SAE International™	SURFACE VEHICLE RECOMMENDED PRACTICE	SAE	**J1750 OCT2010**
		Issued	1995-03
		Revised	2010-10
		Superseding	J1750 MAR1995

(R) Describing and Evaluating the Truck Driver's Viewing Environment

RATIONALE

The 1995 version of this SAE Recommended Practice presented only two methods of evaluation: the Polar Plot and the Horizontal Planar Projection. Each of these methods is insufficient to adequately describe both direct and indirect fields of view around the entirety of the vehicle. However, the document referenced additional "experimental and graphical methods" that were defined at the time as beyond the scope of the document. This release is intended not to replace methods originally presented, and rather adds the preferred Target Evaluation, which allows for utilization of available tools that complete the original purpose of this Recommended Practice.

The Target Evaluation Method may be utilized for alternative vision systems as well (i.e., cameras and monitors), but additional work is necessary to specify system requirements that appropriately consider valid image representation (clarity, acuity, distortion, size, etc.).

A minimum mirror radius of 300 mm for a spherical convex mirror is recommended based on a consensus of the committee. Appendix D describes the rational for this limit which is derived from considerations of visual acuity and typical vehicle layout.

In establishing a Target Evaluation Procedure, care was taken to ensure that the evaluation could be conducted in a simulated environment with appropriate CAD utilization, or equivalently with manual methods. This procedure details target cylinders and spacing, which were selected to be similar to the concept established in the Federal Regulation FMVSS 111, as required for school buses, with notable improvements.

Within the Target Evaluation Method, it is acknowledged that the extrapolation of the solid angles to form a vision cone, are not fully detailed in this Procedure with consideration of ergonomic limitations (i.e., head and eye movement). These limitations should be considered, but as with the previous 1995 version, are beyond the scope of this document.

It is recognized that the Target Evaluation Procedure counts the cylinder targets on the boundary between zones twice but it was judged by the Task Force to be preferable over a more complicated procedure that attempted to resolve the double count. This resolution of boundary target cylinders also allows each zone to be assessed independently, as well as in summary, to achieve a field of view volume evaluation.

The Target Evaluation Procedure requires a setup with the mirrors in the nominal adjustment position. The Task Force intended to require that both the top and bottom corners of the extremities of the vehicle would be visible, but it was determined that in most situations these extremities could not be viewed simultaneously without adjusting the mirror surface from nominal. Therefore, the bottom extremities of the vehicle were chosen as required view points.

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1. SCOPE & PURPOSE

This SAE Recommended Practice establishes three alternate methods for describing and evaluating the truck driver's viewing environment: the Target Evaluation, the Polar Plot and the Horizontal Planar Projection. The Target Evaluation describes the field of view volume around a vehicle, allowing for ray projections, or other geometrically accurate simulations, that demonstrate areas visible or non-visible to the driver. The Target Evaluation method may also be conducted manually, with appropriate physical layouts, in lieu of CAD methods. The Polar Plot presents the entire available field of view in an angular format, onto which items of interest may be plotted, whereas the Horizontal Planar Projection presents the field of view at a given elevation chosen for evaluation.

These methods are based on the Three Dimensional Reference System described in SAE J182a. This document relates to the driver's exterior visibility environment and was developed for the heavy truck industry (Class B vehicles, class 6, 7, 8 vehicles) although the projection principles presented in this document can be applied to any class of motor vehicles.

This document is intended to complement SAE J1050a and provides a visual format that can describe the driver's entire viewing environment. This environment can then be analyzed to determine what the driver is capable of seeing. It should be noted that one of the most important factors affecting the driver's field of view and the ability to make valid vehicle/design comparisons is the location of the driver's eyepoint. SAE J941 defines the Eyellipse which forms the basis for eyepoints chosen as the origin for Polar Plots and Horizontal Planar Projections. The Target Evaluation, Horizontal Planar Projection and Polar Plot create monocular evaluations. Projections/plots of multiple eyepoints must be overlaid to create binocular or ambinocular evaluations.

Analytical methods for creating Target Evaluations, Polar Plots and Horizontal Planar Projections for direct and indirect vision (planar and spherical convex mirrors) are presented. Note that it is possible to create plots and projections for other mirror surfaces and vision devices if the equations for determining reflection points are provided.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.2 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J182a Motor Vehicle Fiducial Marks and Three-dimensional Reference System

SAE J264 Vision Glossary

SAE J941 Motor Vehicle Drivers' Eye Locations

SAE J1050a Describing and Measuring the Driver's Field of View

SAE J1100 Motor Vehicle Dimensions

2.3 Other Publications

TNO 01.OR.NT.011.1/JvdH Research Paper published by TNO Institute regarding Object Acuity in Vision Limitations.

3. SAE J1516 ACCOMMODATION TOOL REFERENCE POINT DEFINITIONS

3.1 Driver's Viewing Environment

The environment surrounding the driver as described relative to the driver and his/her vision abilities.

3.2 Polar Plot

A two-dimensional plot that represents the angle of sight lines tangent to items of interest within the driver's viewing environment relative to the horizontal and vertical plane passing through the origin of the sight line.

3.3 Horizontal Planar Projection

A two-dimensional plot which represents the intersection of sight lines with a ground plane or a specified plane parallel to the ground plane. The sight lines are tangent to items of interest within the driver's viewing environment. The Horizontal Planar Projection maps only the limits of items of interest (in contrast to the Polar Plot). The effect is as if a lamp at the driver's eyes casts a shadow of a window, mirror or other item onto the plane.

3.4 Eyellipse

The contraction of the words "Eye" and "Ellipse" and is so named because of the elliptical shape of the driver's eye range. "Eyellipse" is the statistical model defined in SAE J941.

3.5 Monocular Field of View

The field of view that can be seen by one eye. (Reference SAE J1050a)

3.6 Binocular Field of View

The total field of view that can be seen by both eyes simultaneously. (Reference SAE J1050a)

3.7 Ambinocular Field of View

The total field of view that can be seen by both eyes separately. This includes the binocular field as well as the monocular field visible to the right eye but not the left eye and vice versa. (Reference SAE J1050a)

3.8 Sight Line

A line representing the driver's line of sight from an eye point or a V point to a target point or at a given angle.

3.9 Vision Reference PointsPoints from which sight planes/lines may be constructed. (V point)

3.10 Vision Opening Line

What the driver actually perceives as the D.L.O. (day light opening). It is the intersection of a surface of interest and a sight line from a vision reference point, tangent to the first body component obstructing these sight lines (i.e., window moldings, seals, ceramic paint, concealed wipers, front end surface, etc.)

3.11 Polar Plot/Horizontal Planar Projection Origin Point

Selected by the plot originator. It can be the eyellipse centroid, left or right eyellipse centroid, or a vision reference point.

3.12 Item of Interest

An item which the plot originator chooses to define as part of the driver's viewing environment. It can be vehicle vision opening lines, other vehicles, field of view targets, lane markers, etc. Note that items of interest may be unique to a specific eye point. For example, an item of interest such as the top edge of the dash may disappear as the eye point moves upward. The new item of interest might be the hood.

3.13 Variable/Coordinate System Definitions

The three-dimensional vehicle coordinate system is that established in J182. The positive X axis is to the rear, the positive Y axis to the driver's right and the positive Z axis is up. A second coordinate system is used in the Polar Plot and Horizontal Planar Projection calculations. In this system the axis directions remain the same, but the origin is moved to the eye point. Table 1 is presented to assist in the definition of the variables in both systems:

TABLE 1 - COORDINATE SYSTEM NOTATION

	Vehicle Coordinate System	Eye Coordinate System	Conversion
Point on Item of Interest	Tx, Ty, Tz	tx, ty, tz	tx = Tx - Ex ty = Ty - Ey tz = Tz - Ez
Point on Mirror	Mx, My, Mz	mx, my, mz	mx = Mx - Ex my = My - Ey mz = Mz - Ez
Intercept Point on Horizontal Plane	Nx, Ny	nx, ny	nx = Nx - Ex ny = Ny - Ey

3.14 Class B Vehicles

Those vehicles having an H point height (H30) between 405 and 520 mm and steering wheel diameters (W9) between 450 and 560 mm. This class of vehicles includes heavy trucks and some buses and multipurpose vehicles. (Reference SAE J1516)

3.15 Accommodation Heel Reference Point

Refer to SAE J1516.

3.16 Accommodation Tool Reference Point

A point on the Accommodation Tool Reference Line at height H30 (as specified by the vehicle manufacturer). (Reference SAE J1516)

3.17 Accommodation Tool Reference Line

Refer to SAE J1516.

3.18 Seat Back Angle (A40)

Refer to SAE J1100.

4. TARGET EVALUATION PROCEDURE

4.1 The target evaluation procedure is intended to represent positions of objects around a vehicle in 3-D, typically on a ground plane projection. The exercise described may be conducted with a geometrically accurate 3-D software, or manually with appropriate physical layouts around an actual vehicle.

4.2 Standard Target Description

The standard target is described as a cylinder with three stacked sections, each 04 m (1.312 ft) in diameter and in height. Each section is color-coded from top to bottom as red, yellow and green, resulting in a total cylinder height of 1.2 m (3.937 ft). See Figure 1.

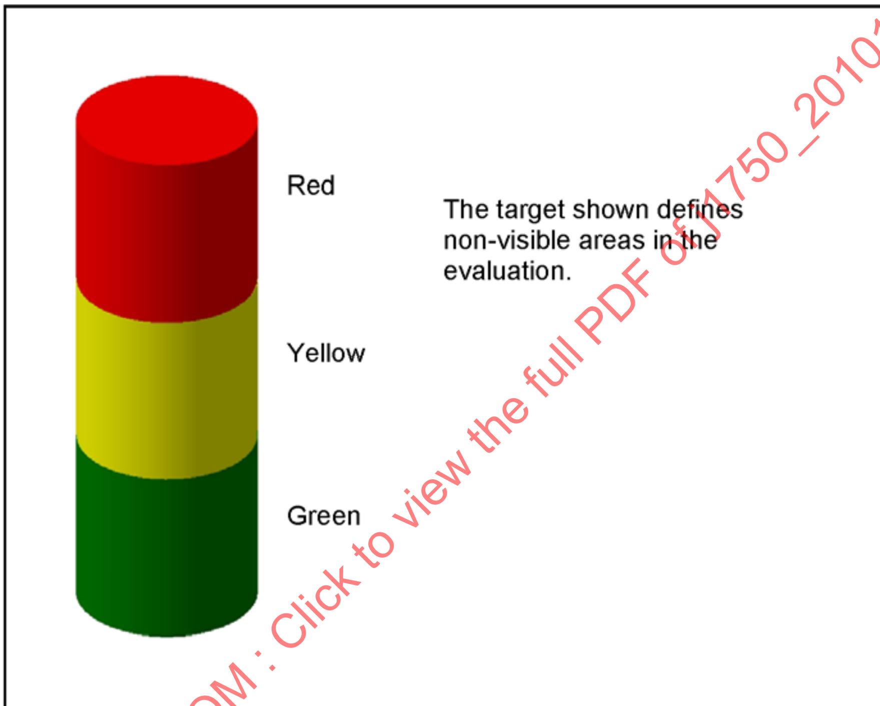

FIGURE 1 - VISION EVALUATION TARGET

4.3 Target Displacement Pattern and Coordinate Identification

The target evaluation procedure is to be conducted specific to a study vehicle. Therefore, coordinates of each cylinder position are defined in relation to a given vehicle (Figure 2). Each cylinder point should be located on a 0.485 m x 0.485 m grid pattern (1.5 ft x 1.5 ft). The front grid should be established starting with the cylinder at position F (0,0) touching the front center of the vehicle bumper. The front grid should extend to the rear extreme of the vehicle. To account for varying vehicle lengths, a secondary grid should be established starting with the cylinder R (0,0) touching the rear center of the vehicle extremity.

This grid layout may result in a narrow spacing between the beginning of the rear grid starting at R (0,0), and the truncation of the front grid, which extends to the back of the trailer. This is judged acceptable because it is more conservative to have closer spacing and it is essential that the rear zones begin at the rear bumper.

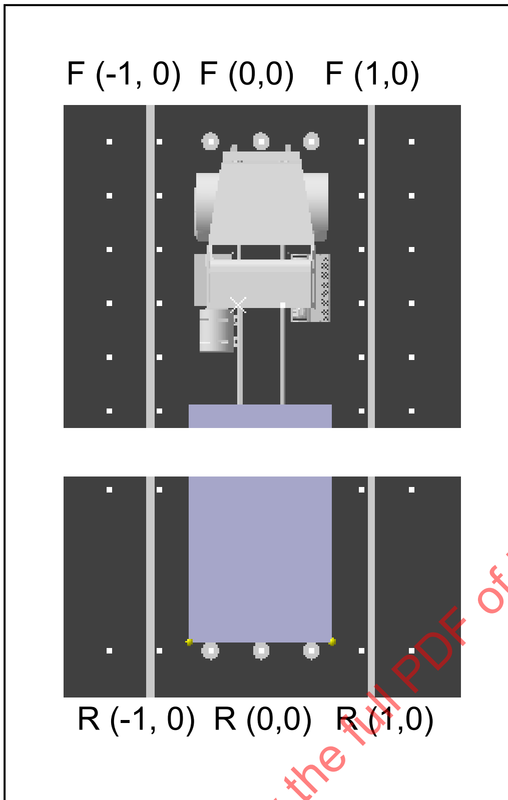

FIGURE 2 - GRID LOCATION NUMBERING

4.4 Field of View Zone Identification

The near field zones around the vehicle are defined as follows (see Figures 3 and 4):

NOTE: While SAE procedures require metric units, the standard U.S. road lane width is 12 ft (3.658 m). The zones dimensions are defined using multiples of “L” (“L” equals 3.658 m).

Front Left (FL) – Left adjacent lane (1 L wide) from a line touching the front bumper forward 2.5 x L, and extending to the back of the cab.

Front Forward (FF) – Vehicle lane (1 L wide) from a line touching the front bumper forward 2.5 x L

Front Right (FR) – Right adjacent lane (1 L wide) from a line touching the front bumper forward 2.5 x L and extending to the back of the cab.

Adjacent Left (AL) – Left adjacent lane (1 L wide) from a line touching the rear of the cab and extending to a line touching the rear bumper of the trailer or truck body (i.e. the overall length of the vehicle OAL)

Adjacent Right (AR) - Right adjacent lane (one L wide) from a line touching the rear of the cab and extending to a line touching the rear bumper of the trailer or truck body (i.e. the overall length of the vehicle OAL)

Rear Left (RL) – Left adjacent lane (1 L wide) from a line touching the rear bumper rearward 2.5 x L

Rear Aft (RA) – Vehicle lane immediately behind the tractor trailer unit or truck (1 L wide) from a line touching the rear bumper rearward 2.5 x L

Rear Right (RR) - Right adjacent lane (1 L wide) from a line touching the rear bumper rearward 2.5 x L

The far or extended field zones beyond the near field zones are defined as follows (see Figure 4):

Far Forward Front (FFF) – The vehicle lane and two lanes to the left and right (5 x L wide) from 2.5 x L forward of the front bumper to 5 x L forward.

Far Adjacent Left (FAL) – The second adjacent lane (1 L to the left of the vehicle lane and 1 L wide) by the overall length (OAL) of the vehicle.

Far Adjacent Right (FAR) - The second adjacent lane (1 L to the right of the vehicle lane and 1 L wide) by the overall length (OAL) of the vehicle.

Far Rearward Aft (FRA) - The vehicle lane and two lanes (L) to the left and right (five total lanes or 5 x L wide) from 2.5 x L feet rearward of the rear bumper to 5 x L rearward.

4.5 Target Evaluation Method

4.5.1 Evaluation Setup

The evaluation procedure should be conducted with the mirror surfaces in the nominal adjustment position. In the nominal adjustment position, specific points should be visible from the driver eye-point position. These include the rear bottom vehicle extremities (i.e., bottom corners of the trailer). For specialty applications with a non-standard rear section, an appropriate bottom extremity should be utilized. (Figure 5)

4.5.2 Target Evaluation of Field of View

Using the vehicle geometry and established target locations, the driver's field of view should be geometrically projected as a solid angle originating at the driver's eyepoint. Sight lines should be extended from a single fixed cyclopean eyepoint (documented by user), and projected until blocked by an obstruction, or continuing to the ground plane if unobstructed. The expansion of the derived solid angle, or field of view cone, is limited in range by the Vision Opening Line. The resultant field of view is truncated at a horizontal surface, typically the ground plane. Figure 6 demonstrates the graphic portrayal of visible and nonvisible areas.

As a simplified model for representative purposes, the Target Evaluation Method uses a single fixed cyclopean eyepoint. If a specific study requires a more refined eyepoint location including head movement, care should be taken to ensure that ergonomic factors are properly considered in these specific applications. Reference: SAE J1050a.

The resultant field of view, which identifies viewable and non-viewable areas, should be extrapolated to include both direct and indirect images. In order to accurately portray areas not visible to the driver, the cylinder targets, or cross-sectional portion of the targets, may be shown graphically if using CAD methods. An open green circle may be used to represent a target location completely visible from the static eye point. An example illustration using this Recommended Practice is shown in Figure 7.

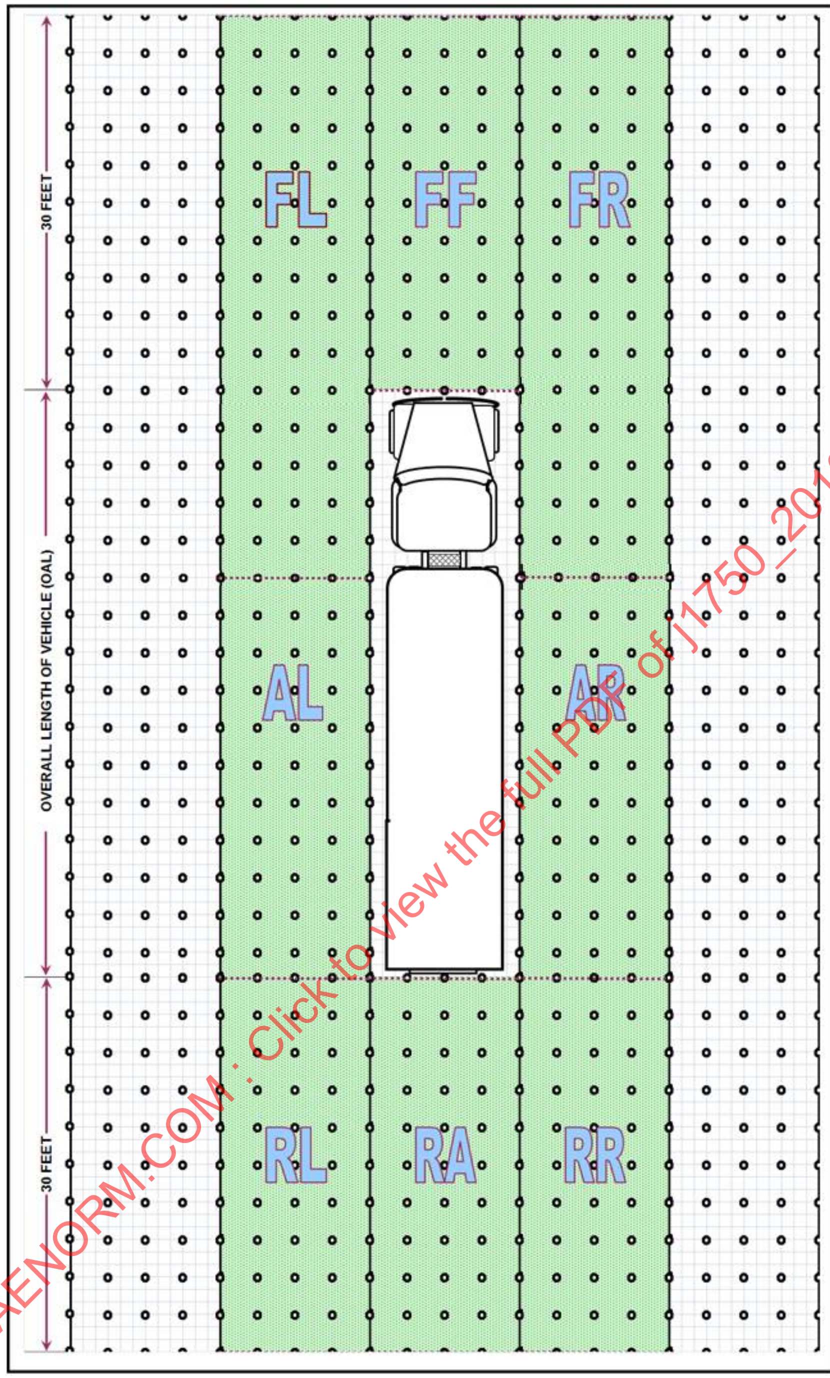

FIGURE 3 - NEAR ZONES

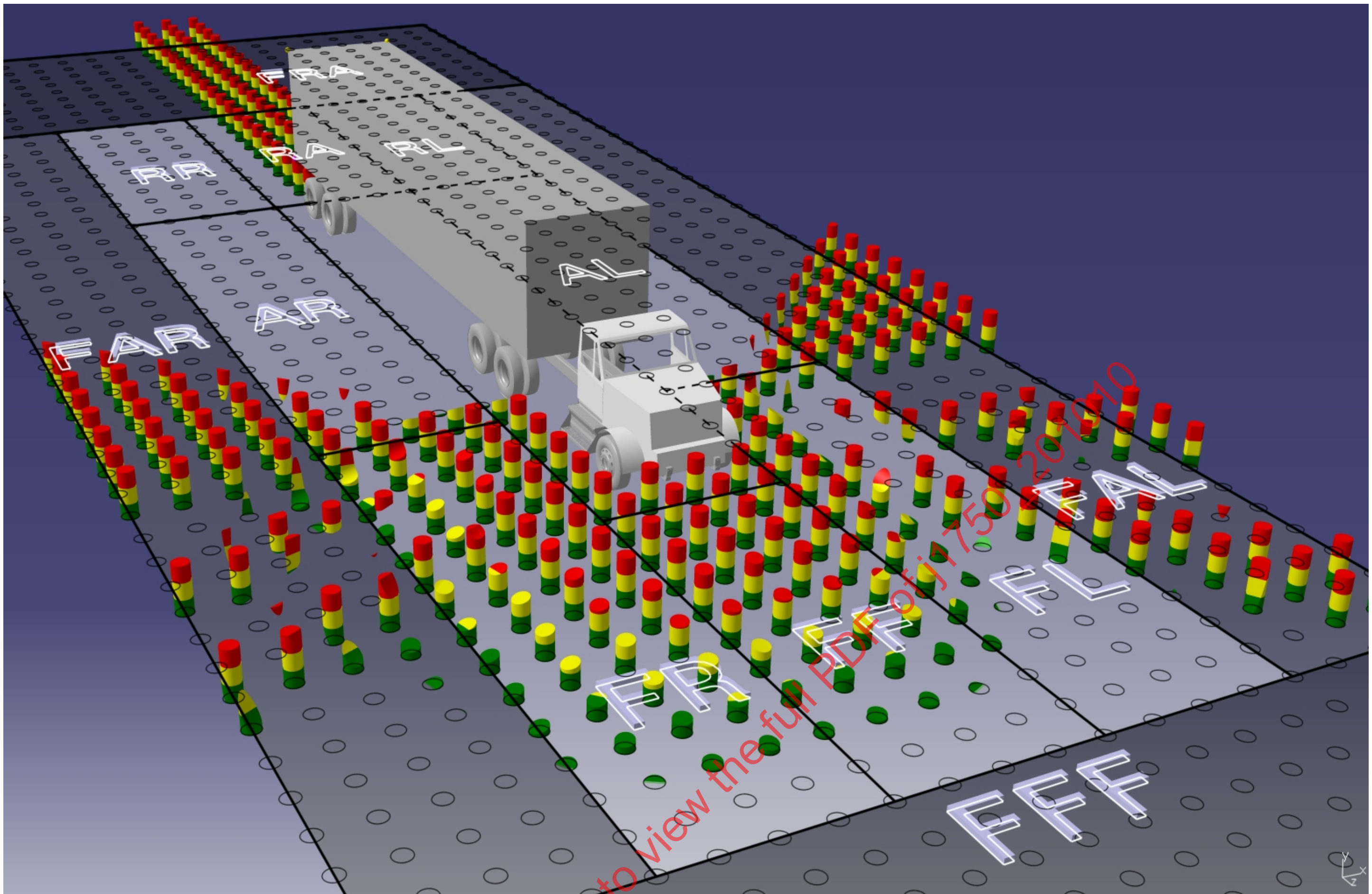

FIGURE 4 - FAR ZONES

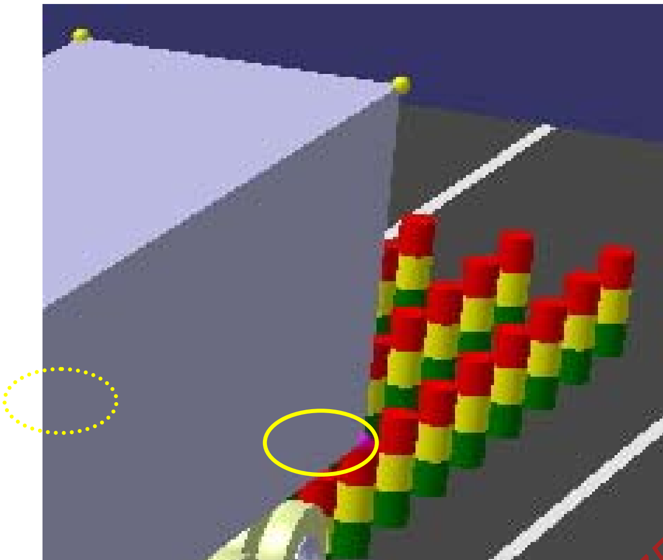

FIGURE 5 - TRAILER / VAN BODY CORNERS

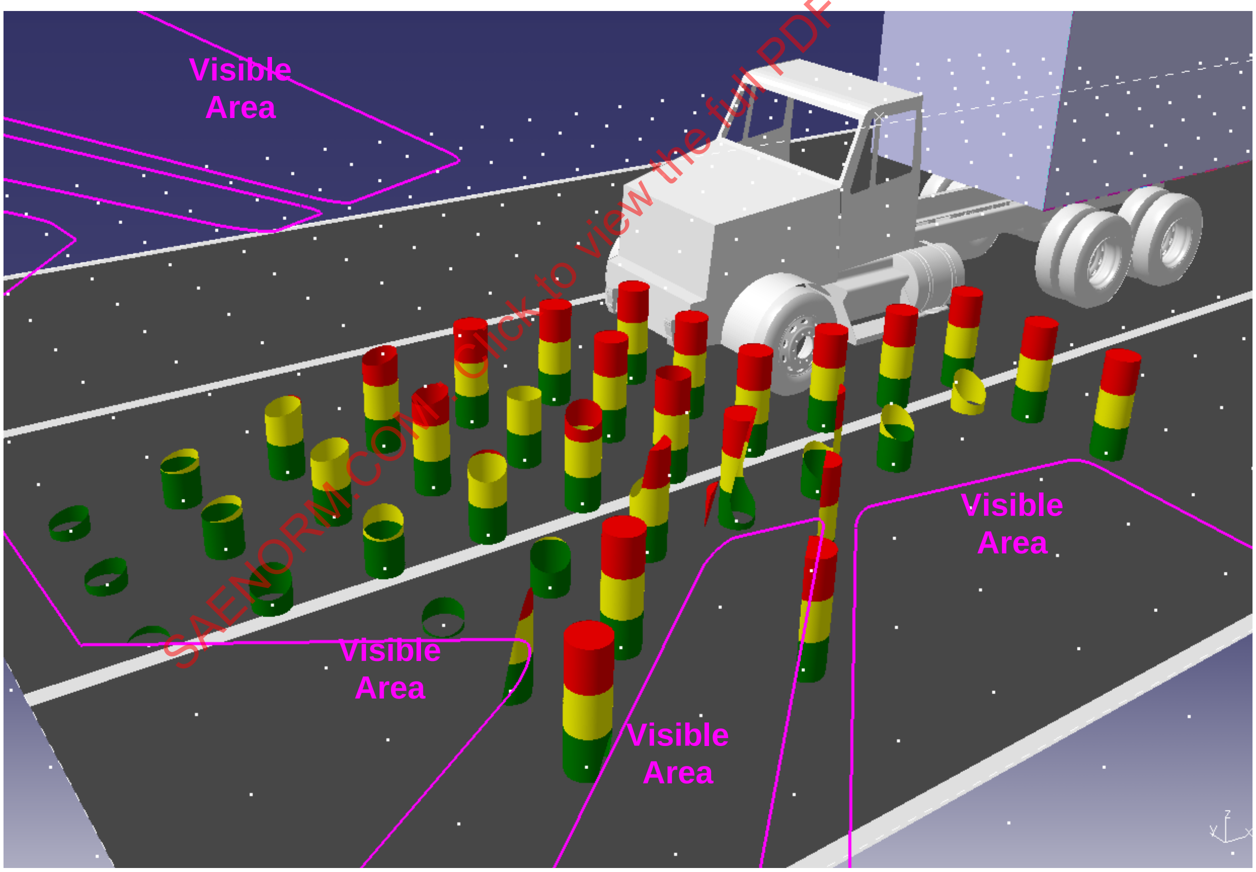

FIGURE 6 - EXAMPLE OF NON-VISUAL TARGETS

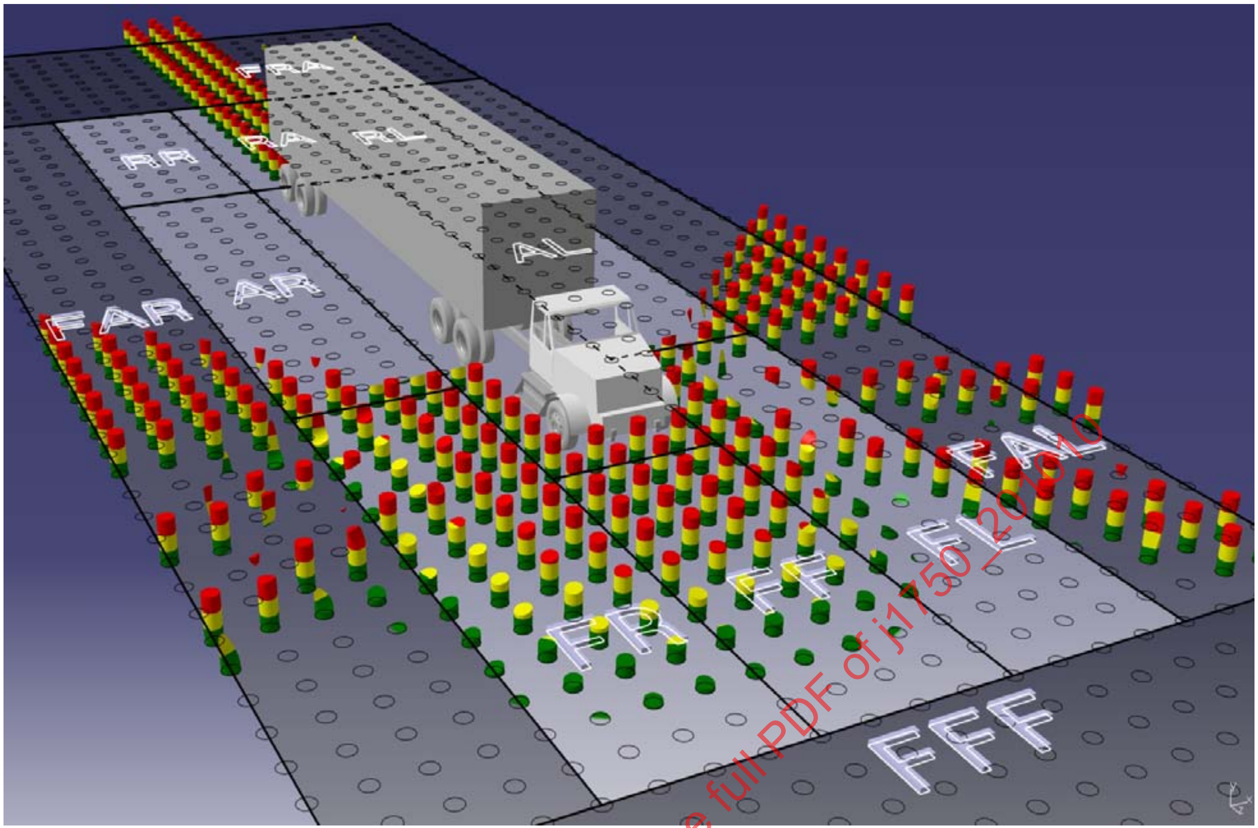

FIGURE 7 - EXTENDED VIEW OF BOTH DIRECT & INDIRECT TARGETS (NON-VISUAL)

5. POLAR PLOT PROCEDURE

Polar plots are found by computing the angles from the eye point to points within the field (items of interest).

5.1 Generation of Polar Angles for the Direct Viewing Environment

5.1.1 Define the Origin

The polar plot origin (Ex, Ey, Ez) in the vehicle coordinate system may be the Eyellipse centroid, left or right Eyellipse centroid or any vision origin point defined by the user.

5.1.2 Define Each Point to be Graphically Represented

Define points on each item of interest using the eye coordinate system (tx, ty, tz) (see 3.12 and 3.13).

$$tx = Tx - Ex$$
$$ty = Ty - Ey$$
$$tz = Tz - Ez \quad \text{(Eq. 1)}$$

5.1.3 Compute the Azimuth and Elevation Angles

Convert the point (–tx, ty, tz) to polar coordinates θ (azimuth) and ϕ (elevation) using the following equations in Figure 8:

NOTE: In this conversion, the negative of the X coordinate is used to provide a presentation with +θ to the right and –θ to the left.

	ty > 0	ty < 0
tx < 0	$\theta = -\arctan\left(\frac{ty}{tx}\right)$	
tx = 0	$\theta = 90$	$\theta = -90$
tx > 0	$\theta = 180 - \arctan\left(\frac{ty}{tx}\right)$	$\theta = -180 - \arctan\left(\frac{ty}{tx}\right)$

FIGURE 8 - EQUATIONS

$$\phi = \arctan\frac{tz}{\sqrt{tx^2 + ty^2}} \quad \text{(Eq. 2)}$$

5.2 Generation of Polar Angles for the Indirect Viewing Environment - Planar Mirrors

The periphery of the mirror is plotted as points in the direct field using 5.1. Other target points viewed in the mirror are plotted using methods in this section.

5.2.1 Define the Origin

The polar plot origin (Ex, Ey, Ez) may be the Eyellipse centroid, left or right Eyellipse centroid or any vision origin point defined by the user.

5.2.2 Determine the Mirror Location and Angle

The mirror location and angle are defined by finding the equation of the surface. Select three points on the mirror surface not in a single line and preferably apart. Using these points, define the equation of the mirror plane in the vehicle coordinate system in the form:

$$A*Mx + B*My + C*Mz + D = 0 \quad \text{(Eq. 3)}$$

One method of finding the coefficients in given in Appendix A.

5.2.3 Define Each Point to be Graphically Represented

Define a point on the item of interest in the vehicle coordinate system as Tx, Ty, Tz.

5.2.4 Find the Reflection Point of Tx, Ty, Tz

Use the following equations with the coefficients from 5.2.2 to solve for the reflection point (Rx, Ry, Rz) for the item of interest (Tx, Ty, Tz).

$$\begin{aligned} Rx &= Tx + 2*A*k \\ Ry &= Ty + 2*B*k \\ Rz &= Tz + 2*C*k \end{aligned} \quad \text{(Eq. 4)}$$

where:

$$k = \frac{-D - A*Tx - B*Ty - C*Tz}{A^2 + B^2 + C^2}$$

Convert the point Rx, Ry, Rz to the eye coordinate system rx, ry, rz as follows:

$$rx = Rx - Ex$$
$$ry = Ry - Ey$$
$$rz = Rz - Ez \quad \text{(Eq. 5)}$$

5.2.5 Compute the Angles

Convert the point (–rx, ry, rz) to polar coordinates θ (azimuth) and Φ (elevation) using the table and equation in 5.1.3 substituting –rx, ry, rz for –tx, ty, tz.

5.3 Generation of Polar Angles for the Indirect Viewing Environment - Spherical Convex Mirrors

The periphery of the mirror is plotted as points in the direct field using 5.1. Other target points viewed in the mirror are plotted using methods in this section.

5.3.1 Define the Origin

The polar plot origin (Ex, Ey, Ez) may be the Eyellipse centroid, left or right Eyellipse centroid, or any vision origin point defined by the user.

5.3.2 Determine the Mirror Location and Angle

The mirror location and angle are defined by finding the equation of the mirror surface in the vehicle coordinate system. Select four points on the mirror surface not in a single line and preferably apart. Using these points, define the equation of the mirror plane in the form:

$$A*Mx + B*My + C*Mz + D + F*(Mx^2 + My^2 + Mz^2) = 0 \quad \text{(Eq. 6)}$$

One method of finding the coefficients in given in Appendix B.

5.3.3 Define Each Point to be Graphically Represented

Define a point on an item of interest in the vehicle coordinate system as Tx, Ty, Tz.

5.3.4 Find the Reflection Point of Tx, Ty, Tz

The point on the mirror at which the target point is seen (reflection point) is most easily found iteratively. Select a mirror point, test if the eye will see the target at that point, and if not, select another. A number of methods may be used to do this. One is presented in Appendix C.

Convert the point Rx, Ry, Rz to the eye coordinate system as rx, ry, rz (see 5.2.4).

5.3.5 Compute the Angles

Proceed as in 5.2.5.

6. HORIZONTAL PLANAR PROJECTION PROCEDURE

The Horizontal Planar Projection is meant to map the limits of windows or other items onto a horizontal plane. The effect is as if a lamp at the driver's eyes cast a shadow of the item onto the plane.

6.1 Generation of Intercepts for the Direct Viewing Environment

6.1.1 Define the Eye Point

Define the eye point in the vehicle coordinate system as (Ex, Ey, Ez). This may be the Eyellipse centroid, left or right Eyellipse centroid or any vision origin point defined by the user.

6.1.2 Define the Location of the Horizontal Plane at Gz

Define the location of the horizontal plane to which the items of interest will be projected by its Z coordinate, Gz, in vehicle coordinates. This plane can be the ground or any elevation of interest.

6.1.3 Define the Point to be Projected

Define the point to be projected in the vehicle coordinate system as Tx, Ty, Tz. For a point to be projected it must lie between the eye point and the plane.

$$Gz < Tz < Ez \text{ or } Gz > Tz > Ez \qquad \text{(Eq. 7)}$$

6.1.4 Calculate the Intercept Point

Calculate the Ratio R.

$$R = \frac{Gz - Ez}{Tz - Ez} \qquad \text{(Eq. 8)}$$

If R is less than or equal to zero, then no intercept exists. If R is greater than zero then calculate the intercept points Nx and Ny. These points are in the vehicle coordinate system.

$$\begin{array}{ll} \text{IF } R \le 0 & \text{NO INTERCEPTS} \\ \text{IF } R > 0 & Nx = Ex + R*(Tx - Ex) \\ & Ny = Ey + R*(Ty - Ey) \end{array} \qquad \text{(Eq. 9)}$$

If the eye point is to form the origin of the Horizontal Planar Projection, convert the points Nx, Ny to the eye coordinate system as nx, ny as follows:

$$\begin{array}{l} nx = Nx - Ex \\ ny = Ny - Ey \end{array} \qquad \text{(Eq. 10)}$$

6.1.5 Convert to Desired Coordinate System

If desired, the intercept points can be converted to another coordinate system with origin at Ox, Oy, Oz. This origin may be at the Eyellipse centroid, a vision point or any other suitable location.

$$\begin{array}{l} nx = Nx - Ox \\ ny = Ny - Oy \\ nz = Nz - Oz \end{array} \qquad \text{(Eq. 11)}$$

6.2 Generation of Intercepts for the Indirect Viewing Environment

6.2.1 Define the Origin

The horizontal planar projection origin (Ex, Ey, Ez) may be the Eyellipse centroid, left or right Eyellipse centroid or any vision origin point defined by the user.

6.2.2 Define the Location of the Horizontal Plane at Gz

Define the location of the horizontal plane to which the items of interest will be projected by its Z coordinate, Gz, in vehicle coordinates. This plane can be ground or any elevation of interest.

6.2.3 Determine the Mirror Location and Angle

The mirror location and angle are defined by finding the equation of the surface.

6.2.4 Planar Mirror

Select three points on the mirror surface not in a single line and preferably apart. Using these points, define the equation of the mirror plane in the vehicle coordinate system in the form:

$$A*Mx + B*My + C*Mz + D = 0 \qquad \text{(Eq. 12)}$$

One method of finding the coefficients is given in Appendix A.

6.2.5 Spherical Convex Mirror

Select four points on the mirror surface not in a single line and preferably apart. Using these points, define the equation of the mirror plane in the vehicle coordinate system in the form:

$$A*Mx + B*My + C*Mz + D + F*(Mx^2 + My^2 + Mz^2) = 0 \qquad \text{(Eq. 13)}$$

One method of finding the coefficients in given in Appendix B.

6.2.6 Define the Point to be Projected

Define the point to be projected as Tx, Ty, Tz in vehicle coordinates.

6.2.7 Calculate the Intercept Point

Using the coefficients of the equation of the mirror surface, calculate Qx, Qy and Qz. Note that for a planar mirror, F = 0.

$$\begin{aligned} Qx &= Ex - 2*(2*F*Mx + A)*K \\ Qy &= Ey - 2*(2*F*My + B)*K \\ Qz &= Ez - 2*(2*F*Mz + C)*K \end{aligned} \qquad \text{(Eq. 14)}$$

$$K = \frac{(2*F*Mx + A)(Ex - Mx) + (2*F*My + B)(Ey - My) + (2*F*Mz + C)(Ez - Mz)}{A^2 + B^2 + C^2 - 4*F*D} \qquad \text{(Eq. 15)}$$

6.2.8 Calculate the Ratio R

$$R = \frac{Gz - Mz}{Mz - Qz} \qquad \text{(Eq. 16)}$$

If R is less than or equal to zero, then no intercept exists. If R is greater than zero, calculate the Intercept points Nx and Ny. These points are in the vehicle coordinate system.

$$\begin{array}{ll} \text{IF } R \leq 0 & \text{NO INTERCEPTS} \\ \text{IF } R > 0 & Nx = Mx + R*(Mx - Qx) \\ & Ny = My + R*(My - Qy) \end{array} \qquad \text{(Eq. 17)}$$

If the eye point is to form the origin of the Horizontal Planar Projection, convert the points Nx, Ny to the eye coordinate system as nx, ny as follows:

$$\begin{aligned} nx &= Nx - Ex \\ ny &= Ny - Ey \end{aligned} \qquad \text{(Eq. 18)}$$

6.2.9 Convert to Desired Coordinate System

If desired, the intercept points can be converted to another coordinate system with origin at Ox, Oy, Oz. This origin may be at the Eyellipse centroid, a vision point or any other suitable location.

$$\begin{aligned} nx &= Nx - Ox \\ ny &= Ny - Oy \\ nz &= Nz - Oz \end{aligned} \qquad \text{(Eq. 19)}$$

7. PLOT FORMAT

7.1 Key Input Parameters

All Polar Plots and Horizontal Planar Projections are highly dependent upon a few key vehicle and driver parameters which have the potential to greatly vary the characteristics of the plots and their interpretation. Care must be taken to define these parameters in order to ensure plot repeatability. These Key Input Parameters are as follows:

7.2 Accommodation Heel Reference Point Height from Ground

Due to the wide variety of chassis configurations available even from a given manufacturer, the Accommodation Heel Reference Point height from ground must be specified. Care must be taken in evaluating competitors and vehicles within one's own product line to avoid misleading results. Vehicles should be specified as equivalently as possible.

7.2.1 Chassis Attitude to Ground

Similar to the Accommodation Heel Reference Point height the chassis attitude to ground must be specified and declared as horizontal about the front axle, unloaded, fully loaded, etc.

7.2.2 Accommodation Tool Reference Point

The location of the Accommodation Tool Reference Point must be specified for each plot to avoid confusion as to how the eyellipse was located.

7.2.3 Seat Back Angle (L40)

The Seat Back Angle used must be specified for each plot to avoid confusion as to how the eyellipse was located.

7.2.4 Origin Point

The plot origin point (eye point) must be labeled so it can be examined relative to the SAE eyellipse position.

7.2.5 Horizontal Intercept Plane

The height of the plane chosen for evaluation in a Horizontal Planar Projection relative to ground must be specified for each plot.

7.2.6 Mirror Size, Position and Attitude

The size, position and attitude of the plane and spherical convex mirrors used in the plots must be specified. The radius of curvature for each spherical convex mirror must also be indicated. In an indirect polar plot the direct plot of the mirror periphery should be shown to indicate what can/cannot be seen by the driver in the mirror. The plane mirror attitude should be such that it picks up the edge of the trailer since Federal Motor Vehicle Safety Standard #111 specifies that the mirror must provide a clear view down the side of the trailer. The spherical convex mirror attitude should represent how the mirror is used in the field.

7.3 Plot Format and Example - Polar Plot

7.3.1 Plot Axes

Plot the azimuth angle (θ) on the horizontal axis with $+\theta$ to the right and the elevation angle (ϕ) on the vertical axis with $+\phi$ up. (The chosen eyepoint forms the origin of the plot.)

7.3.2 Plot Labels

The particular vehicle shown must be indicated. The Key Input Parameters in 7.1 must be completely defined in an attached Data Sheet for the plot. The Data Sheet must be included/published with the plot itself in order for the Polar Plot to meet this document. Labeling the chosen items of interest is also recommended.

7.3.3 Example Plot

See Figures 9 and 10 for an example of a Polar Plot and associated Data Sheet that complies with this Recommended Practice.

7.4 Plot Format and Example - Horizontal Planar Projection

7.4.1 Plot Axes

Plot the calculated intercept points along X, Y axes (orientation per SAE J182) in the eye, vehicle, or other chosen coordinate system.

7.4.2 Plot Labels

The particular vehicle shown must be indicated. The Key Input Parameters in 7.1 must be completely defined in an attached Data Sheet for the plot. The Data Sheet must be included/published with the plot itself in order for the Horizontal Planar Projection to meet this Recommended Practice. Labeling the chosen items of interest is also recommended.

7.4.3 Additional Information

Additional information, such as an outline of the tested vehicle, an outline of another vehicle, lane markers or the like may be included on the plot. If included, they should be clearly labeled.

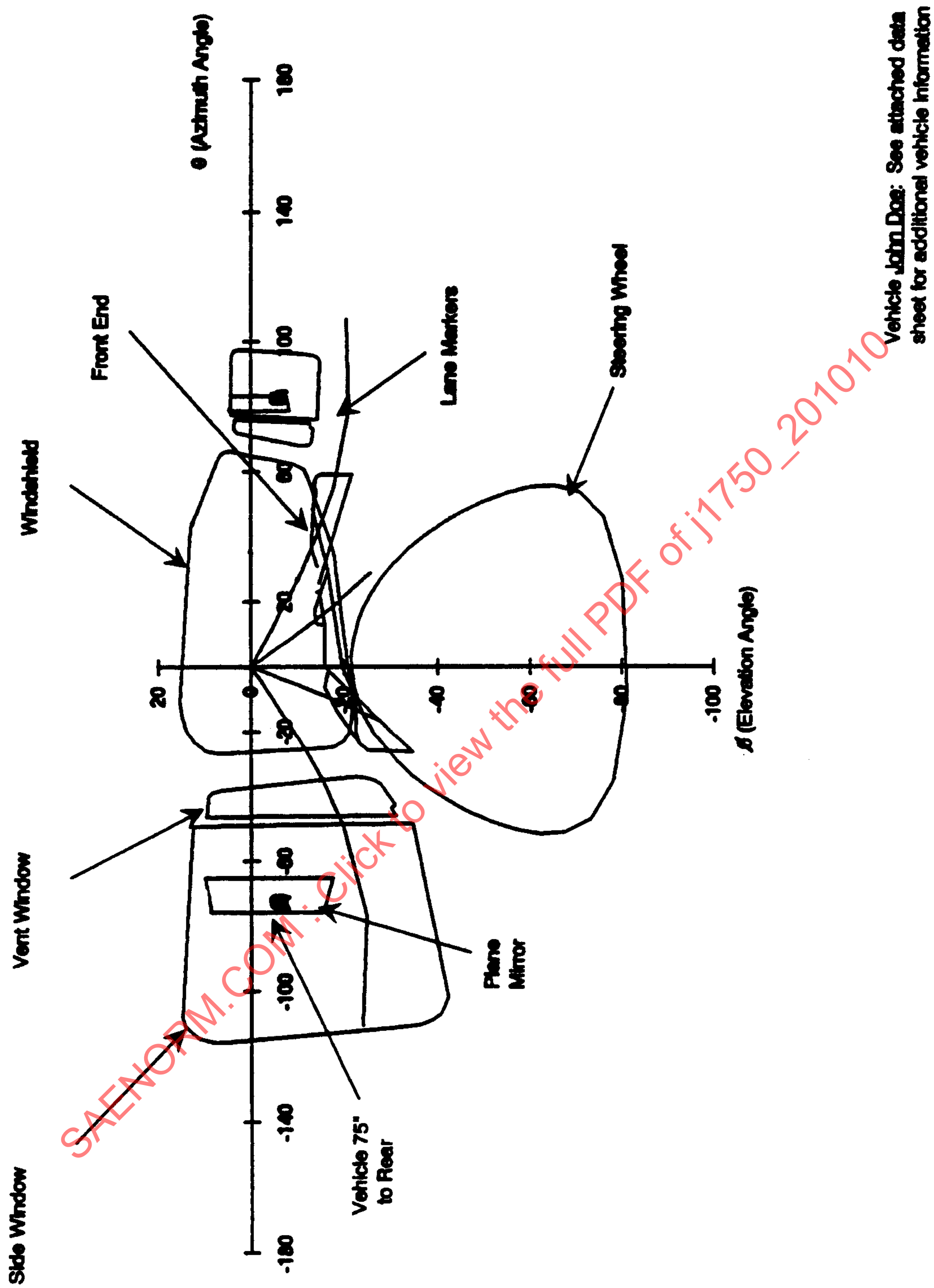

FIGURE 9 - POLAR PLOT EXAMPLE WHICH MEETS SAE J1750

1. ACCOMMODATION HEEL REFERENCE POINT HEIGHT FROM GROUND ____________

2. CHASSIS ATTITUDE TO GROUND ____________
   (Angle to Ground Plane)

   Chassis Load Assumption: ____________

3. ACCOMMODATION TOOL REFERENCE POINT (X, Y, Z) ____________

4. SEAT BACK ANGLE (L40) ____________

5. POLAR PLOT ORIGIN POINT (X, Y, Z) ____________

6. MIRROR REFLECTIVE SURFACE SIZE

   Planar Mirror (Height/Width) ____________

   Spherical Convex Mirror (Diameter/Radius of Curvature) ____________

7. MIRROR LOCATION (VEHICLE COORDINATES)

   Planar Mirror (Geometric Center) ____________

   Spherical Convex Mirror (Geometric Center through plane of mirror periphery) ____________

8. MIRROR ATTITUDE ____________
   (Longitudinal Plan View Angle)

* Vehicle Dimensional Coordinate System per SAE J182a.

FIGURE 10 - DATA INPUT SHEET-POLAR PLOT*

7.4.4 Differentiating Areas

Areas on the plot should be clearly differentiated as to those areas visible through window or mirrors and those that are not visible. For example, those areas visible may be white and those not visible may be cross-hatched.

7.4.5 Example Plot

See Figures 11 and 12 for an example of a Horizontal Planar Projection and associated Data Sheet that complies with this document.

8. NOTES

8.1 Marginal Indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

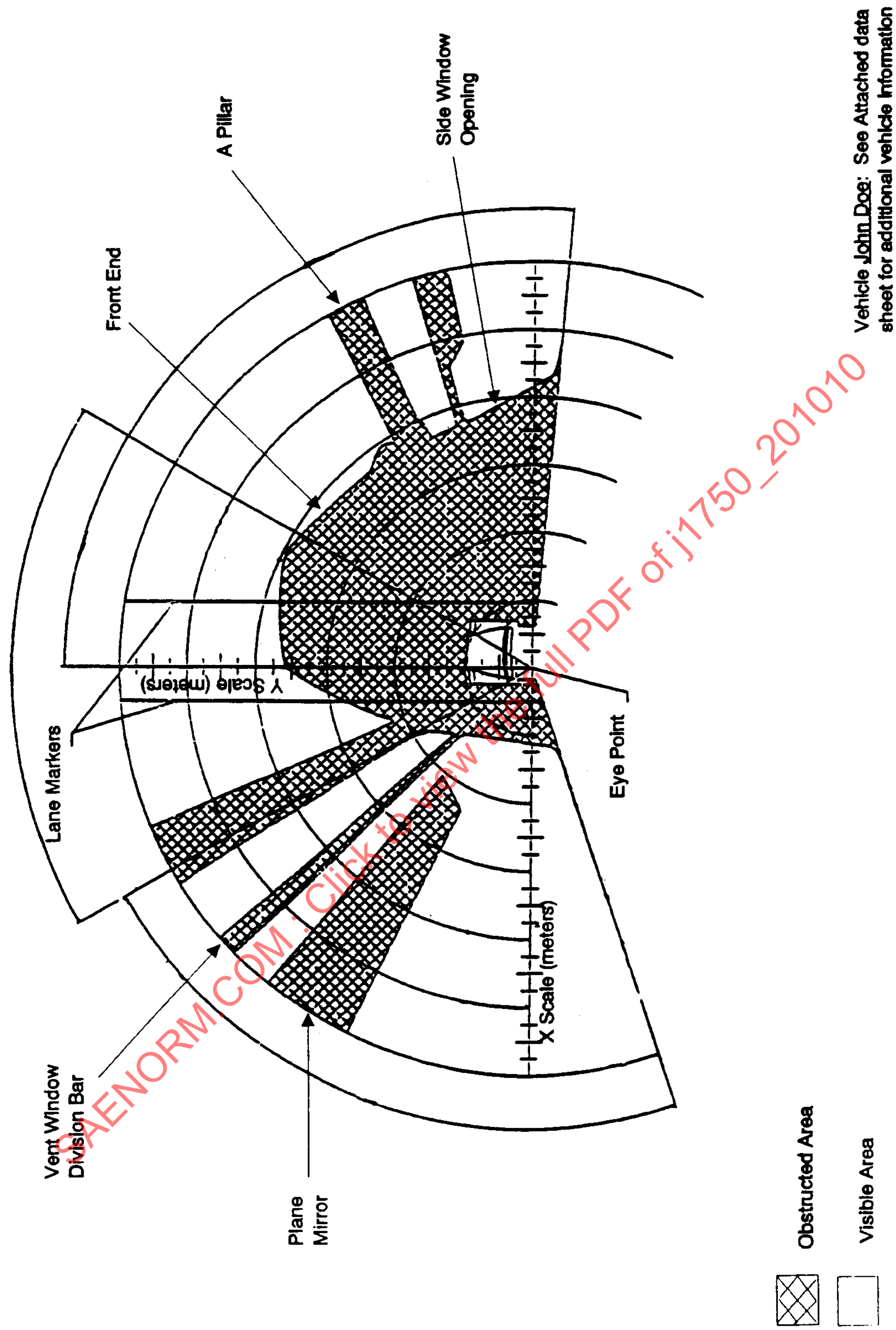

FIGURE 11 - HORIZONTAL PLANAR PROJECTION EXAMPLE WHICH MEETS SAE J1750

1. ACCOMMODATION HEEL REFERENCE POINT HEIGHT FROM GROUND ______________

2. CHASSIS ATTITUDE TO GROUND ______________
(Angle to Ground Plane)

Chassis Load Assumption: ______________________________

3. ACCOMMODATION TOOL REFERENCE POINT (X, Y, Z) ______________

4. SEAT BACK ANGLE (L40) ______________

5. POLAR PLOT ORIGIN POINT (X, Y, Z) ______________

6. MIRROR REFLECTIVE SURFACE SIZE

Planar Mirror (Height/Width) ______________

Spherical Convex Mirror (Diameter/Radius of Curvature) ______________

7. MIRROR LOCATION (VEHICLE COORDINATES)

Planar Mirror (Geometric Center) ______________

Spherical Convex Mirror (Geometric Center through plane of mirror periphery) ______________

8. MIRROR ATTITUDE ______________
(Longitudinal Plan View Angle)

* Vehicle Dimensional Coordinate System per SAE J182a.

FIGURE 12 - DATA INPUT SHEET - HORIZONTAL PLANAR PROJECTION*

PREPARED BY THE SAE TRUCK AND BUS VISIBILITY TASK FORCE
OF THE SAE TRUCK AND BUS HUMAN FACTORS COMMITTEE

APPENDIX A - METHOD FOR DETERMINING COEFFICIENTS OF EQUATION OF PLANAR MIRROR SURFACE

A.1 Select three points on the mirror surface not in a single line and preferably apart and define them as:

$$\begin{matrix} Mx_1, My_1, Mz_1 \\ Mx_2, My_2, Mz_2 \\ Mx_3, My_3, Mz_3 \end{matrix} \qquad \text{(Eq. A1)}$$

NOTE: Points are defined in vehicle coordinates.

A.2 The equation of the mirror plane per 4.2.2 is:

$$A{*}Mx + B{*}My + C{*}Mz + D = 0 \qquad \text{(Eq. A2)}$$

and can be expressed in matrix form as:

$$\begin{vmatrix} A & B & C & D \\ Mx_1 & My_1 & Mz_1 & 1 \\ Mx_2 & My_2 & Mz_2 & 1 \\ Mx_3 & My_3 & Mz_3 & 1 \end{vmatrix} = 0 \qquad \text{(Eq. A3)}$$

A.3 Therefore, the following matrices solve for the coefficients A, B, C, D:

$$A = \begin{vmatrix} My_1 & Mz_1 & 1 \\ My_2 & Mz_2 & 1 \\ My_2 & Mz_3 & 1 \end{vmatrix} \qquad B = \begin{vmatrix} My_1 & Mz_1 & 1 \\ My_2 & Mz_2 & 1 \\ My_2 & Mz_3 & 1 \end{vmatrix}$$

$$C = \begin{vmatrix} My_1 & Mz_1 & 1 \\ My_2 & Mz_2 & 1 \\ My_2 & Mz_3 & 1 \end{vmatrix} \qquad D = \begin{vmatrix} My_1 & Mz_1 & Mz_1 \\ My_2 & Mz_2 & Mz_2 \\ My_2 & Mz_3 & Mz_3 \end{vmatrix} \qquad \text{(Eq. A4)}$$