INSURANCE INSTITUTE
FOR HIGHWAY SAFETY

September 5, 2002

The Honorable Jeffrey W. Runge, M.D.
Administrator
National Highway Traffic Safety Administration
400 Seventh Street, S.W
Washington, D.C. 20590

Petition for Rulemaking
49 CFR 571.208 Occupant Crash Protection
49 CFR 571.214 Side Impact Protection

Dear Dr. Runge:

The Insurance Institute for Highway Safety (IIHS) hereby petitions the National Highway Traffic Safety Administration (NHTSA) to amend the requirements of Federal Motor Vehicle Safety Standard (FMVSS) 208 (S8.1.2 and S8.1.3) and FMVSS 214 (S6.3 and S6.4), which specify vehicle seat track and seat back angle positions for vehicle crash tests. Specifically, we petition NHTSA to amend each standard to incorporate a new seat track and seat back adjustment procedure based on a University of Michigan Transportation Research Institute (UMTRI) Seating Accommodation Model. IIHS is joined in this petition by Dr. Lawrence W. Schneider, Senior Research Scientist and Head of the UMTRI Biosciences Division, which was instrumental in the development of the seat positioning procedures for anthropometric test devices (ATDs). The goal of this petition is to assure that ATD test positions more accurately reflect realistic seating positions in NHTSA-regulated crash tests that require the use of ATDs. Therefore, we also ask NHTSA to incorporate the UMTRI ATD seat positioning procedures specified in this petition in New Car Assessment Program (NCAP) crash tests.

Brief Overview of Petition
The current FMVSS 208 and 214 crash test specifications can result in seating positions that do not reflect the likely seating positions of real occupants represented by the various size ATDs and, hence, may give inaccurate indications of the crash protection some vehicles offer most occupants. For example, both FMVSS 208 and 214 call for the seat to be placed in the fore/aft midtrack position for a 50th percentile male ATD; the full-forward position is specified for the 5th percentile female ATD in FMVSS 208. These seating positions are based on the presumption that the midtrack and full-forward positions are representative of seat fore/aft positions for midsize males and small females, respectively.

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However, the full-forward and rear positions may be influenced by factors other than seated occupant accommodation. The full-forward position in two-door cars may be farther forward than the shortest drivers would choose to sit, in order to facilitate rear seat ingress/egress, for example. The full-forward and full-rear positions also may be chosen by manufacturers to achieve ATD test positions that artificially optimize crash test results. The effect of this can be that results obtained from NHTSA-mandated crash tests do not relate to actual occupant risks in real crashes.

Through this petition, IIHS is asking NHTSA to adopt new driver seat positioning procedures for front and side impact compliance tests based on a study by the UMTRI Biosciences Division of driver seat position-selection behavior. The UMTRI ATD positioning procedure can be used to seat a ATD in a position that is representative of seating positions chosen by drivers who are the same size as the 50th percentile male, 5th percentile female, and 95th percentile male ATDs. The UMTRI ATD seating procedures do not yet address right-front passenger seating positions. It is probable that seating position does not correlate as well with passenger stature as with driver stature, but data are lacking on this issue. Therefore, IIHS suggests that the agency conduct a study of passenger seating positions to determine the most appropriate test positions to represent occupants of different sizes. In the meantime, it would be appropriate to continue current passenger seating procedures for the 5th percentile female and 50th percentile male.

This petition ultimately applies to all tests intended to assess the level of protection a normally seated occupant can expect in a crash. This petition does not, however, seek to alter seating positions that may be chosen to address specific crash injury risks. For example, the newly amended portion of the FMVSS 208 interim rule includes a frontal offset crash test at 25 mph into a deformable barrier with a 5th percentile female ATD seated fully forward. Because the test is intended to address out-of-position airbag injury risks for small female drivers, the full-forward seating position is appropriate. Similarly, FMVSS 201 includes a special provision for a side-into-pole crash test to assess head protection; in this test the seating position must be chosen so as to assess this limited, but important, aspect of crash protection.

Background

An adjustable driver seat track is designed to accommodate a range of occupant sizes. Several studies have shown that the full-forward, midtrack, and full-rearward seat track positions rarely correspond to actual use positions for females of 5th percentile stature and males of 50th and 95th percentile stature, respectively (Backaitis et al., 1995; Husher et al., 1995; Parkin et al., 1993). In a collaborative study conducted by NHTSA and Ford, selected seating positions for 12 midsize males were compared with ATD seating positions in a 1991 Ford Taurus (Parkin et al., 1993). Results showed that, on average, male subjects sat 32 mm rearward of the midtrack seating position and, based on head-to-windshield measurements, their heads were 20-47 mm farther rearward when compared with a 50th percentile ATD seated and positioned in the same vehicle at midtrack position using the current FMVSS procedure. In another study, the mean-selected seating positions of more than 600 adult volunteers were compared with the midtrack positions in 26 vehicles (Manary et al., 1998). Results showed that mean-selected seating positions were 46 mm rearward of midtrack for midsize males, 42 mm rearward of the front of the seat track for 5th percentile females, and close to the rearmost track position for 95th percentile males. This study, like earlier seating position studies, found that the midtrack position is a poor predictor of the seating positions selected by midsize male drivers.

IIHS has conducted more than 100 frontal offset crash tests using NHTSA's ATD positioning procedure (49 CFR 571.208 S11), with the exception of left foot placement. Researchers at the IIHS Vehicle Research Center have found several vehicles in which the midtrack seating position obviously is not representative of how a midsize male would comfortably be positioned. One of the most egregious examples of ATD misplacement was observed in the 1999 Land Rover Discovery Series II (Appendix A). In addition to very low knee-to-knee-bolster clearance values, measurements showed that this seating position resulted in the lowest chest-to-airbag-module clearance (183 mm, or about 7 inches) of any vehicle tested by IIHS. This obviously is an inappropriate seating position because NHTSA (2000) recommends a minimum clearance of 250 mm (about 10 inches) between a driver's chest and the airbag module to minimize the potential for airbag-induced injuries. In 1997, IIHS began measuring chest-to-steering-wheel-hub minimum distances in all ATD-equipped crash test vehicles. Since then, 44 percent of the vehicles (43 of 98) tested in the IIHS crashworthiness evaluation program have had chest clearance measures less than 250 mm (Appendix B). In real-world driving conditions, this minimum clearance usually is achievable for all but the shortest drivers (De Leonardis et al., 1998)

The developers of the Euro NCAP program have made similar observations of the midtrack seating position. Approximately three years ago, the Euro NCAP procedure for adjusting the driver-side seat track was changed to achieve a standard position across a wide range of vehicles. Instead of placing the seat in the middle of its fore/aft travel range, the test position now is defined as the midpoint between the full-forward seating position and the manufacturer-determined 95th percentile hip reference point (H-point). This change was driven by the observation that some vehicles had very long seat tracks, with the rearmost position far beyond the 95th percentile position. In essence, this procedural change moved the test position forward of the midtrack seating position.

Although the Euro NCAP change was implemented to standardize ATD seating positions, it is not acceptable for several reasons. First, a vehicle manufacturer can arbitrarily determine the 95th percentile seat track position and not provide information on how this position was determined. Second, although the rearmost track position no longer affects the calculation of the seat's test position, the full-forward seat track position (which also could be arbitrarily set by a vehicle manufacturer) does. Finally, the Euro NCAP position places a 50th percentile ATD forward of the true midtrack position. This contradicts the results from the occupant positioning studies mentioned previously, which found that in the United States average-size males tend to sit rearward of the midtrack seating position.

Researchers at the IIHS Vehicle Research Center have found unexplained seat adjustment differences between European and U.S. vehicles. The 1999 Volvo S80 and 2001 Mercedes C class, both of which are sold in the United States and Europe, have different seat adjustment ranges depending on where the cars are sold. The European version of the 1999 Volvo S80 has a full-forward seat adjustment that is 25 mm rearward of the full-forward position in S80 models sold in the United States. The seat track designs for these vehicles are identical, but the European version has a bolt in the track that serves as a mechanical stop preventing the seat from moving as far forward as in its U.S. counterpart. Consequently, the midtrack position in the U.S. version of the S80 is 12.5 mm forward of its European counterpart. In the U.S. version of the 2001 Mercedes C class, the seat track is equipped with bracket clips that serve as a mechanical stop to limit the rearward seat pan travel range; the European version does not contain the bracket clips. The clips limit the rearward pan travel by 50 mm, thereby placing the midtrack position 25 mm forward of the midtrack position achievable with the bracket clips removed. The manufacturers have not indicated why these differences exist, but the result is that the same average male ATD is seated in different positions in the same car for mandated crash tests in Europe and the United States. Such differences could affect both regulatory and consumer information test results, even though the vehicles and the way occupants likely would seat themselves are the same.

FMVSS 208 and 214 test requirements are designed to ensure a minimum level of crashworthiness of vehicles sold in the United States. Because an occupant's seating position and proximity to vehicle structures have considerable influence on ATD injury responses (Hardy et al., 1997; Horsch and Colver, 1979; Huelke, 1995; Huelke et al., 1995; Melvin et al., 1993), reasonable preimpact positioning is critical to accurate assessment of vehicle safety performance. In a recent study sponsored by the American Automobile Manufacturers Association and conducted by UMTRI, a new Seating Accommodation Model was developed that can be used to predict where occupants of different statures are most likely to position the driver seat over the adjustable fore/aft seat track range (Flannagan et al., 1998). By applying the UMTRI Seating Accommodation Model to the U.S. safety compliance tests, a more representative assessment can be made of a vehicle's crashworthiness.

UMTRI Seating Accommodation Model

The UMTRI ATD positioning procedure is based on seating position measurements taken from subject populations of 60-120 drivers tested in each of 36 different vehicles. Flannagan et al. first presented the UMTRI Seating Accommodation Model in 1998. Later that year, the UMTRI ATD Seat Positioning Model, which describes the adaptation of the Seating Accommodation Model to ATD positioning, was presented by Manary et al. at the Stapp Car Crash Conference. This procedure uses the geometric relationships between the accelerator pedal, steering wheel, and driver seat to determine an ATD's horizontal and vertical H-point location. This petition presents a revised version of the UMTRI ATD Seat Positioning Model. The revision was recently developed by UMTRI researchers to simplify the application of the model toward ATD positioning in vehicle crash tests (Reed et al., 2001). The technical aspects of the procedure are described briefly in the next two sections; the actual procedure is described in detail in Appendix C.

Seat track fore/aft and height adjustment: The UMTRI method uses a formula to determine where an ATD's H-point should be located aft of the steering wheel center. The formula used to calculate the seat fore/aft position is dependent on occupant stature and vehicle geometry (accelerator pedal and steering wheel location relative to the seat). The formula and accompanying illustration of the model inputs, as well as the procedure for setting the seat fore/aft and height position, are described in Appendix C.

In contrast to current FMVSS 208 and 214 seat location requirements, the UMTRI ATD positioning procedure does not place seats with a vertical adjustment range in the full-down position. UMTRI data show that the vertical variance in seating position is independent of stature or seating position, meaning that the average vertical seat adjustment of short drivers is similar to that of other drivers and lies near the center of the vertical range. This does not mean that all drivers position themselves in the same absolute vertical position. For example, Figure A3 (Appendix A) shows that the vertical positions of short drivers, who tend to sit farther forward, are higher on average because the seat tracks are angled. The procedure presented here takes seat height adjustment into account by establishing a mid-height H-point travel path and forces the ATD's H-point to reside on this path (which is parallel to the seat track for most vehicles), whatever the fore/aft position may be.

Seat back adjustment: The UMTRI ATD positioning procedure states that the seat back angle should be adjusted so that the straight line connecting H-point and the head center of gravity is 12 degrees from vertical. This differs from the current NHTSA protocol in that the seat back is adjusted to produce a specified ATD torso posture (torso recline angle) that is representative of actual driver postures instead of making the ATD torso angle dependent on a manufacturer's recommended seat back recline angle. Research at UMTRI has shown that manufacturers' specified (designed) seat back angles are not related to actual driver-selected seat back angles and do not differ substantially with occupant stature or vehicle type (Manary et al., 1998). Once a seat back angle is selected that will support the ATD in the 12-degree torso recline posture, the ATD should be checked to ensure that head and pelvic angles comply with the current FMVSS 208 (S11) and 214 (S7.2) positioning procedures. If the manufacturer's recommended seat back angle supports the correct 12-degree ATD torso recline, then it can be used.

IIHS Evaluation of UMTRI ATD Positioning Procedure

An IIHS seating position study, based on the UMTRI ATD positioning procedure, was conducted on 15 vehicles (1999-2001 models) ranging from small passenger cars to sport utility vehicles and passenger vans. In this study, NHTSA's compliance test seating position was compared with the seat track position predicted by the UMTRI ATD positioning procedure. Data collected from this study are presented in Appendix D. For the vehicles measured, the UMTRI formula predicted that the mean seating position selected by 50th percentile males would be aft of the seat midtrack position. The difference in fore/aft position between midtrack and the position obtained using the UMTRI procedure ranged from 8 to 124 mm. In the midtrack position, about half (8 of 15 vehicles) had a chest-to-steering-wheel-hub minimum clearance of 250 mm. When the UMTRI Seating Accommodation Model was used to determine the appropriate seat track position, all but one vehicle had an ATD test position with at least 250 mm chest clearance. The UMTRI ATD positioning procedure did not meet the 250 mm recommendation for the 2000 Isuzu Rodeo, but it fell short by only 1 mm with a clearance of 249 mm. Overall, the positioning procedure resulted in realistic ATD seating positions and increased ATD chest-to-airbag-module distance.

Summary and Petition

Comprehensive seating position studies have shown that midtrack positions usually result in ATD placement that is not representative of the positions chosen by drivers the same size as the ATDs. Furthermore, in many vehicles the current NHTSA procedure positions the ATD closer to the driver airbag module than is considered safe. Clearly there are deficiencies with a procedure that produces this kind of result. The application of the UMTRI seat positioning procedure identifies the seat track positions representative of those chosen by occupants the same size as the test dummies regardless of the location of adjustment endpoints.

IIHS petitions NHTSA to adopt the UMTRI ATD positioning procedure as a seat positioning tool in all tests intended to assess the average levels of protection to be expected for occupants of a certain size. Our experience with the UMTRI procedure indicates it is an effective and robust tool for determining driver seat track position. The seat track positions predicted from the model more closely match those of human occupants than the midtrack positions dictated by current compliance test procedures. Representative positions for right-front passengers also should be developed.

IIHS believes this procedural amendment will improve the validity of NHTSA-mandated crash tests by placing ATDs in positions that are representative of how humans actually sit in passenger vehicles.

Sincerely,

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Senior Research Scientist
Head, Biosciences Division, UMTRI

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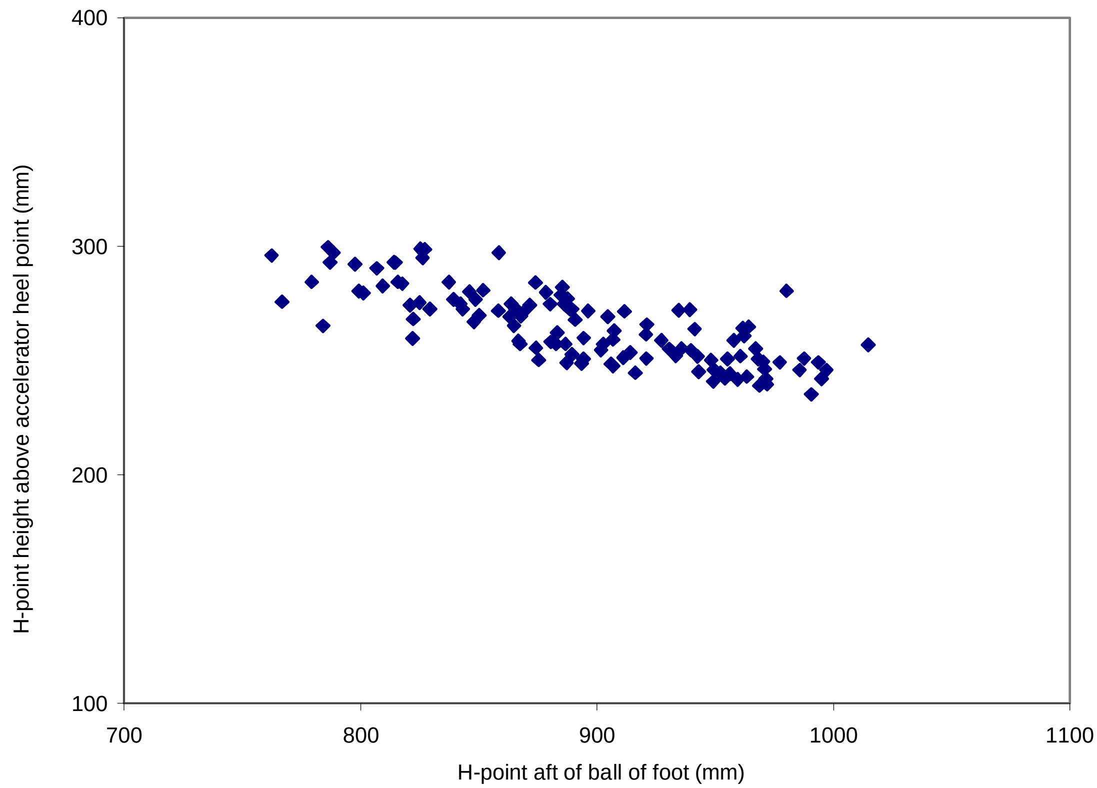
Appendix A

Figure A1
50th Percentile Hybrid III Male ATD Positioned in 1999 Land Rover Discovery Series II Prior to IIHS Frontal Offset Crash Test; Seat Positioned According to FMVSS 208 Specifications

Figure A2
ATD Knee Position in 1999 Land Rover Discovery Series II

Appendix A continued on following page (Figure A3)

Appendix A: Figure A3
Distribution of H-Point Locations for Driver-Selected Seating Positions



Appendix B

Table B1
Steering-Wheel-Hub-to-Chest Minimum (HCM) Clearance Measures in Institute Crashworthiness Evaluation Tests

Test ID	Make and Model	HCM Clearance (mm)	Test ID	Make and Model	HCM Clearance (mm)
CF97018	1997 Volkswagen Jetta	325	CF99002	1999 Ford Windstar	251
CF97022	1998 Toyota Corolla	315	CF99026	1999 Pontiac Grand Am	251
CF00023	2001 BMW X5	300	CF99014	2000 Chevrolet Impala	251
CF00022	2001 Mitsubishi Montero	298	CF00026	2001 Dodge Stratus	251
CF00025	2000 Ford Focus	293	CF00034	2001 Hyundai Elantra	250
CF98013	1998 Kia Sportage	289	CF98004	1998 Chevrolet S-10	246
CF00006	2000 BMW 3 series	281	CF98005	1998 Nissan Frontier	246
CF97020	1997 Hyundai Elantra	280	CF97026	1998 Toyota Sienna	246
CF97021	1998 Nissan Sentra	280	CF99017	1999 Audi A6	246
CEF0106	2001 Toyota RAV4	280	CF99018	2000 Dodge Intrepid	246
CF98002	1998 Volkswagen Passat	278	CF00005	2000 Subaru Legacy	246
CEF0107	2001 Chevrolet Silverado	276	CF98019	1999 Mitsubishi Galant	242
CEF0104	2001 Hyundai Santa Fe	276	CF98023	1999 Nissan Quest	241
CF99015	2000 Buick LeSabre	272	CF00014	2000 Isuzu Rodeo	241
CF00027	2001 Mercedes-Benz E430	272	CF00015	2000 Nissan Maxima	240
CF99025	1999 Chevrolet Malibu	271	CF98006	1998 Dodge Dakota	238
CF99003	1999 Hyundai Sonata	271	CF98007	1998 Ford Ranger	238
CF97016	1997 Ford Escort	270	CF00007	2000 Volvo S80	236
CF98020	1999 Suzuki Grand Vitara	270	CF00031	2001 Honda Civic	235
CF99007	2000 Dodge Neon	270	CF99020	1999 Chrysler LHS	234
CF00020	2000 Nissan Xterra	269	CF00016	2000 Nissan Sentra	234
CF98003	1998 Toyota Tacoma	267	CF98017	1998 Honda CR-V	233
CF98009	1998 Volkswagen New Beetle	267	CF98012	1998 Jeep Cherokee	232
CF98021	1999 Saab 9-5	267	CF99012	1999 Mercedes-Benz M class	231
CF00033	2001 Mercedes-Benz C320	266	CF99016	1999 Cadillac Catera	230
CF97013	1997 Kia Sephia	265	CF00017	2000 Lincoln LS	230
CF97024	1998 Nissan Maxima	265	CF00011	2000 Mazda MPV	230
CF00030	2001 Chrysler LHS	265	CF00003	1999 Daewoo Leganza	229
CF99001	1999 Volkswagen Jetta	263	CF98024	1999 Honda Odyssey	229
CF99006	1999 Lexus GS	262	CF00010	2000 Ford Taurus	228
CF00012	2000 Toyota Avalon	262	CF98001	1998 Honda Accord	226
CF00004	2000 Nissan Altima	259	CF99024	1999 Mazda 626	225
CF99011	1999 Mitsubishi Montero Sport	258	CF99013	1999 Dodge Durango	222
CF99022	2000 Saturn L series	258	CF99009	1999 Jeep Grand Cherokee	222
CF97017	1997 Mazda Protege	255	CF98014	1998 Toyota RAV4	221
CF99008	1999 Kia Sephia	255	CF00028	2001 Dodge Grand Caravan	221
CF99021	2000 Cadillac Seville	255	CF98008	1998 Jeep Wrangler	212
CF99019	1999 Buick Park Avenue	254	CF99005	1999 Mazda Protege	206
CF99004	1999 Saab 9-3	254	CF97023	1998 Toyota Avalon	205
CF98016	1998 Isuzu Amigo	252	CF00021	2000 Isuzu Trooper	200
CF98018	1999 Subaru Forester	252	CF99010	1999 Land Rover Discovery	183
CEF0105	2001 Ford Escape	252			

Appendix C

Guidelines for Using the UMTRI ATD Positioning Procedure for ATD and Seat Positioning

July 2002

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Guidelines for Using the UMTRI ATD Positioning Procedure for ATD and Seat Positioning (Revised July 2002)

Introduction

These guidelines provide a simplified method of applying the University of Michigan Transportation Research Institute (UMTRI) anthropometric test device (ATD) positioning procedure that will be used by the Insurance Institute for Highway Safety for positioning the driver ATD in side impact crash tests. This procedure is based on the original ATD positioning procedure by Reed et al. (2001) but differs slightly in the following forms:

Additional steps to the procedure improve repeatability and reproducibility. Several of these steps include positioning tolerances that are used during the initial H-point measurement as well as the final positioning of the ATD.

In the original procedure, mathematical formulae were provided to determine the UMTRI H-point position and final seat position. This procedures simplifies the process by using an Excel spreadsheet to automatically calculate the UMTRI H-point and seat position.

Electronic Spreadsheets

To determine the UMTRI H-point position for the driver ATD and the seat adjustments needed to support the ATD properly in the UMTRI position, it will be necessary to download an Excel workbook template (*ATD_positioning_template.xls*) from the Institute's website, http://www.highwaysafety.org/ vehicle_ratings/tech_info.htm. The workbook contains the calculations needed to determine the UMTRI position; calculations are presented in the Appendix. For the workbook to function properly, macros must be enabled. Upon opening the workbook, a form is opened that prompts the user for the following: ATD size for which the UMTRI position is being calculated; vehicle model year, make, and model; and basic seat information.

The Excel workbook template contains five worksheets and one chart, which are referred to throughout the procedure. The following describes the purpose of the worksheets and chart.

Seat Information – This worksheet is used to indicate the size of ATD for which the UMTRI position will be determined. It also is used to document, for future reference, the type of seat in the vehicle being measured. This is important because many vehicles available with both manual and electric seats often do not have similar adjustment ranges (horizontally and vertically), which can result in different UMTRI seating positions. The only user inputs required are in the cells labeled as "Manually Entered Data."

CMM Data – This worksheet is used to enter the data obtained with a coordinate measurement machine (CMM). CMM data should only be entered in cells labeled as "CMM Data." Instructions on taking the measurements are provided in the procedure.

Seat Range Calculations – This worksheet requires no user input. It uses data entered in the *CMM Data* worksheet to establish a relationship between the seat reference points and the H-point. It then uses the travel path of these points to establish an H-point travel path.

UMTRI Calculations – This worksheet uses data from the *CMM Data* and *Seat Range Calculations* worksheets to calculate the UMTRI H-point position.

Final H-Point and Seat Position – This worksheet shows the calculated UMTRI H-point position and the seat fore-aft and vertical positions required to obtain the correct H-point position. It also contains several cells that aid the user in positioning the ATD torso recline angle.

Seat Chart – This worksheet provides a graphical representation of the seat and H-point travel path, along with the UMTRI H-point location.

For the calculations to work properly, the data entered into the worksheets must adhere to the following coordinate system: X is positive toward the rear of the vehicle, Z is positive in the upward direction.

Positioning Procedure

With the Excel workbook template open, complete the information in the user form, then click on the *Continue* button. Confirm that the information in the *Seat Information* worksheet is correct, then continue with the positioning procedure

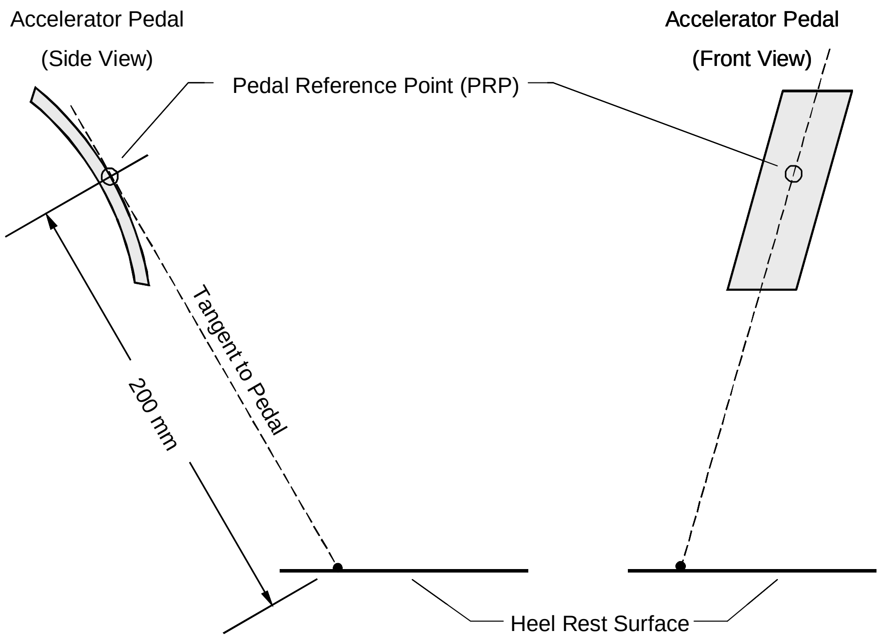
1. Establish the Pedal Reference Point

The pedal reference point (PRP) is a point on the accelerator pedal from which fore-aft dimensions are measured in the UMTRI calculations. The PRP is defined in side view using the midline contour of the accelerator pedal (Figure 1). The PRP lies on the surface of the pedal at the lateral midline and is 200 mm from the heel rest surface (floormat). The heel rest surface is the horizontal plane on the floormat passing through the H-point manikin (or ATD) heel point when the foot is on the pedal. The PRP can be located as follows:

1.1. If the vehicle has an accelerator pedal with fore-aft adjustment, adjust the pedal to its forwardmost position.

1.2. Place masking tape or some other markable material on the accelerator pedal surface. Mark a line defining the lateral center of the pedal. If the pedal is inclined in the plane perpendicular to the surface (e.g., if the top of the pedal is inboard of the bottom of the pedal), make the line pass through the lateral center of the pedal at each vertical level. The PRP is used for fore-aft reference dimensions only, so the lateral position of the pedal centerline is important only as it affects the fore-aft position of the PRP. Using this line, the PRP is located using one of the following methods:

Figure 1
Pedal Reference Point Definition



1.2.1. If a CAD system is not available, the point may be located physically using a straightedge ruler to find the PRP (Figure 1); this method is recommended because it is significantly less time consuming than the alternative measurement method described in step 1.2.2. Continue to step 1.3.

1.2.2. Use a CMM to record points on the line. If the pedal is flat, only two points defining the top and bottom of the line are required. A stream of points should be taken for a curved pedal. Transfer the data to CAD, referencing the points to the vertical position of heel rest surface. Continue to step 1.3.

1.3. Record the PRP using one of the following methods:

1.3.1. For a flat accelerator pedal, construct a line in side view (XZ plane) tangent to the accelerator pedal, i.e., at the angle of the undepressed accelerator pedal. The PRP is the point on this line that is 200 mm from the heel rest surface. For an extremely low or high pedal, the PRP may not lie on the pedal surface. Note that the tangent line generally will not pass through the measured manikin (or ATD) heel location.

1.3.2. For a curved accelerator pedal, construct a line in side view (XZ plane) tangent to the accelerator pedal such that the distance from the contact point on the pedal to the heel rest surface along the tangent line is 200 mm. The contact point when this condition is met is the PRP. Note that the tangent line generally will not pass through the measured manikin (or ATD) heel location.

1.4. Enter the coordinates for the PRP and the heel rest surface into the appropriate cells of the *CMM Data* worksheet.

2. Establish the Steering Wheel Center Point

2.1. The location of the steering wheel center point is determined with the steering wheel at the center of its tilt adjustment range. If there is no setting detent at the mid position, lower the steering wheel to the detent just below the mid position.

2.2. If the steering column has a telescope, adjustment should be positioned as follows:

2.2.1. For the 5th percentile female ATD, adjust the steering column to its full-forward position (untelescoped).

2.2.2. For 50th and 95th percentile male ATDs, adjust the steering column to the middle of its telescoping range.

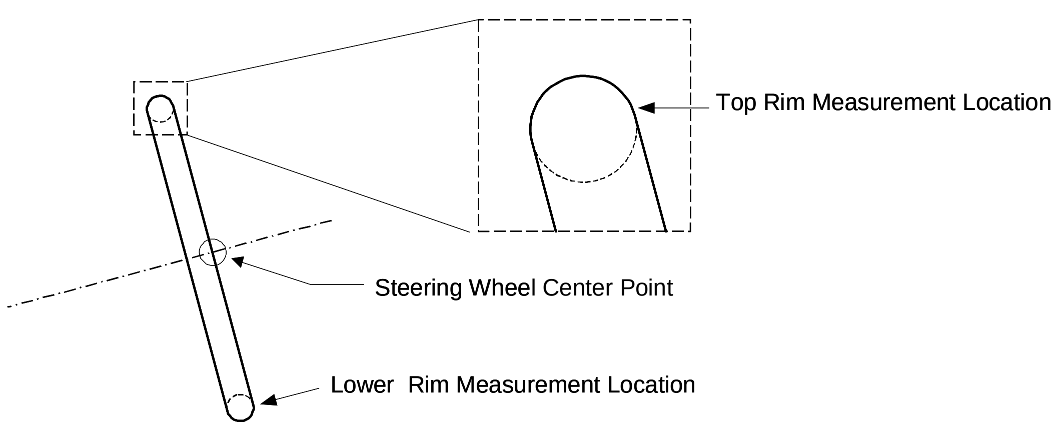
2.3. The steering wheel center point is defined as the intersection between the pivot axis of the steering wheel and the plane tangent to the driver side of the steering wheel rim. To locate this point:

2.3.1. Measure the locations of points on the steering wheel rim at the top and bottom of the wheel with the wheel in the neutral position (Figure 2).

2.3.2. Turn the steering wheel 180 degrees and record the positions again.

The steering wheel center point will automatically be calculated from the spatial average of the points recorded in steps 2.3.1 and 2.3.2.

Figure 2
Steering Wheel Center Point Calculated
from Measured Point Locations on Wheel Rim



3. Define Seat Travel Range

3.1. The objective of this step is to define the full range of available seat position adjustments. For manual seats the full-forward locking position is considered notch 1.

3.1.1. Use the seat controls to place the seat in the full-down, full-rear position. Record the locations of two seat-frame reference points. Ideally, these points will be bolt heads or some other well-defined reference points, one near the front (seat reference point 1) and one near the rear of the seat frame (seat reference point 2). It is useful to move the seat on all its adjustment axes while selecting these points to ensure they are fixed with respect to the seat cushion; however, they should not be on the cushion itself.

3.1.2. With the seat in its full-down position, use the adjuster to move the seat to its full-forward position. Record the reference point locations.

3.1.3. With the seat in its full-forward position, use the height adjuster to raise the seat to its full-up position. Some seats allow further forward adjustment when the seat is in the full-up position. If possible, use the adjuster to move the seat farther forward. Record the reference point locations.

3.1.4. With the seat in its full-up position, move the seat to its full-rear position. Record the reference point locations.

3.2. Enter the data points recorded in step 3.1 into the appropriate cells of the *CMM Data* worksheet. For seats without vertical adjustment, copy the full-down coordinates into the full-up locations for both seat reference points.

4. Conduct Initial H-Point Measurement

4.1. The H-point measurement should be conducted with the seat in the middle of the fore-aft seat adjustment range. If an adjustment position does not exist midway between the forwardmost and rearmost positions, the closest adjustment to the rear of the midpoint is used. If the seat is vertically adjustable, it should be placed in its full-down position. If the seat pan cushion moves independently of the seat back and frame, it should be placed in its lowest and rearmost position. If the front and back of the seat pan cushion adjust independently, adjust both to their lowest positions.

4.2. Determine the initial H-point location according to the current procedure outlined in SAE J826, using the 50th percentile male thigh and leg segment lengths. The seat back angle should be set to 23 degrees (as measured by the manikin torso angle) or to that specified by the manufacturer. Initially set the seat back at an angle that corresponds to a 23-degree manikin torso angle (as measured by the SAE J826 H-Point manikin) or to that specified by the manufacturer.

4.3. Use a CMM to record the initial H-point location along with two reference points on the seat frame that will move with the seat cushion.

4.4. Enter the coordinates for the H-point and seat reference points 1 and 2 into the appropriate cells of the *CMM Data* worksheet (cells L16-N18).

4.5. If the seat has a manual fore-aft adjustment and an even number of adjustment positions, adjust the seat forward one position and use a CMM to record the coordinates of seat reference points 1 and 2 and enter them into appropriate cells of the *CMM Data* worksheet. Confirm that no errors are reported within the *CMM Data* worksheet (cells L14-N15).

If the "Midpoint Discrepancy" message is displayed, the midtrack position calculated using the entire track range does not match the midtrack position (to within ±2 mm) obtained by averaging the measures of seat reference point 2 obtained in steps 4.2 and 4.5. This is due to either a miscount of the initial number of seat locking positions or an incorrect initial adjustment of the seat. This can be confirmed by comparing the amount of seat fore-aft travel per adjustment indicated in the *Seat Information* worksheet (labeled as "Movement per Notch") to the actual amount of fore-aft travel measured when the seat was moved between steps 4.2 and 4.5. If the seat was in the wrong position during the initial H-point measurement, adjust the seat to the correct position and repeat steps 4.1 through 4.5.

4.6. Additional measurement: Record the position of the H-point relative to another point on the vehicle. Typically the front, middle edge of the door striker is used. This measurement is not necessary for the calculation of the UMTRI seat position, but is used for reference in positioning of the test manikin in the vehicle.

5. Position the Seat for Testing

Using the data entered into the *CMM Data* worksheet, the *UMTRI Calculations* worksheet determines the ATD's H-point location with respect to the PRP (X-axis origin) and heel rest surface (Z-axis origin), as well as the original coordinate system. The *UMTRI Calculations* worksheet also shows the amount of seat movement required (from true midtrack) to achieve the UMTRI position. The *Final H-Point and Seat Position* worksheet shows the final coordinates for the H-point and seat reference points 1 and 2. The final seat positioning proceeds as follows:

5.1. Seats with electric adjustment.

5.1.1. Adjust the fore-aft position until the X-axis coordinate of seat reference point 2 matches its calculated UMTRI position shown in the *Final H-Point and Seat Position* worksheet.

5.1.2. Adjust the seat vertically (if applicable) until the Z-axis coordinate of seat reference point 2 matches its calculated UMTRI position in the *Final H-Point and Seat Position* worksheet. If the seat controls adjust the front and rear seat heights independently, they should be adjusted so that both seat reference points 1 and 2 match their calculated UMTRI positions.

5.1.3. Using a CMM, record the position of seat reference point 2. If the measurement does not match the UMTRI position from the *Final H-Point and Seat Position* worksheet, repeat steps 5.1.1 and 5.1.2 until seat reference points 1 and 2 are within ±2 mm of their calculated X- and Z-axis locations.

5.1.4. Using a CMM, record the final positions of seat reference points 1 and 2 and enter them into the appropriate cells of the *Final H-Point and Seat Position* worksheet.

5.2. Seats with manual adjustment.

5.2.1. Adjust the fore-aft position of the seat to a locking position that places the X-axis coordinate of seat reference point 2 closest to its calculated UMTRI position shown in the *Final H-Point and Seat Position* worksheet.

5.2.2. Adjust the seat vertically (if applicable) until the Z-axis coordinate of seat reference point 2 matches its calculated UMTRI position shown in the *Final H-Point and Seat Position* worksheet. If the seat controls adjust the front and rear seat heights independently, they should be adjusted to the position that places both seat reference points (1 and 2) closest to their calculated UMTRI positions shown in the *Final H-Point and Seat Position* worksheet.

6. Final Positioning of ATD in Seat

6.1. Initially set the seat back at an angle that corresponds to a 23-degree manikin torso angle (as measured by the SAE J826 H-Point manikin) or to that specified by the manufacturer.

6.2. Place the ATD into the seat.

6.2.1. For bucket seats, center the ATD on the seat cushion so that its midsagittal plane is vertical and coincides with the vertical longitudinal plane through the center of the seat cushion.

6.2.2. For bench seats, position the midsagittal plane of the ATD vertical and parallel to the vehicle’s longitudinal centerline and aligned with the center of the steering wheel rim.

6.3. Place the lower legs at approximately 120 degrees to the thighs. If the contact occurs between the back of the ATD’s calves and the front of the seat cushion, the ATD should be moved forward until there is no contact at the 120 degree angle.

6.4. Adjust the fore-aft position of the ATD on the seat so the H-point matches the *UMTRI H-point position* shown in the *Final H-point and Seat Position* worksheet. Place the ATD as close to the *UMTRI H-point position* as possible without initiating contact between the back of the calves and the front of the seat cushion.

6.5. Driver leg and foot positioning.

6.5.1. Rest the ATD’s thighs against the seat cushion and set the ATD’s knees as follows:

6.5.1.1. For 5th percentile female ATDs, set the minimum initial transverse distance between the longitudinal centerline of the ATD’s knees at 160-170 mm (6.3-6.7 in.), with the thighs and lower legs of the ATD in vertical planes.

6.5.1.2. For 50th and 95th percentile male ATDs, set the minimum initial transverse distance between the outside flanges of the knees at 270 mm, with the thighs and lower legs of the ATD in vertical planes.

6.5.2. For the right foot position, if the vehicle has an accelerator pedal with fore-aft adjustment, the pedal should be adjusted to its forwardmost position.

6.5.3. Rest the right foot of the ATD on the undepressed accelerator pedal, with the rearmost point of the heel on the floorpan in the plane of the pedal. If the foot cannot be placed on the accelerator pedal, set it initially perpendicular to the lower leg and then place it as far forward as possible in the direction of the pedal centerline, with the rearmost point of the heel resting on the floorpan. If the ball of the foot does not contact the pedal, change the angle of the foot relative to the lower leg such that the toe of the foot contacts (or is in the position closest to contacting) the undepressed accelerator pedal. The angle between the foot and the lower leg should not be less than 90 degrees. If the vehicle has an accelerator pedal with fore-aft adjustment and the right foot does not contact the pedal, the pedal should be adjusted rearward until the sole of the right foot overlaps the pedal surface by at least 20 mm.

6.5.4. Left foot position.

6.5.4.1. Left foot positioning guidelines for vehicles with a footrest: Position the ATD's left foot on the footrest unless:

more than 30 mm of the medial sole of the ATD's shoe measured at the location of the ball of the foot is not directly over the footrest, or

the ATD's leg/foot will not stay unaided in a position with the foot on the footrest and the leg in a vertical plane with the knee-to-knee distance specified in step 6.5.1.

If neither condition above can be met, then position the left foot on the most outboard flat surface of the toepan that is inboard of the footrest unless:

the toepan is too far forward to rest the bottom of the foot on it, or

the foot is under the brake pedal, or

the ATD's leg/foot will not stay unaided in a position with the leg in a vertical plane with the knee-to-knee distance specified in step 6.5.1.

If neither positioning method above can be achieved, then position the ATD's left foot flat on the horizontal part of the floor, with the toes at the corner between the floor and toepan or as far forward as possible while keeping the left knee at the same height as the right knee and with the leg in a vertical plane with the knee-to-knee distance specified in step 6.5.1.

6.5.4.2. Left foot positioning guidelines for vehicles without a footrest: Position the ATD's left foot on the most outboard flat surface of the toepan while maintaining the knee-to-knee distance specified in step 6.5.1 unless:

the toepan is too far forward to rest the bottom of the foot on it, or

the foot is under the brake pedal, or

the ATD's leg/foot will not stay unaided in a position with the leg in a vertical plane with a minimum knee-to-knee distance specified in 6.5.1.

If the positioning method above cannot be achieved, then position the ATD's left foot flat on the horizontal part of the floor, with the toes at the corner between the floor and toepan or as far forward as possible while keeping the left knee at the same height as the right knee and with the leg in a vertical plane with the knee-to-knee distance specified in step 6.5.1.

6.6. Fully recline the seat back.

6.7. Hold the ATD's thighs down and push rearward on the upper torso to maximize the ATD's pelvic angle.

6.8. While holding the thighs in place, rotate the seat back forward until the torso recline angle (the angle of a side view line from the ATD H-point to the head's center of gravity) is set to 12 ±1 degrees. The H-point and head center of gravity coordinates can be entered into the appropriate cells in the *Final H-Point and Seat Position* worksheet, where the torso recline angle is automatically calculated.

6.9. Gently rock the upper torso relative to the lower torso laterally in a side-to-side motion three times through a ±5 degree arc (approximately 50 mm side to side) to reduce friction between the ATD and the seat.

6.10. Reposition feet if necessary.

6.11. Check the H-point and adjust as necessary to position it in the correct position (or as close to the correct position as possible), as indicated in the *Final H-Point and Seat Position* worksheet.

6.12. Check foot position. If the right foot does not reach the accelerator pedal or if the heel does not touch the ground, adjust the seat in the following manner:

6.12.1. Record the current position of seat reference point 2. Adjust the seat forward at increments of one locking position (manual seats) or 10 mm (power seats) until the sole of the right foot contacts a point the pedal surface that is at least 20 mm from the bottom of the pedal, as measured along the plane of the bottom of the foot. This is done with the ATD's right foot and lower leg in the forwardmost stretched position.

6.12.2. If the heel of the foot is not resting on the heel rest surface (floormat), lower the seat vertically at 5-mm increments until contact is made. If the seat has independent front and rear height adjustments, they must both be adjusted equally to ensure the seat pan angle does not change. If the seat is in its lowest position and the foot still cannot contact the heel rest surface, no further adjustment of the seat or ATD should be attempted.

6.12.3. Record the new position of seat reference point 2.

6.13. The new H-point location can be determined using the difference in seat reference point 2 measurements taken in steps 6.12.1 and 6.12.3.

6.14. Measure the ATD's pelvic angle. The angle should be set to 20 ±2.5 degrees for 5th percentile female ATDs and 22.5 ±2.5 degrees for 50th and 95th percentile male ATDs.

6.14.1. If the ATD's pelvic angle is within the specified range, continue to step 6.15.

6.14.2. If the measured pelvic angle is below the specified range, recline the seat back one adjustment position (for seats with manual seat back controls) or 2 degrees (for seats with electric seat back controls). Hold the ATD's thighs down and push rearward on the upper torso to maximize the ATD's pelvic angle. Measure the pelvic angle. Repeat this step until the pelvic angle is within the specified range.

6.14.3. If the measured pelvic angle is above the specified range, hold the ATD's thighs and rotate the torso forward until the pelvic angle is within the specified range. If the ATD's torso is not supported, adjust the seat back forward at increments of one adjustment position (for seats with manual seat back controls) or 2 degrees (for seats with electric seat back controls) until the torso is fully supported in the new position. Measure the pelvic angle. Repeat this step until the pelvic angle is within the specified range.

6.15. Measure the ATD's torso recline angle (the angle of a side view line from the ATD H-point to the head's center of gravity). The angle should be set to 12 ±1 degrees.

6.15.1. If the torso recline angle is within the specified range, proceed to step 6.16.

6.15.2. If the measured torso recline angle is below the specified range, recline the seat back one adjustment position (for seats with manual seat back controls) or 2 degrees (for seats with electric seat back controls). Hold the ATD's thighs down and push rearward on the upper torso to increase the ATD's torso recline angle. Measure the torso recline angle. Repeat this step until the torso recline angle is within the specified range. Return to step 6.14.

6.15.3. If the measured torso recline angle is above the specified range, hold the ATD's thighs and rotate the torso forward until the torso recline angle is within the specified range. If the ATD's torso is not supported, adjust the seat back forward at increments of one adjustment position (for seats with manual seat back controls) or 2 degrees (for seats with electric seat back controls) until the torso is fully supported in the new position. Measure the torso recline angle. Repeat this step until the torso recline angle is within the specified range. Return to step 6.14.

6.16. Measure the head transverse instrumentation platform angle. The angle should be level to within ±0.5 degrees. Adjust the lower neck nodding joint to level the head. If it is not possible to achieve the head level within ±0.5 degrees, minimize the angle.

Note: If the pelvic angle, torso recline angle, and head transverse instrumentation platform angle requirements cannot all be met, priority should be given to the pelvic angle, followed by the head transverse instrumentation platform angle.

6.17. Using a CMM, record the final positions of seat reference points 1 and 2 and enter them into the appropriate cells of the *Final H-Point and Seat Position* worksheet.

6.18. Position ATD arms and hands.

6.18.1. For ATDs with full arms (e.g., Hybrid III), place hands on the 9 and 3 o'clock positions of the steering wheel. If the steering wheel rim has a telescoping adjustment range and the ATD's hands cannot reach the steering wheel, adjust the steering column rearward (if applicable) until the hands reach the steering wheel rim.

6.18.2. For ATDs with half arms (BioSID, EuroSID-1, ES-2, and SID-IIs), adjust the upper arm to the stop position 45 degrees forward of the neutral (down) position.

References

Reed, M.P.; Manary, M.A.; Flannagan, C.A.C.; Schneider, L.W.; and Arbelaez, R.A. 2001. Improved ATD positioning procedure. SAE Technical Paper Series 2001-01-0118. Warrendale, PA: Society of Automotive Engineers.

Appendix

Calculations for Determining UTMRI Position

The following calculations are used by the Excel workbook template (*ATD_positioning_template.xls*) to determine the UMTRI H-point. When using these calculations to independently verify the UMTRI position, the H-point and vehicle measurements must be conducted as described in the procedures above. The measurement locations used for the UMTRI calculations are illustrated in Figure A1.

Coordinate system orientation: X+ toward rear of vehicle, Z+ upwards.

1. Calculate the seat track rise $r = \Delta Z/\Delta X$:

$$r = \frac{HPtFZ - HPtRZ}{HPtRX - HPtFX}$$

where

HPtRZ is the vertical coordinate of the rear of the mid-height H-point travel path with respect to the heel rest surface,

HPtRX is the horizontal coordinate of the rear of the mid-height H-point travel path with respect to PRP,

HPtFZ is the vertical coordinate of the front of the mid-height H-point travel path with respect to the heel rest surface, and

HPtFX is the horizontal coordinate of the front of the mid-height H-point travel path with respect to PRP.

The seat track rise *r* should be zero or positive, indicating the increase in H-point height for each unit of forward movement of the seat along the mid-height H-point travel path. The H-point travel path is based on the relative position of the H-point with respect to the two seat reference points, with the seat in the midtrack and full-down position.

2. Calculate seat H-point location for testing:

The fore-aft H-point location (X coordinate) aft of the PRP to be used for ATD testing is given by

$$HPtX(mm\ aft\ of\ PRP) = -15.0 + 0.433S + 0.41W - \frac{0.24}{1 - 0.3943r}\left(HPtRZ + r(HPtRX - 1054)\right)$$

where

S is the ATD reference stature (see below), and

W is the fore-aft distance between the PRP and steering wheel center point.

S is set to:

1511 mm for the 5th percentile adult female ATD,

1753 mm for the 50th percentile adult male, and

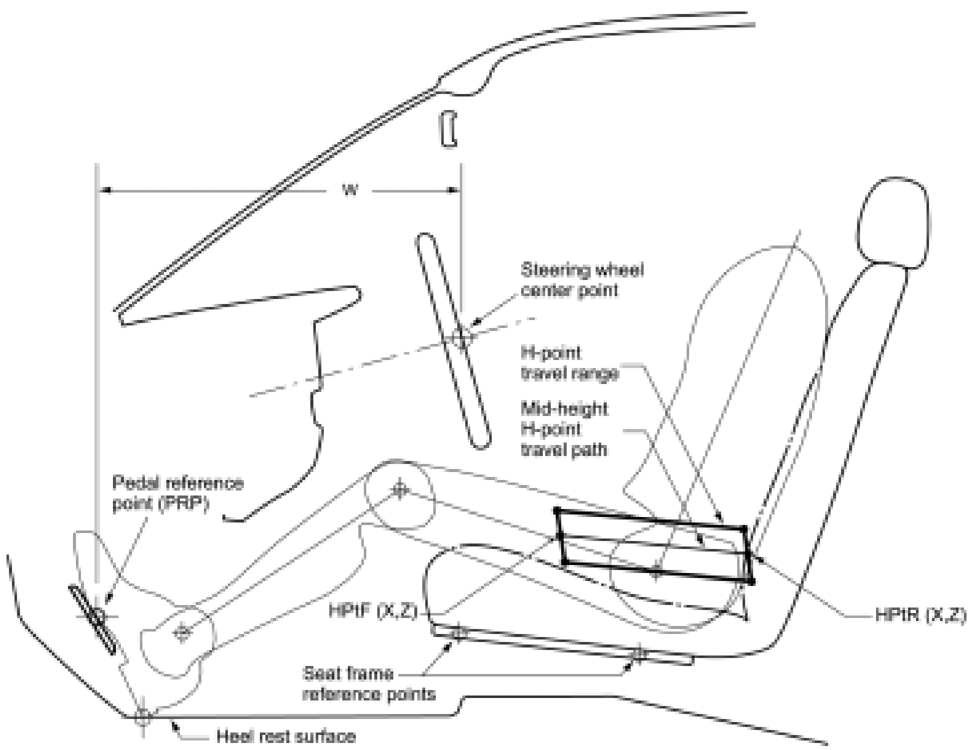
1870 mm for the 95th percentile adult male.

For seats with vertical adjustment, the vertical position of the seat H-point location used for testing is given by

$$HPtZ(mm) = HPtRZ + r\,(HPtRX - HPtX)$$

i.e., the location along the mid-height H-point travel path that lies HPtX mm rearward of PRP.

Figure A1
H-point Travel Range and Other Measurement Locations Used in UMTRI Positioning Procedure



Appendix D

Table D1
UMTRI Seating Position Results and Comparison with Reference Position

		Small Female		Midsize Male		Large Male		Seat		Horizontal	Vertical	
Make and Model	Size Class	Aft of Reference (mm)	Above Reference (mm)	Aft of Reference (mm)	Above Reference (mm)	Fore of Reference (mm)	Above Reference (mm)	Track Adjuster Type	Track Length (mm)	Track Travel (mm)	Track Travel (mm)	Track Rise (deg)
2001 Chrysler LHS	Large car	48	16	48	18	11	24	6 way	217	215	28	7.4
2001 Dodge Grand Caravan	Passenger van	34	-5	64	-10	-40	-6	2 way	151	149	22	8.6
2001 Dodge Stratus	Midsize car	42	18	38	19	20	27	6 way	219	217	30	8.0
2000 Ford Focus	Small car	86	19	72	20	-3	25	4 way	239	238	17	4.1
2001 Honda Civic	Small car	97	-9	82	-8	-13	-1	2 way	241	240	23	5.5
2001 Hyundai Elantra	Small car	22	14	8	15	61	20	6 way	242	241	19	4.4
2000 Isuzu Rodeo	Utility vehicle	12	-2	18	-2	31	4	2 way	200	199	25	7.2
2001 Isuzu Trooper	Utility vehicle	49	-1	64	-2	-26	-1	2 way	179	179	5	1.6
1999 Land Rover Discovery Series II	Utility vehicle	143	14	124	15	-50	19	6 way	250	250	13	3.0
2001 Lexus LS 430	Large car	32	21	16	22	53	28	8 way	241	240	20	4.9
2000 Lincoln LS	Large car	59	12	50	14	15	22	6 way	232	230	27	6.8
2001 Mercedes C 320	Midsize car	31	23	24	23	38	31	6 way	226	224	29	7.5
2001 Mercedes E 430	Large car	67	13	61	14	-1	23	6 way	224	222	34	8.6
2000 Nissan Xterra	Utility vehicle	11	-1	43	-4	-21	-2	2 way	146	145	14	5.4
2000 Volvo S80	Midsize car	90	13	56	15	33	23	6 way	279	278	24	4.9

*Reference positions: small female, full-forward and down; midsize male, midtrack and down; large male, full-rear and down

Appendix D continued on following page (Figure D1)

Appendix D: Figure D1
UMTRI Predicted Seating Position Aft of Midtrack for 50th Percentile Male