A New Era of 3D Sensing: Transforming Industries and Creating Opportunities

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Yole Group

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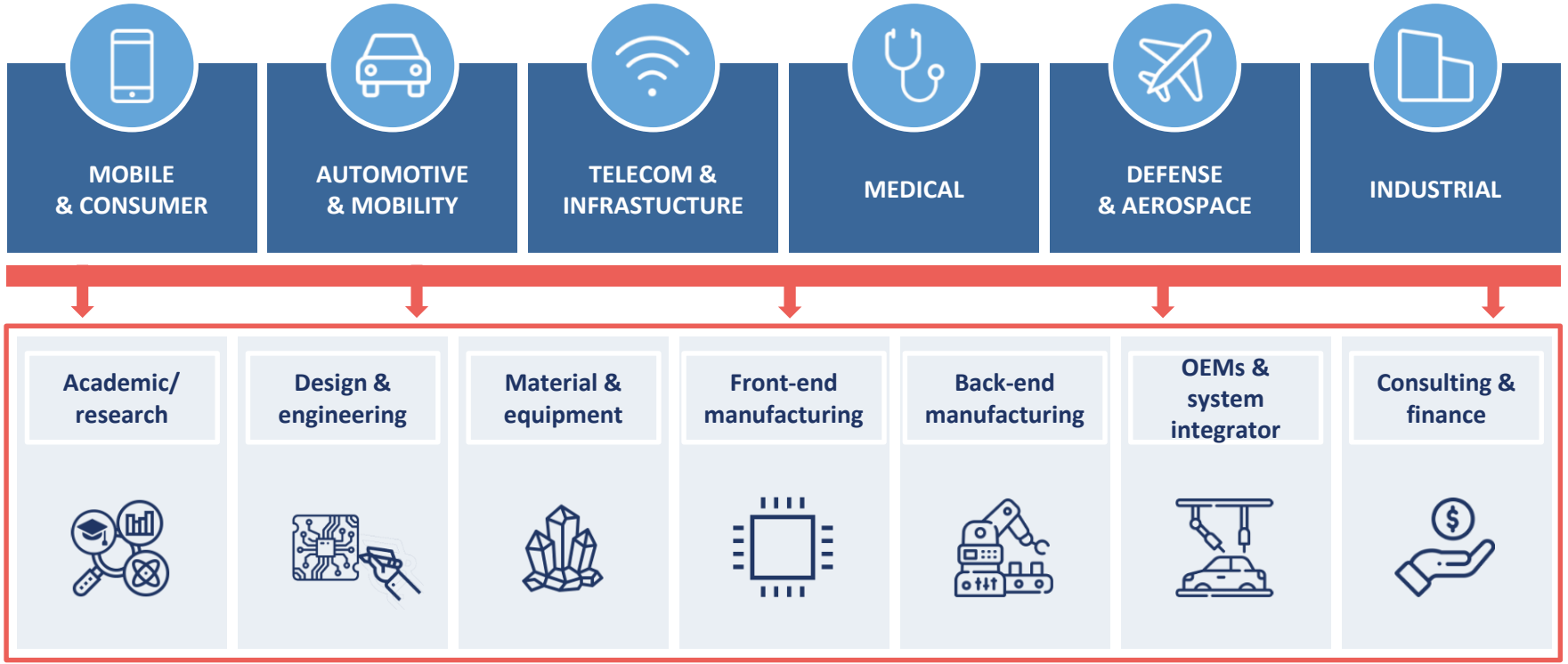
Across the semiconductor supply chain & markets

EMBEDDED VISION SUMMIT



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Outline

- Introduction
- Insights on 3D sensing applications and current trends
- Technologies evolution supporting 3D sensing
- 3D sensing market forecast
- Conclusion

Introduction

3D sensing brings animal perception to machines

Source: Coherent

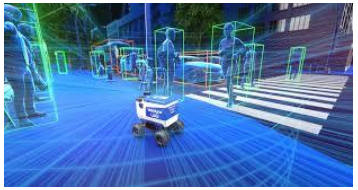
Source: Zoox

Source: Worx

From imaging to sensing diversity

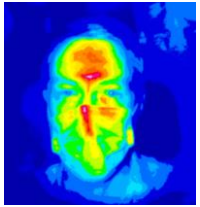
2D Color imaging

3D Depth sensing

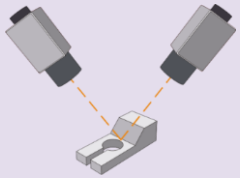
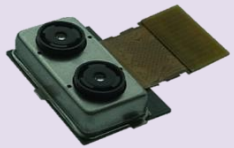
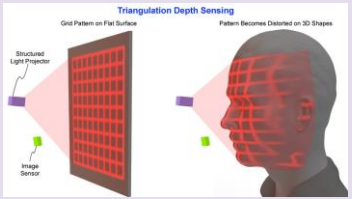
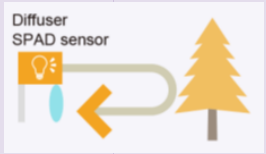


4D Time, motion sensing

5D Multispectral, polarization



99% of the 3D sensing market volume

	Stereo vision	Structured Light	Time-of-Flight (ToF)	
			Low-end LiDAR	High-end LiDAR
Max. depth range	2m-20m	1-2m	10m	200m – 1,000km (space)
Light source	Passive (can be active)	Active	Active	Active
Module example	 	 *Coherent* *Apple* 	*LGIT*    TMF8821 *ams OSRAM* *multizone dToF*	*Valeo*   *Ouster*

3D sensing is continuously spreading into applications

APPLICATION	MARKET				
	Consumer & Mobile	Automotive & Mobility	Medical	Industrial	Defense & Aerospace
 BIOMETRICS	• Smartphone • Smart Doorlock • Laptop, Tablet	• Passenger Car		• Access Control and Payment Camera	
 NAVIGATION	• Consumer Drone • Personal Robotic	• Passenger Car • Robotic Car		• Industrial Robot • Heavy Truck	• Military Vehicle
 PEOPLE MONITORING	• Laptop • Entertainment Cam.	• Passenger Car		• Infrastructure Monitor System	
 ENVIRONMENT TRACKING	• Smartphone, Tablet • XR Headset, Projector • Entertainment Cam.			• Machine Vision • Energy, Construction • AR Headset	• Surveillance • Space and Scientific
 MEDICAL DIAGNOSIS			• CT Scanner • OCT Imaging • Cone Beam CT		

Insights on 3D sensing applications and current trends

Consumer: main drivers for 3D sensing adoption

- The quest for an enhanced user experience and safety




- The starting reign of personal robotics



- The rise of spatial computing



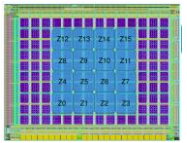
- The era of photography, video and streaming



Smartphone 3D sensing evolution

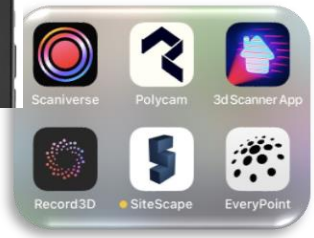
BIOMETRICS		ENVIRONMENT TRACKING	
Structured Light	iToF	dToF LiDAR - ‘high res’	Multizone dToF - ‘low res’
	HONOR		SAMSUNG
	HUAWEI		SONY
			HUAWEI
			Google
			realme
			HONOR

Low res. dToF cameras success for autofocus



Digital wallet

From consumer AR to Pompeii



3D sensing continues proliferating into consumer products

NAVIGATION

Personal robots:

Roborock S7 MaxV Ultra

Stereo

Mammotion YUKA 1500

3D ToF LiDAR

Stereo & fisheye

DJI Air 3S

ENVIRONMENT TRACKING

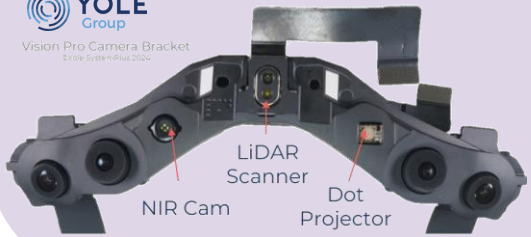
Projectors:

Hisense C2-ULTRA

3D ToF

XR headsets:

Apple Vision Pro



30+ sensors for full autonomy, including LiDARs

	Tesla Model 3  ~$40k	Mercedes S-class  ~$100k	Waymo 5th gen 	Didi 
 LiDARs	No LiDAR	Long-range x1	Short/Mid range x4	Short-/Mid range x6 Long-range x1
 Radars	No Radar	Long-range x1 Short/Mid range x4	360° view x6	Long-range x6
 Cameras	360° view x8	360° view x7	360° view x29	360° view x24 Thermal camera x1
TOTAL	**8 sensors**	**13 sensors**	**39 sensors**	**38 sensors**

‘Hands-off’ → ‘Eyes-off’ Highway driving → ‘Eyes-off’ Full autonomy

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Huawei introduction of LiDAR is a game changer

OEM	Dimensions (mm)	Weight (g)	Imaging technology	Ranging technology	Laser	Receiver	Processing	Manufacturing cost
Luxeed S7 AITO M9	205x155x62	1073	Rotating mirror	Direct ToF	VCSEL 905nm 70 W	Sony SPAD 600x189 pixels	Texas Instruments SoC	~$191

LATTICE SEMICONDUCTOR

FPGA

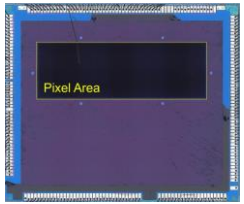
LUMENTUM

Quad 905nm multi-junction
VCSEL: 178 dots (66 x 3)

TEXAS INSTRUMENTS

SoC

SONY



Sony SPAD sensor
IMX459

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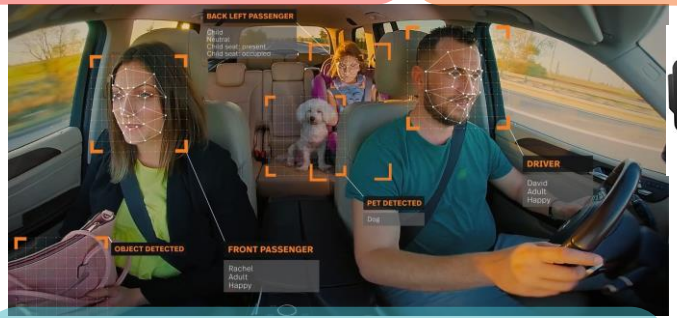
In-cabin 3D sensing opportunities?

Child presence detection
- Presence detection and classification
- Vital signs detection

Driver monitoring
- Distraction/drowsiness detection
- Head, hands, seatbelt detection
- Face recognition

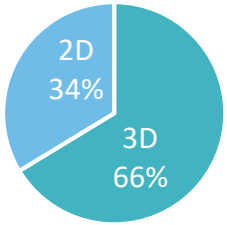
Continental
trinamiX

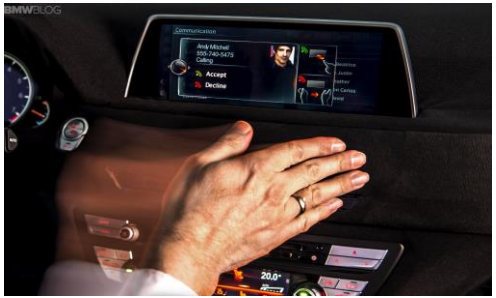
CES 2024



Occupant monitoring
- Occupant detection, identification
- Position, seatbelt, object detection
- HVAC control, smart airbag
- Emotion and vital signs detection

2024 3D in-cabin OMS
(in volume)





Source: BMW

- For 3D use case, gesture control has remained so far the main driver for OMS with 3D iToF VGA cameras.

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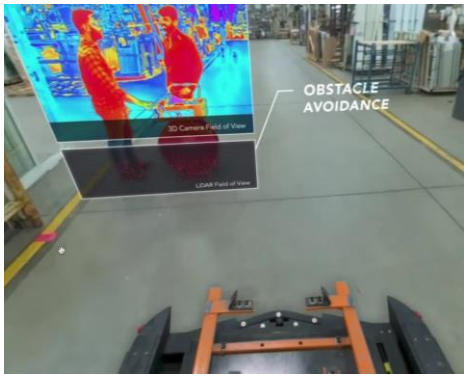
Logistics automation remains a strong trend in industry

- Cumulative $2B investments from 2021 for logistics robots, and multiple M&A: drones, AGV, AMR, autonomous trucks…that use advanced perception including 3D sensing.
- In June 2024, DHL reaches a 500 million picks using LocusBot autonomous mobile robots (AMRs).



Corvus one

- Front LiDAR
- 12 cameras

CarryPick

- Front LiDAR
- No cameras

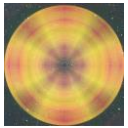
PalletTransport1500

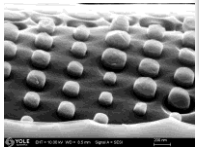
- 2 lidar sensors
- 8 3D cameras

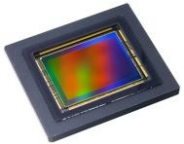
Technology evolution supporting 3D sensing

Convergence of new architectures, emerging technologies

Wafer-level optics
Optical metasurfaces





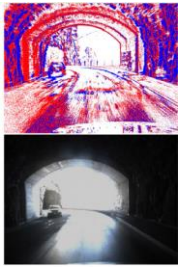


Pixel size
BSI stacked sensor
RGB and depth fusion
Near-infrared and SWIR sensitivity

Extended wavelengths
New materials
Multi-junction technology

Low power
Single passive cameras
Edge AI computing

Gehrig et al., 2021



Quantum Dots sensors
Germanium sensors
Neuromorphic, event-based imaging

VCSEL PERFORMANCE

OPTICS REVOLUTION

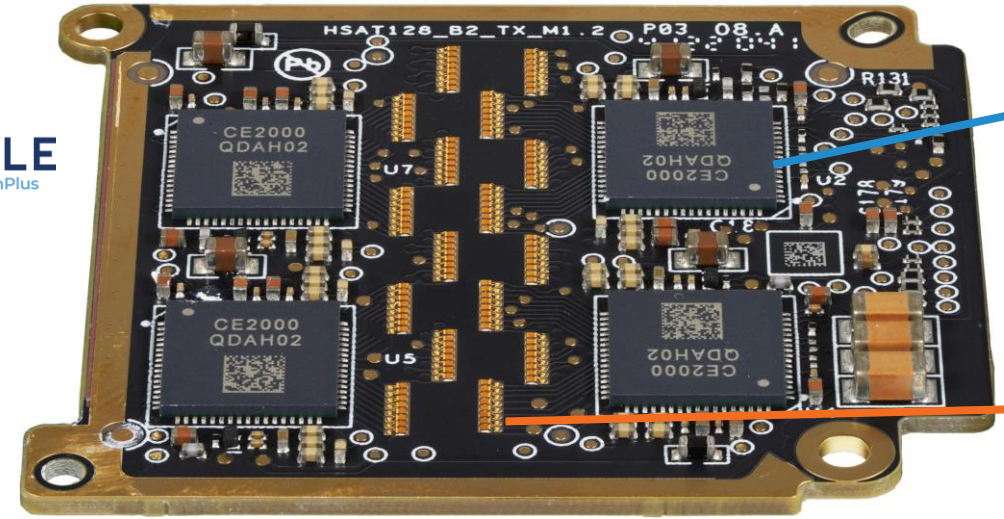
CAMERA TECHNOLOGY

SENSOR PERFORMANCE

IMAGING TECHNOLOGY

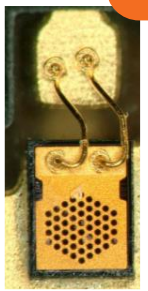
NEW CIS TECHNOLOGIES

Multi-junction VCSEL: Hesai AT128 LiDAR



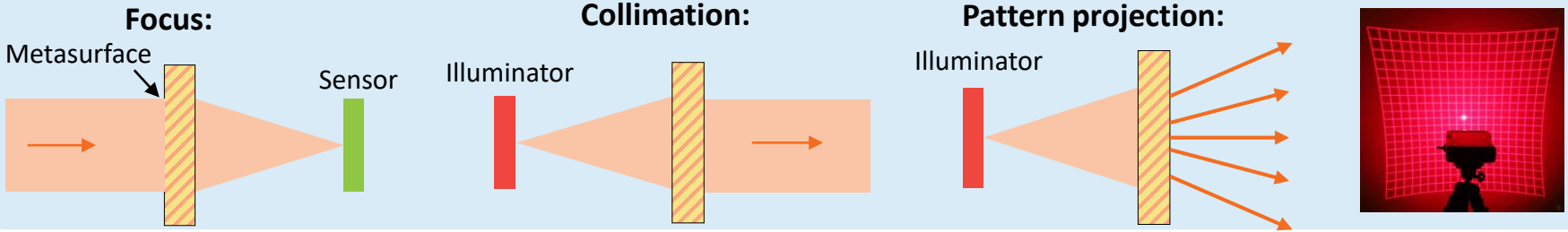
Eight ASICs designed by Hesai, to drive the different VCSEL arrays.

128-VCSELs implemented for the light emission.

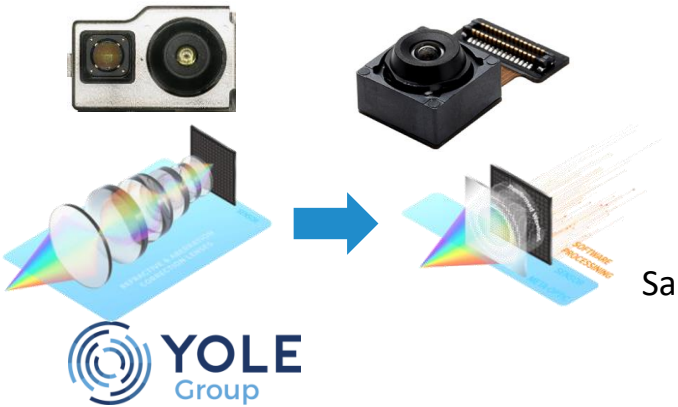


- Multi-junction technology provides enough optical power to replace EELs. Each VCSEL is 0.19mm² with an optical peak power of 70W, using five junction layers to increase the optical power while limiting the die size.

Optical metasurfaces coming to consumer products



Reduce camera or illuminator size and cost:

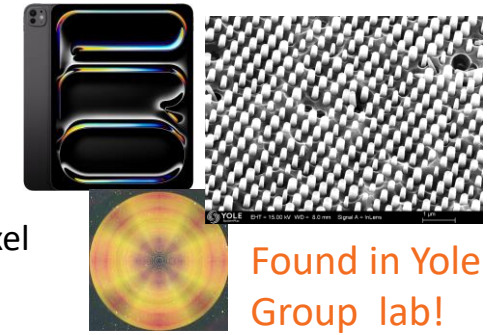


2023 2024 2025

Samsung S23 & S24 Ultra

Google Pixel 8 Pro

Apple iPad Pro M4
Face ID illuminator

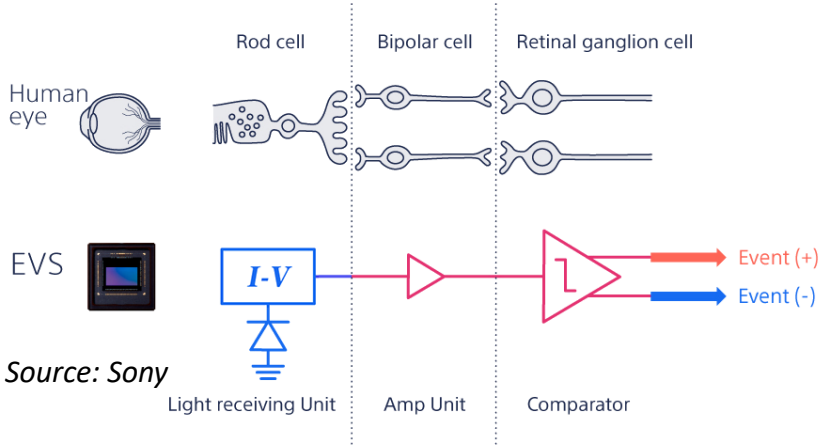


Found in Yole Group lab!

Biometrics modules (under-display)?

A $2.9B neuromorphic market by 2034

Mimicking the human retina:



Source: Sony

From: Boxin Shi, Peking University, CVPR 2023

- Minimal data loading
- Lower power
- Lower latency
- Higher sensitivity

and intra-scene dynamics

>2020 Machine vision

>2025 Smartphone

>2026 Security camera

>2027 Extended reality

>2028 Automotive

Emerging to compete with traditional 3D sensing

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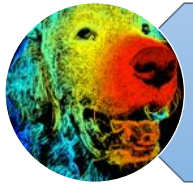
	Application scope	Principle	Advantages	Involved players
 From Airy3D **Single depth cameras optics**	PEOPLE MONITORING ENVIRONEMENT TRACKING MEDICAL DIAGNOSIS	Enhances standard 2D cameras with depth-sensing optics	• Lower cost • Lower power • No short-range occlusions	AIRY3D photonicSENS PxE
 From Metalenz **Polarization sensing metasurface**	BIOMETRICS PEOPLE MONITORING	Metasurface to capture light polarization and detects face and skin	• More compact • Lower cost • Under-display compatibility	metalenz SAMSUNG
 From Opteran **Neuromorphic intelligence**	NAVIGATION PEOPLE MONITORING	Mimics biological neural networks for real-time, low-power 3D perception	• Lower cost • Edge AI oriented • Camera hardware-agnostic	Opteran oculi Institute of Semiconductors CAS

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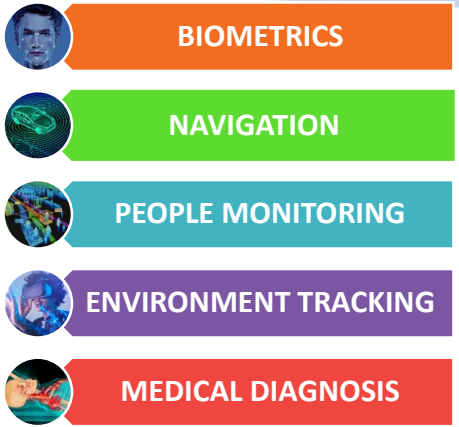
3D sensing market forecast

2020-2030 3D sensing market forecast



Conclusion

From Face ID to LiDAR, 3D sensing is expanding across biometrics, navigation and tracking applications

- **Market**
  - 3D sensing, projected to reach $17.6B by 2030, grows in security, robotics, XR, and media.
  - Smartphones like Face ID lead, with strong growth in industrial and automotive sectors.
- **Ecosystem**
  - LG Innotek, STMicroelectronics, and Sony dominate consumer; Trimble, Hexagon AB, and Sick AG lead industrial; Hesai, Robosense, and Huawei top automotive LiDAR, with myriad of challengers.
- **Technology**
  - Time-of-Flight rises for navigation, structured light stays key for biometrics.
  - Semiconductor + Photonics + AI enhance 3D sensing technology.

Resources

- **Yole Group reports:**

3D Sensing 2025: https://www.yolegroup.com/product/report/3d-imaging-and-sensing-2025/

Apple Face ID Comparison – Including Metasurface: https://www.yolegroup.com/product/report/apple-face-id-comparison-2025---including-metasurface/

Apple Vision Pro 3D Cameras Comparison 2024: https://www.yolegroup.com/product/report/apple-vision-pro-3d-cameras-comparison-2024/

- **Edge AI and Vision Alliance:**

Webinar on CMOS image sensors: https://www.edge-ai-vision.com/2024/10/free-webinar-explores-cmos-image-sensor-trends-and-applications/

2025 Embedded Vision Summit

“Technology and Market Trends in CMOS Image Sensors” (Interview)

Florian Domengie, Shung Chieh - Thursday, 2:40PM