



Visibility Modeling from a Heavy-Vehicle OEM's Perspective

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Navistar, Inc.

Human Factors and Ergonomics Group

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Introduction

NAVISTAR[®]
TRUCK GROUP

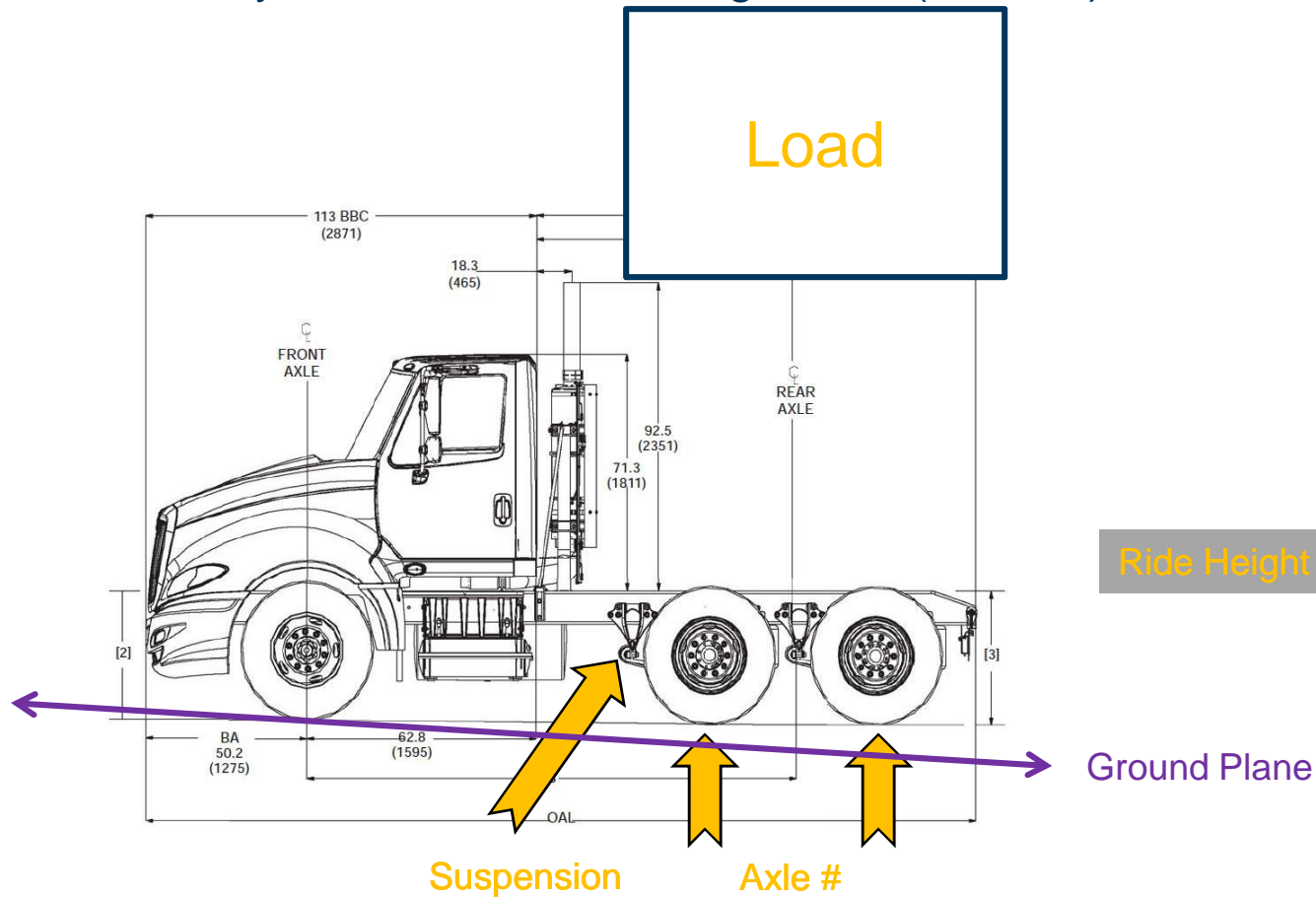


- Balancing the outside world's needs (exo) against the driver/vehicle's needs (endo)
 - How do the avoidance/guidance objects in the world effect the driver's decisions?
 - Choice to start/stop
 - Choice to change direction
 - Choice to take evasive maneuvers
 - How do the driver's decisions effect the objects in the world?
- The emerging technologies for collision avoidance and drive assistance hold great promise for the future but will not be discussed in this modeling overview.
- Even in the case where sensor systems provide the best reaction times or control strategies, observation of traffic information, routing information, and object avoidance all still rely primarily on a clear view by the human eye.
- Therefore, it is critical to know what the driver(s) of a 40 ton vehicle can see.



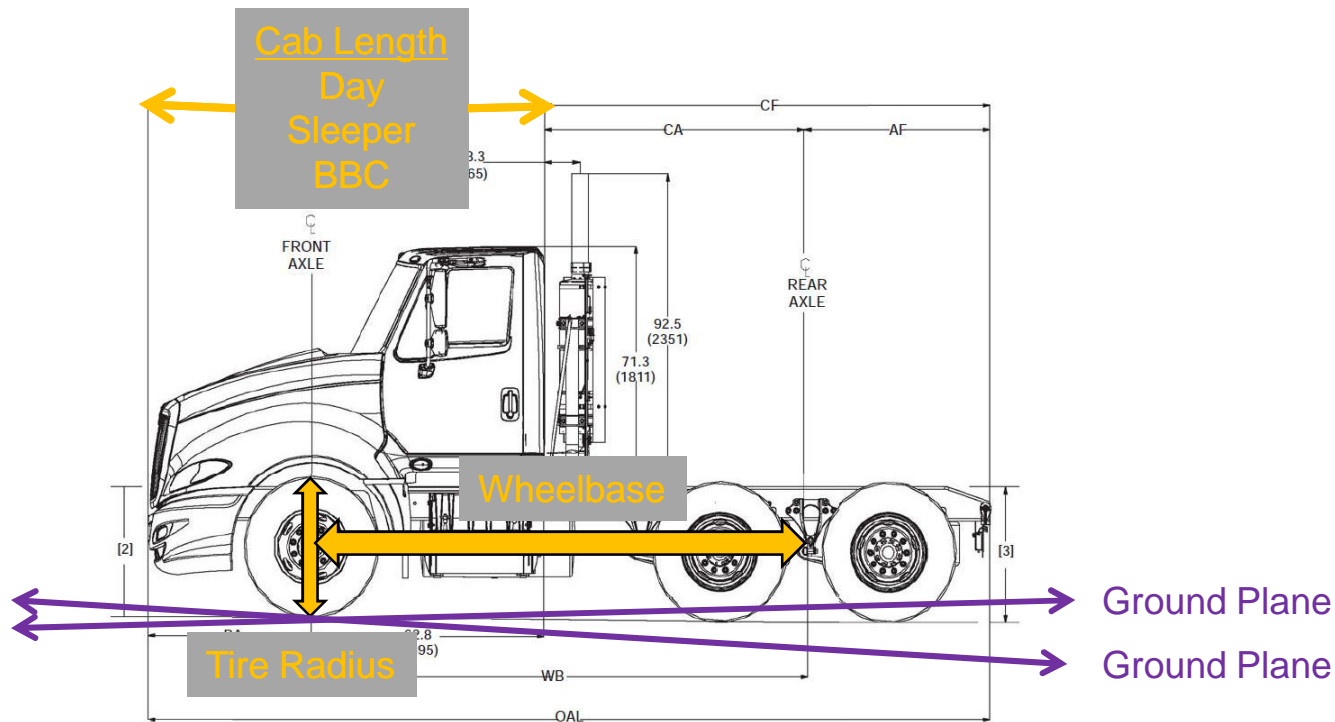
Heavy Vehicle Environment

- Variability in one vehicle's configuration (ProStar) that affects visibility modeling

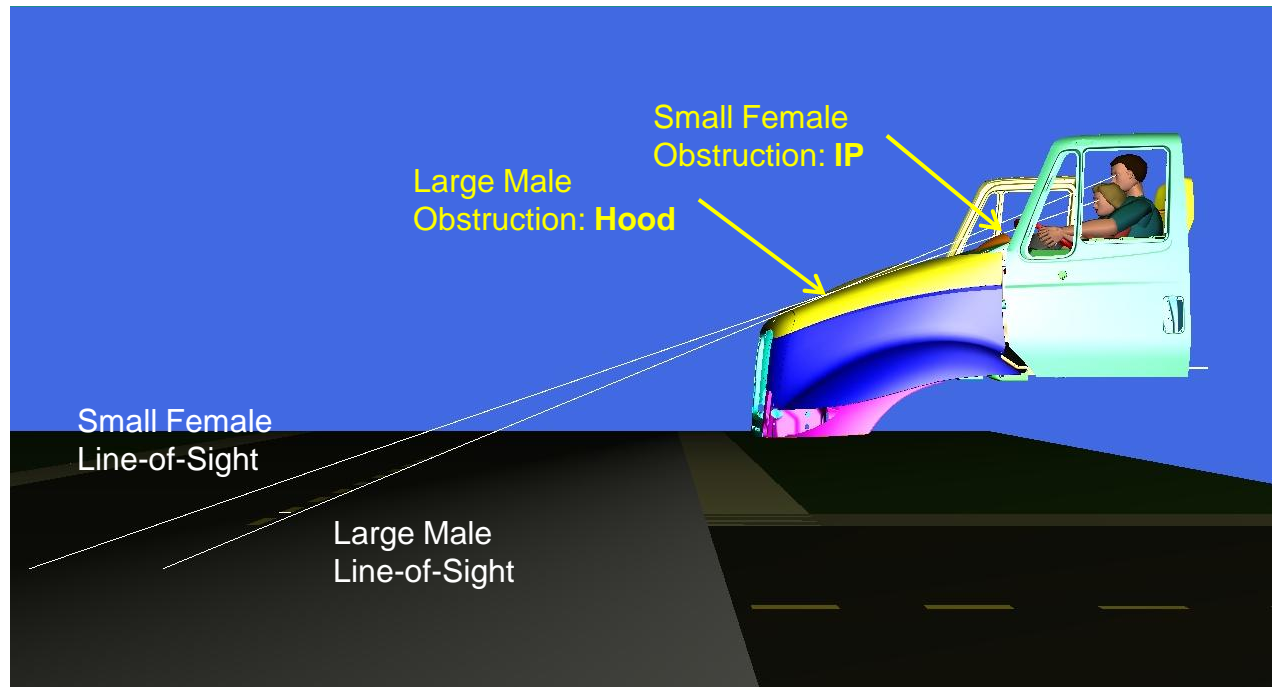


Heavy Vehicle Environment

- Variability in one vehicle's configuration (ProStar) that affects visibility modeling
 - Defining the orientation of the outside world is critical to measuring the driver's internal view



- Variability in driver preferences that affect visibility modeling within one vehicle configuration
 - Driver size (e.g. 5th %ile Female to 95th %ile Male Sitting Eye Height)
 - Seat position fore-aft: 185 to 226 mm horizontal adjustment available
 - Seat position vertical: up to 150 mm vertical adjustment available
 - Preferred backrest angle: typically 10 to 26 degrees rear of vertical
 - Predicted versus real driver back posture





Benjamin Carpenter, 21, was crossing a Michigan highway in his wheelchair when he became stuck in a tractor-trailer's grille and pushed for miles before the unknowing driver was pulled over, police said on Thursday. Carpenter escaped unharmed, saying, "It was quite a ride," police said.

Carpenter was attempting to cross on Wednesday when the light turned green and his wheelchair became hooked onto the front grille of the truck, which reached 50 mph during the 4-mile trip down Red Arrow Highway, Michigan State Police Trooper Michael Sinke said witnesses reported.

When the truck finally was stopped, the driver didn't believe officers until he stepped from his cab and saw for himself. "When he saw us, he was like, 'What's going on?'" Morton said. "The truck driver had no idea," Sinke said. "[He] was in a state of shock."

Heavy Vehicle Environment

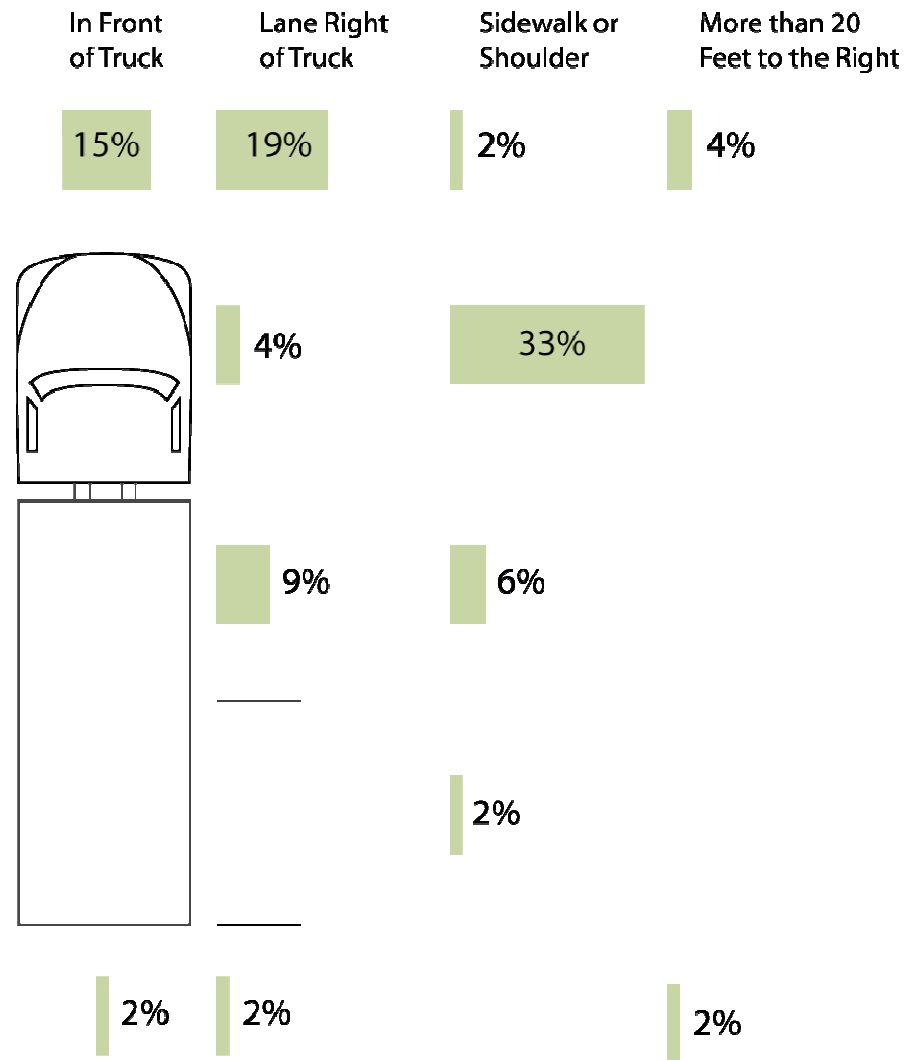


Non-Motorist Right-Turn Fatalities

Non-motorist location at decision point for truck driver in right-turn crashes was coded from police accident reports.

In about 2/3 of the cases, the non-motorist was on the sidewalk or shoulder to the right of the cab, in front of, or at the right front of the cab immediately prior to the truck driver beginning the turn.

16 of 70 cases had insufficient information and are excluded from the percentage calculations.

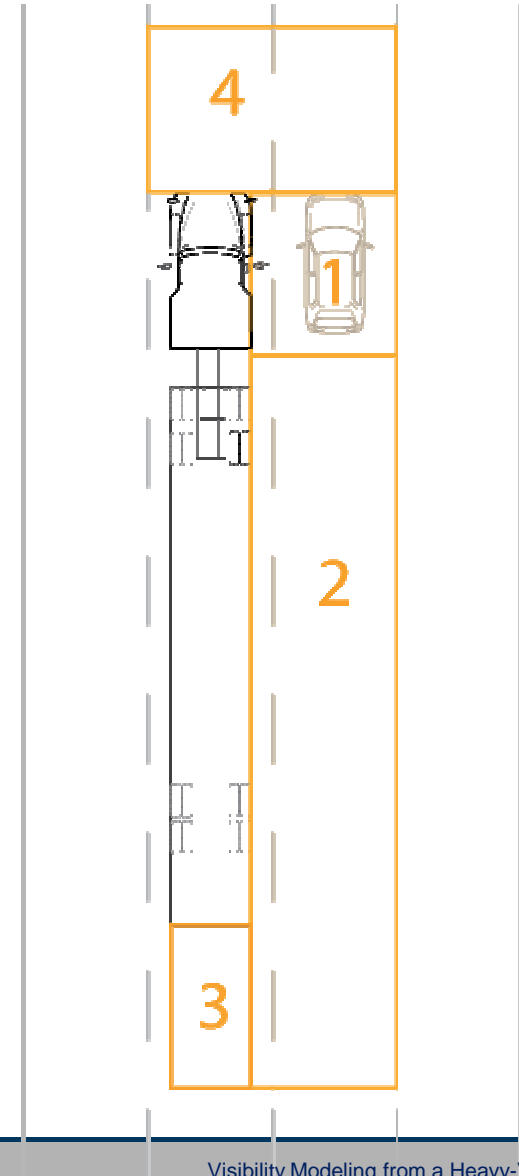


“Prioritizing Improvements to External Vision for Truck Drivers: Results from Crash Data, Experimental Studies, and Simulations”

By: Matthew P. Reed, Daniel Blower, Michael J. Flannagan

- Priorities for Vision Improvements
 1. The area immediately to the right of the cab extending about one lane width from the side of the vehicle
 2. The entire right side of the vehicle, extending to the rear of the trailer
 3. The area directly behind the truck or trailer
 4. The area directly in front of, and to the right-front of, the cab

Rationale provided in referenced report.



“Prioritizing Improvements to External Vision for Truck Drivers:
Results from Crash Data, Experimental Studies, and Simulations”

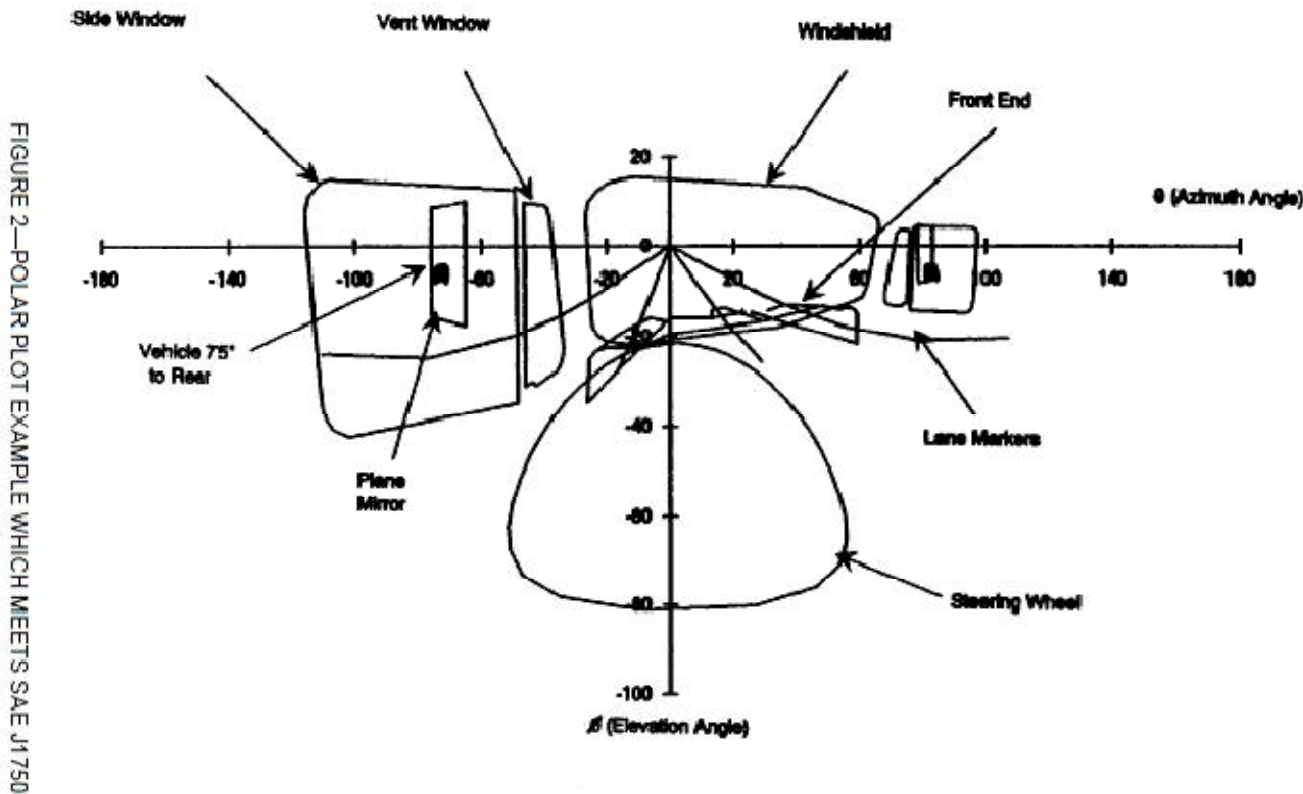
By: Matthew P. Reed, Daniel Blower, Michael J. Flannagan

North American Direct and Indirect Visibility Modeling Standards and Processes



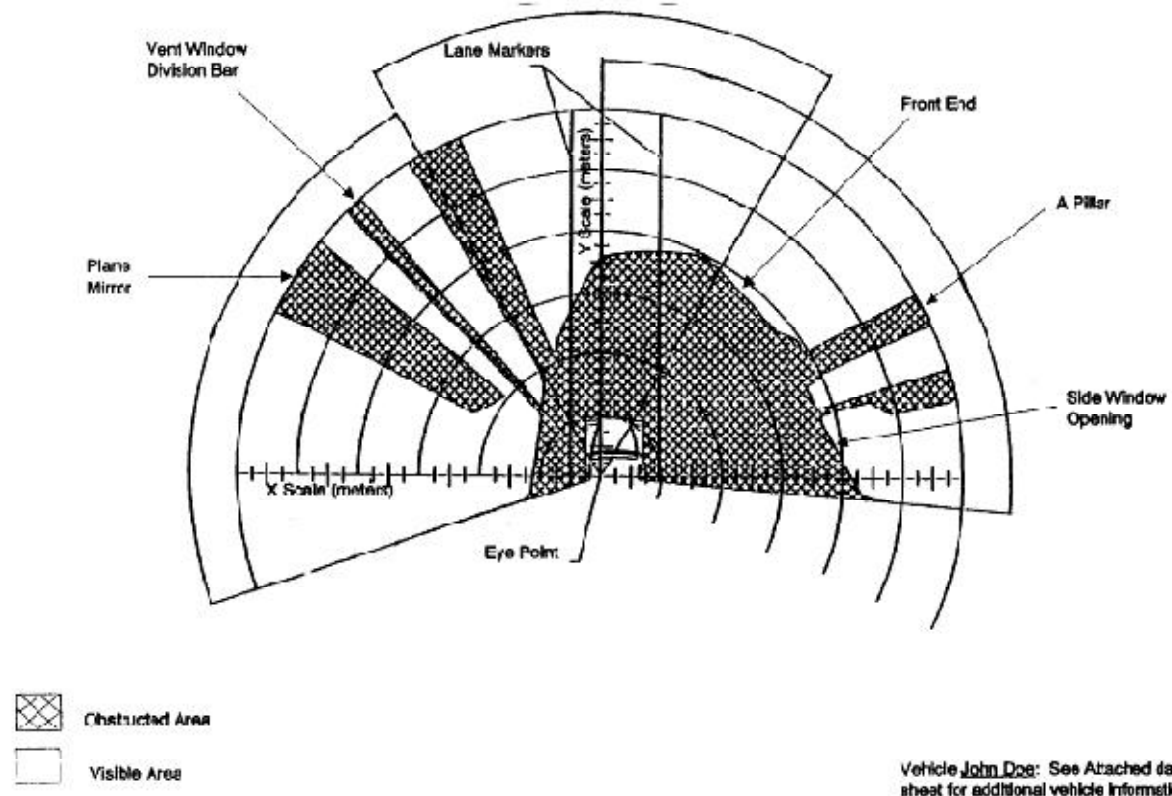
- SAE J1750 Issued: March 1995

DEFINE THE ORIGIN—The polar plot origin (E_x , E_y , E_z) in the vehicle coordinate system may be the Eyellipse centroid, left or right Eyellipse centroid or any vision origin point defined by the user.



- SAE J1750 Issued: March 1995

FIGURE 4—HORIZONTAL PLANAR PROJECTION EXAMPLE WHICH MEETS SAE J1750



Application Note: “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 J1750 Issued MAR95, pg 18

- SAE J941 Revised: Oct 2008
 - *Eyellipse*: “A contraction of the words eye and ellipse used to describe the statistical distribution of eye locations in three-dimensional space located relative to defined vehicle interior reference points.”
 - In other words: Boundary zones surrounding many different possible eye locations.

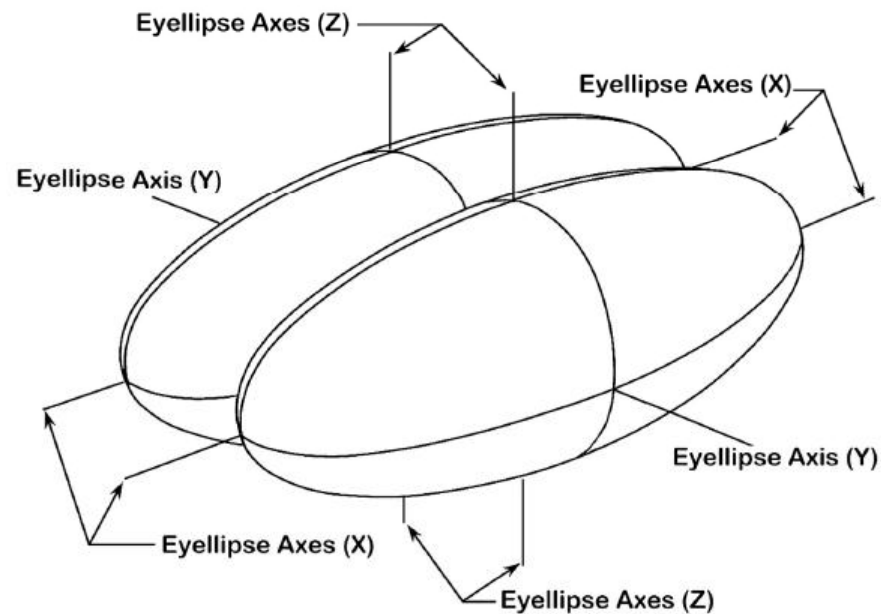


FIGURE 1 - TYPICAL THREE-DIMENSIONAL TANGENT CUTOFF EYELIPSES FOR THE LEFT AND RIGHT EYES

- SAE J941 Revised: Oct 2008; Appendix E – Eyellipses for Class B Vehicles [Informative]; Unchanged since 1987.

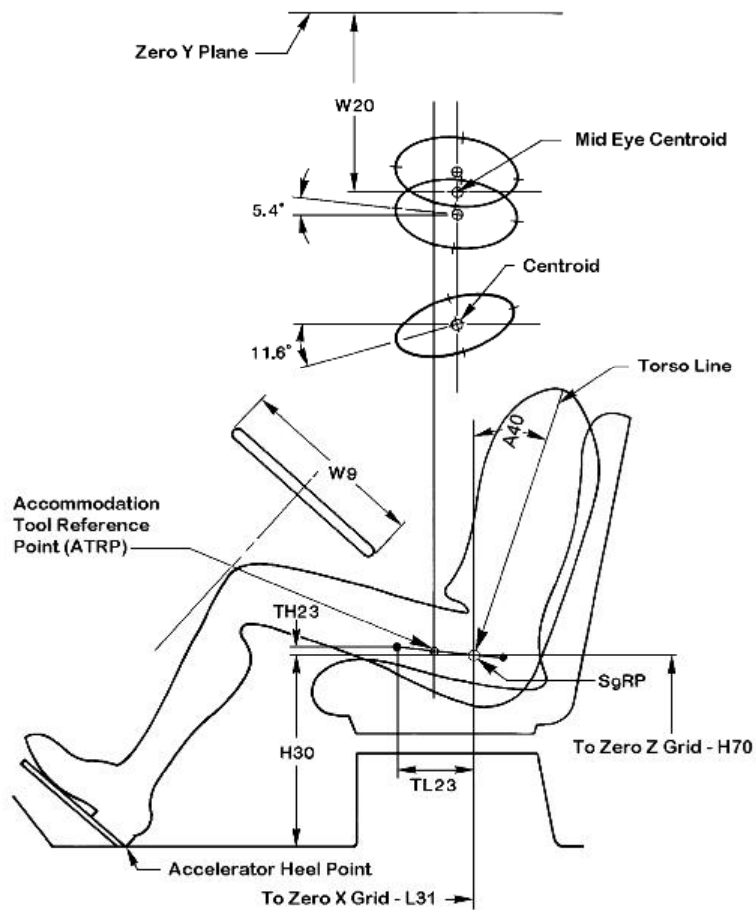


FIGURE E1 - EYELIPSE LOCATION IN CLASS B VEHICLES

- Tied to one population US, over 20 years outdated with varying gender ratios

- Tied to ATRP seating h-point process which was issued in 1985 and reaffirmed several times, most recently December 1998.

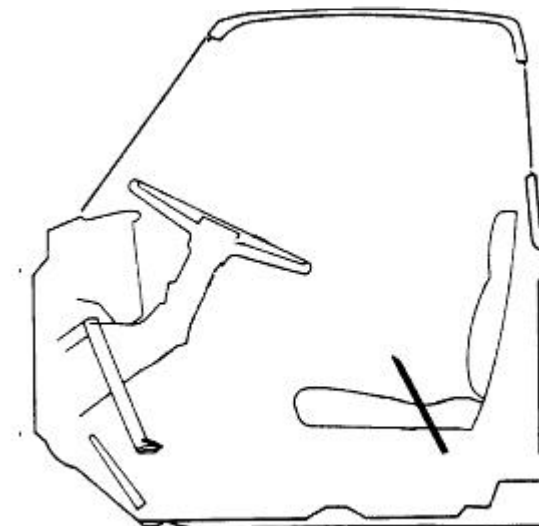


FIGURE 1—TRUCK ACCOMMODATION TOOL REFERENCE LINE

- SAE J198 Rev: July 2003, SAE J381 Rev: Sep 2000

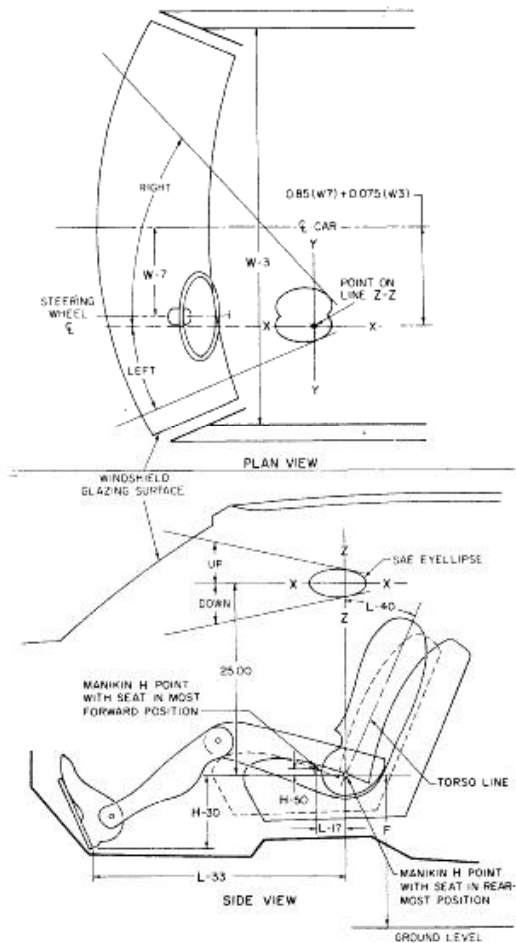
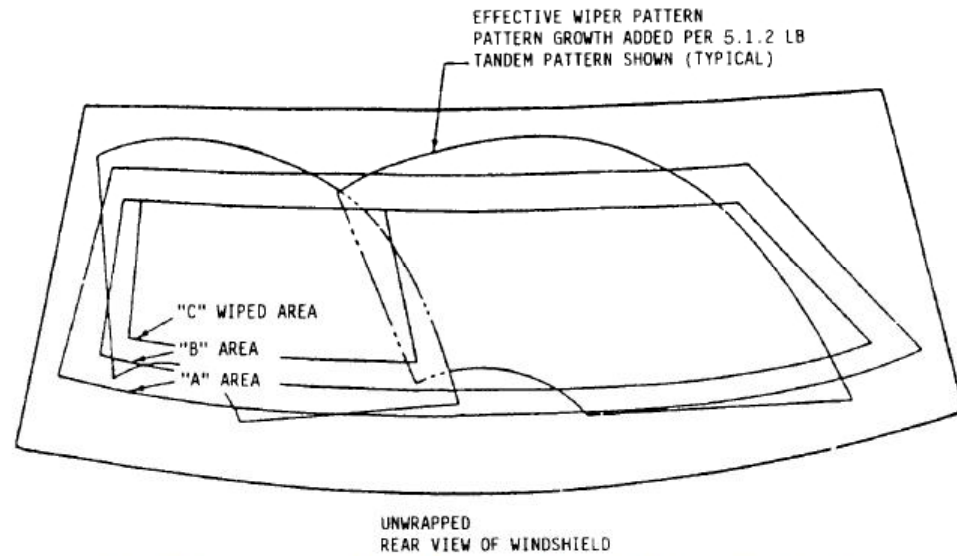


FIGURE 4—EYELIPSE TEMPLATE LOCATION



UNWRAPPED REAR VIEW OF WINDSHIELD
FIGURE 6—WIPED AREA EVALUATION, DRAFTING TEST PROCEDURE—UNWRAPPED VIEW SHOWING WIPED PATTERN AND AREAS A, B, AND C

- SAE J1050 Issued: Rev Jan 2003

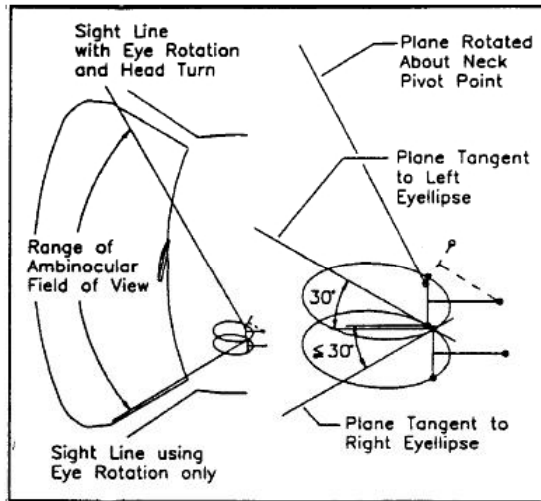


FIGURE 10—THE RANGE OF HORIZONTAL AMBINOCULAR FIELD OF VIEW FOR A GROUP OF DRIVERS USING EYE ROTATION AND HEAD TURN.

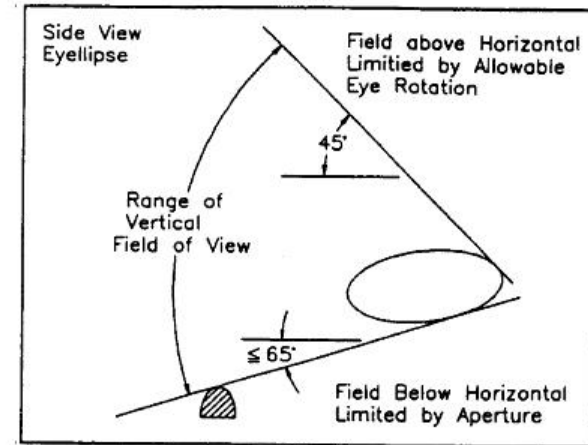


FIGURE 11—RANGE OF VERTICAL FIELD OF VIEW FOR A GROUP OF DRIVERS.

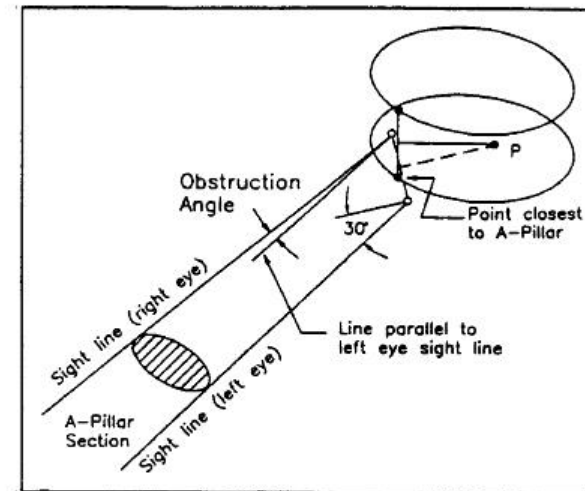


FIGURE C1—METHOD FOR DETERMINING A-PILLAR OBSTRUCTION ANGLE

- FMVSS 111: Rearview Mirrors
 - *“S3. Application. This standard applies to passenger cars, multipurpose passenger vehicles, trucks, buses, school buses and motorcycles.”*

- FMVSS 111: Truck Mirrors
 - *“S8.1 Each multipurpose passenger vehicle and truck with a GVWR of 11,340 kg or more shall have outside mirrors of unit magnification, each with not less than 323 cm² of reflective surface, installed with stable supports on both sides of the vehicle. The mirrors shall be located so as to provide the driver a view to the rear along both sides of the vehicle and shall be adjustable both in the horizontal and vertical directions to view the rearward scene.”*

Short and Sweet...

- FMVSS 111: School Bus Mirrors

- “(b) Includes one or more mirrors which together provide, at the driver’s eye location, a view of: (1) For the mirror system on the right side of the bus, the entire top surface of cylinder N in Figure 2, and that area of the ground which extends rearward from cylinder N to a point not less than 61 meters from the mirror surface...”

Fields of View Defined

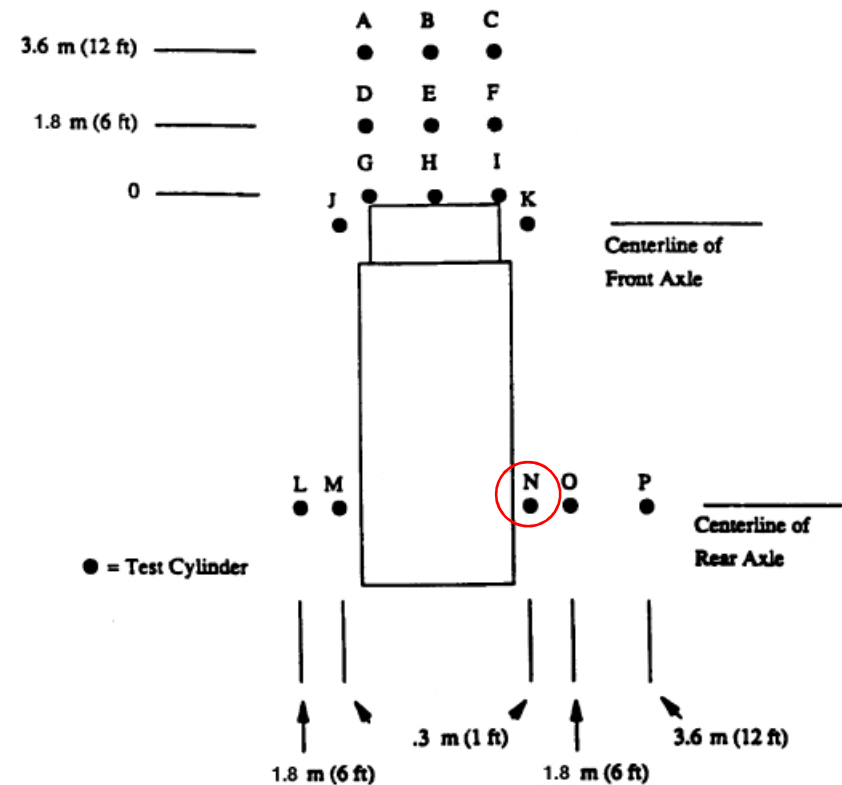


Figure 2.—Location of Test Cylinders for School Bus Field-of-View Test
All Dimensions in Meters (m)

GLOBAL

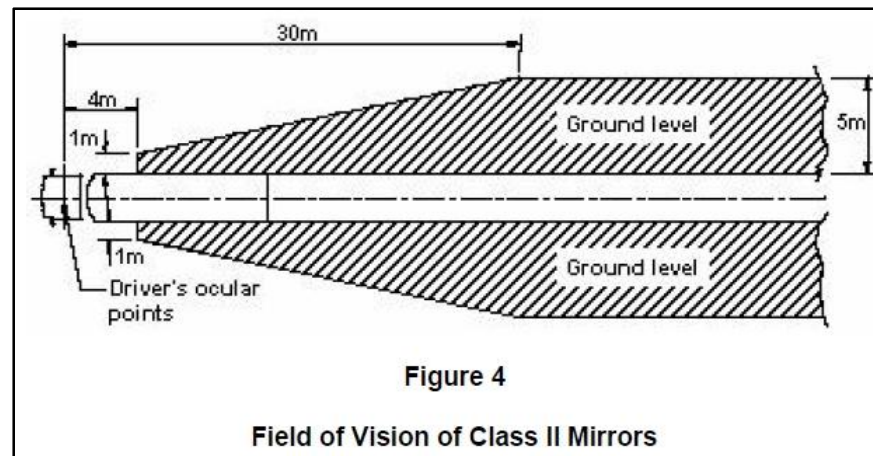
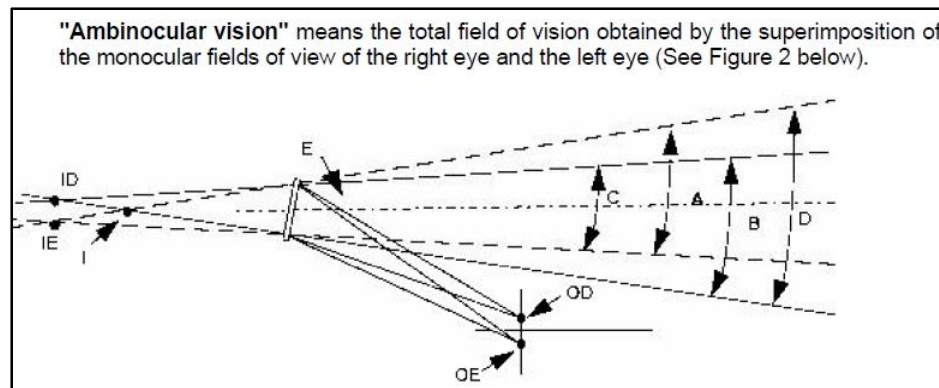
Direct and Indirect Visibility Modeling Standards and Processes



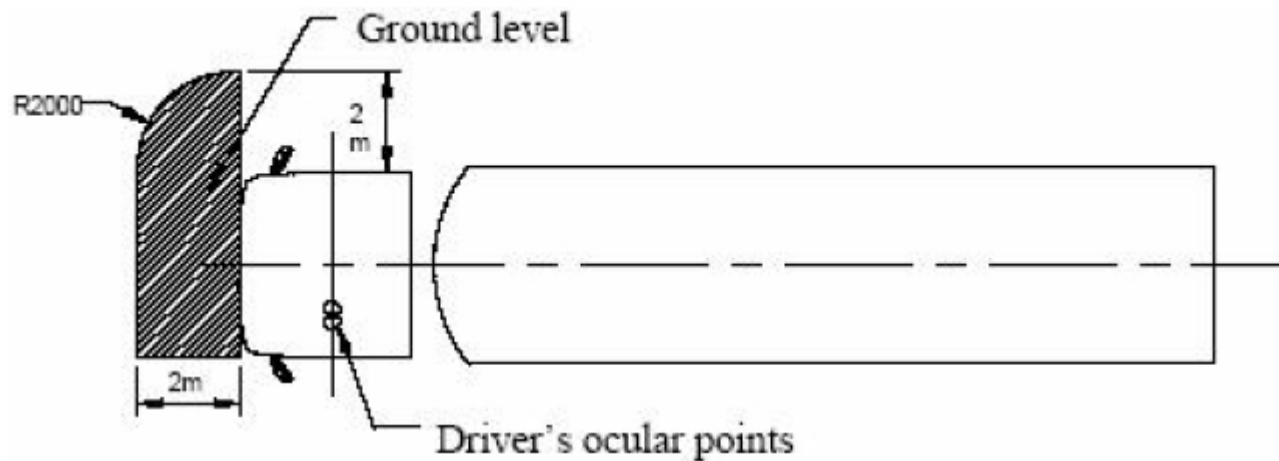
- ECE 46-02: Truck
 - 6.1.2.2.1. The reflecting surface of a mirror must be either flat or spherically convex. Exterior mirrors may be equipped with an additional aspherical part provided that the main mirror fulfils the requirements of the indirect field of vision.

Vehicle Category	Mirror Class	Mirror Type	Min number of mirrors
N2>7.5T	I	Interior	Optional (No requirements for field of view)
	II and III	Main (Large)	1 on driver's side, 1 on passenger's side (Class III is not permitted)
	IV	Wide Angle	1 on driver's side, 1 on passenger's side
	V	Close proximity	1 on passenger's side, optional on driver's side.
	VI	Front	Compulsory 1 front mirror
N3	I	Interior	Optional (No requirements for field of view)
	II and III	Main (Large)	1 on driver's side, 1 on passenger's side (Class III mirror is not permitted)
	IV	Wide Angle	1 on driver's side, 1 on passenger's side
	V	Close proximity	1 on passenger's side, optional on driver's side
	VI	Front	Compulsory 1 front mirror

- ECE 46-02: Truck, Class II Mirror Example
 - Field of vision zone for Class II Mirrors is the closest system to the FMVSS 111 unit-magnification mirrors, but the field of vision requires a very large flat mirror to qualify.
 - FMVSS Truck and ECE 46-02 Vehicle Class N2/N3 mirror requ.'s are in direct conflict.



ECE 46-02: “Devices for Indirect Vision and of Motor Vehicles with regard to the Installation of these Devices”, page 30

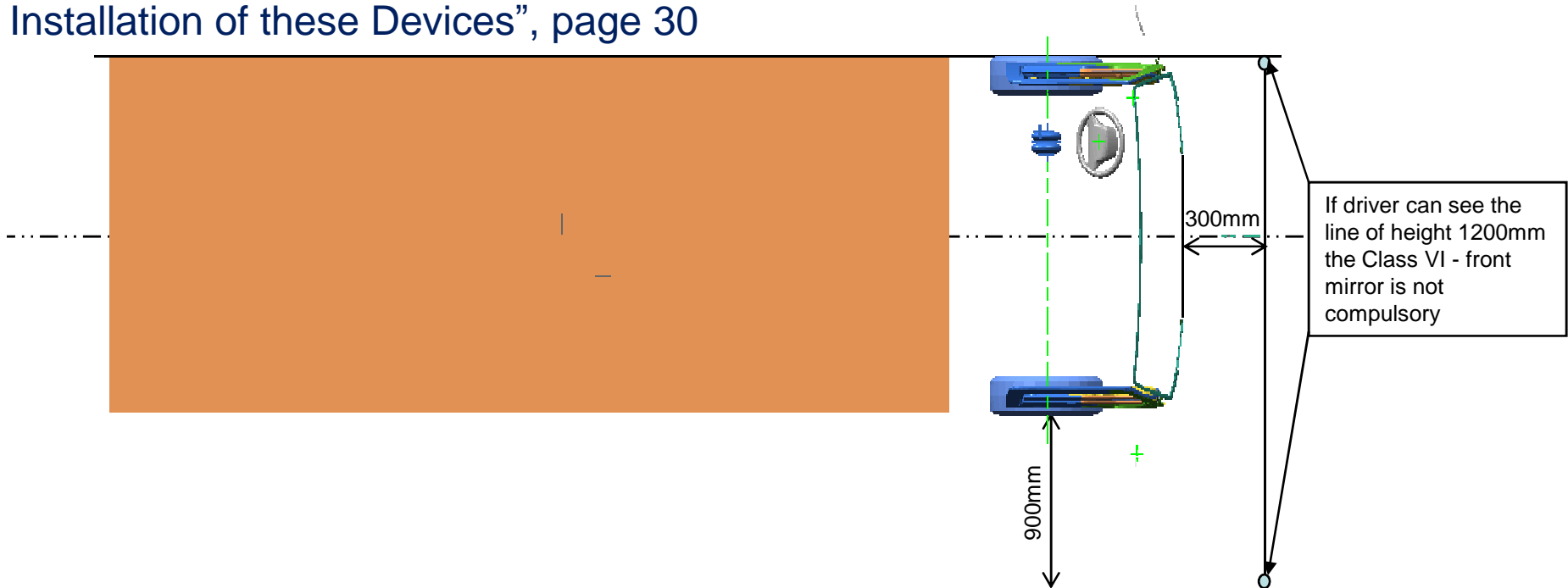


[15.2.4.6] “Front” mirror:

The field of vision must be such that the driver can see at least a flat horizontal portion of the road, which is bounded by:

1. One traverse vertical plane through the outermost point of the front of the vehicle-cab,
2. one traverse vertical plane 2,000 mm in front of the vehicle,
3. one longitudinal vertical plane parallel to the longitudinal vertical median plane going through the outermost side of the vehicle at the driver's side and
4. one longitudinal vertical plane parallel to the longitudinal vertical median plane 2,000 mm outside the outermost side of the vehicle opposite to the driver's side.
5. The front of this field of vision opposite to the driver's side may be rounded off with a radius of 2,000 mm

ECE 46-02: “Devices for Indirect Vision and of Motor Vehicles with regard to the Installation of these Devices”, page 30



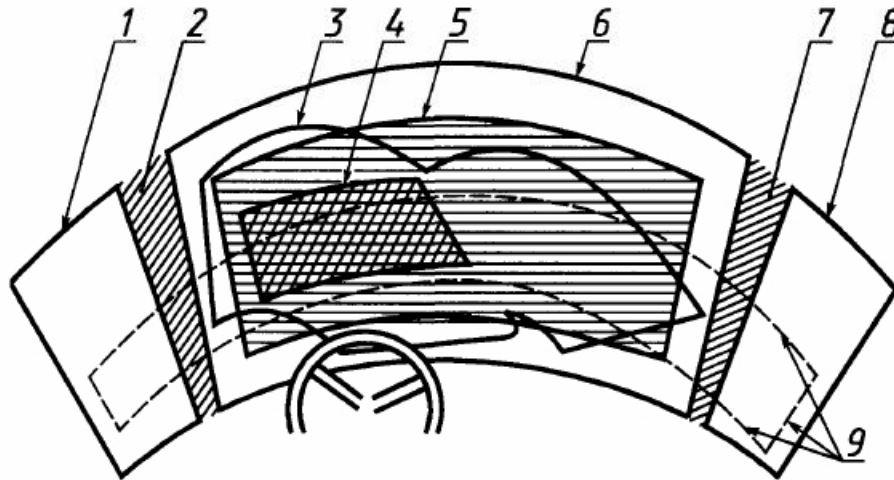
15.2.4.6.2.

However, if the driver can see, taking into account the obstructions by the A-pillars, a straight line 300 mm in front of the vehicle at a height of 1 200 mm above the road surface and which is situated between a longitudinal vertical plane parallel to the longitudinal vertical median plane going through the outermost side of the vehicle at the driver's side and a longitudinal vertical plane parallel to the longitudinal vertical median plane 900 mm outside the outermost side of the vehicle opposite to the driver's side, a front mirror of Class VI is not mandatory.

State Standard of the Russian Federation GOST R 51266-99: “Forward View from the Driver’s Seat”

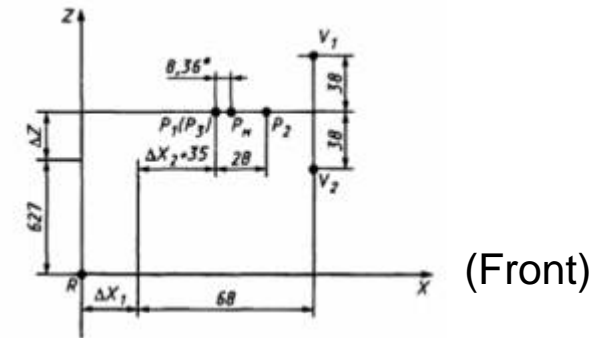
Forward view is determined by the following parameters specified in figure 1:

- dimensions and arrangement of the normative zones A and B of the windscreen;
- wiping degree of the normative zones A and B of the windscreen;
- blind zones created by dividing posts of the windscreen;
- blind zones of the normative view field II.

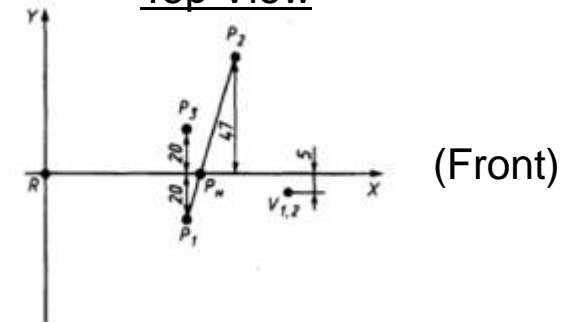


Forward View Standard Summary

Side View

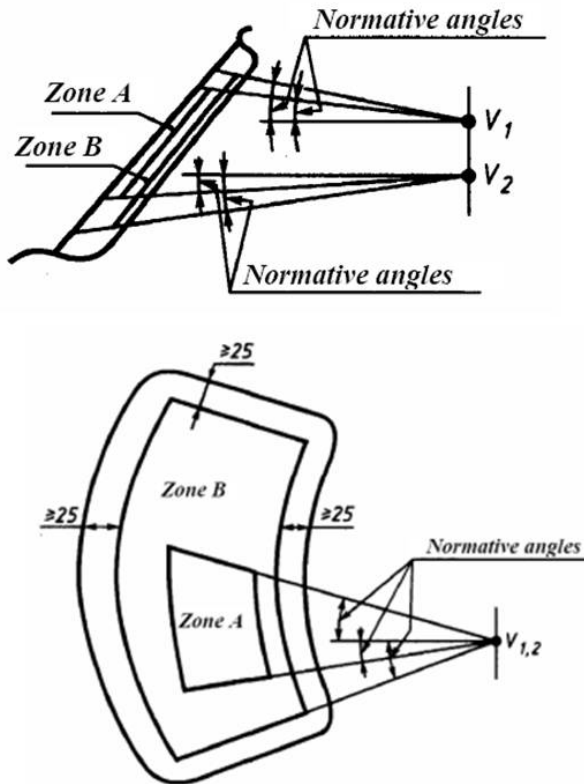


Top View

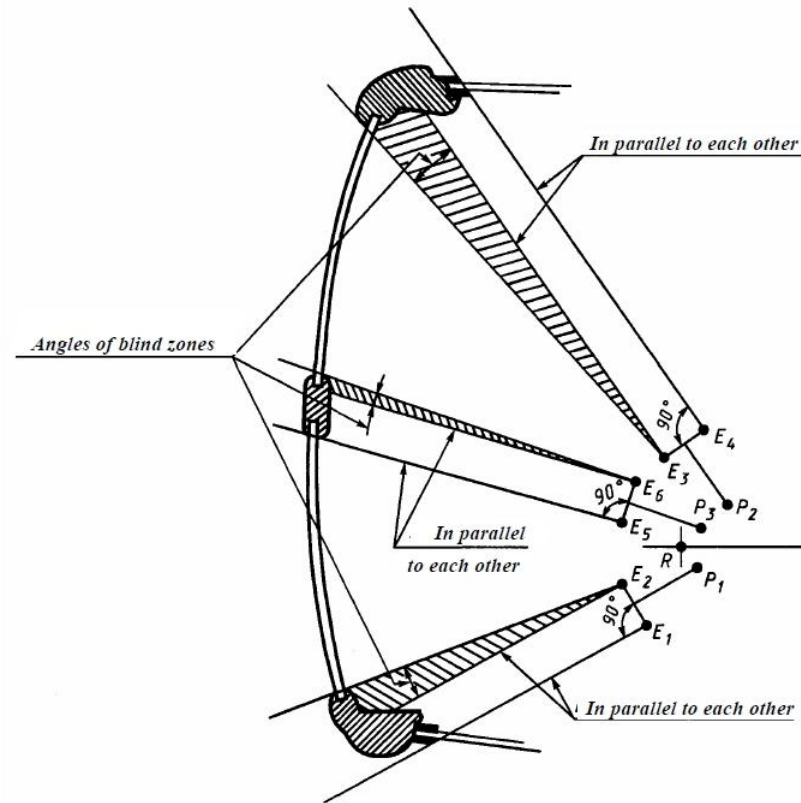


Origin (V) and Rotation (P) Points

State Standard of the Russian Federation GOST R 51266-99: "Forward View from the Driver's Seat"

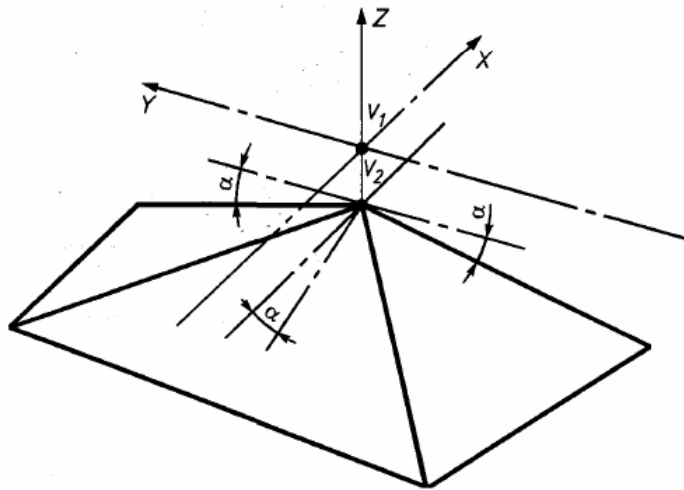
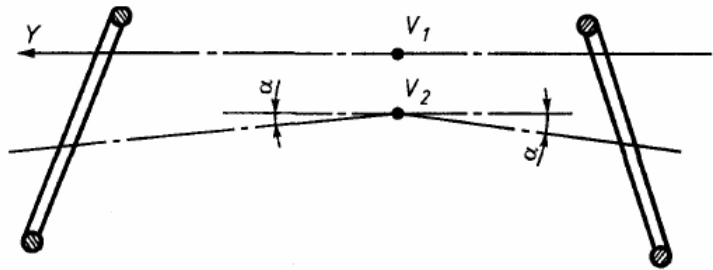


A and B Windshield Zones

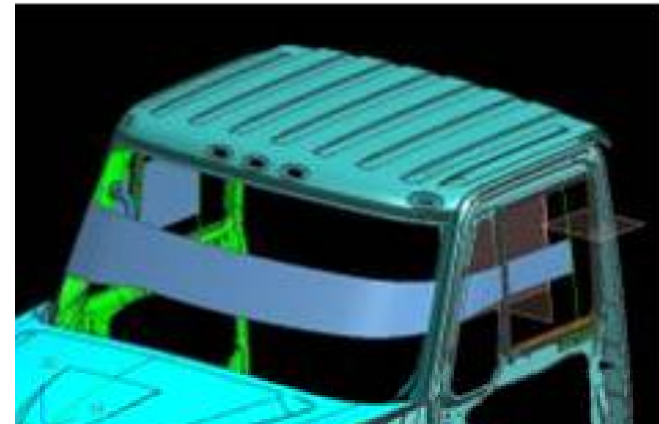


A-Pillar (Dividing Post) Blind Zones

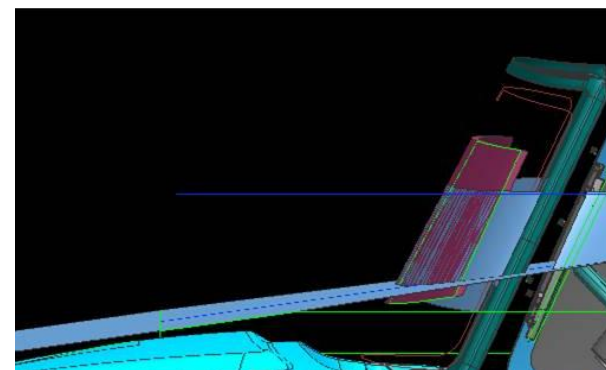
State Standard of the Russian Federation GOST R 51266-99: "Forward View from the Driver's Seat"



Normative View Field "Pi" Planes



View Field "Pi" Projection onto Glass



View Field "Pi" Projection over Hood

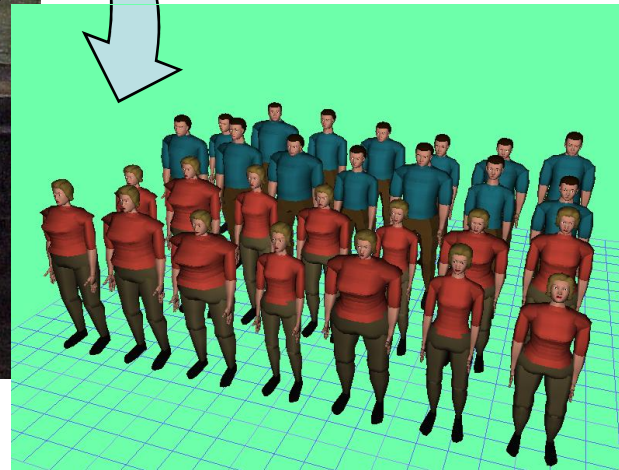
Navistar Human Factors and Ergonomics Group's Visibility Processes and Tools



Visibility Origin: Measure Drivers



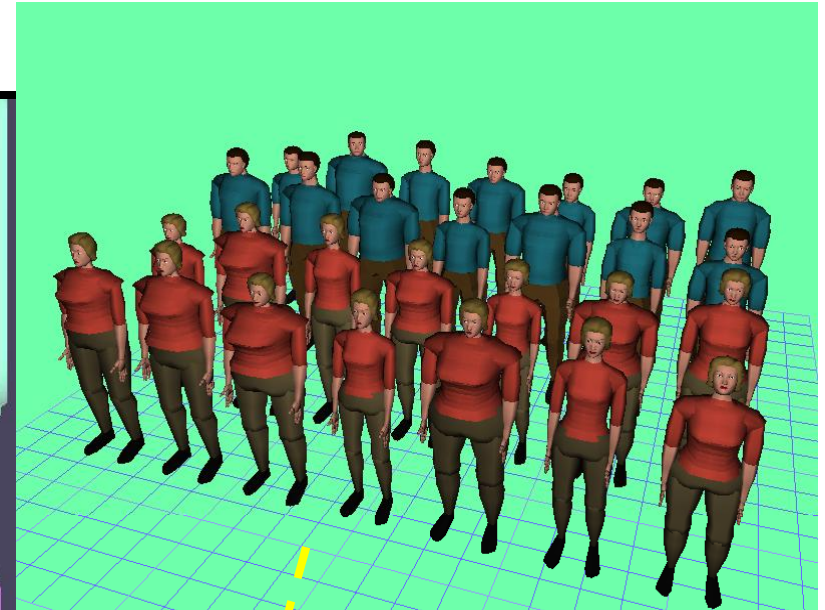
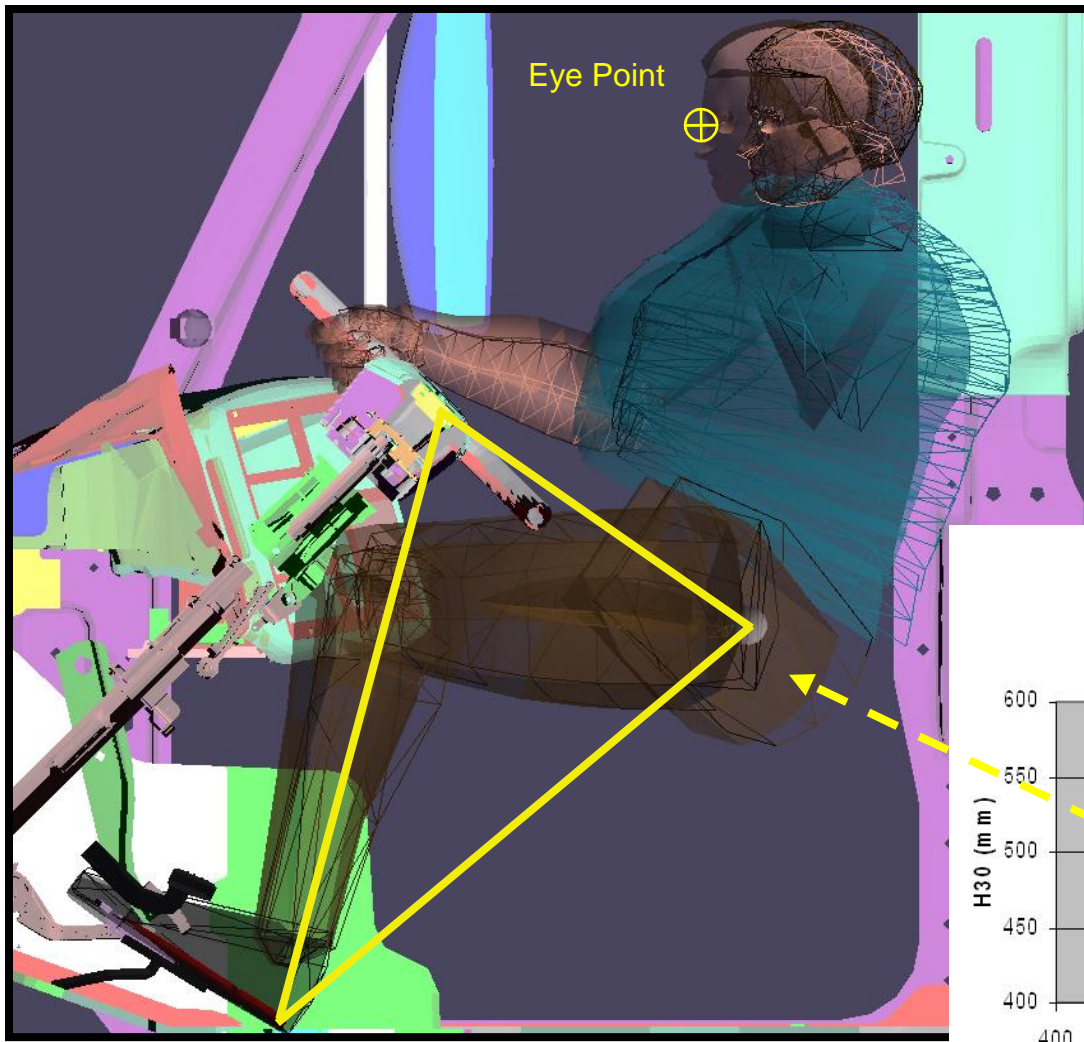
Measure drivers and create digital representations in Jack



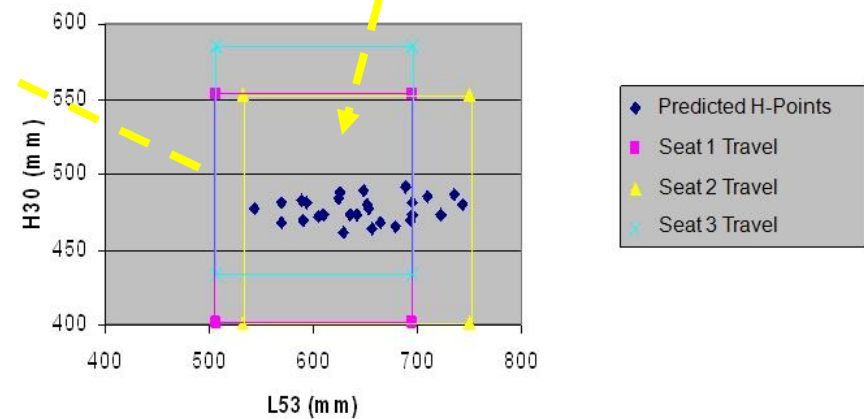
Statistical Method: Principal Component Analysis

Navistar HFE Modeling

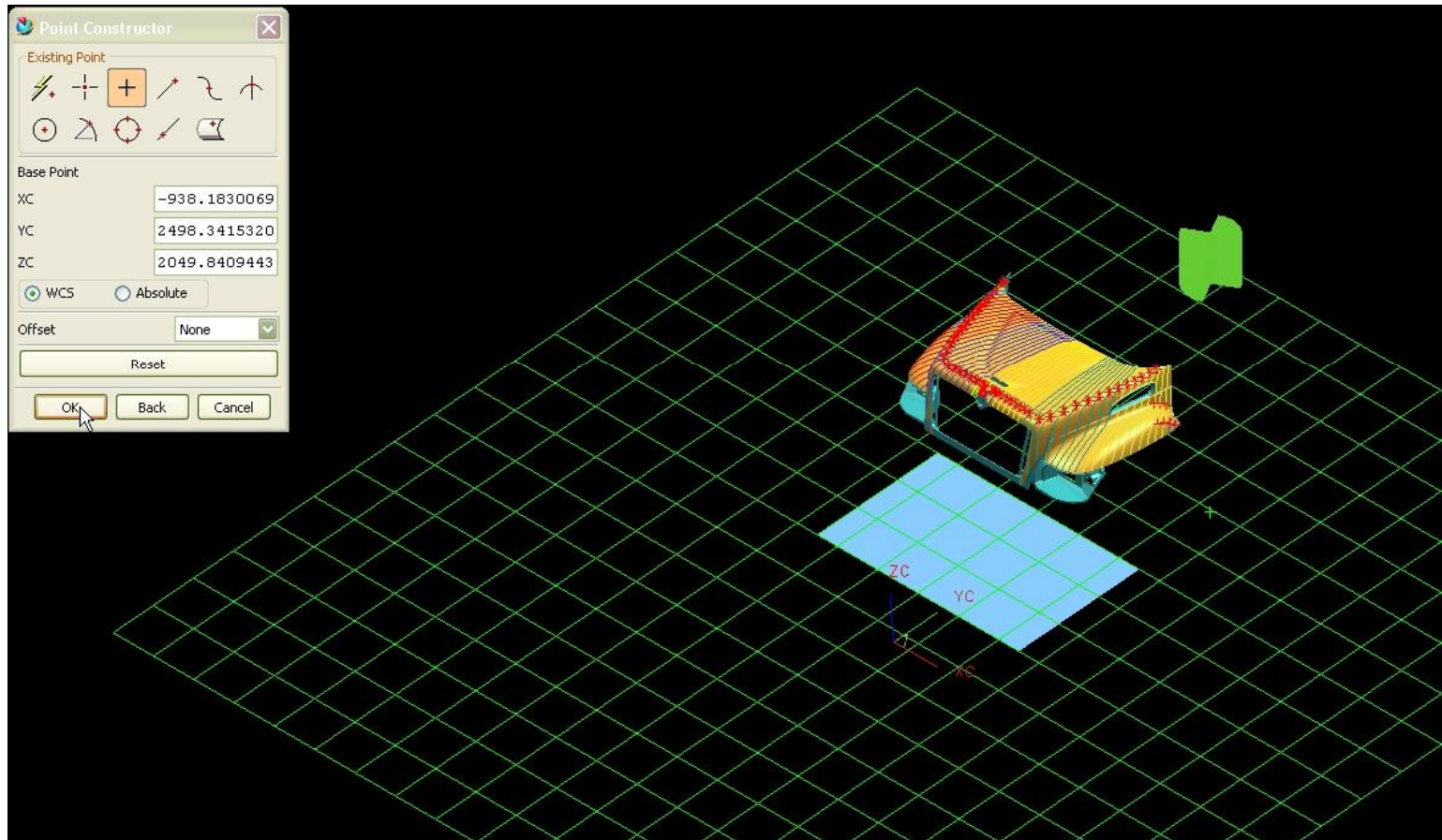
Visibility Origin: Class B Postural Prediction



**Driver Accommodation
(Postural Prediction)**



- Vehicle Obstruction and External Object Targeting Tool



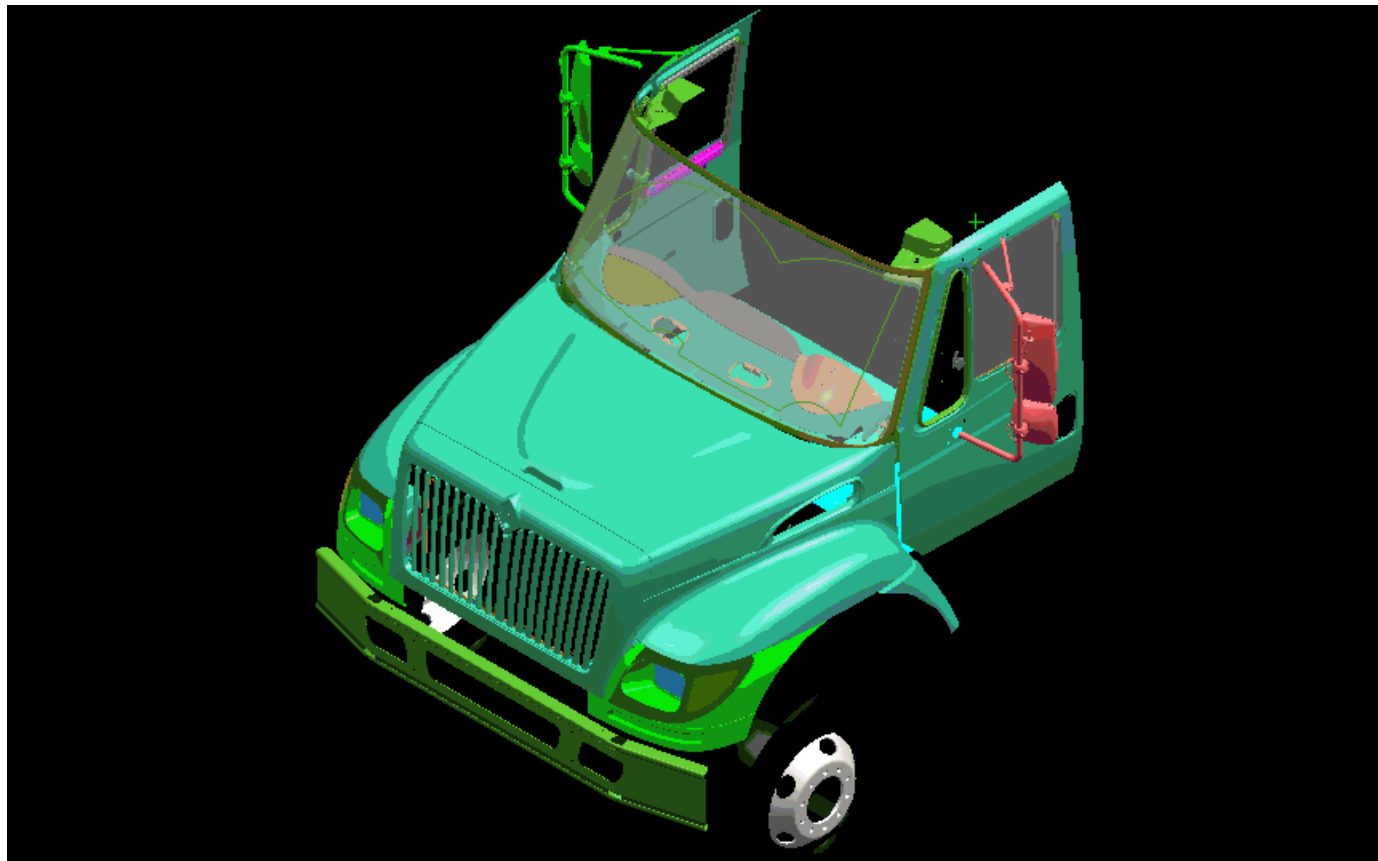
Navistar HFE Modeling

- Legacy Physical Validation



Navistar HFE Modeling

- ABC Zone Creation Tool



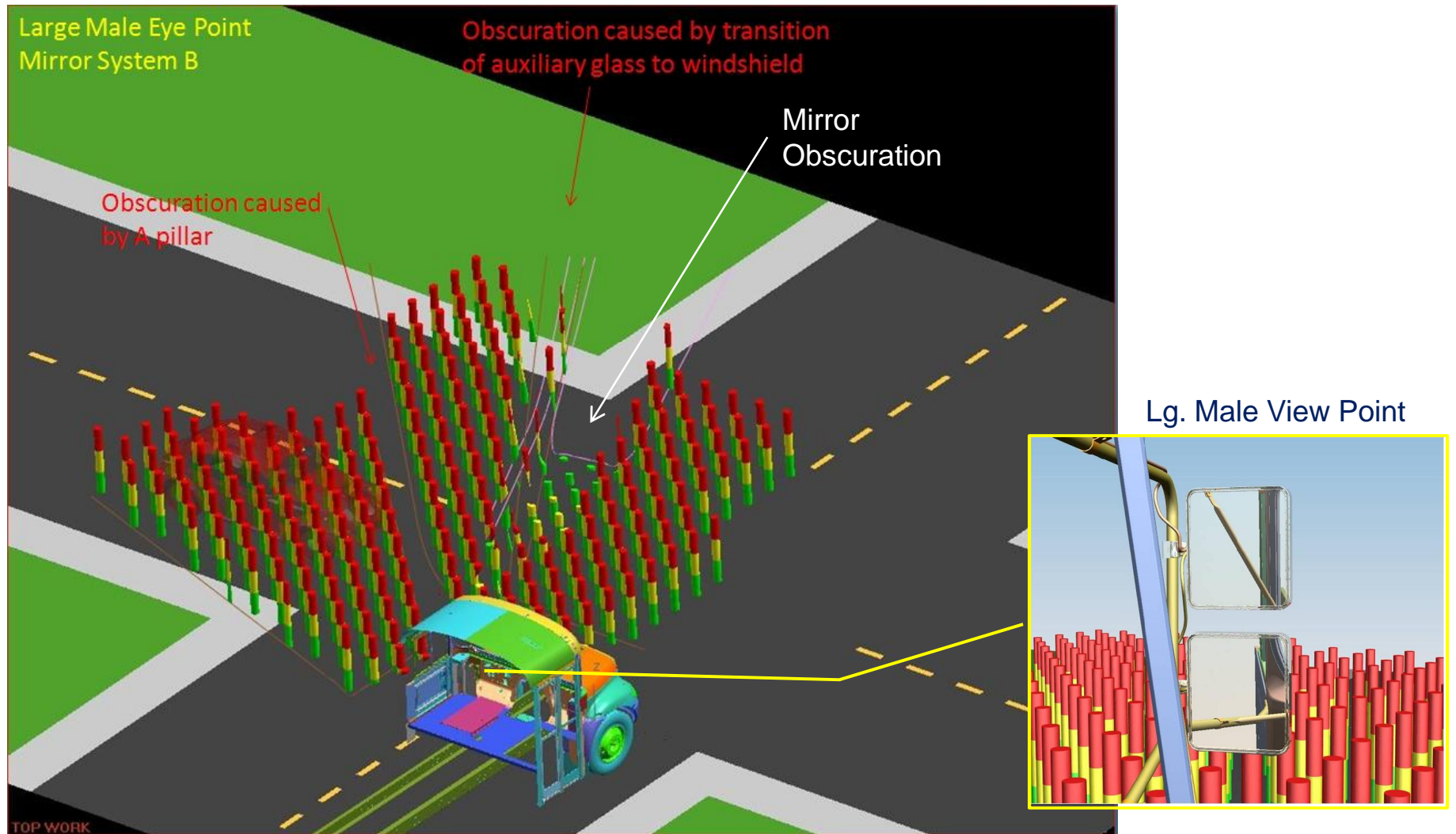
Navistar Visibility Analysis Examples



- Bus Pedestrian and Vehicle Direct Visibility
 - Q: What areas along side the road should always be visible (i.e. direct visibility), while accounting for mirror location which provides optimal view of blind zones (i.e. indirect visibility)?
 - Factors
 - Range of driver eye points
 - Cab structure obstructions ; gaps between obstructions that provide opportunities for spotting objects of interest
 - Height at which objects should be viewed (e.g. pedestrian: legs, torso, shoulder, age ; vehicle: wheels, hood, roof)
 - Priority zones based on consequence (i.e. pedestrian vs. vehicle)
 - Goal:
 - Observe and avoid objects around cab structure and mirror obstructions

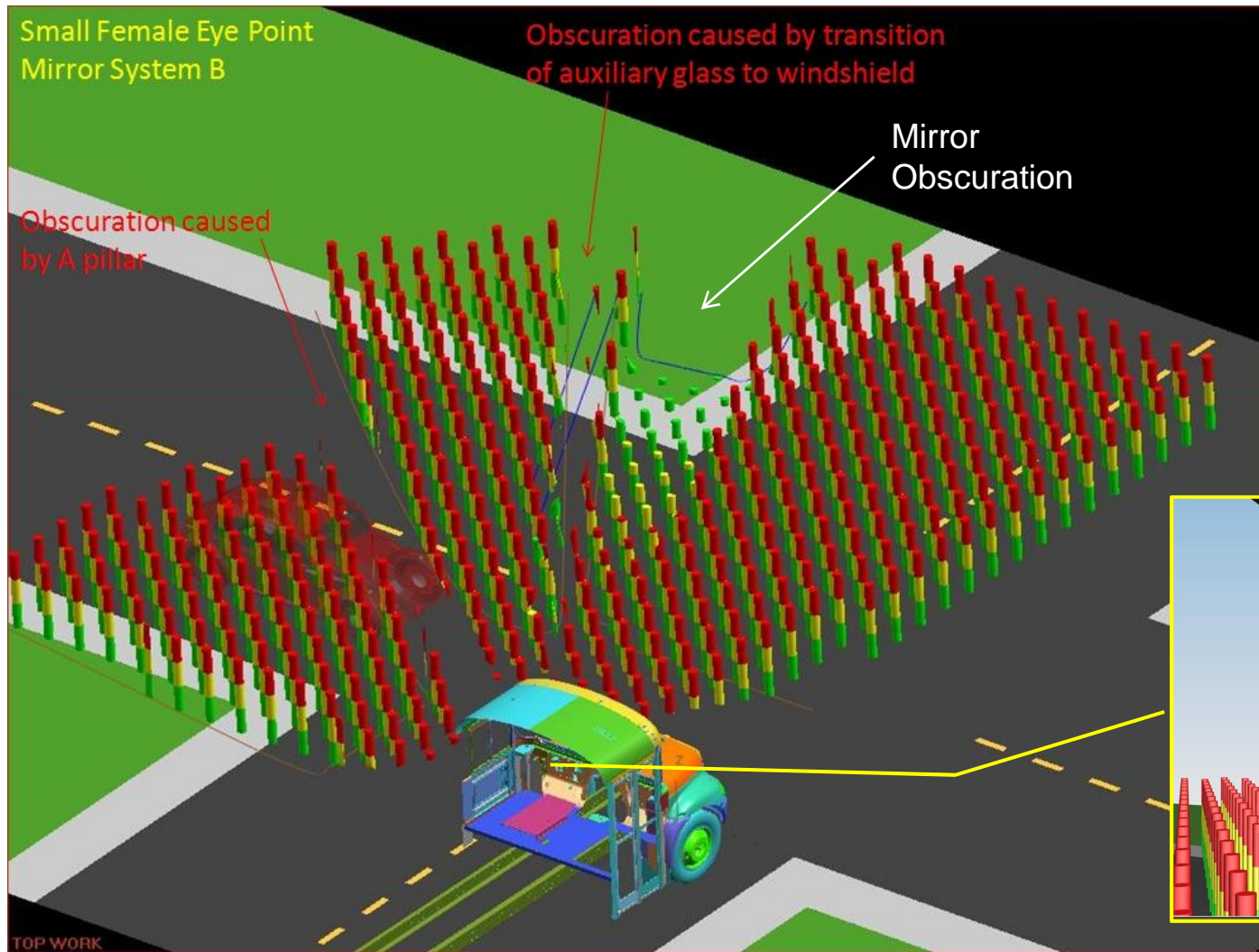
Navistar Visibility Analyses

- Bus Pedestrian and Vehicle Visibility

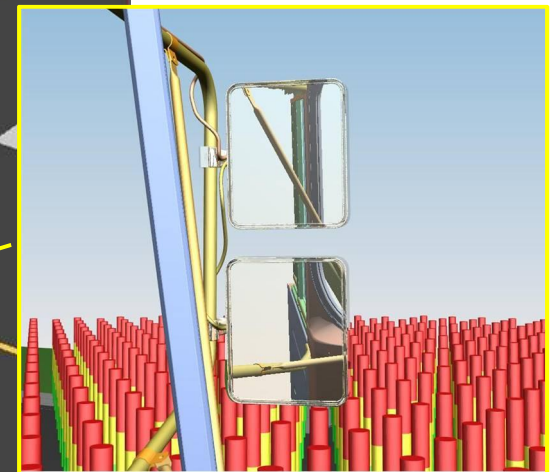


Navistar Visibility Analyses

- Bus Pedestrian and Vehicle Visibility

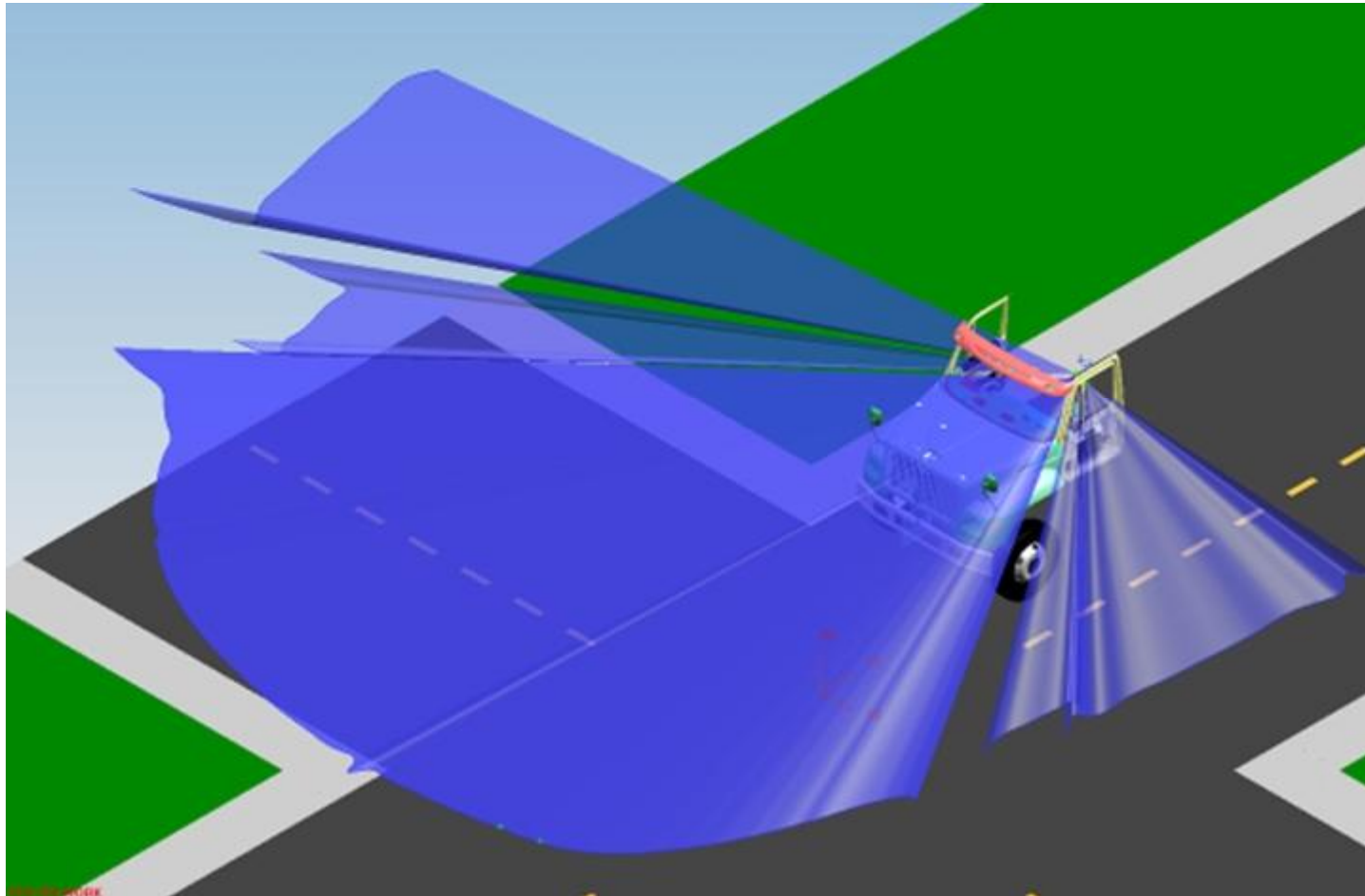


Sm. Female View Point



- Direct vs. Indirect Visibility Zones and Crosswalks
 - Q: At what proximity can objects be observed next to a large severe service truck through day-light openings or in mirrors that demonstrate view of near-cab zones?
 - Factors:
 - Worst-case eye point (e.g. small female)
 - Day-light opening heights relative to driver eye heights
 - Indirect visibility views close to cab
 - Redundancy and overlap of direct-view and mirror-view zones
 - Hood and door obstructions
 - Conventional cab bumper location effect on passenger-side obstructions
 - Goal:
 - Identify possible increases/reductions in direct versus indirect visibility zones to maximize opportunity to view objects near passenger-side.

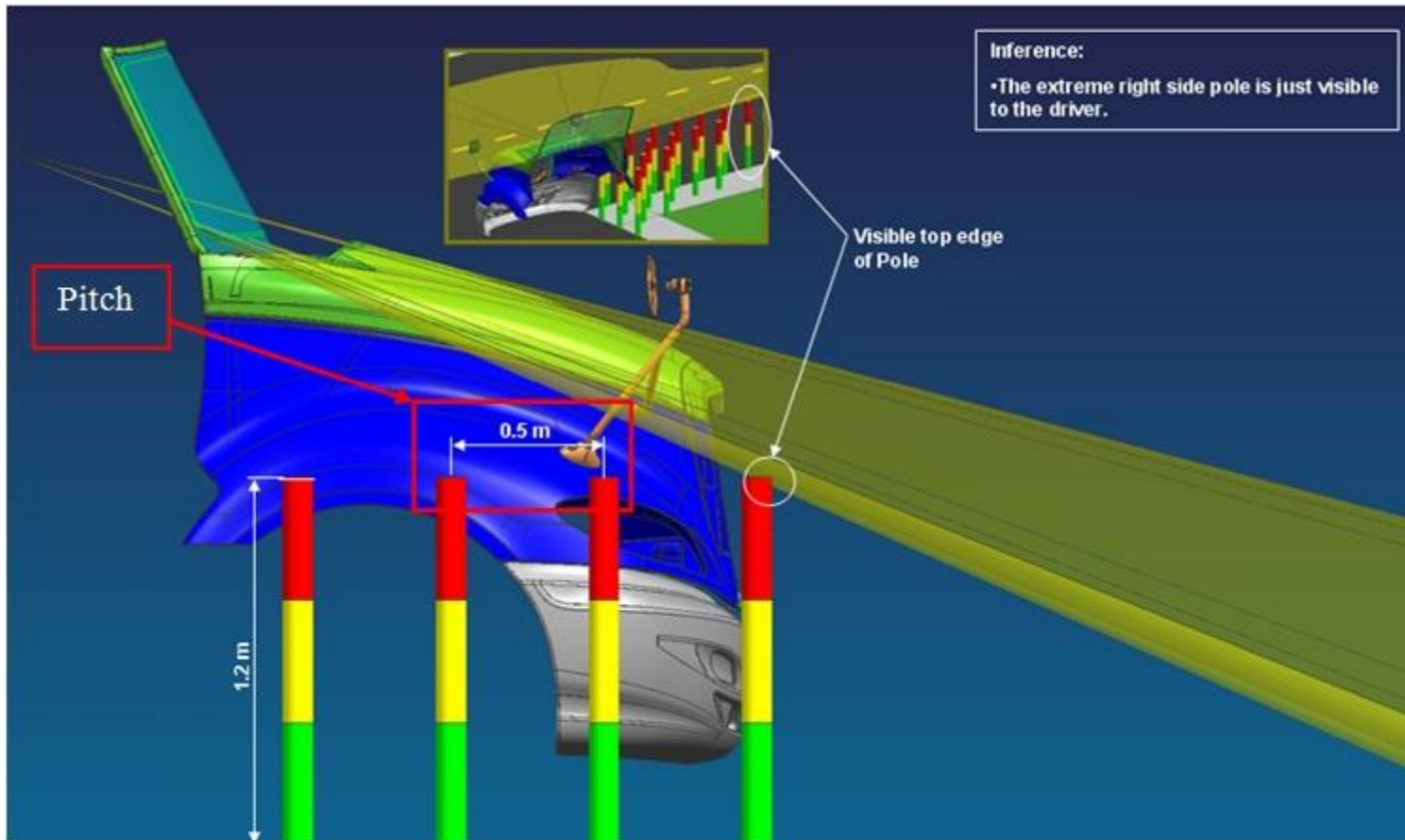
- Direct vs. Indirect Visibility Zones and Crosswalks



Direct Visibility: Downward Visibility Sheets

Navistar Visibility Analyses

- Direct vs. Indirect Visibility Zones and Crosswalks (Different Vehicle)



Navistar Visibility Analyses

- Direct vs. Indirect Visibility Zones and Crosswalks

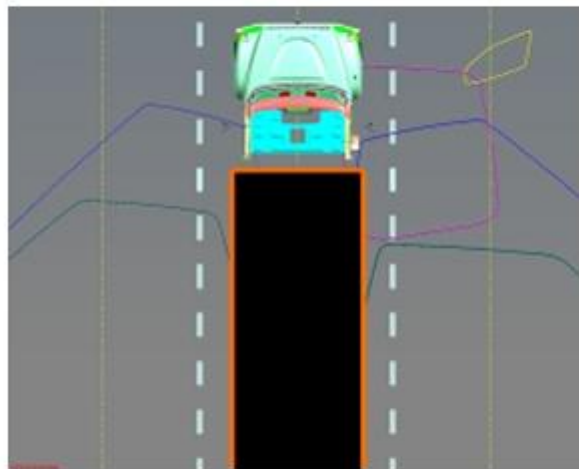


Competitive
Peep Windows

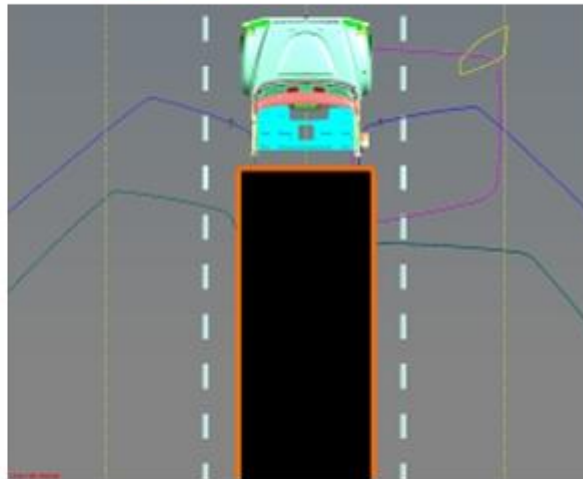


- Direct vs. Indirect Visibility Zones and Crosswalks
 - Flat unit magnification mirror not demonstrated, as focus of analysis is to determine where drivers might perceive motion of passing vehicles or pedestrians.

Sm Female Mirror Zones



Lg Male Mirror Zones



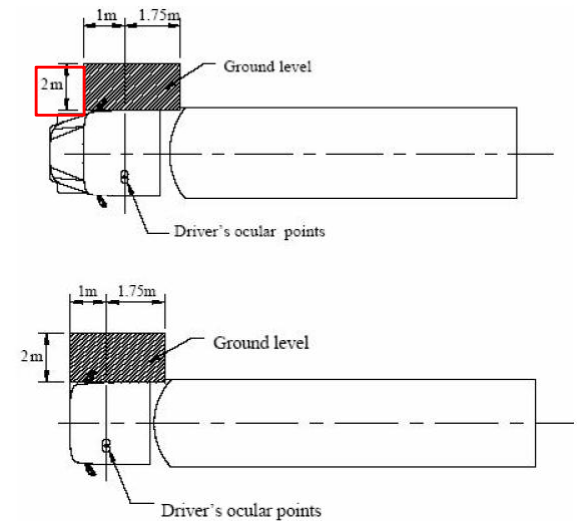
Legend:

- Peep Window
- Close Proximity Mirror
- Fender Mounted Mirror
- Wide Angle Mirror

Intersection of Mirror FOV Sheets with Ground

Indirect Visibility: Mirror View Overlap with Possible Direct View Window

ECE 46-02, pg. 29
Conv. Zone Exemption



Figures 7a and 7b

Field of Vision of Class V Close-proximity Mirror

- FMVSS 111 Bus Mirror Indirect Visibility
 - Q: What level of consistency exists for indirect visibility mirror view testing between CAD simulation and physical processes?
 - Factors:
 - Consistent eye point between physical and CAD cameras
 - Consistent mirror head and reflective mirror face position
 - Goals:
 - Define a repeatable and consistent process by which eye point (origin), body panels (obstructions), mirror faces (direct visibility targets), and test cylinders (indirect visibility targets) can be compared between physical and simulation parts.
 - Create a simulation practice that can predict compliance with FMVSS requirements during vehicle architecture, body panel, and mirror concept part(s) development.

- FMVSS 111 Bus Mirror Visibility

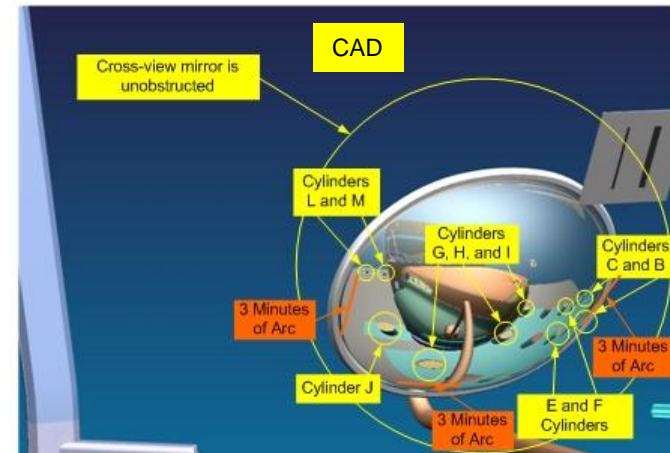
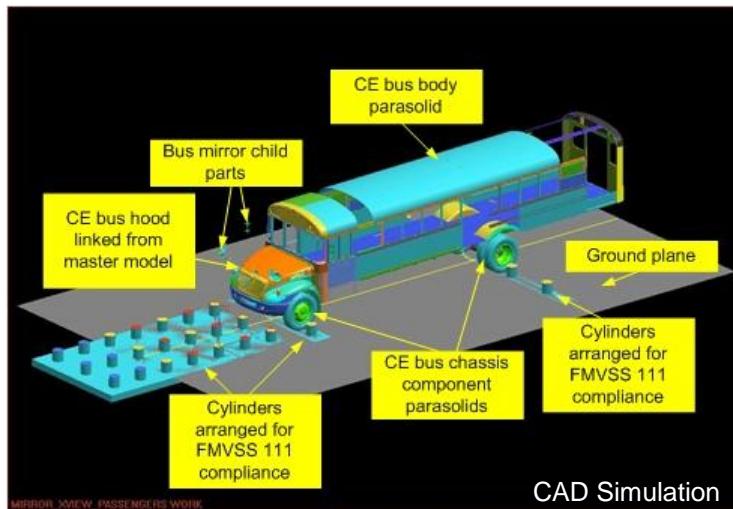


Figure 12. Screenshot of driver-side cross-view mirror

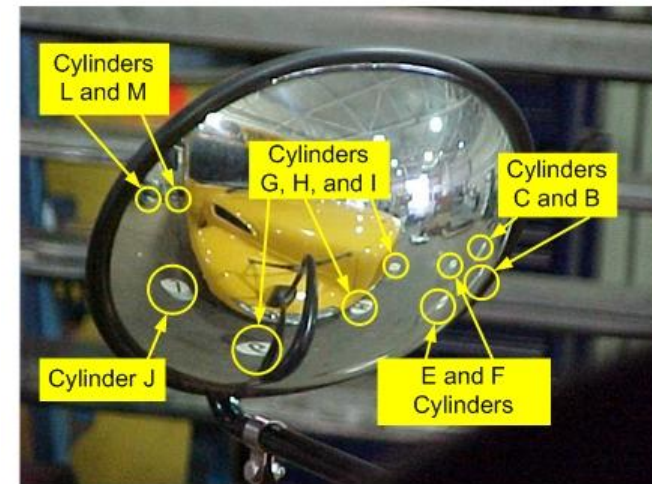
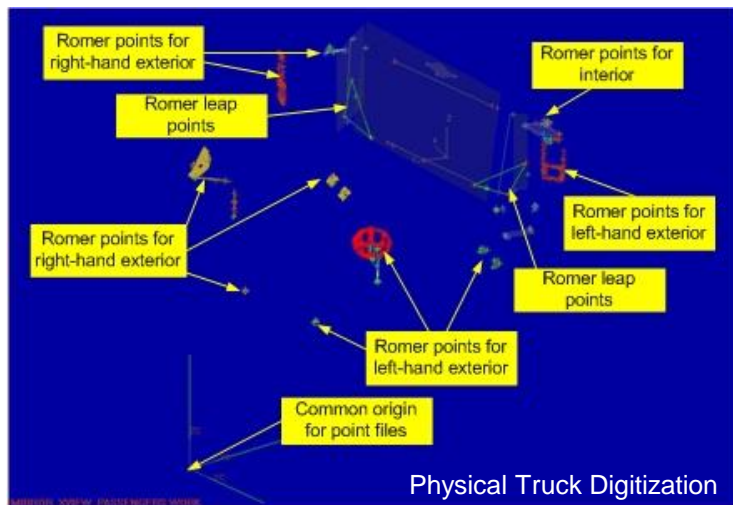


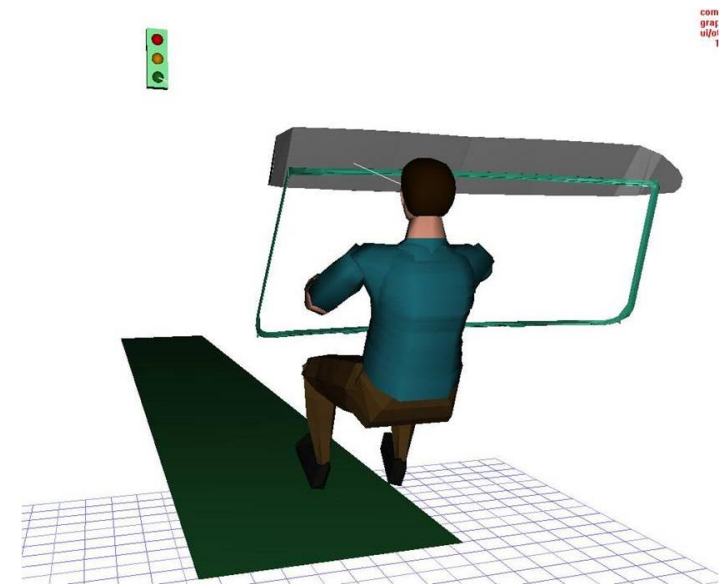
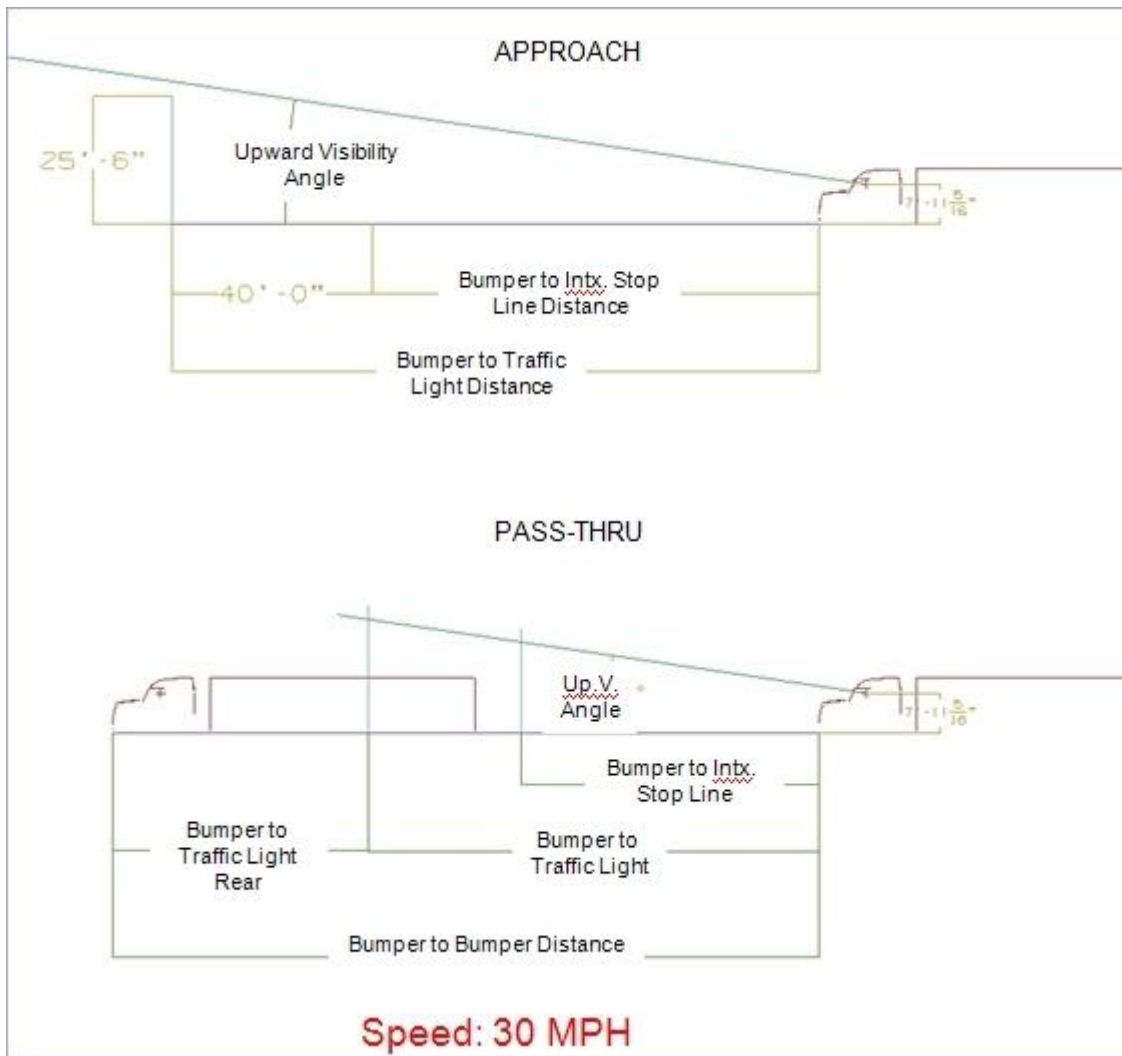
Figure 13. Snapshot of driver-side cross-view mirror

- Traffic Light Upward Visibility
 - Q: What upward angle of DLO visibility is required for the driver to see the traffic light change and decide to modify vehicle speed?
 - Factors:
 - Worst-case driver eye-point (large male)
 - Maximum traffic light module and light color (i.e. red) height
 - Minimum traffic light module and light height
 - FMVSS 121 stopping requirement: 355 feet at 60 mph, 89 feet at 30 mph
 - Goals:
 - Stop fully loaded vehicle in front of intersection stop line or pass vehicle and trailer completely under light before light turns red on highest traffic light module.
 - When stopped at traffic light, view highest traffic light module with minimum amount of head and torso forward lean.
 - Maximize sun-shade size for appearance and shading performance



Navistar Visibility Analyses

- Traffic Light Upward Visibility



Special thanks to Steve Oliver from Navistar, Inc., Body Exteriors Group, who planned and performed this analysis.

- Upward Visibility of Highway Signs vs. Sun Shading
 - Q: What is the location of a highway road sign with respect to the windshield day-light opening?
 - Factors:
 - Worst-case eye point (large male)
 - Height of cab and windshield with respect to road sign height
 - Blackout or other obstruction regions on windshield
 - Lateral location of road sign versus vehicle position: lane 1, lane 2, lane 3.
 - Velocity of vehicle which defines time to observe sign and read it
 - Goal:
 - Maximize sun blocking while minimizing obstruction of objects in world viewing through upward zone in day-light opening.

Navistar Visibility Analyses

- Upward Visibility of Highway Signs vs. Sun Shading



Lg. Male View, Vehicle in Lane 2, Sign in Motion



DOT, FHWA D8-1
"Weigh Station" Sign

- Bus Defog/Defrost Visibility Zones

- Q: What areas on the day-light openings should be defrosted in a similar fashion to the windshield A and C zones due to bus glass and mirror systems?

- Factors:

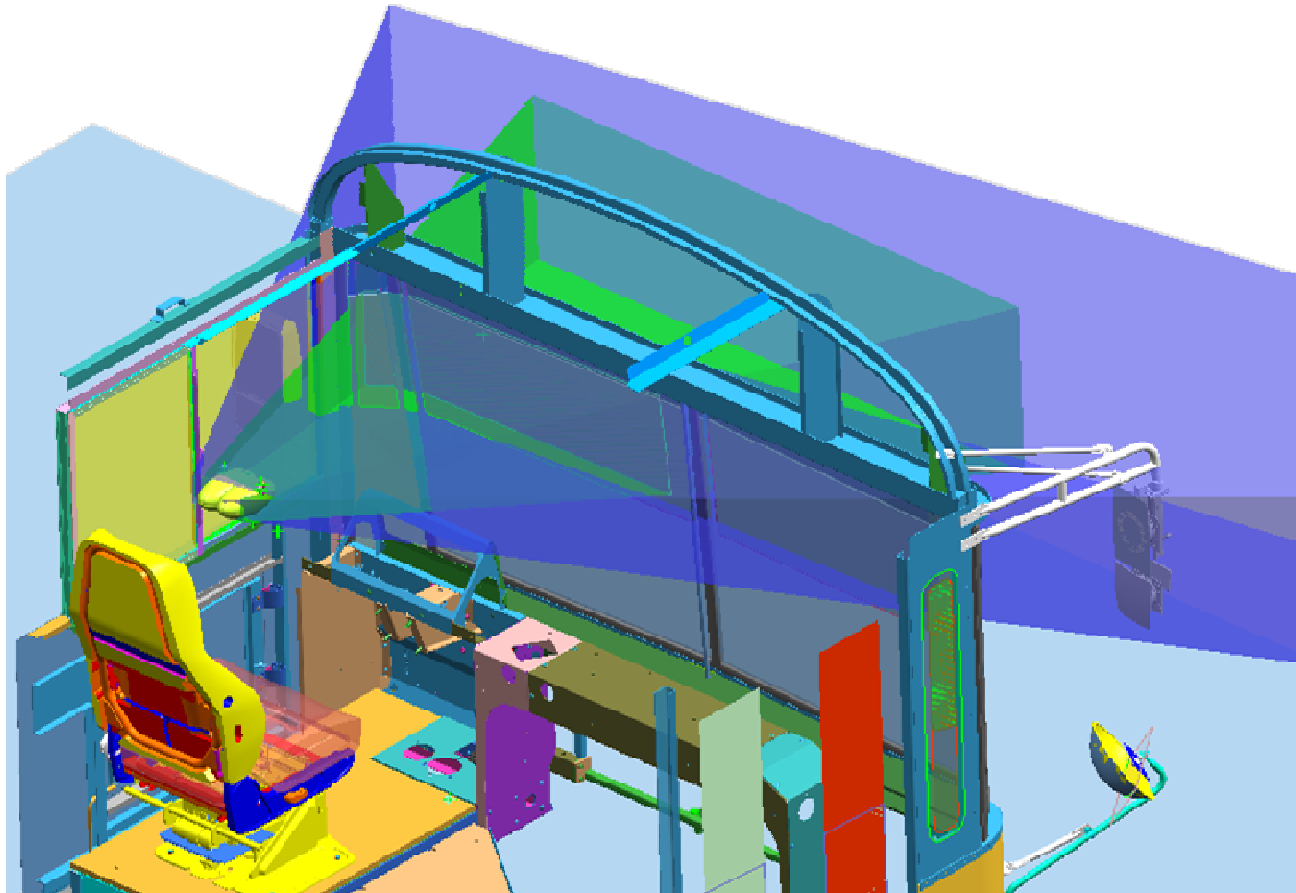
- Eyellipse location and associated worst case tangencies
 - Height of bus and windshield with respect to sidewalk
 - Bus glass structures and door glass structures as obstructions
 - Location and height of pedestrians near bus and loading zone.

- Goal:

- Provide defog/defrost targets for all visibility zones needed for direct and indirect visibility of road\vehicles and pedestrians.

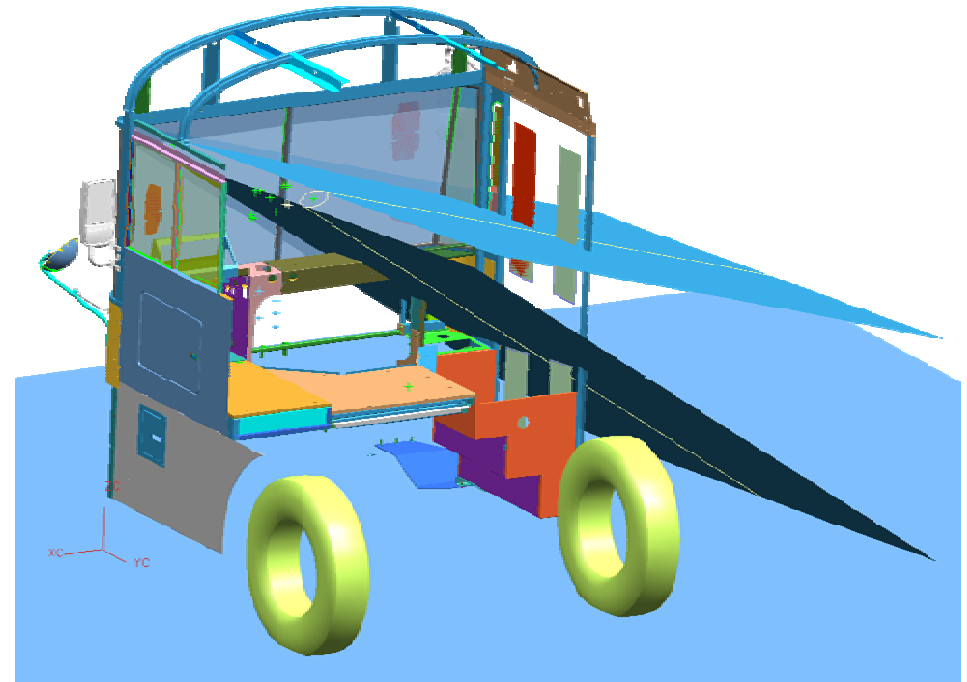
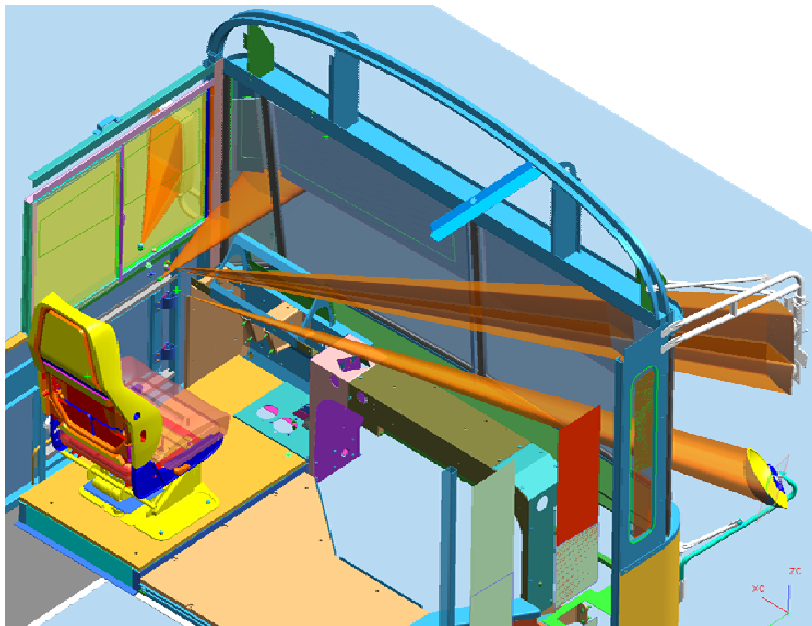
Navistar Visibility Analyses

- Bus Defog/Defrost Visibility Zones: A and C Zones



Navistar Visibility Analyses

- Bus Defog/Defrost Visibility Zones: Mirror Zones, Pedestrian Loading Zone



- Iteration of Tools
- Balancing Direct and Indirect Visibility
- Application of NIOSH/SAE Truck Driver Anthropometry Study
 - SAE Class B processes need to be updated
 - Update tools to match criteria
 - Provide benchmarking data for internal design standards and external recommended practices

- Any/all new processes, modeling to physical validation, vehicle benchmarking needed to support updating of SAE RP's for Class B vehicles!!!
- Validation of priority zones around vehicle for direct visibility metrics
- Definition of FMVSS mirror zones for truck and truck tractor indirect visibility
- Definition of FMVSS camera zones for truck and truck tractor indirect visibility
- Support the balance of direct and indirect visibility
 - European drivers often comment that ECE 46-02 mirrors are great for viewing old mirror blind spots, but create new direct visibility blind spots.
- Support novel solutions for front-of-cab and right-side of hood visibility aids for conventional vehicles.

Questions?

