



SURFACE VEHICLE STANDARD

J1757™-2

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Standard - Optical System HUD for Automotive

RATIONALE

This SAE Standard defines a consistent terminology and metrology for vehicular Head Up Display (HUD). It allows measurement of automotive HUD attributes in accordance to SAE J1757-1 and ISO 15008.

NOTE: All definitions and units are for the metric system (SI) unless noted otherwise.

1. SCOPE

This SAE Standard provides measurement methods to determine HUD optical performance in typical automotive ambient lighting conditions. It covers indoor measurements with simulated outdoor lighting for the measurement of HUD virtual images. HUD types addressed by this standard includes w-HUD (windshield HUD) and c-HUD (combiner HUD) with references to Augmented Reality (AR) HUD as needed. It is not the scope of this document to set threshold values for automotive compliance; however, some recommended values are presented for reference.

2. REFERENCES

2.1 Applicable Documents

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.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J941 Motor Vehicle Drivers' Eye Locations

SAE J1757-1 Standard Metrology for Vehicular Displays

2.1.2 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO 4513 Road Vehicles - Visibility - Method for Establishment of Eye-Ellipses Location

ISO 15008 Road Vehicles - Display Legibility Standard

ISO 16505 Road Vehicles - Ergonomic and Performance Aspects of Camera-Monitor Systems - Requirements and Test Procedures

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2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 CIE Publications

Available from CIE Central Bureau, Babenbergerstrasse 9/9A, 1010 Vienna, Austria, Tel: +43 1 714 31 87, www.cie.co.net.

- CIE 85 Technical Report - Solar Spectral Irradiance
- CIE 15.2 Recommendations on Uniform Color Spaces, Color Differences Equations, Psychometric Color Terms
- CIE 17.4 Recommendations - CIE International Lighting Vocabulary
- CIE S003/E CIE Standard - Spatial Distribution of Daylight - CIE Standard Overcast Sky and Clear Sky

2.2.2 ICDM Publications

Available from SID organization at SID - Society of Information Display, 1475 S Bascom Ave, Ste 114, Campbell, CA 95008; Tel: (408) 879-3901, www.sid.org; or directly on the ICDM webpage, www.icdm-sid.org.

- IDMS1 Information Display Measurements Standard

2.2.3 U.S. Government Publications

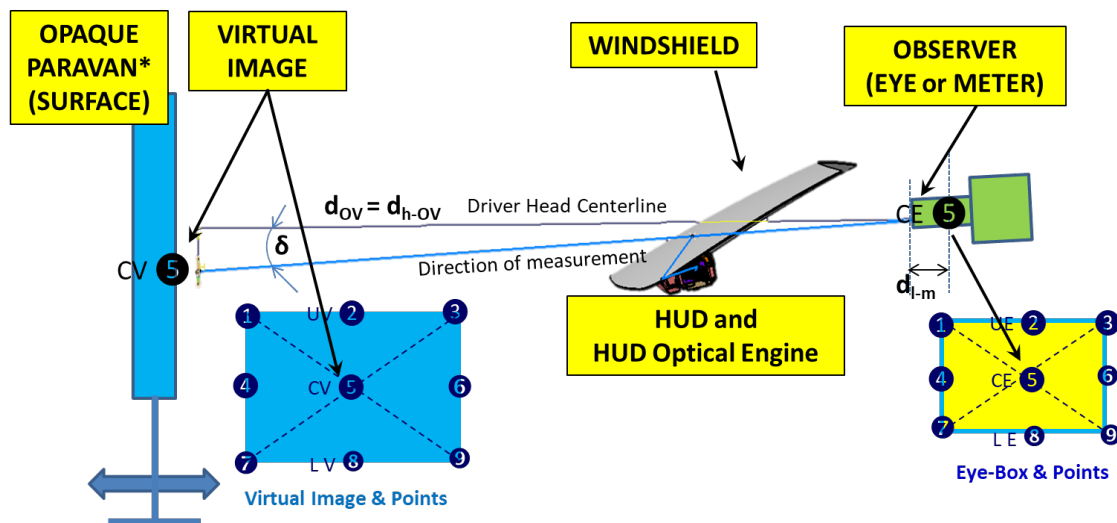
Copies of these documents are available online at <http://quicksearch.dla.mil>.

- MIL-87213 Military Handbook - Electronically/Optically Generated Airborne Displays

3. DEFINITIONS

3.1 THE DRIVER HEAD CENTERLINE

A longitudinal reference line that passes through the centroid of Eyellipse along the longitudinal axis (x Axis) of the vehicle. See Figure 2.



(a)

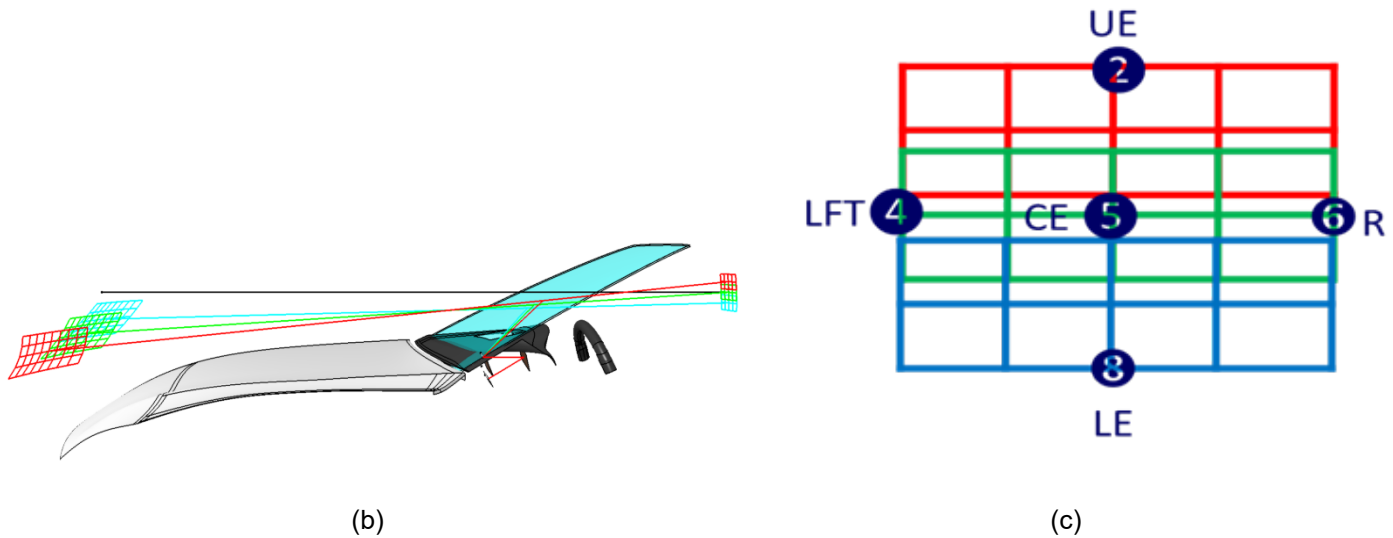


Figure 1 - System HUD and setup for measurements

(a) Overview of the setup

(b) Illustration of driver's perception of the virtual image, as seen from three eye positions

(c) Illustration of the measuring points and their relationship to traditional HUD eye-boxes

3.2 EYELLIPSE

The statistical distribution of driver's eye locations relative the SAE SgRP (H-pt) as defined by SAE J941.

3.3 EYEBOX

A vertical plane projected through the centroid of an Eyellipse (see Appendix A for details). The Eyebbox width and height limits are the Y (cross-car) and Z (Vertical) boundaries of the Eyellipse and used to define where the HUD virtual image can be seen by the population of driver's eyes. (See Figure 2).

3.4 PARAVAN

A vertical screen (physical object) with orthogonal horizontal (Y) and vertical (Z) rulings (graduated perpendicular lines) used to evaluate HUD virtual image qualities like luminance, size, color, virtual image distance from the Eyebbox, X and Z adjustment ranges, and HUD Field of View (FOV).

3.5 MEASURING POINTS FOR AN OBSERVER OR METER

Defined by the Eyebbox; see Figures 2 a1 and a2 (Observer / Instrument Meter Locations) for details. The CE5 (Center), UE2 (Upper), LE8 (Lower), LFT 4 (Left), and R6 (Right) are the Eyebbox measuring points and describe the front side of the sensor surface for positioning of optical instrumentation. The standardized measurement points for the virtual images are located on the paravan, as shown in Figure 1.

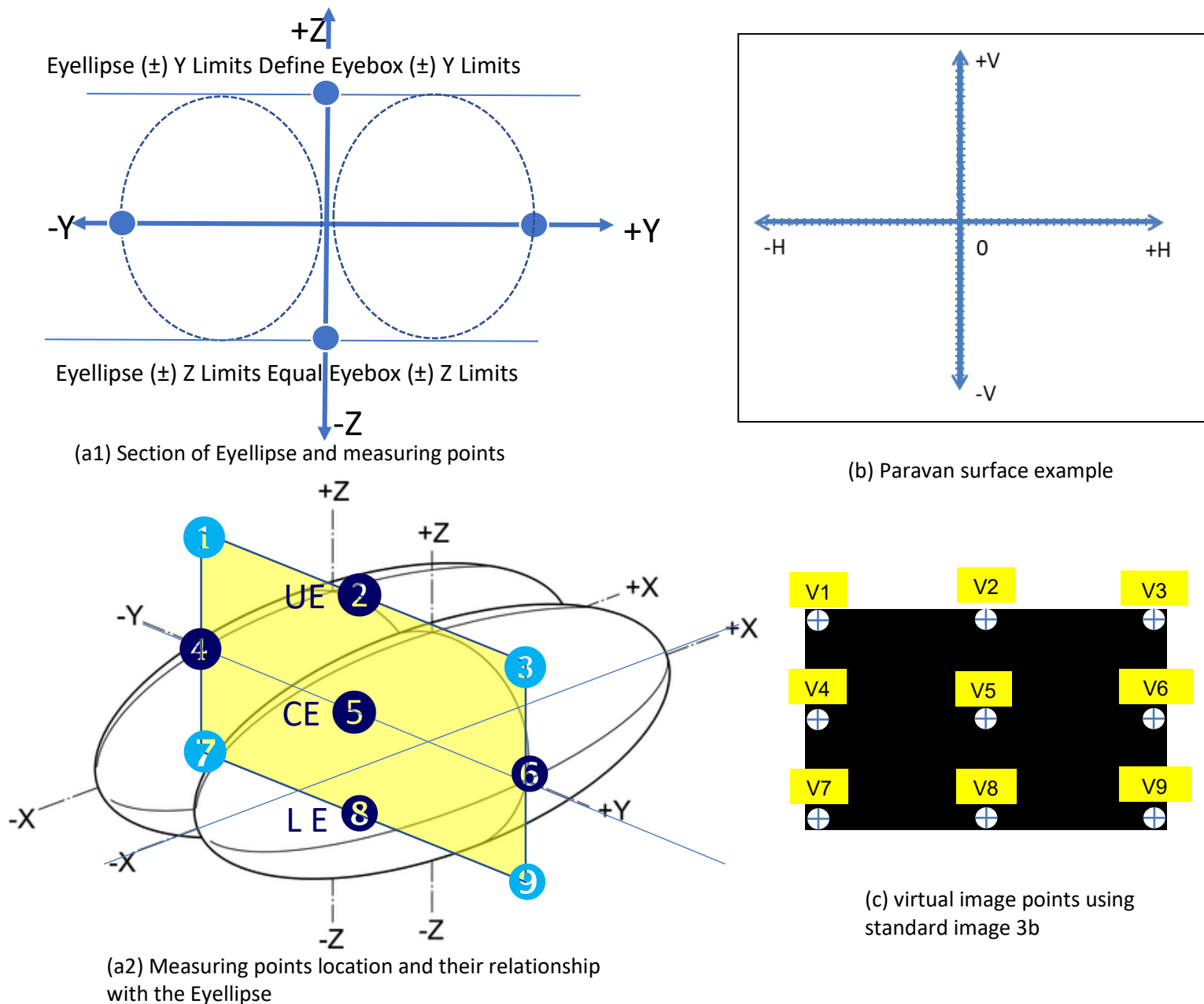


Figure 2 - Illustration of measuring points location

- (a) a1 and a2 illustrations are related to the Eyellipse (includes cross-section shown in a1)
- (b) Coordinate system on the paravan surface example
- (c) virtual image points using standard image 3b

3.6 SYSTEM HUD ORIGINAL IMAGE SOURCE

The HUD's optical engines active area and generates the virtual image (see Figure 1). This standard image is either a set of even squares (as shown in Figure 3a for $n=m=5$), or a set of one-surface dots with a minimum of three dots per line (as shown in Figure 3b for $n=m=1$). Full white and full black images should be used for optical performance measurements, as defined by CIE.

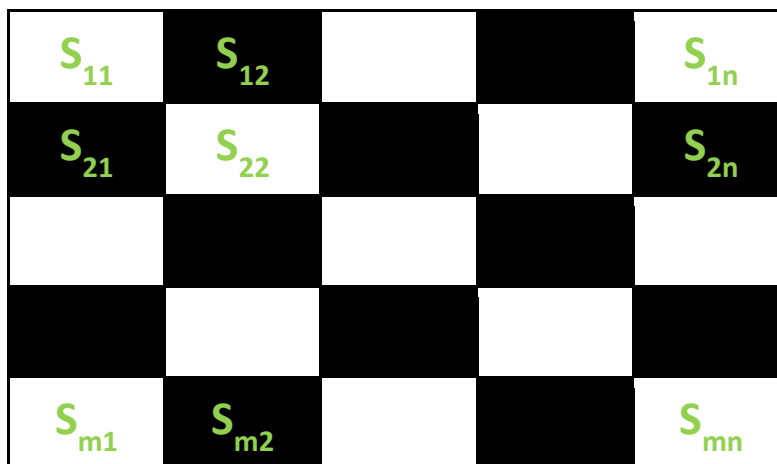


Figure 3a - Standard Image for Luminance measurements option (a) - shown for $n=5$; $m=5$.

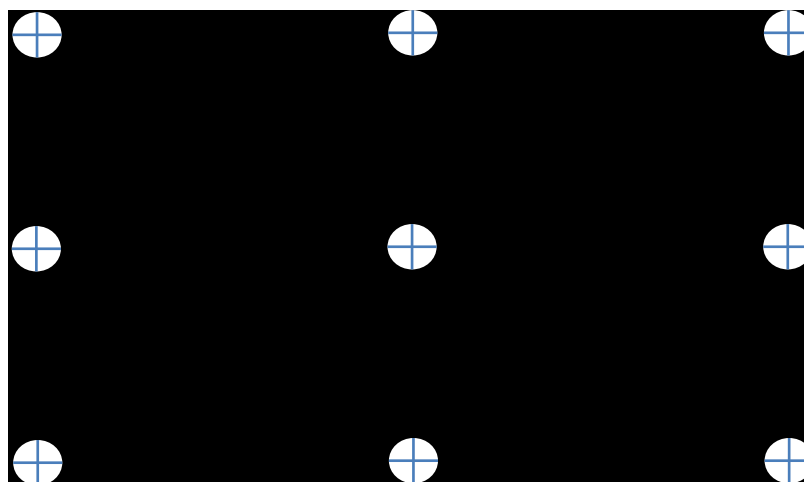


Figure 3b - Standard image for measurements option (b) - the circles are tangent to the edges of the image

Figure 3 - Standard images options

3.7 FIELD OF VIEW (FOV)

For a HUD's virtual images active area, FOV is defined as its size in horizontal (X) and vertical (Z) dimensions, and measured in degrees (from the CE5 point). This solid cone, with its apex at the centroid of the Eyellipse, is at point CE5. Therefore, the FOV is the combined angular measurements of the vertical (Z) and horizontal (Y) angles. Points V2, V8, V4, and V6 on the target image determines the measured FOV. See Figure 1 for details.

3.8 OBSERVER-EYE LOCATIONS

Defined by the Eyellipse, Eyebox, and the measurement points, as shown in Figure 2.

3.9 MEASUREMENTS

Defined by the points located on the observer/instrument meter surface and points on the virtual image. See Figure 1 for details.

3.10 VIEWING ANGLE (δ)

A side-view angle using the centroid of the Eyellipse/Eyeball as the horizontal datum to measure viewing angles up or down from this reference plane.

3.11 DISTANCE FROM OBSERVER TO VIRTUAL IMAGE ($d_{OV} = d_{h-OV}$)

Defined from center of the Eyebox to the virtual image on the paravan surface. Since the windshield is between the observer and the virtual image, the virtual image distance to windshield (d_{wv}) and distance between windshield to observer (d_{ow}) is considered in these calculations. See Figure 1 for details.

$$d_{OV} = d_{ow} + d_{wv} \quad (\text{Eq. 1})$$

NOTE: The optical path for light when the observer-to-virtual image measuring distance is different than the quantitative distance is not considered in this standard.

3.12 LUMINANCE OF THE VIRTUAL IMAGE

Defined as the luminous flux (Φ) emitted by the virtual image from a surface per unit solid angle per unit area in an Eyebox direction. The SI unit is candela per square meter (cd/m^2), the English unit is footlambert (fL) ($1 \text{ fL} = 3.4263 \text{ cd/m}^2$). Refer to SAE J1757-1.

3.12.1 $L_{[\text{dark},w]}$ = Luminance for the virtual image white icon (information) is measured in the dark ambient light (ambient light is OFF).

3.12.2 $L_{[\text{dark},k]}$ = Luminance for the virtual image black icon (background) is measured in the dark ambient light (ambient light is OFF).

3.13 CONTRAST (C)

Defined as:

$$C = (L_{(\text{information})} - L_{(\text{background})}) / L_{(\text{background})} \quad (\text{Eq. 2})$$

For contrast measurements, refer to SAE J1757-1 Table 1A.

3.14 CONTRAST RATIO (CR)

The ratio between the information luminance and background luminance:

$$C = L_{(\text{information})} / L_{(\text{background})} \quad (\text{Eq. 3})$$

Contrast (C) and contrast ratio (CR) are related by the formula:

$$C = CR - 1 \quad (\text{Eq. 4})$$

Contrast ratio in high ambient light illumination is defined as CRd for diffuse (skylight) illumination and CRh for direct sunlight illumination. Refer to SAE J1757-1 Table 1 in 4.1 for more information.

For this document, the information is considered white color ($L_{\text{(information)}} = L_{\text{[dark,w]}}$) and the background is dark color ($L_{\text{(background)}} = L_{\text{[dark,k]}}$). See contrast (3.13).

NOTE: The contrast ratio value is critical to determine display legibility in all ambient light conditions (daylight with and without direct sunlight and night). Contrast (and CR) at any ambient is influenced by road/ambient illumination and reflections toward the display, and influences both background and measured information luminance.

3.15 HUD IMAGE RESOLUTION

Depends on original optical engine and magnifications. It is defined in H and V direction as the number of optical engine pixels (or equivalent pixels)/degree.

$$\text{HUD } H_{\text{Res}} = P_{x-H} / \text{HUD } H_{\text{angle}} \quad (\text{Eq. 5a})$$

$$\text{HUD } V_{\text{Res}} = P_{x-V} / \text{HUD } V_{\text{angle}} \quad (\text{Eq. 5b})$$

$$\text{HUD }_{\text{Res}} = \min\{\text{HUD } H_{\text{Res}}, \text{HUD } V_{\text{Res}}\} \quad (\text{Eq. 6})$$

Where P_{x-H} and P_{x-V} are respectively the number of horizontal and vertical pixels the optical engine or source that contribute to the virtual image.

See also active area-source and number of pixels.

3.16 ACTIVE AREA

For a HUD's optical engine, there is the area covered by pixels or equivalent pixels that creates the virtual image. Refer to SAE J1757-1.

3.17 DISPLAY ADDRESSABILITY

Expressed in $P_h \times P_v$ (number of horizontal pixels x number of vertical pixels), such as VGA (640 x 480) or SVGA (800 x 600).

3.18 ASPECT RATIO (W:H)

The active area width-to-height ratio (such as 4:3 for NTSC displays, or 16:9 for wide view displays).

3.19 CANDELA (cd)

The unit of luminous intensity (I) and is the luminous flux (Φ) in lumens (lm) emitted per unit solid angle (lm/sr).

3.20 SYSTEM HUD VOLUME

The total volume occupied within the instrument panel/cockpit area.

4. MEASUREMENTS

4.1 System HUD Virtual Image Measurements

A measuring device for luminance, uniformity, and color must be NIST (or National Standard Lab) traceable, with a 5% expanded uncertainty, with a coverage factor of two for luminance and ± 0.008 for color (UV); refer to SAE J1757-1 for details. Distance between observer and paravan must be measured with an uncertainty similar or better than optical meter requirements of 5%.

The following set up steps are necessary for any measurements.