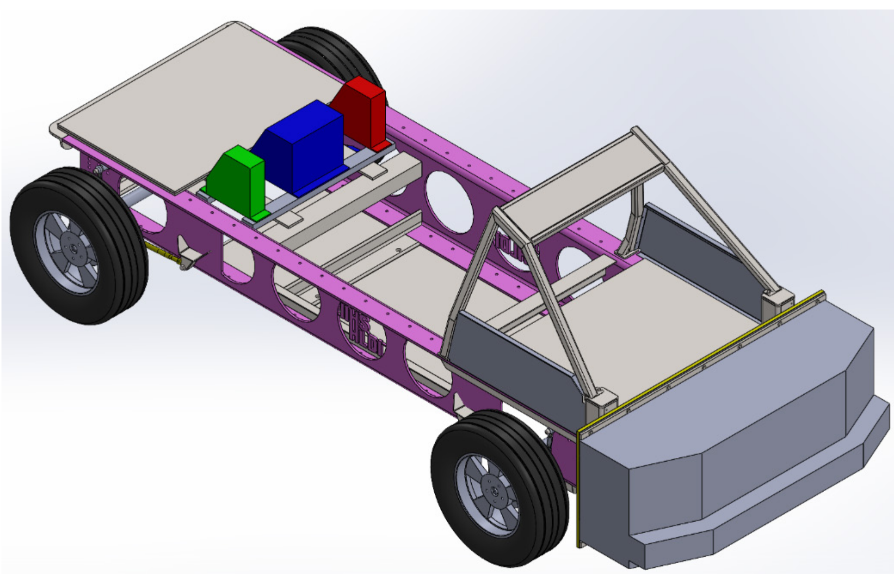
The MDB is accelerated by the crash propulsion system until it reaches the test speed (60 km/h) and then is released from the propulsion system 25 cm before the point of impact with the test vehicle. The impact point tolerance is ± 2.5 cm of the target in the horizontal and vertical axes. The impact speed tolerance is 60 ± 1 km/h. The MDB braking system, which applies the test cart service brakes on all four wheels, is activated 0.2 second after it is released from the propulsion system. The brakes on the test vehicle are not activated during the crash test.

IIHS MDB Properties

The MDB consists of an IIHS deformable aluminum barrier (2.0) and the cart to which it is attached. The crash cart dimensions, mass, and inertial properties are based on those of a midsize SUV (Figure 2). The cart is equipped with suspension at both the front and rear axles, and the wheels are aligned with the longitudinal axis (0 degrees) to allow for perpendicular impact.

The MDB test weight is 1,900 ± 5 kg with the deformable element, test instrumentation, camera, and camera mount. The MDB center of gravity in the fully equipped test condition is 1,236 ± 10 mm rearward of the front axle, 0 ± 10 mm from the lateral centerline, and 651 ± 10 mm from the ground. The MDB roll (I_X), pitch (I_Y), and yaw (I_Z) moments of inertia are 581 kg-m^2, 3,688 kg-m^2, and 4,049 kg-m^2, respectively. Tolerances for moments of inertia are ± 5%.

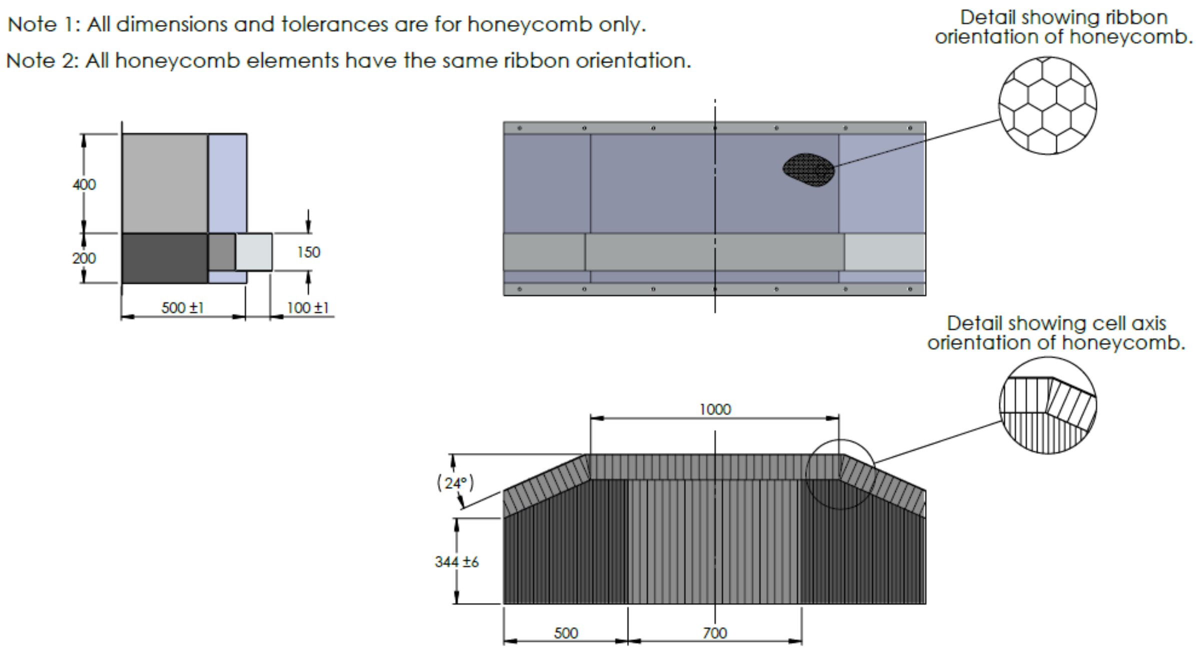
Figure 2
IIHS Test Cart with Deformable Barrier Element Attached



The deformable element has a width of 1,700 mm, a height of 600 mm, and a ground clearance of 350 mm ±0.5 cm when mounted on the test cart (Figure 3).

The IIHS deformable barrier design and performance criteria are documented in the *Side Impact Deformable Barrier Specification 2.0* (IIHS, 2022); detailed drawings are also included.

Figure 3
IIHS Deformable Barrier Element (all dimensions in millimeters)



Test Vehicle Preparation

Each vehicle is inspected upon arrival at the research center. Vehicles are examined to verify that they are in satisfactory operating condition and to note defects such as prior collision damage, missing parts, maladjustments, or fluid leaks. If directly relevant to testing, such deficiencies are corrected or a replacement vehicle is procured.

Fluids

Gasoline is removed from the fuel tank and fuel lines. The fuel tank then is filled with Stoddard solvent to 90%–95% of useable capacity. Purple dye is added to the Stoddard to better identify leaks postcrash. The fuel pump is run for a short period to ensure that the Stoddard solvent has filled the fuel lines. Additional fluids may be drained from the vehicle should the vehicle exceed the maximum allowable test weight.

High-Voltage Batteries

High-voltage batteries in vehicles with full-electric drivetrains are tested at a state of charge (SoC) of 12.5 ± 2.5%, with a minimum of 25 miles of travel capacity on the battery. To avoid the possibility of the hybrid system attempting to begin a charge cycle, (i.e., engine start), the high-voltage batteries in hybrid vehicles are tested at the minimum SoC recommended by the manufacturer. Maintenance fuses are not removed, but additional precrash and postcrash precautions specified by the vehicle manufacturer are followed. Equipment is added to the high-voltage system in accordance with manufacturer-recommended procedures for monitoring electrical isolation as per Federal Motor Vehicle Safety Standard (FMVSS) 305. Thermocouple(s) also are attached to the high-voltage battery to detect temperature increases that may indicate a thermal runaway condition.

Test Vehicle Instrumentation

An aluminum instrumentation rack, which supports the test equipment, is installed in the cargo area of the vehicle. The carpeting in this area is removed to allow access to the floor. If necessary, the spare tire, accessory jack, tool compartments, and third row seats may be removed. The following test equipment is installed on the instrumentation rack located in the cargo area:

12-volt battery and monitoring system: This system supplies electrical power for the data acquisition system (DAS) and a wireless bridge for DAS communication. The system weighs approximately 25 kg. The wireless device for DAS-to-network communication is mounted to the outside of the vehicle and weighs 2 kg. A two-conductor cable connects the 12-volt battery in the instrumentation rack to the vehicle battery terminals.

High-speed camera and onboard lighting power supply: This system supplies electrical power and control to the onboard high-speed video cameras and LED lighting. The weight of the camera/lighting system is approximately 20 kg.

Two camera mount platforms are installed on the nonstruck side of the vehicle at locations adjacent to the front- and rear-passenger windowsills; the front and rear platforms weigh 10 and 15 kg, respectively. Three digital onboard high-speed cameras (500 frames per second), along with a camera router, are mounted on the platforms to observe dummy kinematics throughout the crash. Additionally, four LED light fixtures are mounted inside the vehicle.

A plastic block containing an array of high-intensity LEDs is attached to the roof of the vehicle with sheet metal screws. Additional LEDs are placed inside the vehicle in view of the onboard high-speed cameras. A pressure-sensitive tape switch is applied to the driver side of the vehicle such that it makes first contact with the barrier during the crash. Pressure applied to this tape completes an electrical circuit that signals the start of the crash (time-zero) for the data acquisition systems and illuminates all the LEDs.

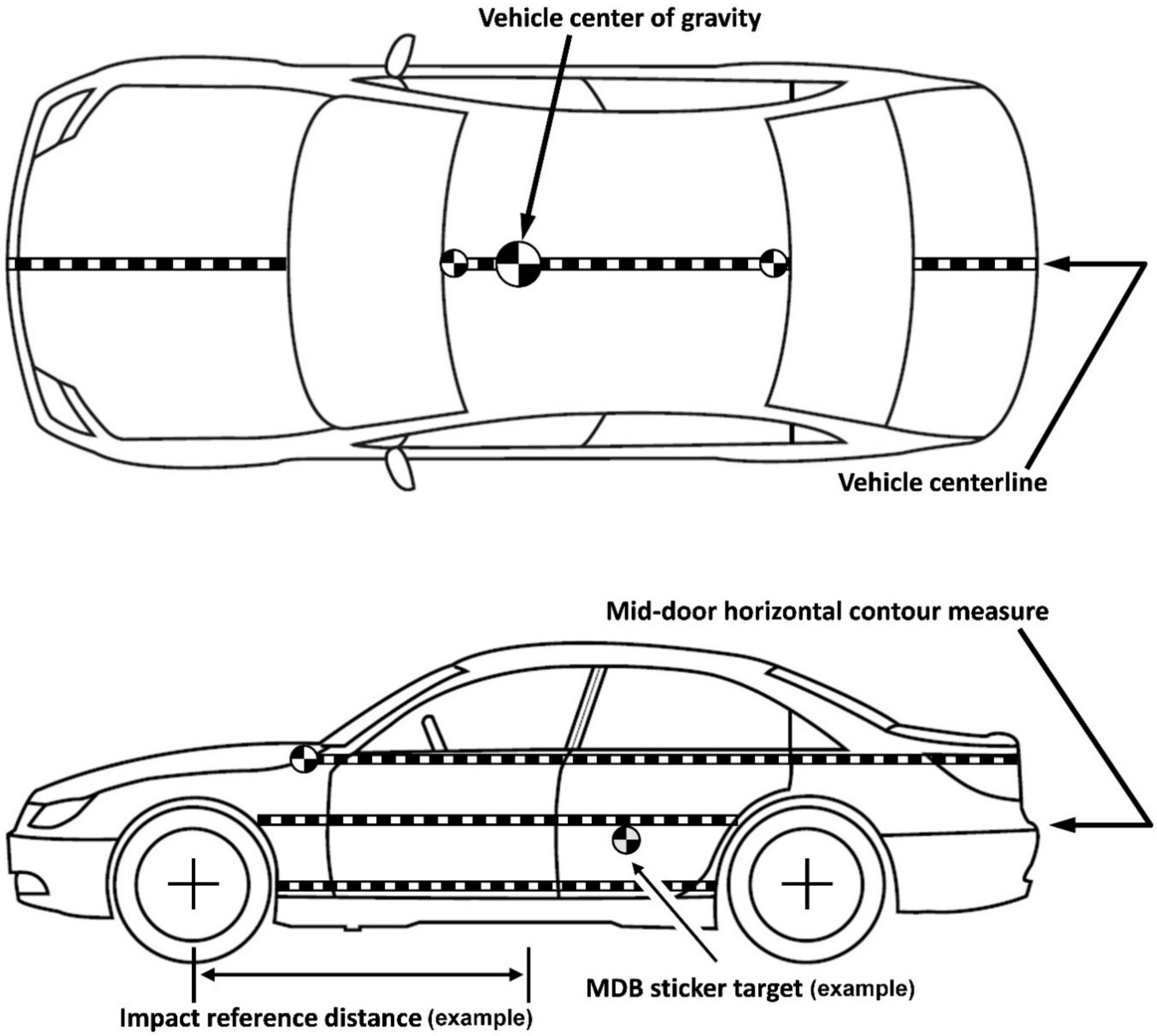
If floormats are standard or offered as an option through the manufacturer or dealership, they are installed in the driver footwell and left rear-passenger floorpan.

The location of the vehicle precrash longitudinal center of gravity is marked with a photographic target applied to the appropriate top surface of the vehicle (Figure 4).

The front-passenger head restraint and passenger-side windows are removed to prevent possible obstruction of camera views during the test.

If the vehicle is equipped with running boards, they are removed unless they are standard equipment across the entire model line for the specific drive configuration being tested (two-wheel or four-wheel drive).

Figure 4
Exterior Surface Marking



Attachment of Antiroll Device to Vehicles with a High Center of Gravity

To prevent possible damage to cameras and equipment caused by a rollover subsequent to the side impact, vehicles with a high center of gravity (typically those classified by IIHS as midsize and large SUVs, all pickups, or all passenger vans) will be tested with an antiroll device attached to the nonstruck side of the vehicle (Figure 5).

The antiroll device is made primarily of 4130 Chromoly structural tubing and weighs approximately 50 kg. It attaches to the vehicle where the passenger side B-pillar intersects the roof rail and at two points on the pinch welds, beneath the front and rear doorsills.

The device is designed so that it can be adjusted to allow the vehicle to rotate up to 5 degrees, before further rotation is countered by three coaxial springs that will produce up to 8.091 kN at full compression.

These springs, which are located in the telescoping upper strut member, will allow an additional 20 degrees of rotation before the upper strut bottoms out.

Detailed drawings of the antiroll device are available upon request.

Figure 5
Antiroll Device for Tests of Midsize and Large SUVs, Pickups, and Passenger Vans

Test Vehicle Mass and Weight Distribution

The test weight of the vehicle, which includes the vehicle instrumentation, three cameras, and two SID-IIs dummies, is 150–225 kg greater than the measured curb weight of the vehicle (as delivered from the dealer with full fluid levels). If the vehicle test weight needs to be increased to fall within the range, ballast weight is distributed in a manner that comes closest to replicating the original front/rear and left/right weight distributions of the vehicle. If the vehicle test weight needs to be decreased, nonessential, nonstructural items are removed from the vehicle.

Driver Seat and Driving Control Placement

The driver seat and adjustable steering controls are adjusted according to the *Guidelines for Using the UMTRI ATD Positioning Procedure for ATD and Seat Positioning (Version V)* (IIHS, 2004). The outboard upper seat belt anchorage point (if adjustable) is set in the full-down position, unless otherwise specified by the test vehicle manufacturer. After the driver seat has been adjusted, the latching mechanism is examined to note whether all of its components are interlocked. If partial interlocking is observed and normal readjustment of the seat does not correct the problematic misalignment, the condition is noted and the test is conducted without repairing the mechanism. The right front-passenger seat is positioned to approximately match the position of the driver seat.

The driver head restraint (if manually adjustable) is set in the full-down position, unless otherwise specified by the test vehicle manufacturer. The locking mechanism for adjusting the head restraint height (if equipped) is examined to ensure the mechanism has engaged. All manually adjustable, head restraint tilting mechanisms are adjusted to their full-rearward position.

The manually adjustable inboard armrest for the driver seat (if equipped) is moved to its lowered position. For vehicles equipped with multiple locking armrest positions, the position that results in the top surface of the armrest being closest to parallel with the ground is chosen. When seats have inboard and outboard armrests, both are placed in the lowered position.

Rear-Passenger Seat Placement

If applicable, the rear-passenger seat is positioned according to the *Dummy Seating Procedure for Rear Outboard Positions* (IIHS, 2022).

If manually adjustable, the rear-passenger head restraint is set in the full-down position, unless otherwise specified by the test vehicle manufacturer. In cases where the head restraint can be lowered for stowage or positioned for nonuse, it shall be set to the first usable locking position. All manually adjustable head restraint tilting mechanisms are adjusted to their full-rearward position.

The manually adjustable inboard armrest for the rear seat (if equipped) is moved to its lowered position. For vehicles equipped with multiple locking armrest positions, the position that results in the top surface of the armrest being closest to parallel with the ground is chosen. When seats have inboard and outboard armrests, both are placed in the lowered position.

Side Windows and Door Locks

The nonstruck side doors are fully latched and locked, whereas the struck side doors are fully latched but not locked. However, if the vehicle is equipped with automatic locking doors that cannot be set to remain unlocked when the vehicle is in forward motion, the struck side door locks are kept in their automatic state. The front and rear driver-side windows are fully raised.

Transmission and Ignition

The ignition is turned to its on position, and the transmission is shifted into its neutral position prior to the test. The parking brake is activated. The front left tire is chocked to prevent the vehicle from moving prior to the test.

Vehicle Ride Height

If the vehicle has an adjustable suspension or is equipped with automatic leveling, those systems are deactivated. The ride height will be set to the default/vehicle parked condition.

Vehicle Active Side Crash Safety Systems

If the vehicle has an active safety system designed for crash protection in similar crash configurations to this laboratory test, such as an active chassis lift, seat bolster deployment, external airbag, or other technology, all reasonable efforts are made to test with the feature activated. For systems that require test setup modifications, decisions are made on a case-by-case basis. External or manual triggering of systems is not permitted.

Crash Dummy Preparation and Setup

A 5th percentile female SID-IIs dummy is positioned in the driver seat according to the *Guidelines for Using the UMTRI ATD Positioning Procedure for ATD and Seat Positioning (Version V)* (IIHS, 2004). A second SID-IIs dummy is positioned in the left rear seat according to the *Dummy Seating Procedure for Rear Outboard Positions* (IIHS, 2022).

Standard Build Level D SID-IIs (Humanetics Innovative Solutions, 2011) dummies are used for the IIHS side impact program. Each dummy has been modified by removing the upper and lower shoulder rib stops on the spine box (Humanetics Innovative Solutions, Inc., part numbers 180-3369 and 180-3370 or an alternative that meets performance specifications). Removal of the shoulder rib stops restores the shoulder deflection to the range that was allowable in the Standard Build Level C SID-IIs. The Build Level D shoulder potentiometer has been replaced with a potentiometer that has a longer travel range (Humanetics Innovative Solutions, Inc., part number 180-3882 or an alternative that meets performance specifications). Photographic targets are placed on both sides of the head to mark the location of its center of gravity.

The dummies used in these tests are certified according to 49 C.F.R. § 572 (V) after being subjected to no more than five crash tests. Additionally, the shoulder, thorax, and abdomen regions are individually recertified if deflections recorded during a test exceed 50 mm or if postcrash inspection reveals damage. All visible damage is repaired before the dummy is used again.

The dummies and vehicle are kept in a climate-controlled area in the crash hall where the temperature is maintained at 20.0–22.2 degrees Celsius and the relative humidity at 10%–70% for at least 16 hours prior to the test. The driver and rear-passenger seat belts are fastened around the dummies.

For vehicles with continuous-loop lap/shoulder seat belts, the slack from the lap portion of the driver seat belt is removed, and the webbing is pulled fully out of the retractor and allowed to retract under tension a total of four times. The lap belt slack then is removed again with a small pulling force.

For vehicles with separate lap and shoulder seat belt retractors, the webbing from each is pulled fully out of the retractor and allowed to retract under tension a total of four times.

Prior to the crash, neck shields are installed, and the heads of both dummies are colored with grease paint to facilitate postcrash identification of impacts with the vehicle interior and/or the striking barrier face.

Photography

Still Photography

The precrash and postcrash conditions of each test vehicle are photographed. Two precrash and two postcrash views show the left side and left front quarter of the test vehicle. Additional photographs document the precrash position of the driver and rear-passenger dummies.

Three standard views each of the vehicle and MDB together in their postcrash positions, of the struck side of the vehicle, and of the MDB face are recorded. Additional photographs document the postcrash positions of the driver and rear-passenger dummies, as well as any paint transfer areas due to dummy contact with the vehicle or MDB. Once the dummies are removed from the vehicle, both seating compartment areas are photographed as a means of illustrating vehicle intrusion and dummy head contact points. Additional photographs are taken with the struck side doors removed.

High-Speed Motion Picture Photography

Motion picture photography is made of the test with 10 high-speed digital imagers along with real-time cameras. The coordinates and lens focal length of each offboard camera are listed in Table 1. The camera view and focal length of the onboard high-speed cameras are listed in Table 2. All high-speed imagers record at 500 frames per second. The positions of the offboard and onboard cameras are illustrated in Figures 6A and 6B, respectively.

Table 1
Crash Hall High-Speed Phantom Cameras — Coordinates, Focal Points, and Settings

	A	B	C	D	E	F
Camera Position	**Overhead**	**Left Side Oblique**	**Front**	**Rear Oblique**	**Front Oblique (driver)**	**Front Oblique (passenger)**
Coordinate X (cm)	−16	−536	−33	−320	415 [a]	415 [a]
Coordinate Y (cm)	−33	1350	768	−510	740 [a]	740 [a]
Coordinate Z (cm)	910	149	194	140	146	146
Focal length (mm)	35	50	95	75	135	135

[a] Varies by vehicle size and type

Table 2
Onboard High-Speed IDT Digital Cameras — Focal Points and Settings

	G	H	I	J
Camera Position	**Centered On MDB**	**Front-Passenger Windowsill**	**Front-Passenger Windowsill**	**Rear-Passenger Windowsill**
Focal point	Impact from perspective of the MDB	Oblique view of driver and passenger	Lateral view of driver	Lateral view of passenger
Focal length (mm)	8.5	12	12	12

Note. IDT = Integrated Design Tools, Inc.

Figure 6A
Offboard and MDB High-Speed Camera Positions in Crash Hall

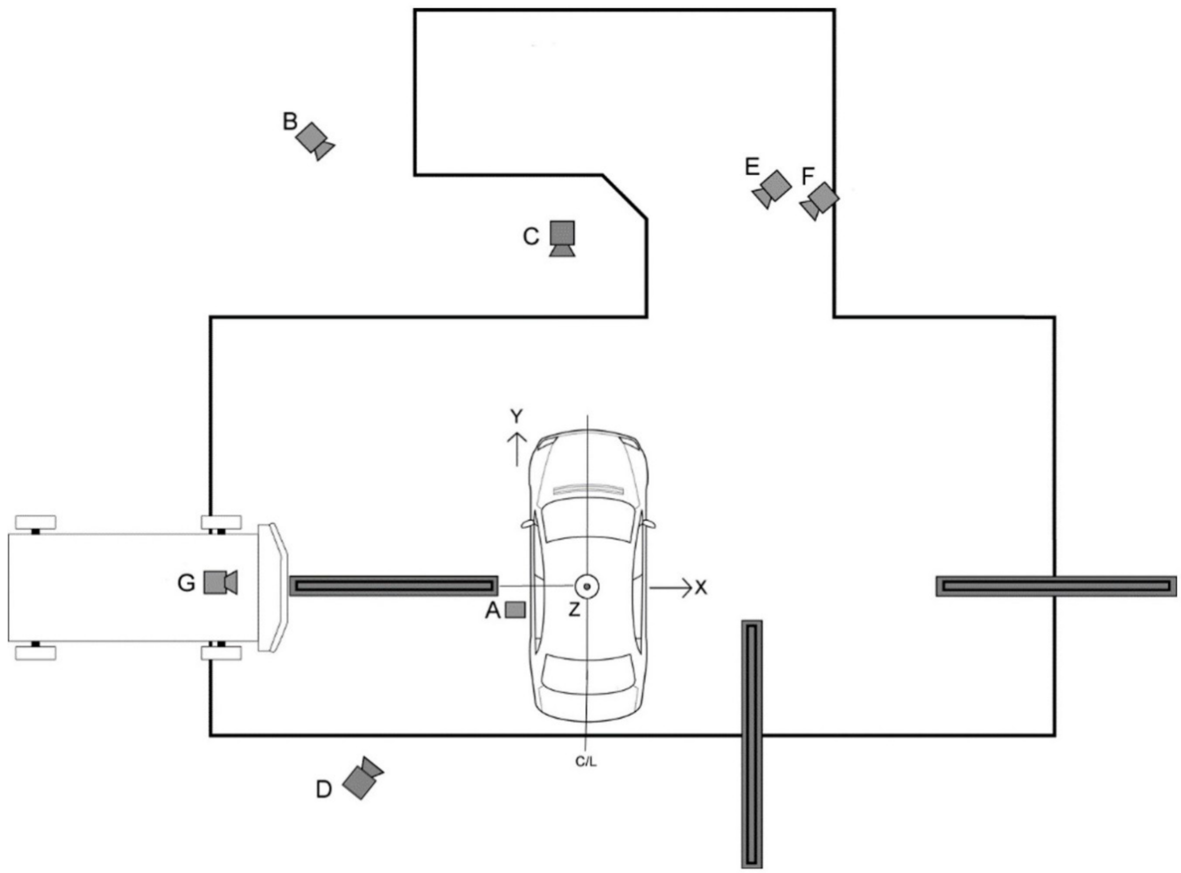
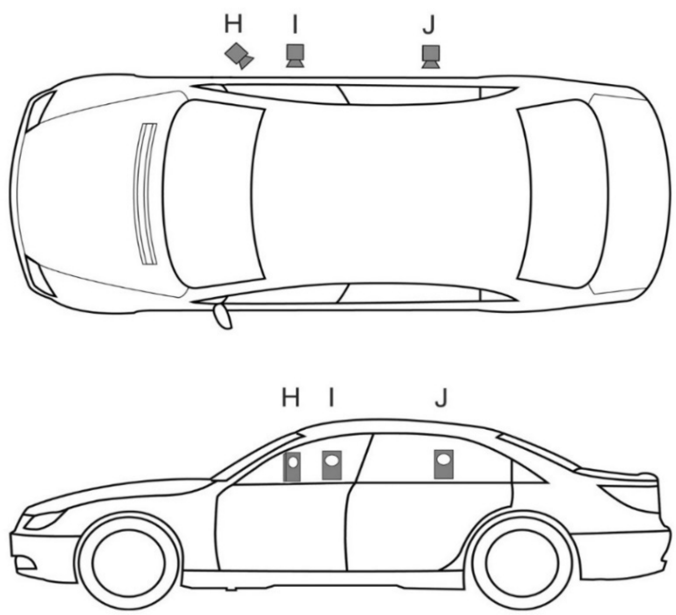


Figure 6B
Onboard High-Speed IDT Camera Positions



Note. IDT = Integrated Design Tools, Inc.

TEST WEIGHT

The test weight of the vehicle is measured at each of the four wheels. The vehicle is weighed with all test equipment installed (ballast weight is added to account for the driver and passenger dummies). The front and rear axle weights are used to determine the longitudinal position of the center of gravity for the test vehicle.

Impact Speed

The impact speed of the MDB is determined by sensors in the crash propulsion system. Alternatively, video analysis can be used to determine the MDB's impact speed.

Impact Point

A threaded 3-mm rod with a sharpened tip is attached to a tapped hole in the leading edge of the MDB bumper aluminum cladding. The horizontal location of this impact striker is selected such that it contacts the vehicle structure rearward of the driver door at the point of impact. The impact striker extends 20–30 mm from the front edge of the barrier face; thus, it makes first contact between the barrier and the vehicle. A 3-inch (76-mm) diameter photo target is placed on the vehicle (Figure 4) so that the tip of the impact striker is located in the center of the target during precrash vehicle positioning. At the point of impact, the striker punctures the target, thus providing an indication of the initial MDB alignment with respect to the vehicle.

Vehicle Accelerations

The lateral acceleration of the vehicle occupant compartment is measured (by uniaxial piezoresistive accelerometers; Endevco 7264B-2000 or 7264A-2000 or an alternative that meets performance specifications) at two locations on the floor, just rearward of the A- and B-pillars (nonstruck side) and recorded by the data acquisition system. Positive vehicle accelerations are to the right along the lateral axis. The data are presented filtered according to the channel frequency class (CFC) 60 as defined in Society of Automotive Engineers (SAE, 2014) Surface Vehicle Recommended Practice J211/1.

Fuel System Integrity

Observations about fuel system integrity are recorded for each test. Any Stoddard solvent leaked from the fuel system within 1 minute after the impact is collected as the first sample. This typically is done by soaking up the fluid with an absorbent pad of known mass. The second sample of leaked Stoddard solvent is collected during the 5 minutes immediately following the collection of the first sample. This sample typically is collected in pans placed under the sources of identified leaks. The third sample is collected during the 25 minutes immediately following the collection of the second. The pans used to collect the second sample are replaced with clean empty pans. The volume of each sample is determined by dividing the weight of the sample by the density of Stoddard solvent (790 g/l). The elapsed time is determined using a stopwatch. The entire process is recorded with a video camera equipped with an internal timer, which displays the time in each frame.

High-Voltage System Integrity

Vehicles with a hybrid or full-electric drivetrain are monitored to ensure the high-voltage electrical system has not been compromised. Postcrash observations include a measure of electrolyte spillage (if any), battery retention, and electrical isolation of the high-voltage system as per FMVSS 305. Additionally, the battery temperature is monitored to detect a rapid increase in temperature that may indicate a thermal runaway condition.

Coordinate System Definition

A right-handed, three-axis orthogonal coordinate system is used for these measures: longitudinal (front to rear is positive), lateral (left to right is positive), and vertical (bottom to top is positive). The precrash coordinate system is defined with the vehicle unloaded (no occupants) on a level floor. The plane of the ground is used to define the X-Y plane, and the two end points on the centerline of the roof are used to define the X-axis (Figure 4). Coordinates of three marked reference points on the nonstruck side vehicle structure are recorded before the crash to establish the postcrash coordinate system.

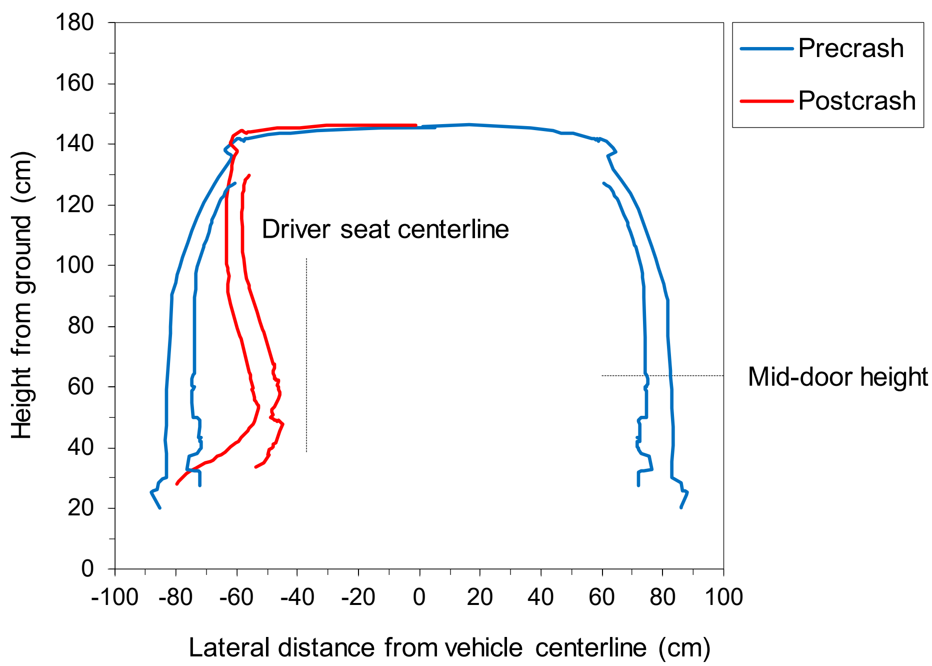
Vehicle Crush Profile and Compartment Intrusion

The spatial coordinates of the test vehicle B-pillars and profile of the driver-side structure are measured before and after the crash. A horizontal contour line is marked on the driver side of the vehicle at the level of the mid-door and then recorded using a coordinate measuring machine (CMM); the mid-door line is the horizontal line through the center point between the driver windowsill and the bottom of the driver door (Figure 4). This contour line is measured after the crash using the same reference coordinate system.

Precrash measures are recorded to determine the driver seat centerline. The driver seat centerline is defined from an average of Y-coordinates of left and right seat pan reference points. Seat pan upholstery lines may be used as reference points. If the seat pan has no usable reference lines, seatback upholstery lines may be used. Precrash measures are recorded down the middle of the struck side B-pillar exterior and the nonstruck side B-pillar exterior and interior (with interior trim removed); postcrash measures are recorded on the struck side B-pillar exterior and interior (with interior trim removed).

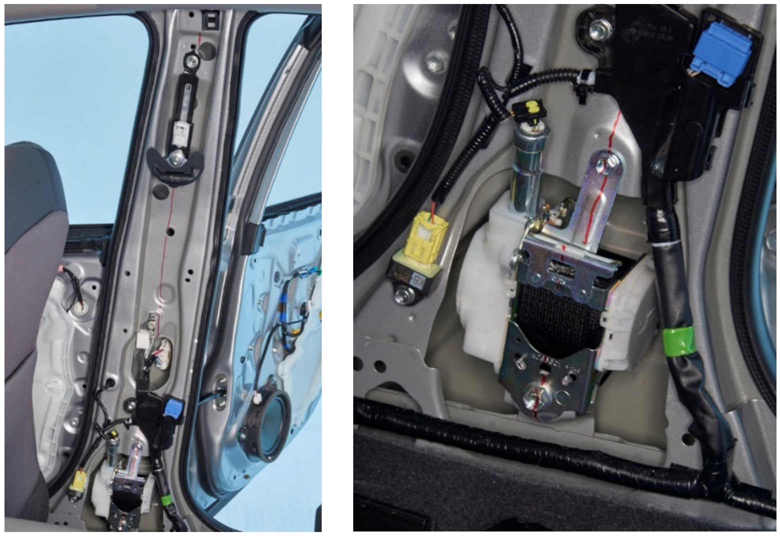
Precrash measures on the struck side B-pillar interior are not recorded, due to the possibility that removal and reattachment of the interior trim could affect the deployment of roof-rail-mounted head curtain airbags. A mirror image of the nonstruck side B-pillar interior vertical profile is used to determine the relative movement of the B-pillar interior. Figure 7 shows an example of precrash and postcrash B-pillar vertical profile measures.

Figure 7
Example B-Pillar Vertical Profiles



Seat belt retractors are included in the precrash measures if they are located within the vertical measurement range of the interior B-pillar (Figure 8). Only the structural components of the retractor, or crash tensioner, are measured (i.e., metal bracketry and bolts), not the seat belt webbing spool.

Figure 8
Example of Interior B-Pillar and Crash Tensioner Profile Measure — Precrash



Dummy Kinematics and Contact Locations

Both dummies are inspected in their undisturbed postcrash positions. Any damage to or unusual final resting position observed for either dummy is documented. The locations of grease paint transferred from the heads of the dummies to the vehicle interior and/or barrier face are noted and photographed. Any entrapment of the lower extremities also is documented when the dummies are extricated from the vehicle.

Review of the high-speed video helps determine dummy kinematics and estimate the time after the start of the crash that various events occur. For each event, the camera that provides the clearest view of the event is used. The start of the crash is considered to be the first frame in the video from each camera in which the LEDs mounted on the roof and inside the vehicle are illuminated. The time recorded for each event is based on the number of frames elapsed from the start of the crash and the nominal operating speed of the camera. For the cameras operating at 500 frames per second, the estimate of the crash start time can be up to 2 ms late, and the event time, as determined from the video, can be early or late by 2 ms. The times of the driver- and passenger-side airbag deployments, full inflation, and first dummy contacts are recorded as well as any other notable events.

Dummy Responses

Each SID-IIs dummy is equipped with instrumentation for measuring the following:

Head

Triaxial accelerations (three Endevco 7264B-200 or 7264A-2000 accelerometers or an alternative that meets performance specifications)

Triaxial angular rate sensors (three DTS ARS Pro — 18k or an alternative that meets performance specifications)

Neck

A-P shear force

L-M shear force

Axial force

L-M moments

Twist moments

Shoulder

Triaxial forces

Lateral shoulder compression (Humanetics 180-3882, 0.5-inch linear potentiometer, or an alternative that meets performance specifications)

Spine

T1, base of the neck, lateral acceleration (Endevco 7264B-200 accelerometers or an alternative that meets performance specifications)

T4, first thoracic rib level, lateral acceleration (Endevco 7264B-200 accelerometers or an alternative that meets performance specifications)

T12, first abdominal rib level, lateral acceleration (Endevco 7264B-200 accelerometers or an alternative that meets performance specifications)

Chest and Abdominal Ribs (three thorax and two abdominal ribs)

Struck-side lateral rib accelerations (Endevco 7264B-200 or 7264A-2000 accelerometers, or an alternative that meets performance specifications)

Lateral rib compressions

Pelvis

Lateral acceleration (Endevco 7264B-200 or 7264A-2000 accelerometers, or an alternative that meets performance specifications)

Lateral acetabulum force

Lateral ilium crest force

Instrument Calibration

All instruments are regularly calibrated to a known standard. Accelerometers and load cells are calibrated every 12 months. All measurements recorded from these instruments comply with the recommendations of SAE (2007) Surface Vehicle Information Report J1733.

Data Acquisition and Calculations

All measurements are recorded at a sample rate of 10 kHz. Signals in all channels convert simultaneously, so the time reference for different channels is not skewed.

After the data have been downloaded from the data acquisition systems, any initial offset from zero is removed from each channel by computing the mean value for 100 data points preceding the crash event (from 50 to 40 ms before impact) for each channel and subtracting each mean from the respective data channel. All data are digitally filtered using the frequency response classes recommended in SAE (2014) Surface Vehicle Recommended Practice J211/1. All filtering and subsequent calculations are completed by data analysis software.

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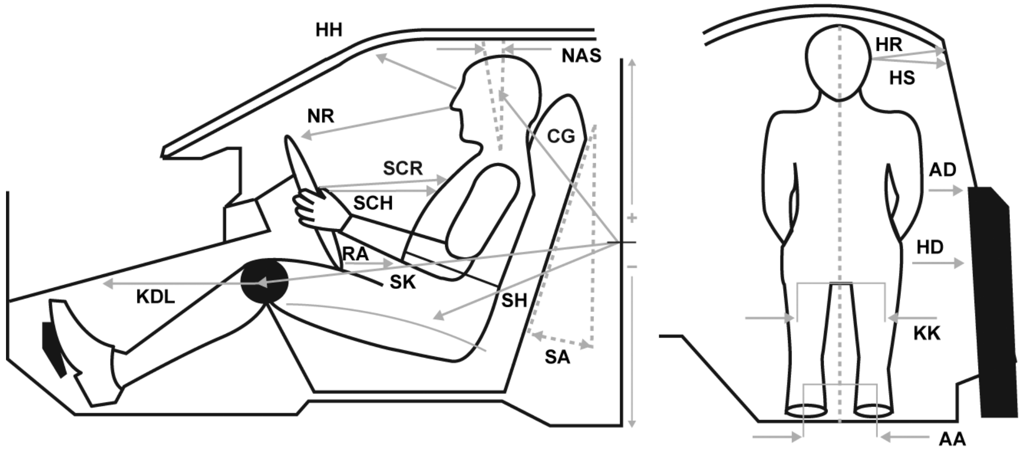
APPENDIX A

Driver Dummy Clearance Measurement Definitions



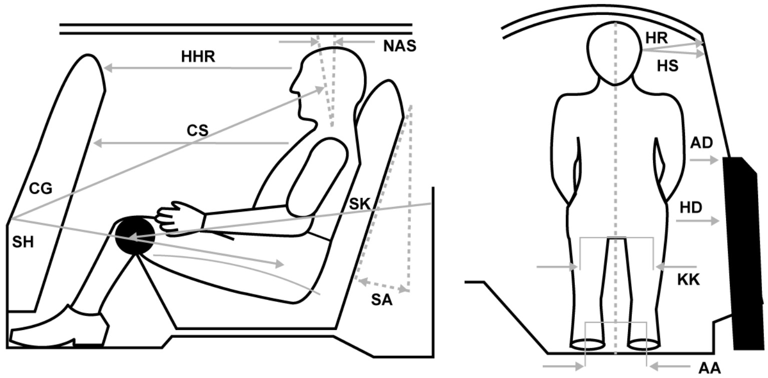
Location	Code	Definition of Measurement
Ankle to ankle	AA	Taken between the center points of both ankles, after the feet are placed per IIHS protocol.
Arm to door	AD	Horizontal measurement taken from the center point of the elbow to the first contact point of the door panel.
Armrest to dummy, minimum	ADM	Minimum horizontal measurement taken from the vehicle armrest to the dummy.
Head to A-pillar	HA	Horizontal measurement taken from the center of the head outboard center of gravity target to the A-pillar *(not shown in figure)*.
Hub to chest, minimum	HCM	Minimum horizontal distance measured from the hub to the dummy chest *(not shown in figure)*.
H-point to door	HD	Horizontal measurement taken from the H-point hole to the first contact point of the door panel.
Head to header	HH	Taken from the center point between the eyes to the header directly in front of dummy.
Head to roof	HR	Taken from the center of the outboard target to the roof edge (not the upper edge of the vehicle door), perpendicular to the longitudinal axis of the vehicle. If a tape measure is held from the target and extends below the roof, the point to measure is at the low edge of the roof line, which will make contact with the tape measure.
Head to side window	HS	Taken from the center of the outboard target to the side window, measured horizontally and perpendicular to the longitudinal axis of the vehicle. In cases where the window is not fully up, a flat bar should be placed across the window opening to simulate the position of the window.
Knee to dash, left	KDL	Taken from the knee pivot point to the point on the dash that is directly level with the center of the knee.

continued

Location	Code	Definition of Measurement
Knee to knee	KK	With the legs in a vertical plane after the feet are placed per IIHS protocol, the measurement is taken from the outside flange to the outside flange of the knees. The minimum distance is 270 mm (10.6 inches).
Neck angle, seated	NAS	Taken from the neck when the dummy is seated across two of the "vertebral disks" of the neck.
Nose to rim	NR	Taken from the tip of the nose to the steering wheel rim at the 12 o'clock position.
Pelvis angle	PA	Taken from the instrumented pelvis sensor (if available) or by placing an inclinometer on the H-point bar, which is used to align the H-point with previous measurements *(not shown in figure)*.
Rim to abdomen	RA	Taken from the point where the bottom of the chest jacket and the pelvis structure meet the steering wheel rim at the 6 o'clock position.
Seatback angle	SA	Taken from the lower left corner of the driver seatback unless otherwise directed by the manufacturer, at which time it will be properly noted along with the measurement.
Steering wheel to chest, horizontal	SCH	Horizontal measurement taken from the center of the steering wheel to the dummy chest.
Steering wheel to chest, reference	SCR	Taken from the center of the steering wheel to the top rib guide (SID-IIs dummies).
Striker to head CG, horizontal	CGH	Horizontal measurement taken from the head center of gravity to the driver door striker. Value is negative if the head center of gravity is forward of the striker.
Striker to head CG, lateral	CGL	Lateral measurement taken from the head center of gravity to the driver door striker.
Striker to head CG, vertical	CGV	Vertical measurement taken from the head center of gravity to the driver door striker. Value is negative if the head center of gravity is below the striker.
Striker to H-point, horizontal	SHH	Horizontal measurement taken from the H-point to the driver door striker. Value is negative if the H-point is forward of the striker.
Striker to H-point, lateral	SHL	Lateral measurement taken from the H-point to the driver door striker.
Striker to H-point, vertical	SHV	Vertical measurement taken from the H-point to the driver door striker. Value is negative if the H-point is below the striker.
Striker to knee	SK	Taken from the center point of the knee to the front door striker.
Striker to knee angle	SKA	Calculated using the coordinates of the knee pivot point and the location of the driver door striker.
Torso recline angle	TRA	Taken from the H-point to the head center of gravity *(not shown in figure)*.

APPENDIX B

Rear-Passenger Dummy Clearance Measurement Definitions



Location	Code	Definition of Measurement
Ankle to ankle	AA	Taken between the center points of both ankles, after the feet are placed per IIHS protocol.
Arm to door	AD	Horizontal measurement taken from the center point of the elbow to the first contact point of the door panel.
Armrest to dummy, minimum	ADM	Minimum horizontal measurement taken from the vehicle armrest to the dummy.
Chest to seat, horizontal	CS	Horizontal measurement taken from the top rib guide in the chest to a point on the back of the driver seat.
Head to B-pillar	HB	Horizontal measurement taken from the center of the head outboard center of gravity target to the B-pillar *(not shown in figure)*.
H-point to door	HD	Horizontal measurement taken from the H-point hole to the first contact point of the door panel.
Head-to-head restraint	HHR	Horizontal measurement taken from center point between the eyes to the back side of the driver head restraint directly in front of the dummy.
Head to roof	HR	Taken from the center of the outboard target to the roof edge (not the upper edge of the vehicle door), perpendicular to the longitudinal axis of the vehicle. If a tape measure is held from the target and extends below the roof, the point to measure is at the low edge of the roof line, which will make contact with the tape measure.
Head to side window	HS	Taken from the center of the outboard target to the side window, measured horizontally and perpendicular to the longitudinal axis of the vehicle. In cases where the window is not fully up, a flat bar should be placed across the window opening to simulate the position of the window.
Knee to knee	KK	With the legs in a vertical plane after the feet are placed per IIHS protocol, the measurement is taken from the outside flange to the outside flange of the knees. The minimum distance is 270 mm (10.6 inches) *(not shown in figure)*.

continued

Location	Code	Definition of Measurement
Neck angle, seated	NAS	Taken from the neck when the dummy is seated across two of the “vertebral disks” of the neck.
Pelvis angle	PA	Taken from the instrumented pelvis sensor (if available) or by placing an inclinometer on the H-point bar, which is used to align the H-point with previous measurements *(not shown in figure*).
Seatback angle	SA	Taken from the lower left corner of the rear-passenger seatback unless otherwise directed by the manufacturer, at which time it will be properly noted along with the measurement.
Striker to head CG, horizontal	CGH	Horizontal measurement taken from the head center of gravity to the rear door striker. Value is negative if the head center of gravity is forward of the striker.
Striker to head CG, lateral	CGL	Lateral measurement taken from the head center of gravity to the rear door striker.
Striker to head CG, vertical	CGV	Vertical measurement taken from the head center of gravity to the rear door striker. Value is negative if the head center of gravity is below the striker.
Striker to H-point, horizontal	SHH	Horizontal measurement taken from the H-point to the rear door striker. Value is negative if the H-point is forward of the striker.
Striker to H-point, lateral	SHL	Lateral measurement taken from the H-point to the rear door striker.
Striker to H-point, vertical	SHV	Vertical measurement taken from the H-point to the rear door striker. Value is negative if the H-point is below the striker.
Striker to knee	SK	Taken from the center point of the knee to the rear door striker.
Striker to knee angle	SKA	Calculated using the coordinates of the knee pivot point and the location of the rear door striker.
Torso recline angle	TRA	Taken from the H-point to the head center of gravity *(not shown in figure*).