Glass Performance Days 2025

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GLASS PERFORMANCE DAYS 2025

Head Up Display and Augmented Reality in Automotive Glass

A Technological and Industry Perspective

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Overview

- What is AR?
- How Does HUD Work With AR?
- History of HUD
- Why HUD Matters
- Current HUD Technology
- Limitations
- Regulations
- Opportunities
- The Future of AR
- Industry Recommendations

What is Augmented Reality (AR)?

- AR enhances real-world environments by overlaying digital information.

Image source: Canva (Free media library)

What is Head Up Display (HUD)?

- Automotive HUD units project critical driving information onto windscreens.

Image source: Canva (Free media library)

A Brief History of HUD

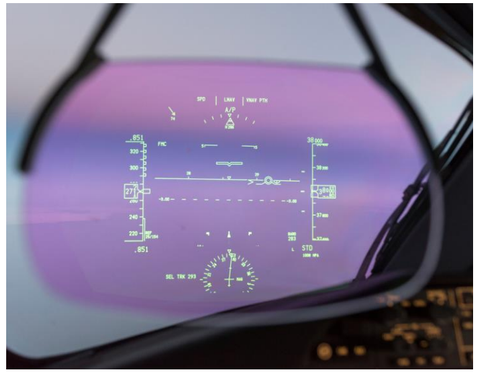


Image source: Canva
(Free media library)

1886
Automobile Invented

1904
Windscreen Introduced

1919
Laminated Windscreen Developed

1942
Aviation HUD Developed

1988
HUD 1st Seen in Production Vehicles

2000s
ADAS Features 1st Seen in Production Vehicles

2012
HUD Integrates GPS

2014
Holographic HUD 1st Seen in Production Vehicle

Image source: Canva
(Free media library)

Why Does HUD Matter?

- The global automotive HUD market is predicted to grow from $1.6B USD in 2025 to $4.6B USD by 2030 (24% Compound Annual Growth Rate (CAGR)).
  (Mordor Intelligence Research & Advisory, 2024)

- Studies show HUDs can improve driver reaction times by up to 25%, significantly enhancing safety and convenience.
  (Smith et al., 2023)

Image source: Canva (Free media library)

How HUDs Enhance Driver Safety

Maintain Eyes on the Road Benefit (EORB)

- HUDs project essential driving information (e.g., speed, navigation) within the driver's line of sight, reducing the need to look away from the road.
  (Russell et al., NHTSA, 2023)

Reduce Cognitive Load

- By presenting information directly in the driver's field of view, HUDs decrease mental effort required to process driving data, leading to improved reaction times.
  (Russell et al., NHTSA, 2023)

Enhance Hazard Detection

- HUDs improve the driver's ability to detect pedestrians and other hazards, especially during the time surrounding display glances. www-nrd.nhtsa.dot.gov
  (Russell et al., NHTSA, 2023)

Improve Night Driving Attention

- Augmented Reality HUDs (AR-HUDs) significantly enhance driver attention to risky areas during night driving conditions. ScienceDirect
  (Li et al., ScienceDirect, 2020)

Facilitate Faster Refocusing

- Advanced HUD technologies, such as those being tested by Jaguar Land Rover, enable drivers to switch attention between the HUD and the road with minimal refocusing time, benefiting especially older drivers.
  (Charlton, WIRED, 2025))

How AR Enhances Driver Safety

A study published in *Transportation Research Interdisciplinary Perspectives* found that AR-HUDs significantly improve drivers' attention to risky areas:

"The experiment results showed that the AR-HUD system can significantly improve the subjects' attention to risky AOIs (Area of Interest),“

-Li, R., Chen, Y. V., Zhang, L., & Zhangfan, C. (2020)

(Li et al., Transport Policy, 2023)

How AR Can Enhance Passenger Comfort

"Initial use cases will focus on infotainment for passengers (4D cinema experience, wellness, energizing comfort, POIs, etc.), followed by driver-related use cases (navigation, assistance, etc.). We see AR glasses as a device that extends our infotainment system and offers an enhanced visual experience for our customers."

-Mercedes Spokesperson

(Hawkins, Newsweek, 2024)

Adoption and Opportunities

- Recent growth: HUD availability increased from 5% to 35% of new vehicles from 2015-2025.
  (Automotive Insight, 2024)
- Increased safety features.
- Immersive AR experience for drivers and passengers.

"While traditional HUDs have improved the driving experience, the advent of AR HUDs is truly transformational. A seamless meshing of electronics, software, and optics, **it could become the most important screen in the car.**"

Nokia

(Nokia, n.d.)

Current Production Vehicles With HUD

Make	Model
Acura	MDX, RDX
Audi	A4, A6, A8, e-tron GT, Q3, Q4 e-tron, Q5, Q6 e-tron, Q7, Q8
BMW	3 Series, 5 Series, 7 Series, i4, i5, i7, iX, X1, X3, X5
BYD	Han, Tang, Seal
Cadillac	CT5, Escalade, Escalade IQ, XT6
Changan	CS75 Plus, UNI-K
Chery	Tiggo 7, Tiggo 8
Chevrolet	Blazer, Silverado, Suburban, Tahoe, Traverse
Dongfeng Motor	Aeolus Yixuan, Fengon ix5
Fiat	500X, Tipo
Ford	Explorer, Expedition, Mustang Mach-E
GAC Group	Aion LX, Trumpchi GS8
Geely	Preface, Xingyue L
Genesis	G70, G80, G90, GV60, GV70, GV80
GMC	Acadia, Sierra, Yukon
Great Wall Motors	Haval H6, Wey VV7
Honda	Accord, CR-V, Pilot
Hyundai	Ioniq 5, Palisade, Santa Fe, Sonata, Tucson
Infiniti	QX50, QX60
Jaguar	F-Pace, I-Pace
Jeep	Grand Cherokee, Wagoneer
Kia	EV6, EV9, K5, Telluride

Make	Model
Land Rover	Range Rover, Range Rover Sport, Velar
Lexus	ES, LS, NX, RX, UX
Li Auto	Li ONE, Li L9
Lincoln	Aviator, Nautilus, Navigator
Mazda	CX-5, CX-50, CX-60, CX-90, Mazda3
Mercedes-Benz	C-Class, E-Class, EQE, EQS, GLE, GLS, S-Class
MINI	Cooper, Countryman
Mitsubishi	Outlander
Nissan	Altima, Pathfinder, Rogue
NIO	ES6, ES8, ET5, ET7
Opel	Astra, Insignia
Peugeot	3008, 508
Porsche	Cayenne, Panamera, Taycan
Renault	Austral, Espace
Skoda	Enyaq, Kodiaq
Toyota	Camry, Crown, Highlander, Land Cruiser, Prius, RAV4, Sienna, Venza
Volkswagen	ID.4, ID.7
Volvo	EX90, S90, XC60, XC90
XPeng	G9, P7
Zeekr	Zeekr

Table created by author

Current Production Vehicles With AR

Make	Model
Audi	e-tron GT, Q4 e-tron, Q6 e-tron
BMW	7 Series, i7, iX
BYD	Han EV, Tang EV
Cadillac	Escalade, Escalade IQ
Changan	UNI-K
GAC Group	Aion LX
Genesis	G70, G80, G90, GV60, GV70, GV80
Great Wall Motors	Wey Mocha DHT-PHEV
Honda	Accord, CR-V, Pilot
Hyundai	Ioniq 5, Ioniq 6
Kia	EV6, EV9
Li Auto	L9
Mazda	EZ-60
Mercedes-Benz	EQE, EQS, GLE, S-Class
NIO	ES7, ET7
Volkswagen	ID.4, ID.7
Xpeng	G9, P7
Zeekr	001, X

Table created by author

Types of HUD and Their Technology

Projected HUD

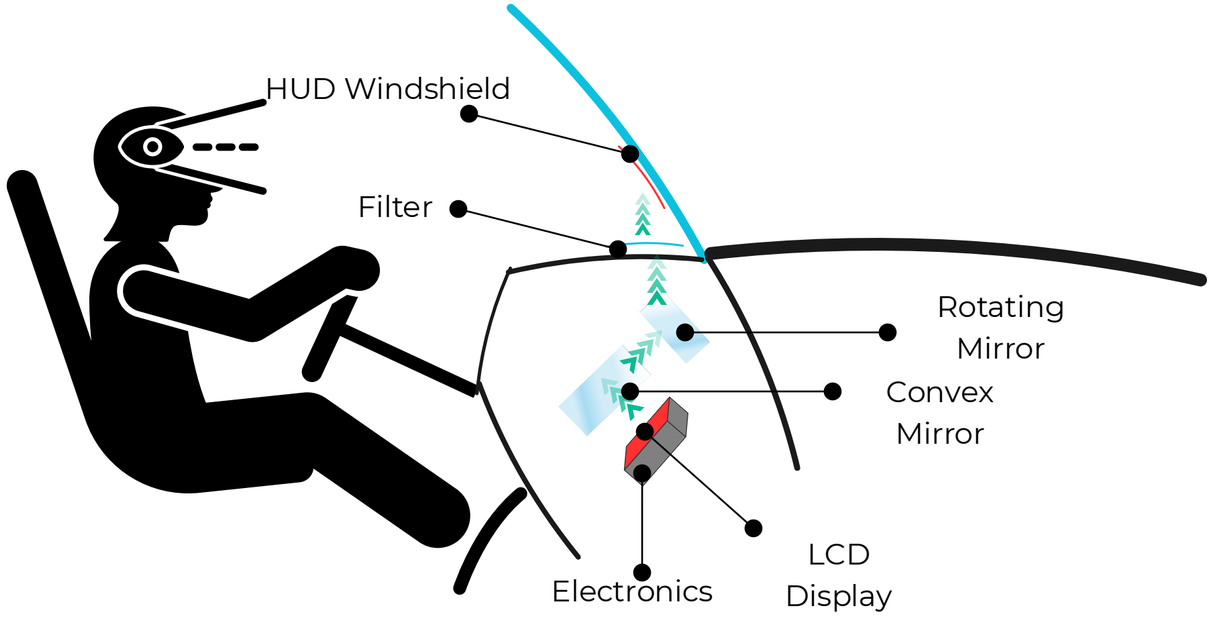
Utilizes a LED projector and mirrors along with windscreen combiner to display the image.

Pros:

- Proven technology.
- Economical

Cons:

- Limited projection size
- 2-dimensional limited projection features



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Types of HUD and Their Technology

Holographic HUD

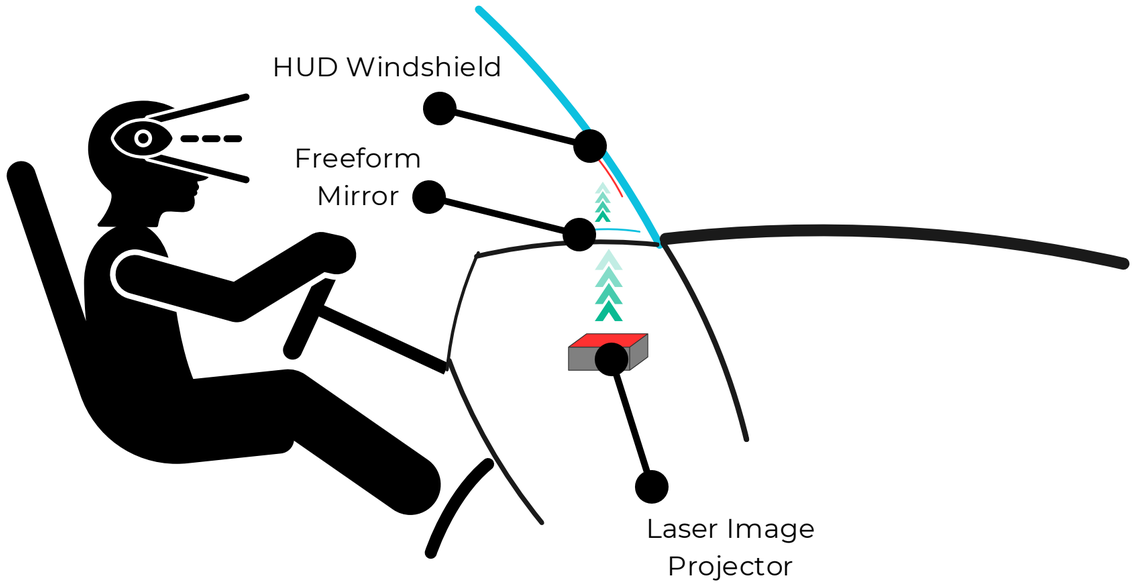
Utilizes a laser projector along with a mirror to display an image.

Pros:

- 3-dimensional (AR) experience
- Large display

Cons:

- Expensive
- Requires large dashboard space



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Types of HUD and Their Technology

Emissive HUD

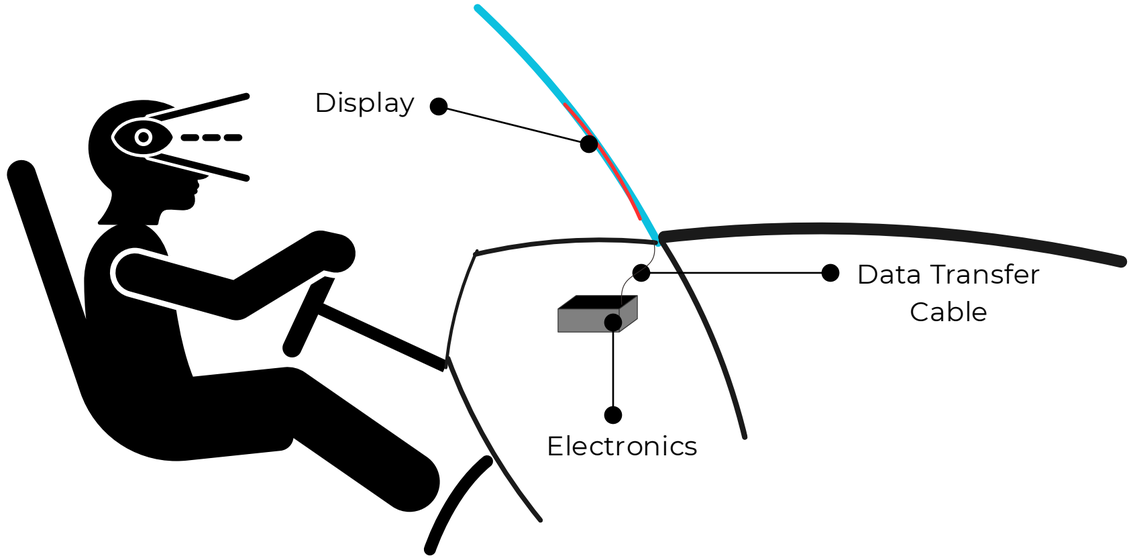
Utilizes an LED screen laminated inside of the windscreen.

Pros:

- Larger display capabilities
- High-quality display

Cons:

- Currently only available for flat glass
- Requires technology advancements for curved glass



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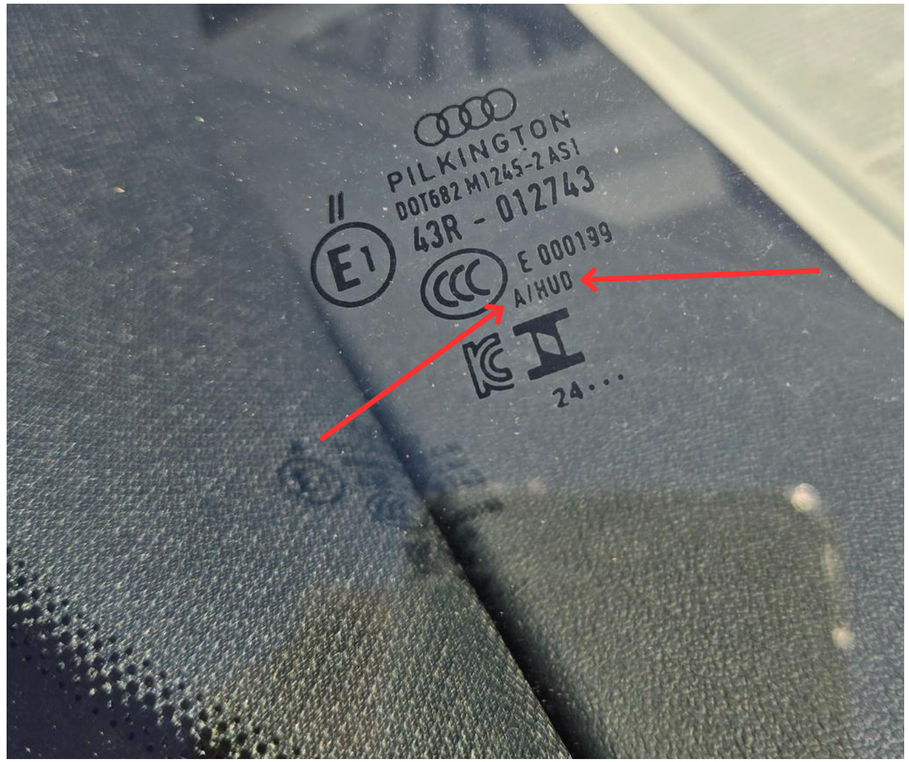
HUD Windshield Requirements

Glass manufacturers directly impact HUD effectiveness through quality and design innovations, including:

- Glass
- Polyvinyl-Butyral (PVB) Interlayer
- Coatings



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HUD Glass Requirements

Optical-Grade Glass Standards

- Ensures HUD image remains sharp, stable, and accurately positioned.
- Uniform refractive index

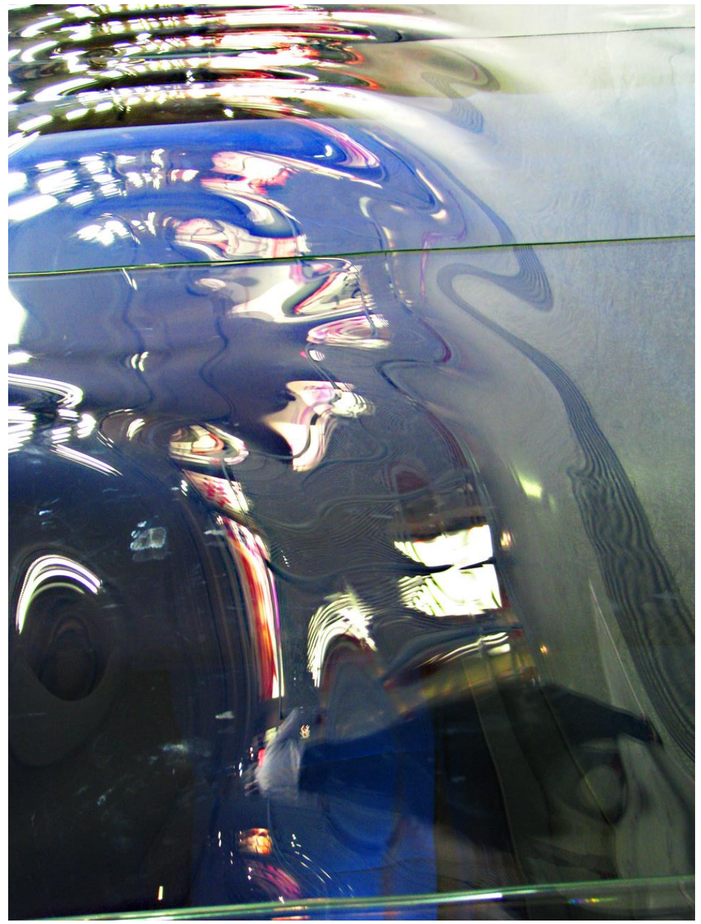


Image source: Canva (Free media library)

HUD PVB Requirements

Wedge-Shaped PVB Interlayer

- Prevents double images (ghosting) by correcting light refraction between glass layers.

Base images from Canva (edited by author)

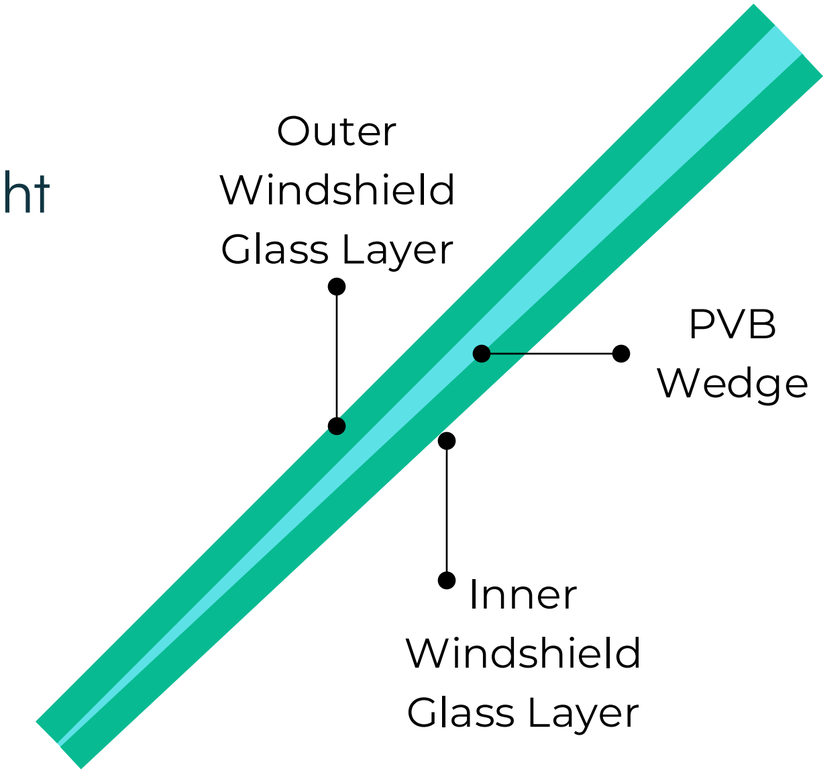


Image created by author

HUD Coating Requirements

Polyethylene Terephthalate (PET) metalized film

- Can replace wedged PVB interlayer to eliminate ghosting.
  - (Mareška et al., TOTS, 2022)
- Applied using sputtering technique.
  - (Mareška et al., TOTS, 2022)

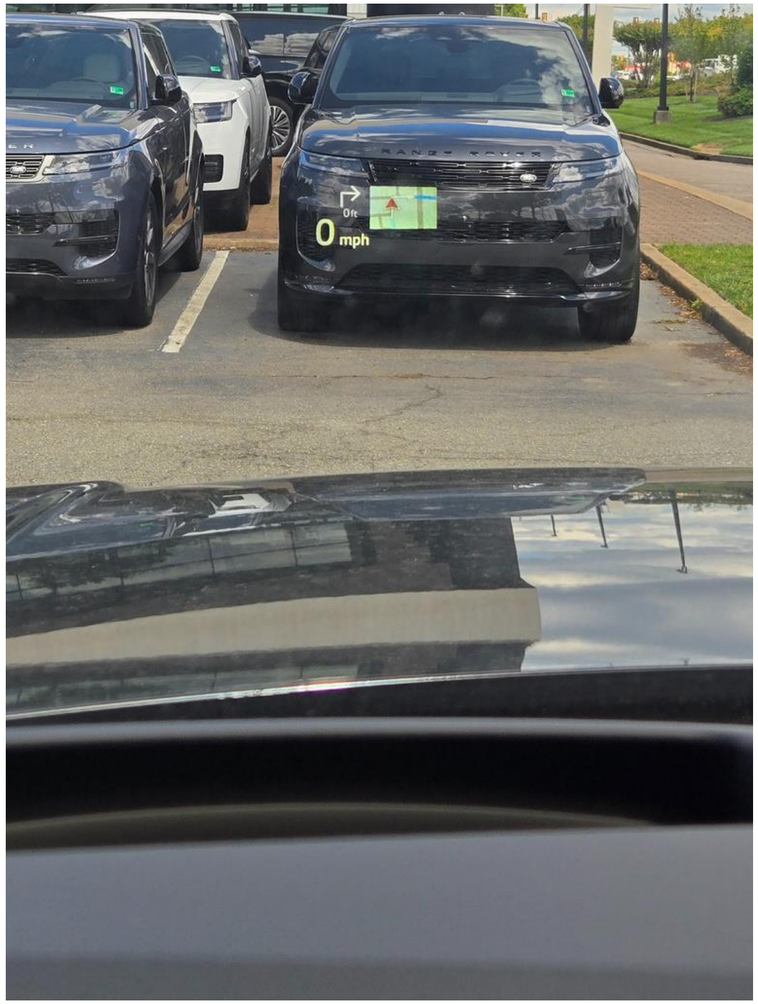
Image source: USGlass Magazine, 2024

Real-World Observations

- Luxury brands differentiate between HUD vs. AR HUD.
- Direct correlation between features and HUD unit size.

Photo by author

Real-World Observations



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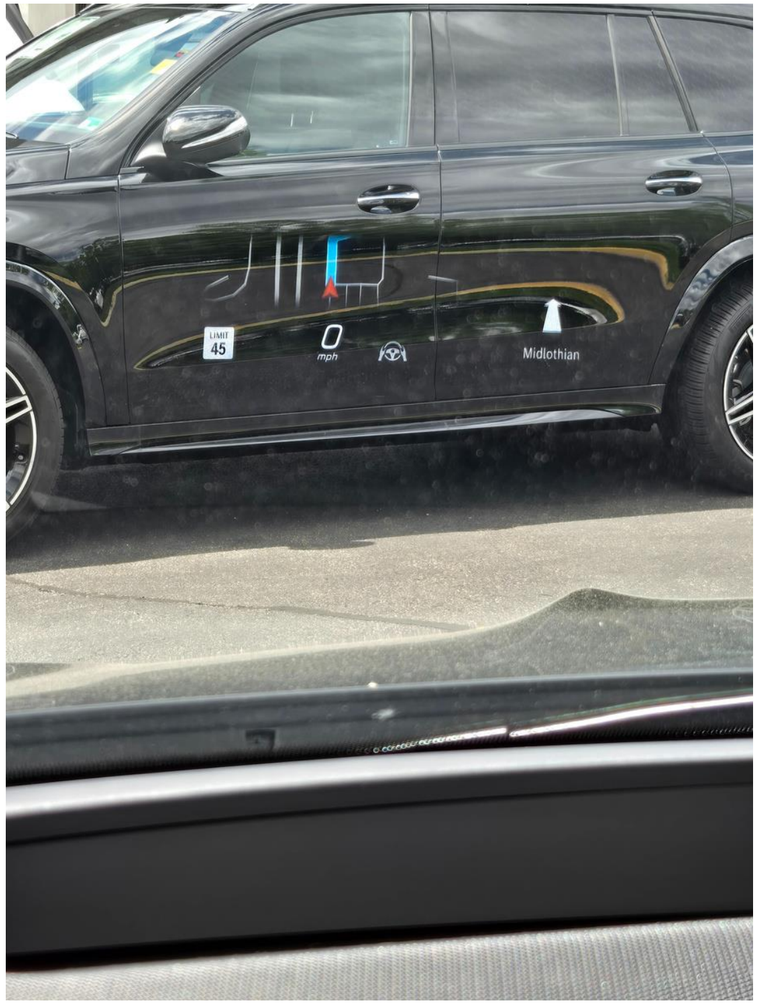
Real-World Observations



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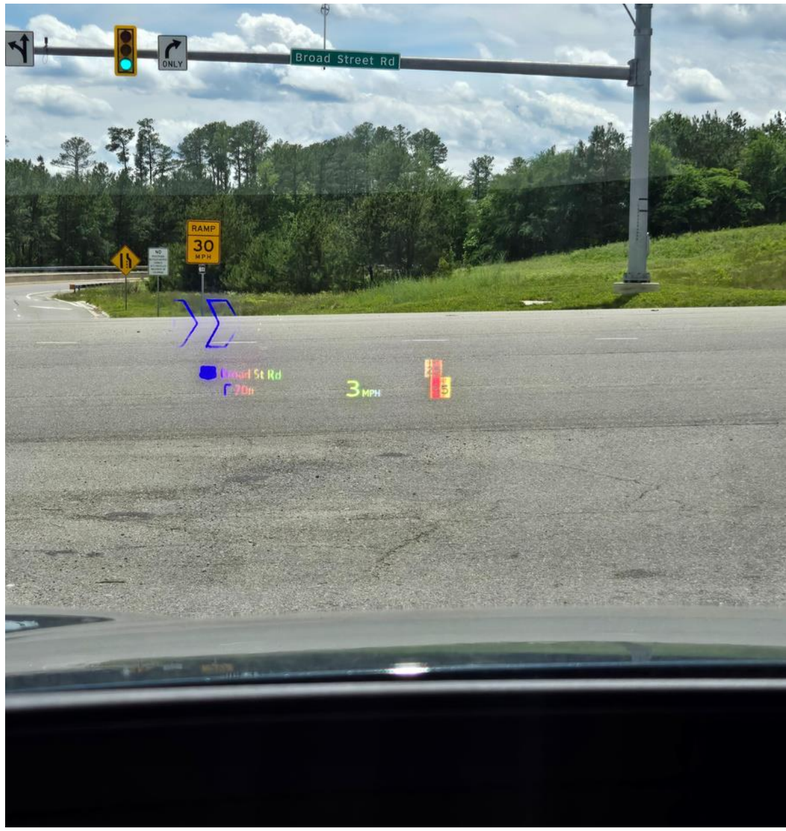
Real-World Observations

Photos by author

Real-World Observations



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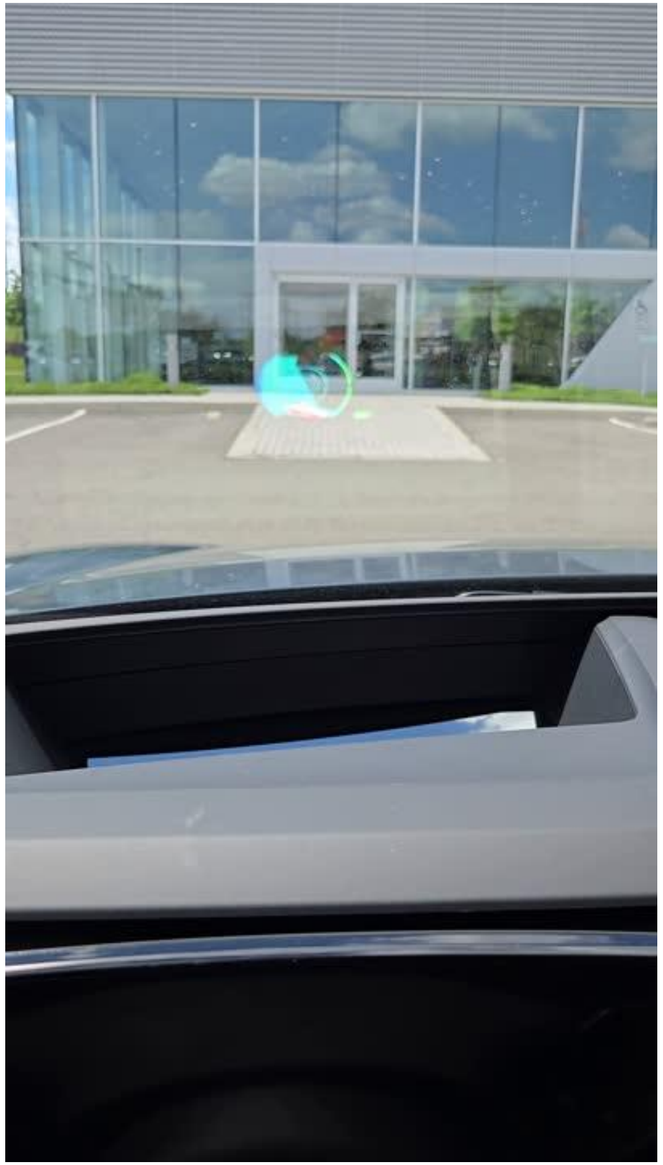
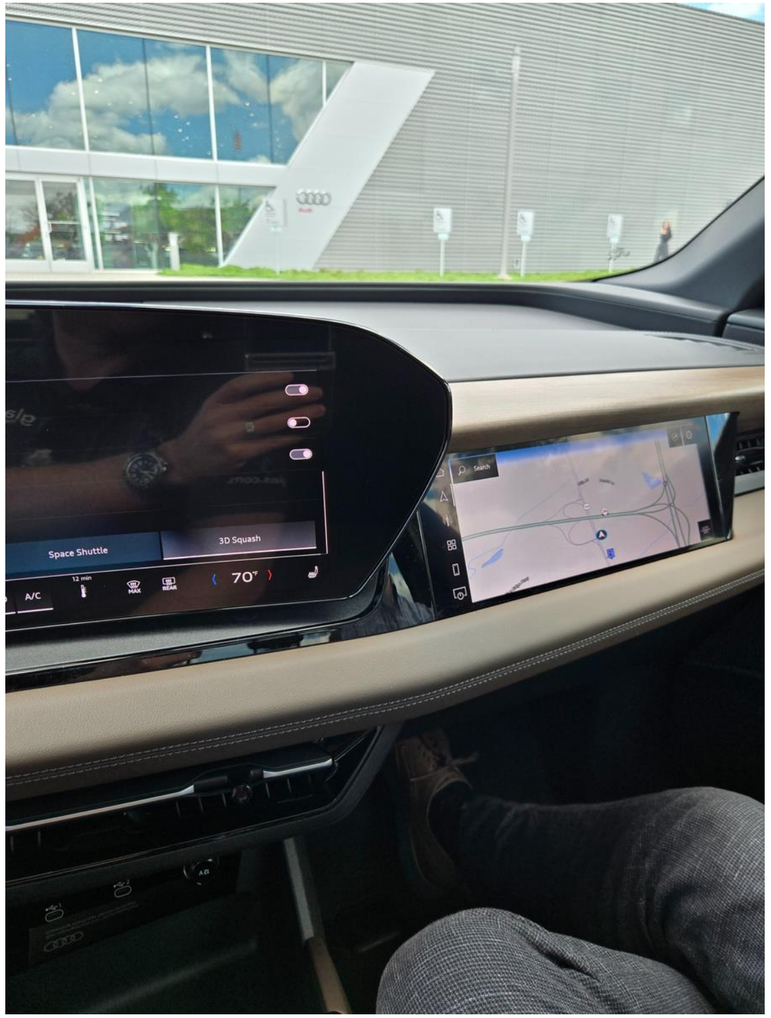
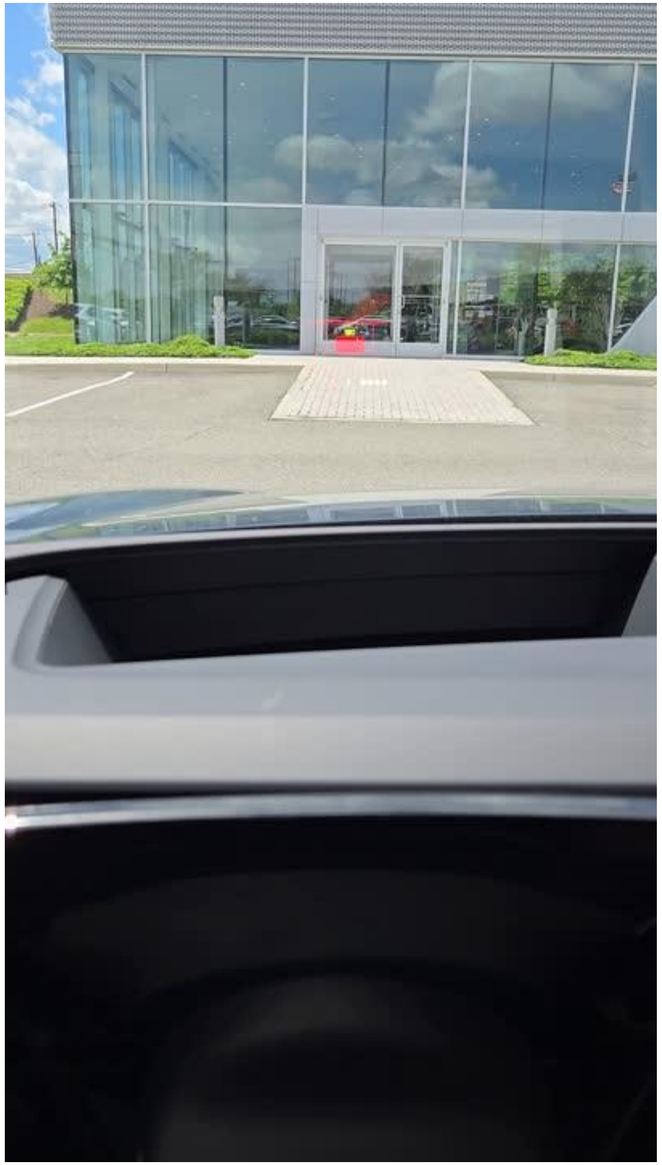
Emerging Technology







Media by author

(BMWBLOG, YouTube Shorts, 2023)

(Supercar Blondie, YouTube Shorts, 2024)

(Drive 4 Drive, YouTube, 2024)

Challenges and Considerations

- Reduced visibility in bright sunlight or variable lighting conditions.
- Optical distortion and image ghosting caused by windshield curvature variations or eyewear.
- Driver distraction from excessive or poorly managed visual data.
- Hardware limitations of windshields, HUD units, and vehicle dashboards.
- Software limitations of vehicle Electronic Control Unit (ECU) and HUD processors.
- Economic barriers of emerging technology costs.

Regulatory Considerations

Region	Governing Body	Key Standard	Notes
China	MIIT	GB 7258 (general)	No direct HUD rules yet; general display safety
EU	UNECE WP.29	ECE R121	Limits info shown in driver's line of sight
Japan	MLIT	UNECE-aligned + national	Focus on glare control and display brightness
USA	NHTSA	FMVSS 101	No HUD-specific rule; must avoid driver distraction
🌐 **Global**	ISO	ISO 15008:2017	Ergonomic and legibility standards for displays

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Regulatory Considerations

HUDs are regulated under broader vehicle safety and display standards. Specific HUD rules are still evolving.

Regulation Focus Areas:

- Driver distraction and cognitive load
- AR HUD placement and occlusion risks
- Display brightness, contrast, and timing

The Bright Future of AR

1. Widespread Adoption of Augmented Reality (AR) Holographic HUDs
Project contextual overlays (e.g., navigation arrows, hazard alerts) onto the real-world road view.
Already featured in high-end models (e.g., Mercedes EQS, Audi E-Tron), with wider adoption expected.

2. Large Field-of-View HUD, Passenger AR, and Full-Windshield AR
Moving beyond small projections to cover full width of the windshield.
Enables layered data display: speed, safety alerts, navigation, and infotainment all in separate zones.

3. Emissive HUD AR (e.g., OLED, MicroLED)
HUDs where the display generates its own light rather than using projection.
Still in development for curved glass applications. Faces challenges in creating 3-D imaging.

Ford Motor Company in conjunction with Ceres Holographic demonstrating HoloFlekt laminated holographic film

Image source: Display Daily (2023)

Industry Recommendations

- Don’t let AR glasses become a substitute for AR HUDs.
- Meet consumer demand for larger displays with more information by advancing display technology.
- Don’t ignore passenger display possibilities.
- Consider future interactive capabilities when developing current displays.

Image source: Canva (Free media library)

Manufacturing Recommendations

- If you're not already optimizing product and manufacturing for HUD glass, you're missing out on a growing market segment
- Focus on optical glass clarity.
- Focus on precise PVB interlayer angles.
- Focus on high-quality coatings.

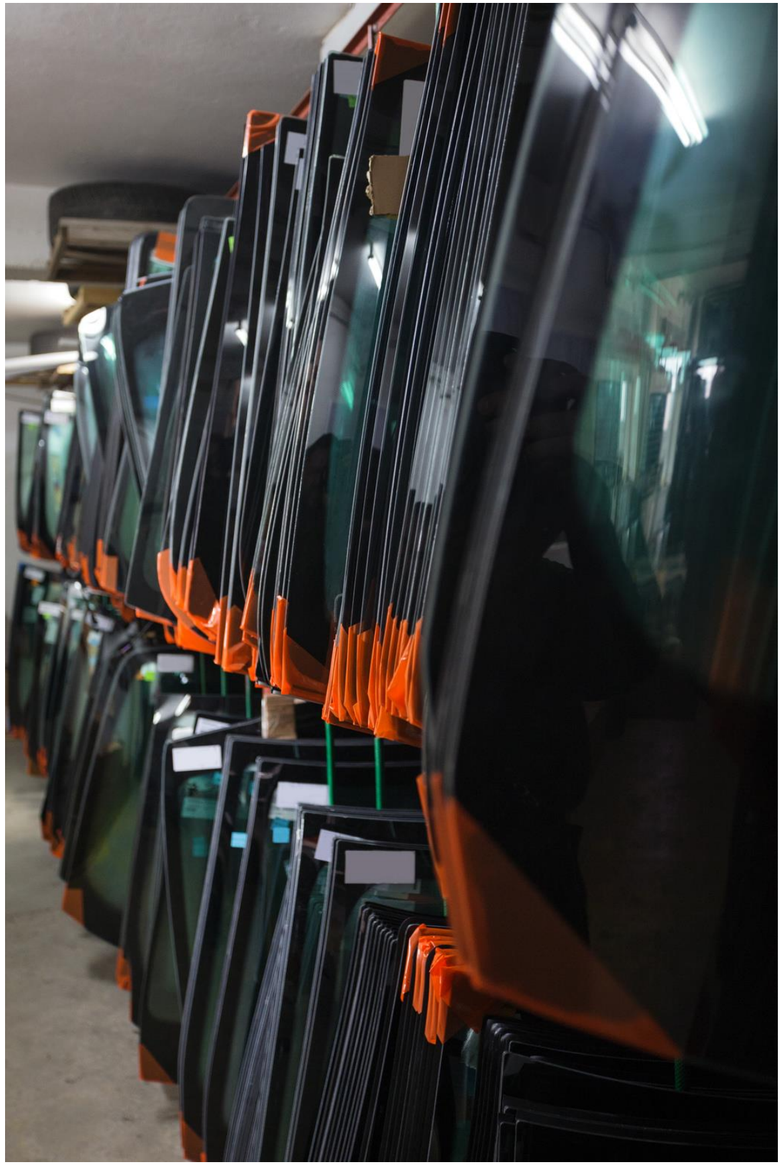

Image source: Canva (Free media library)

Conclusion

- Glass component quality fundamentally impacts HUD performance.
- Collaboration and innovation are key to leveraging future HUD advancements.
- Manufacturers who act proactively will lead the market.

Image source: Canva (Free media library)

Thank You

Questions?

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