Crashworthiness Evaluation Offset Barrier Crash Test Protocol (Version VI)

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Insurance Institute for Highway Safety
Offset Barrier Crash Test Protocol (Version VI)

SUMMARY

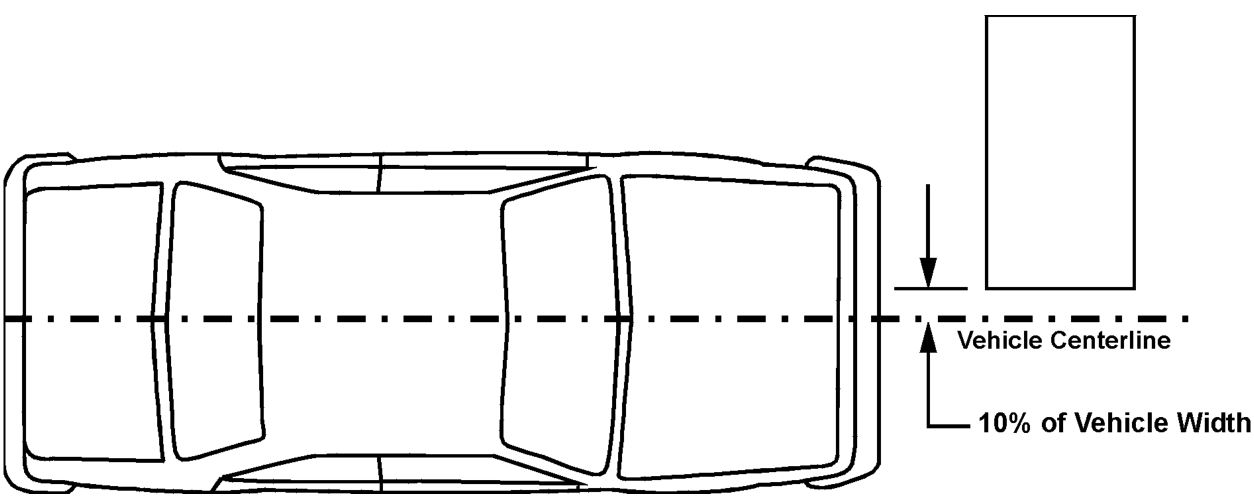
Version VI of the Insurance Institute for Highway Safety Offset Barrier Crash Test Protocol differs from the earlier versions (IV and V) in three ways. The description of intrusion measurements provides methods for establishing the reference coordinate systems for intrusion measurements in cars, passenger vans, and utility vehicles (previously version IV) as well as for pickup trucks and vehicles with removable or convertible roofs (previously version V). Also, the calculation by which intrusion measurements are adjusted to reflect movement of the steering wheel, instrument panel, and toepan relative to the driver has been added. Finally, the sign convention and digital filtering for electronically recorded measurements has been changed to comply with the Society of Automotive Engineers (SAE) recommendations for impact testing.

TEST CONDITIONS

Impact Speed and Overlap

Offset barrier crash tests are conducted at 40 mi/h (64.4 km/h) and 40 percent overlap. The test vehicle is aligned with the deformable barrier such that the right edge of the barrier face is offset to the left of the vehicle centerline by 10 percent of the vehicle's width (Figure 1). The vehicle width is defined and measured as indicated in SAE J1100 – Motor Vehicle Dimensions, which states, "The maximum dimension measured between the widest part on the vehicle, excluding exterior mirrors, flexible mud flaps, and marker lamps, but including bumpers, moldings, sheet metal protrusions, or dual wheels, if standard equipment."

Figure 1
Vehicle Overlap with Deformable Barrier

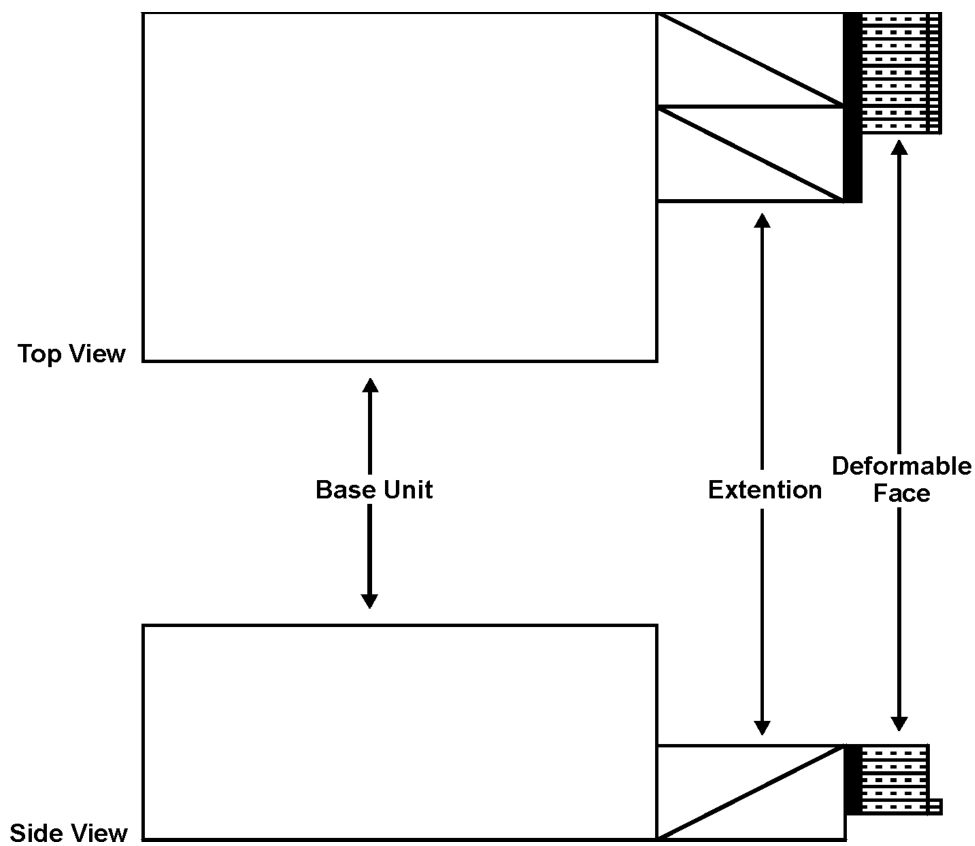


The vehicle is accelerated by the propulsion system at an average of 0.3 g until it reaches the test speed and then is released from the propulsion system 25 cm before the barrier. The onboard braking system, which applies the vehicle's service brakes on all four wheels, is activated 1.5 seconds after the vehicle is released from the propulsion system. A tether between the vehicle and the propulsion system breaks when the vehicle is released and thus initiates the onboard braking sequence.

Barrier Composition and Preparation

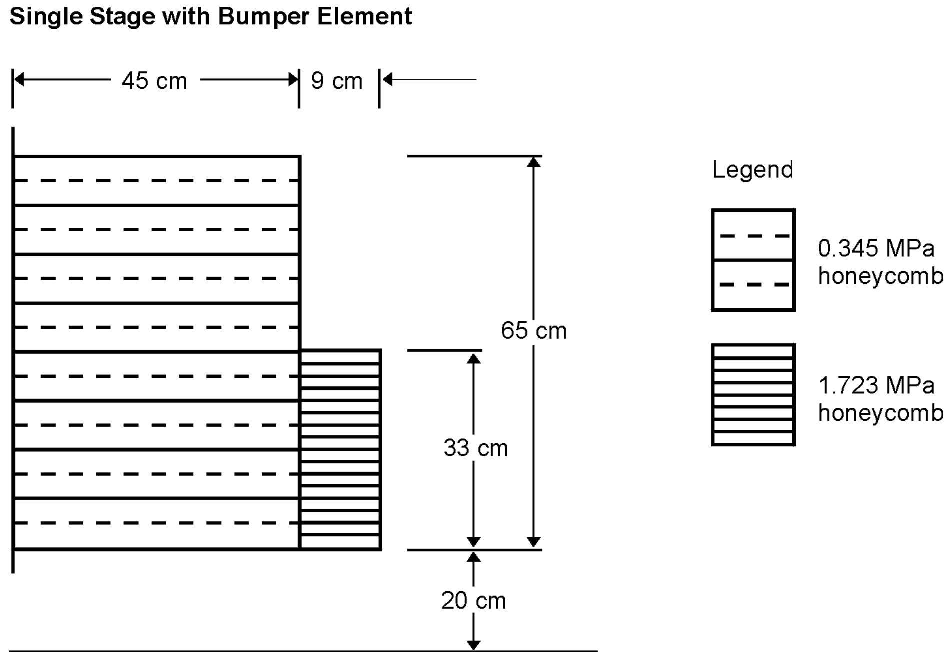
The barrier is composed of three elements: base unit, extension, and deformable face (Figure 2). The base unit is 184 cm high, 366 cm wide, and 542 cm deep. It is composed of laminated steel and reinforced concrete with a total mass of 145,150 kg. The extension is 91 cm high, 183 cm wide, and 125 cm deep. It is made of structural steel and has a 1.9-cm thick piece of plywood attached to the 4.5-cm thick face plate. The deformable face is 1 m wide and consists of a bumper element of 1.723 MPa honeycomb material attached to a base of 0.345 MPa honeycomb material. The face is attached to the extension at a height of 20 cm from the ground. The profile (height and depth) of the deformable face is shown in Figure 3.

Figure 2
Deformable Barrier Elements



Inch tape (1-inch increments alternating in black and yellow) is applied to the right and leading edges of the top surface of both the bumper element and base to highlight them for the overhead camera views. In addition, both barrier surfaces are marked with a 61-cm length gage consisting of two circular photographic targets (yellow and black reference points).

Figure 3
Deformable Barrier Face Profile and Dimensions



Test Vehicle Preparation

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

Many of the vehicles evaluated in the offset test have been used in the Institute's Low-Speed Crash Test Program. Such vehicles have been 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 the same speed into a full-width flat barrier (see the Institute's Low-Speed Crash Test Protocol). All structural damage on the front of the vehicle is repaired before the 64 km/h offset test. Cosmetic damage is repaired at the Institute's discretion. Parts are replaced or repaired as appropriate based on the judgment of two professional insurance appraisers.

All engine and transmission fluids are drained from the vehicle prior to the test. The gasoline is removed from the fuel tank and fuel lines and replaced with Stoddard solvent to full capacity. The engine is started for short period to ensure the Stoddard solvent has filled the fuel lines. Stoddard solvent is added to the fuel system within 48 hours of the test. The electrolyte is drained from the battery. The air conditioning system's refrigerant is recovered by a means that complies with applicable environmental regulations.

The front of the vehicle is attached to the propulsion system through a yoke with steel chains and turnbuckles for adjustment. The center section of the yoke is attached to the propulsion system. The trailing chains and turnbuckles are attached to the car by steel hooks, which are welded to the left and right sides of the front suspension. The front attachment hardware weighs 7 kg.

The rear of the vehicle is attached to the propulsion system with a nylon strap and ratchet strap assembly. Nylon straps are wrapped around the left and right sides of the rear axle. The straps are linked together at the center by an attachment that is secured to the propulsion system by a nylon ratchet strap assembly. The rear attachment hardware weighs 4 kg.

An aluminum instrumentation rack, which supports the test equipment, is installed in the cargo area of the vehicle with four bolts through the floor of the cargo area. The carpeting in this area is removed to allow access to the floor. If necessary, the spare tire and accessory jack may be removed to permit installation of the instrumentation rack. The instrumentation rack weighs 19.5 kg, and the total weight of the rack and mounted test equipment is 62 kg. The following test equipment is installed on the instrumentation rack located in the cargo area:

> *Onboard emergency braking system:* When activated, this system applies pressurized nitrogen gas against the brake fluid in the lines, which normally connect the brakes with the master cylinder, to activate the brakes on all four wheels. The remaining brake fluid in the master cylinder is removed. Flexible hoses connect the emergency braking system to the brake lines in the engine compartment. The onboard braking system weighs 10.6 kg.
>
> *12-volt battery and monitoring system:* This system supplies electrical power for the vehicle, emergency braking system, and the Denton Intelligent Dummy Data Acquisition System (IDDAS). A two-conductor cable connects this battery to the vehicle's battery terminals. The system weighs 32.0 kg.

A steel plate is welded to the floor of the rear seating area along the centerline of the vehicle for mounting accelerometers. The carpeting in this area is removed to allow access to the floor. If floormats are standard or offered as an option through the manufacturer or dealership, a floormat is installed only in the driver footwell.

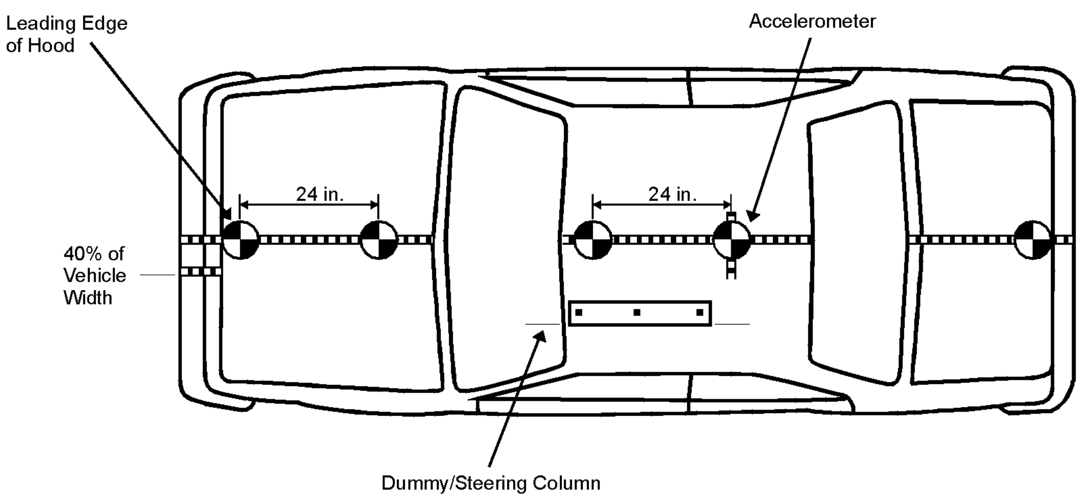
The antilock braking system (if equipped) and daytime running lights (if equipped) are disabled by means of removing fuses or relays to these devices to reduce the electrical power required for the test.

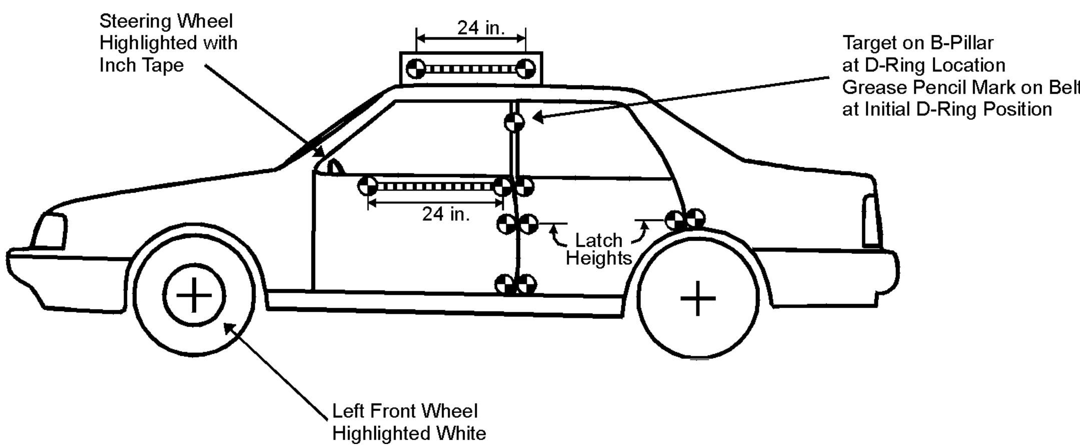
A plastic block containing an array of high-intensity light emitting diodes (LED) is attached to the hood of the vehicle with sheet metal screws. The LEDs are illuminated when the vehicle first contacts the barrier.

A pressure-sensitive tape switch is applied to 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 system and illuminates the LEDs mounted on the hood.

The exterior surfaces of the vehicle are trimmed with inch tape and photographic targets to facilitate analysis of the high-speed crash films (Figure 4). The scheme consists of four 61-cm length gages in four separate reference planes: the surface of the roof, the surface of the hood, the surface of the driver door, and a vertical plane passing through the centerline of the driver seat. The location of the vehicle accelerometers and the location of the vehicle's precrash center of gravity are marked with photographic targets applied to the appropriate top surfaces of the vehicle. An additional target also is placed at the rear of the vehicle on the centerline. The locations of driver door latch, left rear door latch, and driver shoulder belt upper anchorage D-ring are marked on the side surfaces with photographic targets. The steering wheel is highlighted with inch tape, and the left front wheel is highlighted with white shoe polish.

Figure 4
Exterior Surface Marking





The driver seat and adjustable steering controls are adjusted according to 49 *CFR* 571.208. The seat back angle and position of the adjustable seat belt upper anchorage are set according to the specifications provided by the test vehicle's manufacturer. After the driver seat has been adjusted, the adjustment latching mechanism is examined to note whether all the components of the mechanism are interlocked. If partial interlocking is noted 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 driver seat manually adjustable inboard armrest (if equipped) is adjusted to its stored up position prior to the test.

The driver's head restraint (if manually adjustable) is adjusted upward until the top of the head restraint is level with the top of the dummy's head. If the head restraint lacks sufficient height adjustment to reach to top of the dummy's head, the test is conducted with the head restraint set at its highest setting. The head restraint height adjustment locking mechanism (if equipped) is examined to ensure the mechanism has engaged. All manually adjustable head restraint tilting mechanisms are adjusted to their full-rearward position during the test.

All side windows are lowered to their lowest position, the ignition is turned to its on position, and the transmission is shifted into its neutral position prior to the test.

Crash Dummy Preparation and Setup

A Hybrid III 50th percentile male dummy (49 *CFR* 572 (E)) with instrumented lower legs is positioned in the driver seat according to 49 *CFR* 571.208 with the exception of the left foot position. The dummy's left foot is placed on the footrest or on the floor in the area where a footrest typically would be located. The dummy is equipped with feet and ankles described in the final rule incorporating Hybrid III dummy modifications (Docket 74-14 Notice 104; *FR* vol. 61, no. 249, pp. 67953-67962). The feet have been further modified to include two accelerometers. The dummy's knees are equipped with ball-bearing sliders, and the neck is fitted with a neck shield. In addition, the dummy's thoracic spine has been modified to accommodate an onboard data acquisition system (IDDAS). The mass and moments of inertia of the modified thoracic spine are similar to those of the standard dummy.

The dummies used in these tests are calibrated according to 49 *CFR* 572 (E) after being subjected to no more than five crash tests. Additionally, individual parts are recalibrated if levels exceed published injury reference values during a test or if postcrash inspection reveals damage. All visible damage is repaired before the dummy is used again.

The dummy and vehicle are kept in a temperature controlled area at the beginning of the runway where the temperature is maintained at 20.6-22.2 degrees Celsius and the relative humidity at 10-70 percent for at least 16 hours prior to the test. The driver seat belt is fastened around the dummy. 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 is then removed again with a small pulling force. The dummy's head, knees, and shins are colored with grease paint to facilitate postcrash identification of impacts with the vehicle interior. Photographic targets are placed on both sides of the head to mark the location of its center of gravity.

Photography

Still Photography

The precrash and postcrash conditions of each test vehicle are documented on 35-mm color slide photographs. Two precrash views and two postcrash views show the side and left front quarter of the test vehicle.

Five different views of the underbody are recorded for both precrash and postcrash conditions. These photographs are taken by rotating the vehicle 90 degrees around its longitudinal axis onto its passenger side. The postcrash series of photographs includes three overhead views.

Additional photographs include a minimum of four views that document the precrash position of the driver dummy and close-up views of the dummy's legs.

Eight standard views of the vehicle in its postcrash position in front of the barrier also are recorded. Additional photographs document the postcrash position of the driver dummy.

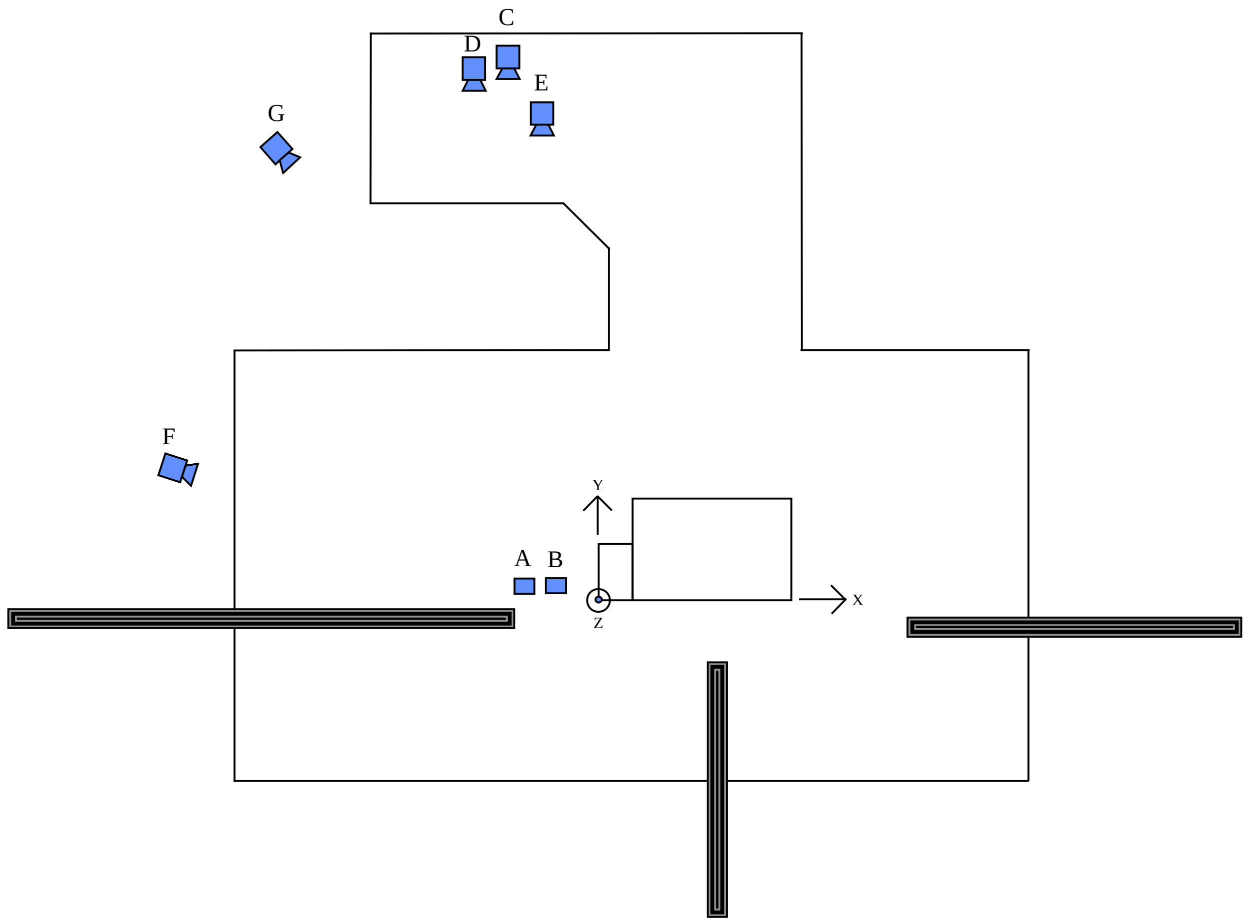
High-Speed Motion Picture Photography

Motion picture photography is taken of the test with six Model 51 Locam II cameras and one Sony Betacam SD video camera. The lens size and frame rate of each camera are described in Table 1. Frame rates for the Locam II are accurate to ±1 percent of the set frame rate. The positions of all cameras are shown in Figure 5.

Table 1
High-Speed Camera Coordinates and Settings

	A	B	C	D	E	F	G
Camera Position	**Wide Over-head**	**Tight Over-head**	**Wide Left**	**Med. Left**	**Tight Left**	**Down Left Side**	**Real-time Left Pan**
Coordinate X (cm)	–61	0	–97	–132	–15	–2,013	–825
Coordinate Y (cm)	0	0	1,420	1,367	1,246	774	1,806
Coordinate Z (cm)	894	894	119	94	155	157	203
Lens (mm)	16	25	25	50	75	63	8.5-127 zoom
Film Speed (frames/second)	500	500	500	500	500	500	30

Figure 5
High-Speed Camera Positions



Measurements/Observations

Test Weight

The test weight of the vehicle is measured using an Intercomp Model SW 8800 scale at each of the four wheels. The vehicle is weighed with all test equipment installed including the driver dummy. 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 is determined by averaging two speed trap measurements. Both speed traps measure the average velocity of the vehicle at 1-1.5 m before impact with the barrier.

Overlap

The actual overlap is determined from the film taken by the high-speed camera tight overhead view (position B in Figure 5). The lateral distance between the centerline of the vehicle and the right edge of the deformable barrier is measured using a film analyzer and software package. This measurement is subtracted from half the vehicle's overall width, and the result is divided by the vehicle's overall width to determine the actual overlap percentage. The photographic targets applied to the top surfaces of the deformable barrier are used for the image scaling.

Vehicle Accelerations

The linear accelerations in three orthogonal directions (longitudinal, lateral, and vertical) of the vehicle's occupant compartment are measured by accelerometer arrays (three Endevco 7264A-2000 accelerometers) and recorded by IDDAS. Positive vehicle accelerations are forward along the longitudinal axis, to the right along the lateral axis, and downward along the vertical axis. The data are presented filtered according to the channel frequency class (CFC) 60 as defined in SAE J211 – Instrumentation for Impact Tests (SAE, 1998).

Fuel System Integrity

Observations about fuel system integrity are recorded for each test. Any Stoddard fluid 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 fluid 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 fluid (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.

Additional Stoddard fluid that is leaked when the test vehicle is turned onto the passenger side for underbody photography also is collected. Six samples are collected if appropriate. The first sample is collected during the interval of time required to rotate the vehicle 90 degrees from upright (typically less than 5 minutes). The remaining samples are taken each minute for the next 5 minutes The samples either are collected in pans or soaked up with absorbent pads of known mass, depending on the nature of the leak. The volume of each sample is determined as described in the preceding paragraph.

Crush Profile

The profile of the vehicle's front bumper is measured both before and after the crash. Eleven measurements equally spaced along the lateral reference axis are recorded using a FARO Technologies Inc. Bronze Series FARO ARM. The profile of the underlying bumper support bar (if equipped) also is measured before and after the crash at eleven equally spaced points along the lateral reference axis. These measurements are made with the bumper cover removed. The bumper cover and related attachment hardware are reassembled prior to the test. In addition, the top surface of the forwardmost lateral crossmember, which typically supports components such as forward engine mounts, the radiator, and headlamp assemblies, is measured before and after the crash at eleven equally spaced intervals along the lateral reference axis.

> *Coordinate system definition*: A left-handed, three-axis orthogonal coordinate system is used for these measures: longitudinal (front to rear is positive), lateral (right to left is positive), and vertical (bottom to top is positive). The longitudinal and lateral axes and the origin are defined on the vehicle prior to the crash and also necessarily define the vertical axis.
>
> The longitudinal-lateral plane is defined by points on the bottom of the left and right door sills, 20 cm rearward and forward of the front and rear wheelwells, respectively. The longitudinal axis is defined by the centerline of the vehicle, and the origin is defined as the most forward portion of the front bumper on the centerline. Before the test, five recovery points are chosen and marked on the rear of the right frame rail, and their coordinates are recorded. The postcrash coordinate system is reestablished by assigning the precrash coordinates to any three of these points. The FARO ARM data collection software alerts the user if crash damage in the area of the recovery points altered their precrash orientation.

Underbody Structures Deformation

Six locations are marked on the underside of the frame rails of the vehicle, and their longitudinal, lateral, and vertical coordinates are recorded using the FARO ARM. These six marks are measured after the crash using the same reference coordinate system. In addition, the contour of the side rails (between the front bumper and a point corresponding to the longitudinal position of the B-pillar), floor rails (or door sills, depending on vehicle construction), and engine supports are measured before and after the crash using the same reference coordinate system. The resulting precrash and postcrash contours are plotted.

> *Coordinate system definition*: The same left-handed, three-axis orthogonal coordinate system used for crush profile measurements is used for measurements of underbody deformation.

Measurement Point Locations

Front bumper mount: The intersection of the underside of the left and right frame rails and the front bumper.

A-pillar: The points on the underside of the left and right frame rails (or door sills) that correspond to the longitudinal coordinate of the base of the A-pillar.

B-pillar: The points on the underside of the left and right frame rails (or door sills) that correspond to the longitudinal coordinate of the base of the B-pillar.

Intrusion Measurements

A total of 18 locations are marked on the driver side interior and exterior of the vehicle, and their longitudinal, lateral, and vertical coordinates are recorded using the FARO ARM. These same marks are measured after the crash using the same reference coordinate system. Intrusion of the steering wheel, instrument panel, and footwell relative to the driver is calculated by subtracting the average component displacements (difference between precrash and postcrash coordinates) 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.

Coordinate system definition: A right-handed, three-axis orthogonal coordinate system is used for these measures: longitudinal (rear to front is positive), lateral (right to left is positive), and vertical (bottom to top is positive). The lateral and vertical axes and the origin are defined and marked on the vehicle prior to the crash and also necessarily define the longitudinal axis. The axis marks are used after the crash to reestablish the coordinate system.

The precrash coordinate system is defined with the vehicle unloaded (no occupants) on a level floor. The lateral axis is defined by placing a level rod against the right and left B-pillars inside the front window frames (with the front doors open) as close to the intersection of the B-pillars and roof rails as possible. For pickup trucks and vehicles with removable or convertible roofs, the vertical position of the lateral axis is at the base of the side windows. The origin is then defined as the intersection of this level rod (lateral axis) and the most inboard trim piece on the right B-pillar and marked. A plumb line suspended from this point to the right rear floor defines the vertical axis. The lateral axis is marked on both B-pillars and the origin point is marked on the right B-pillar. A mark is made on the right rear floor that corresponds to the plumb line location.

The postcrash coordinate system is reestablished by first defining the plane created by the previously created marks on the B-pillars and right rear floor. The vertical axis is then explicitly defined as the line between the right B-pillar mark and the plumb mark on the right rear floor. Note that defining the vertical axis on the lateral-vertical plane necessarily defines the lateral axis. The precrash origin mark is used again to define the origin, which along with the vertical axis, necessarily defines the longitudinal axis.

Measurement Point Locations

Lower instrument panel (two points): The left and right lower instrument panel lateral coordinates are defined by adding 15 cm to and subtracting 15 cm from the steering column reference lateral coordinate, respectively. The vertical coordinate is the same for both left and right references and is defined as 45 cm above the height of the floor (without floormats).

Steering column (one point): The marked reference is the geometric center of the steering wheel, typically on the airbag door. After the crash, this point is measured by folding the airbag doors back into their undeployed position.

Brake pedal (one point): The geometric center of the brake pedal pad (top surface).

Toepan (three points): The vertical coordinate for all toepan measurement locations is the vertical coordinate of the brake pedal reference. The lateral coordinates of the left, center, and right toepan locations are obtained by adding 15 cm to, adding 0 cm to, and subtracting 15 cm from the brake pedal reference lateral coordinate, respectively. A utility knife is used to cut a small "v" in the carpet and underlying padding at each point on the toepan. The point of the "v" is peeled back, and the exposed floor is marked and measured. The carpet and padding are then refitted prior to the crash.

Left footrest (one point): The geometric center of the left footrest pad. For vehicles without a footrest pad, the geometric center of the floor in the area that many manufacturers install a footrest is used. In these cases, the procedure described above for cutting the carpet is used to mark and measure the underlying structure.

Seat bolts (typically, four points): Each of the four (or fewer) bolts that anchor the driver seat to the floor of the vehicle.

Seat (four points): Each of the corners of a 20-cm square, whose sides are aligned with the lateral and longitudinal reference axes, is centered on the surface of the seat cushion.

A-pillar (one point): The A-pillar is marked on the outside of the vehicle at the same vertical coordinate as the base of the left front window.

B-pillar (one point): The B-pillar is marked on the outside of the vehicle at the longitudinal center of the pillar at the same vertical coordinate as the lower A-pillar mark.

Seat Belt Retractor Spool-Out and Crash Tensioner Spool-In

Slack seat belt webbing that is allowed to spool off the retractor is measured during the crash. Only the maximum length of spool-out is measured and recorded. After the seat belt is fastened around the dummy, a piece of string is stitched into the belt webbing above the retractor housing.

The free end of the string is pulled taut and taped against the B-pillar trim panel. The precrash position of the string relative to the tape is marked. After the crash, the position of the string relative to the tape is marked. The reported maximum belt spool-out is the distance between the precrash and postcrash marks on the string measured to the nearest centimeter.

For belts equipped with crash tensioners, a second piece of string is stitched into the belt webbing near the upper anchorage D-ring. The free end of the string is pulled taut and taped against the B-pillar trim panel, usually above the D-ring. The precrash position of the string relative to the tape is marked. After the crash, the position of the string relative to the tape is marked. The reported maximum belt spool-in is the distance between the precrash and postcrash marks on the string measured to the nearest centimeter. Because separate strings that show pull in opposing directions are used, the measured belt spool-out and spool-in values are independent of each other.

Dummy Kinematics and Contact Locations

Dummy kinematics are studied by reviewing the high-speed film using a Visual Instrumentation Corporation Model 1214A Motion Analysis System and Motion Analysis Systems Package Ver. 6.22a analysis software (Concurrent Processing Inc., 1996). Contact of the dummy's head or knees with the vehicle interior are recorded on the basis of postcrash grease paint deposits.

The dummy is inspected in its undisturbed postcrash position. The condition of the ankle joints, resting positions of the feet, and positions of the knees are recorded, and photographs are taken of these components. Any damage to the dummy or unusual dummy resting position information is noted. The locations of paint transferred from the dummy to the vehicle interior are noted, and the contacted components are photographed.

The high-speed film record is used to 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 film from each camera in which the LEDs mounted on the hood of 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/second, the estimate of the crash's start time can be up to 2 ms late, and the event's time, as determined from the film, can be early or late by 2 ms. The time of the driver airbag deployment, full inflation, and first dummy contact are recorded as well as any other notable events.

A film analyzer and analysis software are used to measure the movements of the dummy and vehicle components at various times during the crash (Concurrent Processing Inc., 1996). The photographic target scale mounted on the roof of the vehicle or the scale on the driver door is used for scaling images on the film.

Dummy Responses

Each Hybrid III dummy is equipped with instrumentation for measuring the following:

Head
Triaxial accelerations (three Endevco 7264A-2000 accelerometers)

Neck
A-P shear force
Axial force
A-P moments (R.A. Denton Model 2564 or 1716A upper neck load cell)

Chest
Triaxial accelerations (three Endevco 7264A-2000 accelerometers)
Rib compression

Lower Extremities
Femur axial forces (R.A. Denton Model 2121A load cell)
Tibia-femur displacements
Upper tibia A-P moments
Upper tibia L-M moments (R.A. Denton Model 1583 load cell)
Lower tibia A-P moments
Lower tibia L-M moments
Lower tibia axial forces (custom R.A. Denton Model 3093 load cell)
Biaxial foot accelerations (A-P and I-S) (two Endevco 7264A-2000 accelerometers)

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 Information Report J1734 – Sign Convention for Vehicle Crash Testing DEC94 (SAE, 1998).

The Denton IDDAS is installed in the thorax of the Hybrid III dummy and used for all dummy and vehicle data acquisition. During the crash, all measurements are recorded in the system's random access memory with 12-bit resolution at a sample rate of 10 kHz. Signals in all channels convert simultaneously, so the time reference for different channels is not skewed. To ensure digital fidelity, all signals are filtered by an analog low-pass prefilter with a 2.5 kHz cutoff frequency.

After the data have been downloaded from the IDDAS, 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. The data are digitally filtered using the frequency response classes recommended in SAE Recommended Practice J211/1 – Instrumentation for Impact Test – Part 1. Electronic Instrumentation MAR95. All filtering and subsequent calculations are executed using DSP Development Corporation's DADiSP Ver. 4.1 NI NK B07 (DSP Development Corporation, 1997).

In addition to summary metrics for each of the recorded data channels, the following calculations are made: vector resultant of the head acceleration, 3-ms clip of the vector resultant head acceleration, head injury criterion (HIC),* vector resultant of the spine accelerations, 3-ms clip of the vector resultant thoracic spine acceleration, viscous criterion, vector resultant of the tibia bending moments, tibia index, and vector resultant of the foot accelerations. All calculations comply with the recommendations of SAE Information Report J1727 – Injury Calculation Guidelines AUG96 (SAE, 1998).

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* HIC is calculated two ways: the first limits the maximum HIC interval to 36 ms, and the second limits the maximum HIC interval to 15 ms (HIC-15).

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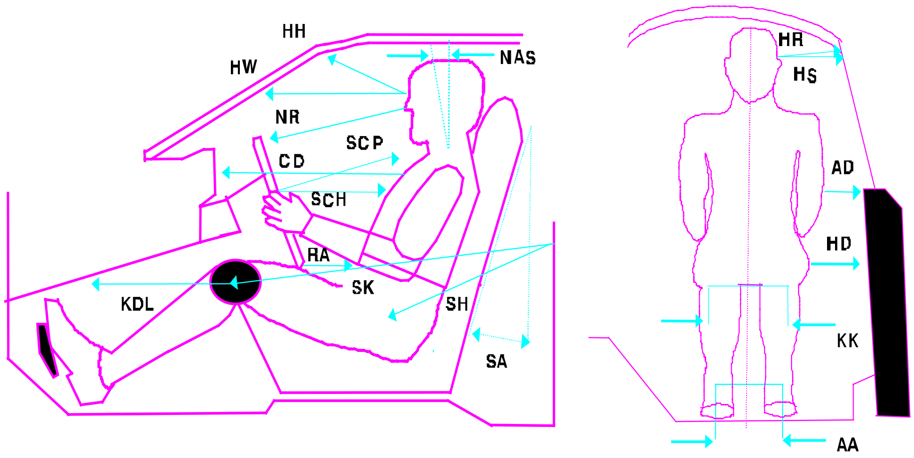
Society of Automotive Engineers. 1998. *1998 SAE Handbook, Vol. 3 – On-Highway Vehicles and Off-Highway Machinery*. Warrendale, PA.

APPENDIX
Dummy Clearance Measurement Definitions



Location	Code	Definition of Measurement
Ankle to ankle	AA	Taken between the center points of both ankles.
Arm to door	AD	Taken from the center point of the elbow to the first contact point of the door panel.
Chest to dash	CD	Taken from the clavicle adjustment holes in the chest to the point on the dash at level of chest landmark.
Head to A-pillar	HA	Horizontal measurement taken from the center of the outboard target to the A-pillar.
Hub to chest, minimum	HCM	Minimum horizontal distance measured from the hub to the dummy's chest.
H-point to door	HD	Taken from the H-point hole to the first contact point of the door panel.
Head to header	HH	Taken from center point between eyes to 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 car door), perpendicular to the long axis of the car. 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 long axis of the car. 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.
Head to windshield	HW	Taken from the center point between dummy's eyes to the point on the windshield directly level with the dummy's forehead.

continued

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.
Knee to dash, right	KDR	Taken from the knee pivot point to the point on the dash that is

Location	Code	Definition of Measurement
		directly level with the center of the knee.
Knee to knee	KK	With the legs in a vertical plane after the feet are placed per Institute protocol, the measurement is taken from outside flange to outside flange of the knees. The minimum distance is 270 mm (10.6 inch).
Neck angle, seated	NAS	Taken from the neck when the dummy is seated across two of the “vertebral disks” of the neck.
Neck angle, torso 90	NAT90	Taken from the neck when the torso is at 90 degrees vertical. This measurement is taken in the dummy lab prior to dummy seating.
Nose to rim	NR	Taken from the tip of the nose to the steering wheel rim at the 12 o’clock position.
Pelvic 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.
Rim to abdomen	RA	Taken from the point where the bottom of the chest jacket and the abdominal insert meet to the steering wheel rim at the 6 o’clock position.
Seat back angle	SA	Taken from the lower left corner of the driver’s seat back 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’s chest.
Steering wheel to chest, perpendicular	SCP	Taken from the center of the steering wheel to the dummy’s chest, measured perpendicular to the plane of the steering wheel rim.
Steering wheel to chest, reference	SCR	Taken from the center of the steering wheel to the center of the clavicle adjustment holes (on the Hybrid III dummies).
Striker to H-point, horizontal	SHH	Taken from the center points of the horizontal armature of the laser sighting device.
Striker to H-point, vertical	SHV	Taken from the center points of the vertical armature of the laser sighting device. Value is negative if the striker is above the H-point and positive if the striker is below the H-point.
Striker to knee	SK	Taken from the center point of the knee to the striker.
Striker to knee angle	SKA	Taken on the top of the tape measure while it is extended from the center point of the knee to the striker.
Torso angle	TA	Angle taken from the neck when the torso is at 90 degrees vertical, minus the angle of the neck once properly seated in the vehicle (NAT90 – NAS).