



# 3D Sensing: Market and Industry Update

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# Introduction

# 3D sensing technologies

## Single-frame 3D

### Structured Light



*Courtesy of  
Orbbec*

### Time-of-Flight



*Courtesy of  
Apple*

### Stereo Vision



*Courtesy of  
Stereo Labs*

### Interferometric (OCT)



*Courtesy of  
Hellotis*

### Laser Triangulation



*Courtesy of  
Keyence*

### Plenoptic



*Courtesy of  
Raytrix*

### Computational



*Courtesy of  
Light*

## Multiple-frame 3D

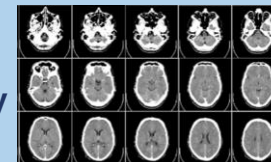
### Structure from Motion



### Time-gated



### Computed Tomography




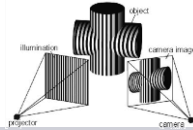

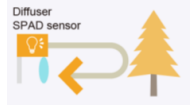

# Focus on high volume technologies



## Stereo vision

## Structured light

## Time-of-flight

	Stereo vision	Structured light	Time-of-flight
<b>Image resolution</b>	Several MP	Max. 1-3 MP	Max. 1 MP
<b>Depth range</b>	Limited (up to 20m for drone)	Shorter (<1-2m)	Higher (up to 8m)
<b>Hardware</b>	Simple cameras; Complex system	Demanding illumination; Complex system	Simple illumination; Complex sensors
<b>Computational power</b>	High	Medium	Low
<b>Limitations</b>	May require illumination in low light, good for outdoor	Best indoors Need power	Best indoors Low resolution
<b>Picture (example)</b>		  <i>Courtesy of Apple</i>	  <i>Courtesy of LGIT</i>
<b>Best suited for</b>	Robotic & drone navigation	Short-range face recognition	3D mapping

### Players (non-exhaustive)



>99% of the 3D imaging and sensing market volume in 2022

# Applications and market trends

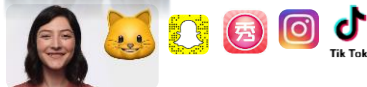
# Mobile 3D camera applications

## Use-cases and opportunities for the **front** 3D camera

Easy unlocking



Morphing  
Augmented reality



Payment  
Facial recognition



Gaming  
Avatar



Enhanced video call



Thanks to Apple, face ID is the unbeatable unlocking experience.

Holographic displays



## Use-cases and opportunities for the **rear** 3D camera

Better photography



Augmented reality



Gaming



Daily life



3D Picture

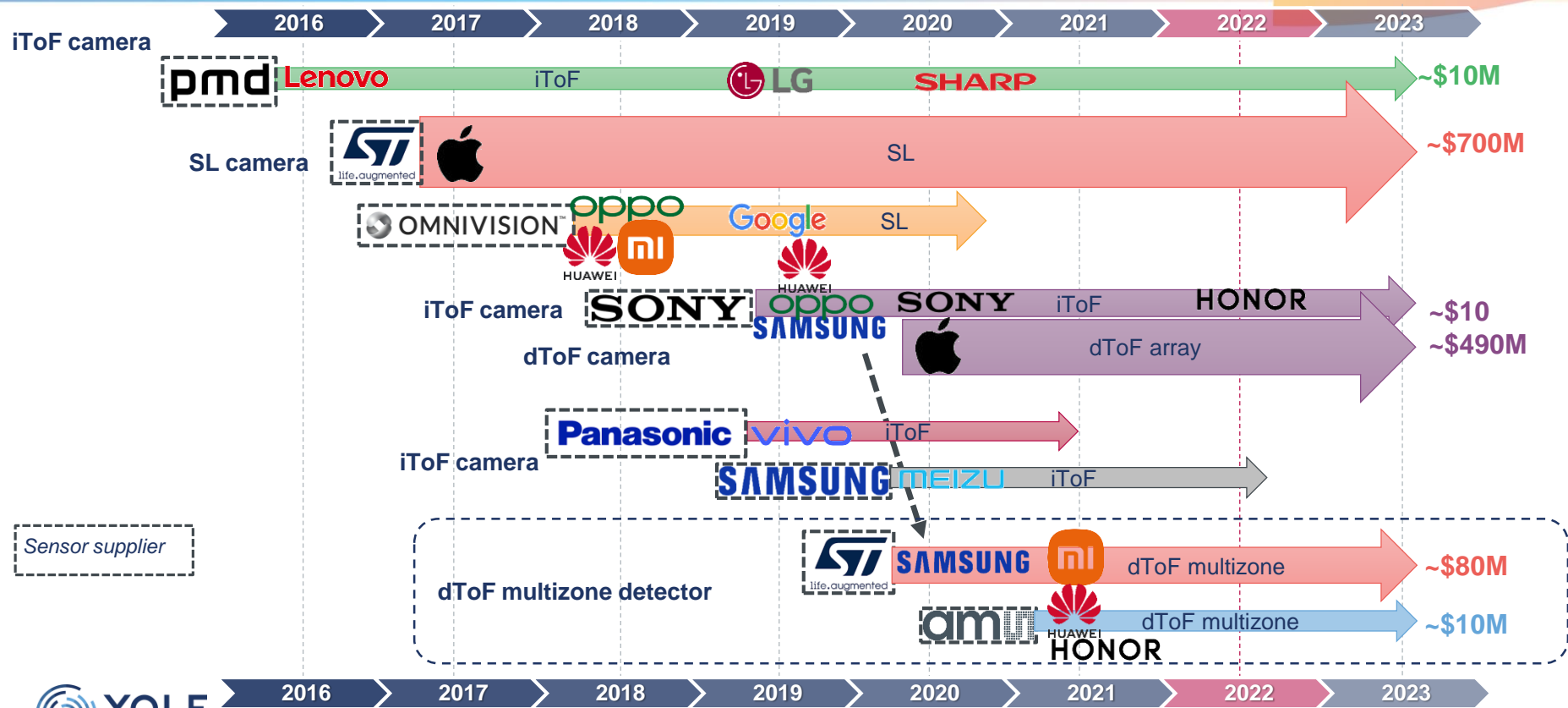


Market had a good start with Huawei, but now is led by Apple. We expect novel AR applications next.

Others?



# A brief history of 3D sensing design-wins in mobile – sensor level





# 3D sensing spreading into home appliances



Smart TV

- Facial detection
- Gesture interaction



Smart door-lock

- Facial recognition
- Replacing physical keys



Robot cleaners

3D cameras enable facial recognition, gesture interaction, and detecting behavior or body movement, which has the potential to make home appliances intelligent.



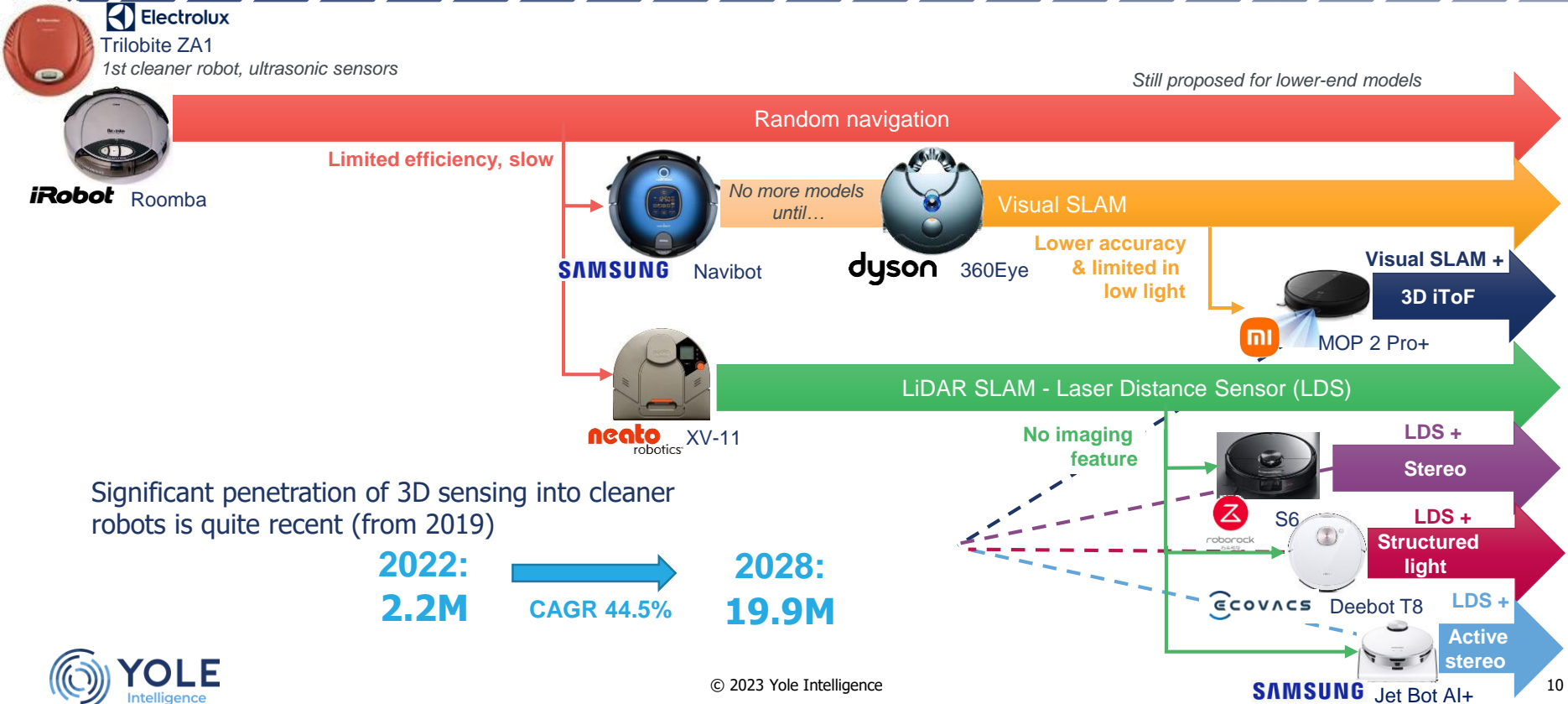
Smart fitness

**TEMPO**

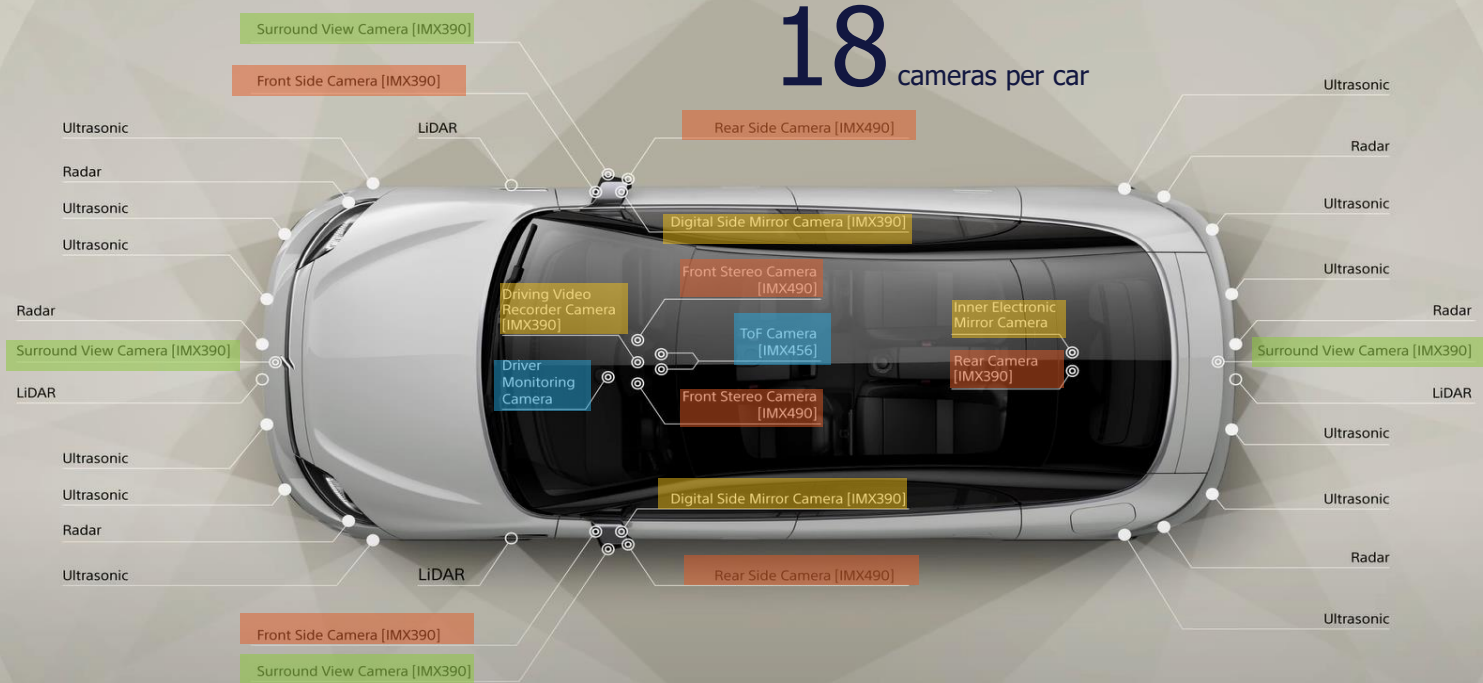
- Fitness guide
- Personal training

# Vacuum cleaner robots: from random navigation to 3D sensing

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023



# Going beyond the eight cameras per car benchmark



courtesy of Sony

**40**  
sensors

- ⊙ Camera / ToF : 18
- Radar / Ultra Sonic : 18
- LiDAR : 4

- x7 ADAS cameras
- x4 surround cameras
- x4 eMirrors & recorder
- x 3 DMS & ToF

• A rationale for 18 cameras per car has emerged.

# Driver monitoring – Use cases vs. technologies

Complexity  
Computing power



- Position on seat
- Face recognition (high level)
- Smart airbag deployment

**3D imaging** is needed in order to obtain accurate depth estimation. This increases system complexity.

- Head orientation
- Head position
- Eye direction monitoring
- Seatbelt detection
- Object detection
- Hands position on wheel
- Face recognition (low level)
- Eye position (for HUD and/or mirror adjustment)

**2D NIR or RGBIR image sensor** can be used. More complexity at the software level.

- Drowsiness detection
- Distraction detection

**2D NIR image sensor** is good enough to comply with regulation.

# New opportunities for 3D sensing in automotive



NIR 3D sensing system

Touchscreen

Exterior access  
Source: Cadillac



LiDAR system  
Source: Valeo

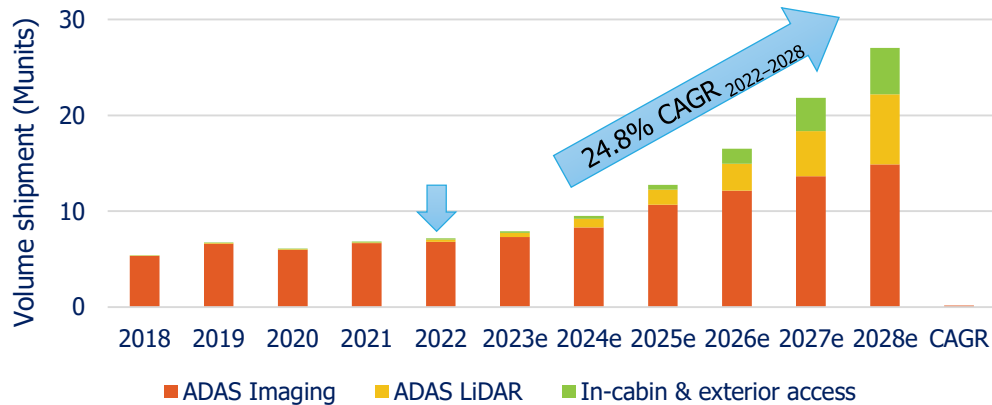


Occupancy monitoring system  
Source: EyeSight



ADAS stereo camera  
Source: Ricoh

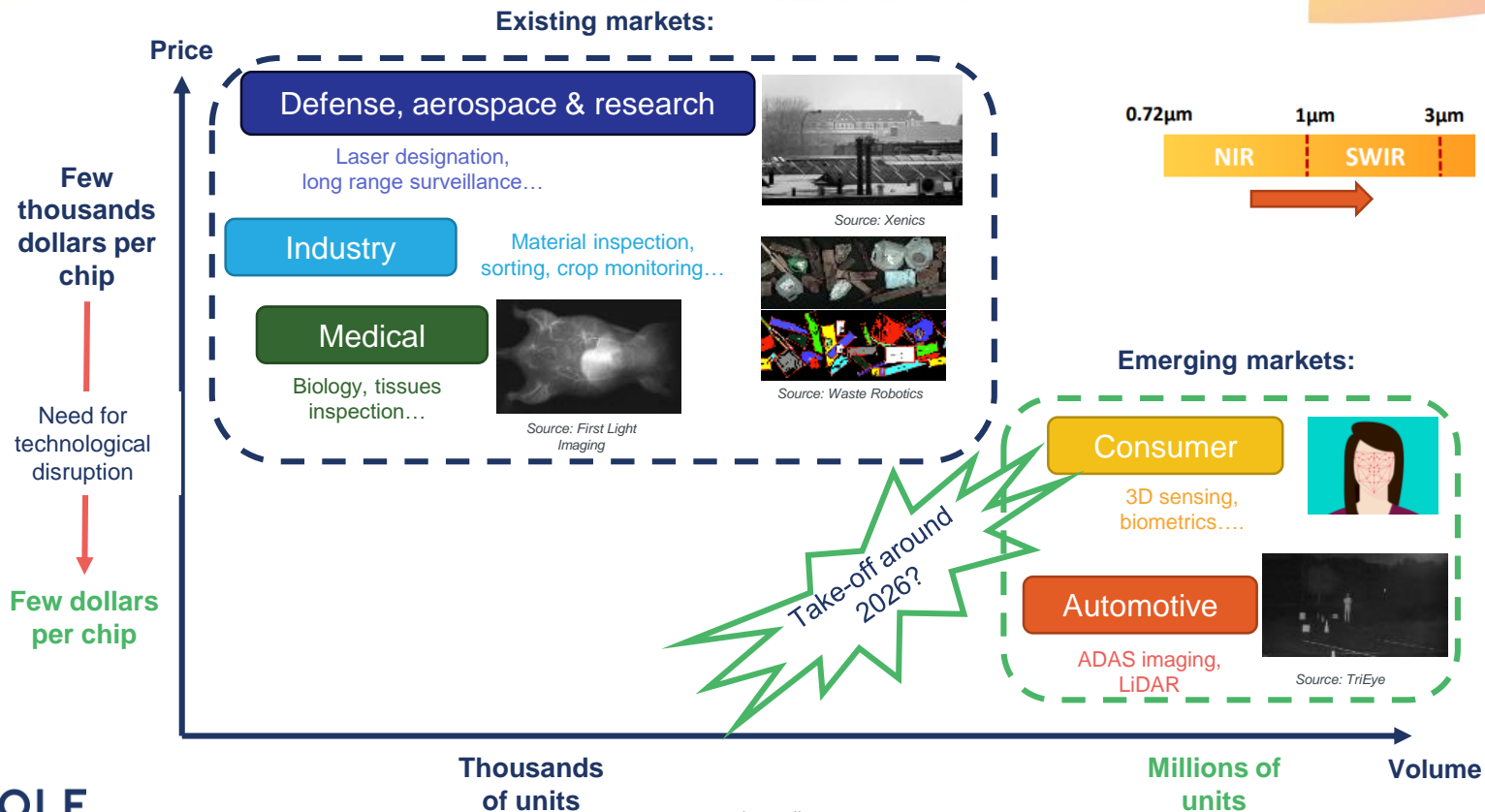
## 2018-2028 Automotive 3D camera market forecast (in Munits)



- We expect 27 million automotive 3D cameras to be shipped in 2028, including more than 7 Munits for LiDAR and nearly 5 Munits for in-cabin and exterior access applications.

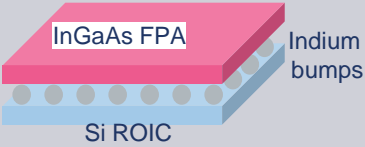
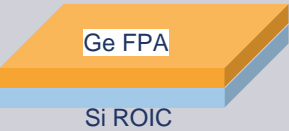

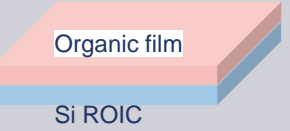
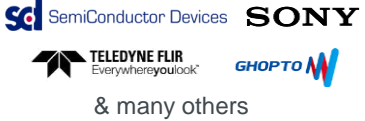



# Technology trends

# SWIR 3D sensing in consumer and automotive



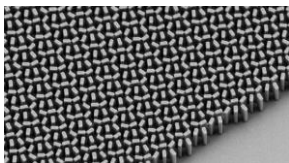


# SWIR imager manufacturers synthesis

Technology	InGaAs	Ge-on-Si	Quantum dots	Organic photodiodes
<b>Visual</b>	 <p>InGaAs FPA Indium bumps Si ROIC</p>	 <p>Ge FPA Si ROIC</p>	 <p>QD film Si ROIC</p>	 <p>Organic film Si ROIC</p>
<b>Manufacturing</b>	InGaAs is grown on InP wafers, focal plane array is bonded to the Si ROIC thanks to Indium bumps at chip level.	Ge is grown on 8 or 12-inch Si wafer. It uses standard CMOS image sensors process.	Quantum dots (nanoparticles of PbS or InAs) are trapped in polymer ligands, film can be spin coated directly on the Si ROIC wafer.	The organic film is composed of several organic materials. Manufacturing is similar to quantum dots.
<b>Maturity</b>	++++	++	++	+
<b>Price</b>	\$1,000 – \$10,000	Target: \$1-\$100	Target: \$1-\$100	Target: \$1-\$100
<b>Weaknesses</b>	Price	Image quality (elevated dark current)	Robustness, response time of the material	Robustness, response time of the material
<b>Players</b>	 <p>SemiConductor Devices SONY TELEDYNE FLIR Everywherelook™ GHPTO &amp; many others</p>	 <p>R&amp;D ARTILUX Stratio.Inc. R&amp;D TRIEYE (Yole's assumption)</p>	 <p>life.ougmented R&amp;D qury R&amp;D</p>	 <p>EMBERION isorg R&amp;D SAMSUNG R&amp;D</p>

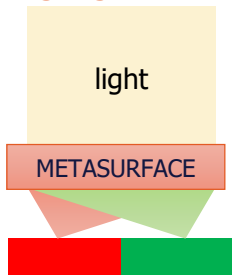


# Metasurfaces: the ultimate evolution of flat optics



Source: Capasso group, Harvard university

## INCREASE SENSOR SENSITIVITY



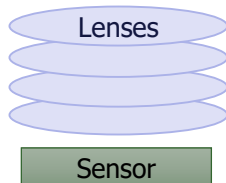
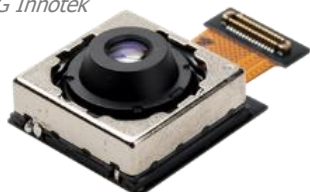
## BEAM STEERING

Source: Lumotive

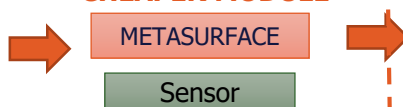


## Color camera module

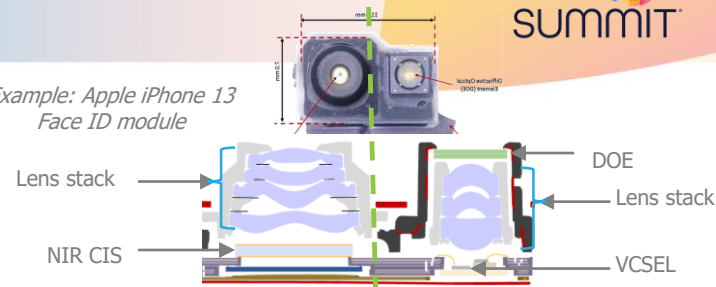
Source: LG Innotek



## THINNER, CHEAPER MODULE

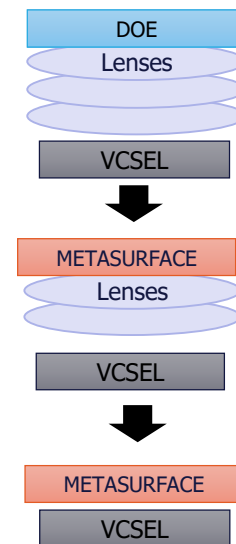
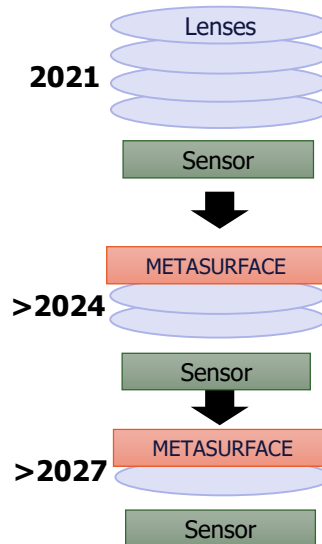


Example: Apple iPhone 13 Face ID module



## Camera module

## Dot projector

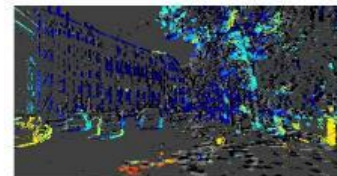


Active companies:  
(non-exhaustive)



# Event-based imaging for 3D sensing

- Event-based sensors use a neuromorphic and asynchronous structure: speed not limited by frame rate, minimal data loading, lower power, better latency, speed, sensitivity, intra-scene dynamics.
- Current applications include machine vision industrial cameras. Further applications are being demonstrated, as mobile live deblurring and 3D sensing (laser triangulation, structured light, stereo...).



Source:  
Prophesee



**SAMSUNG**

PROPHESÉE  
METAVISION FOR MACHINES



**SONY**



## Application examples in 3D sensing:



**Industrial inspection**

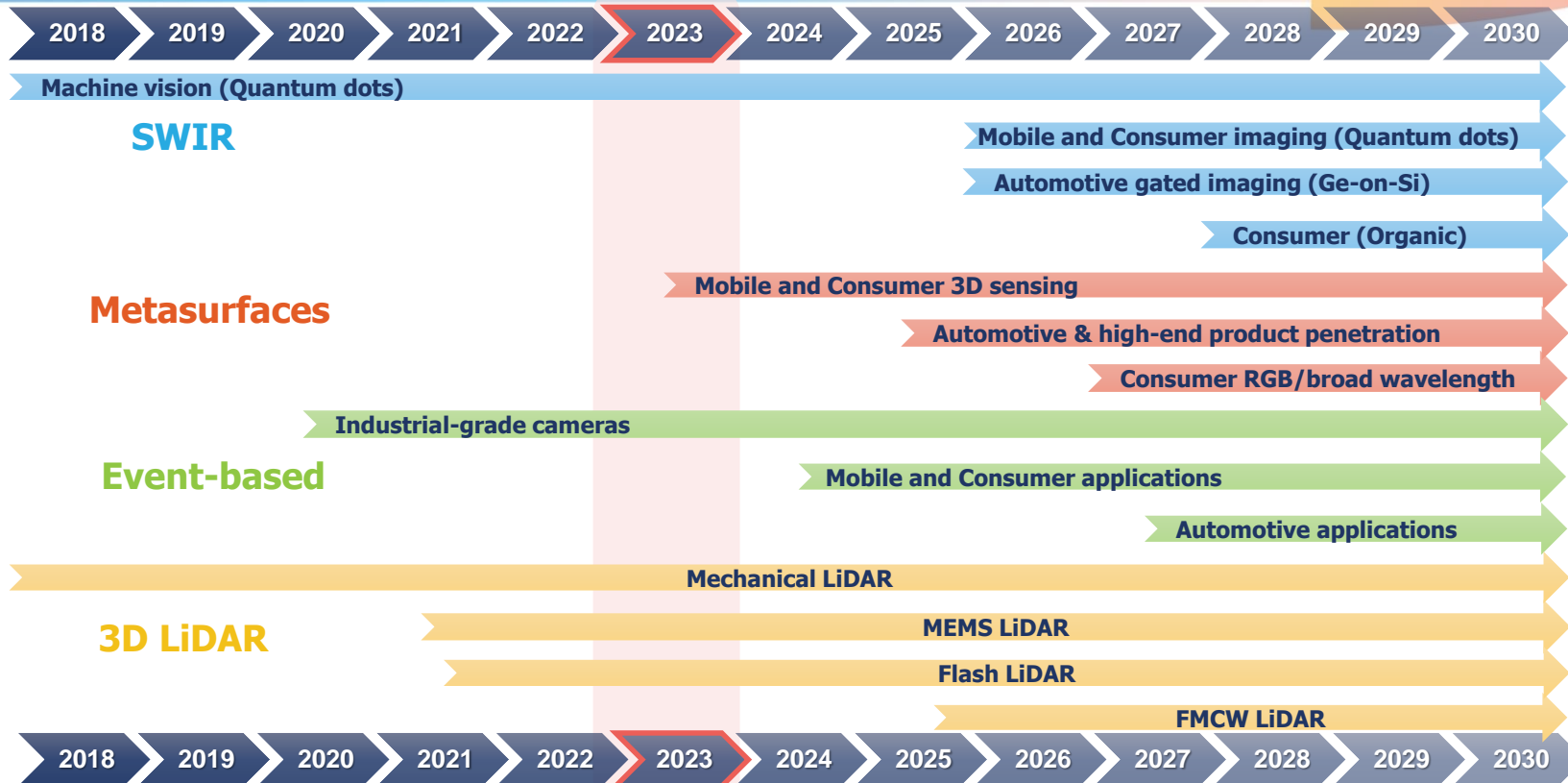
**Hand tracking**

**Environment reconstruction**

**SLAM**

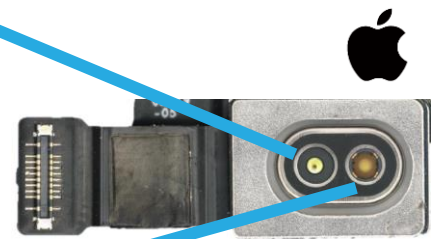
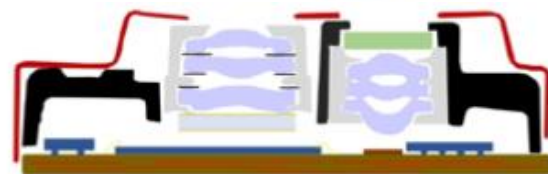
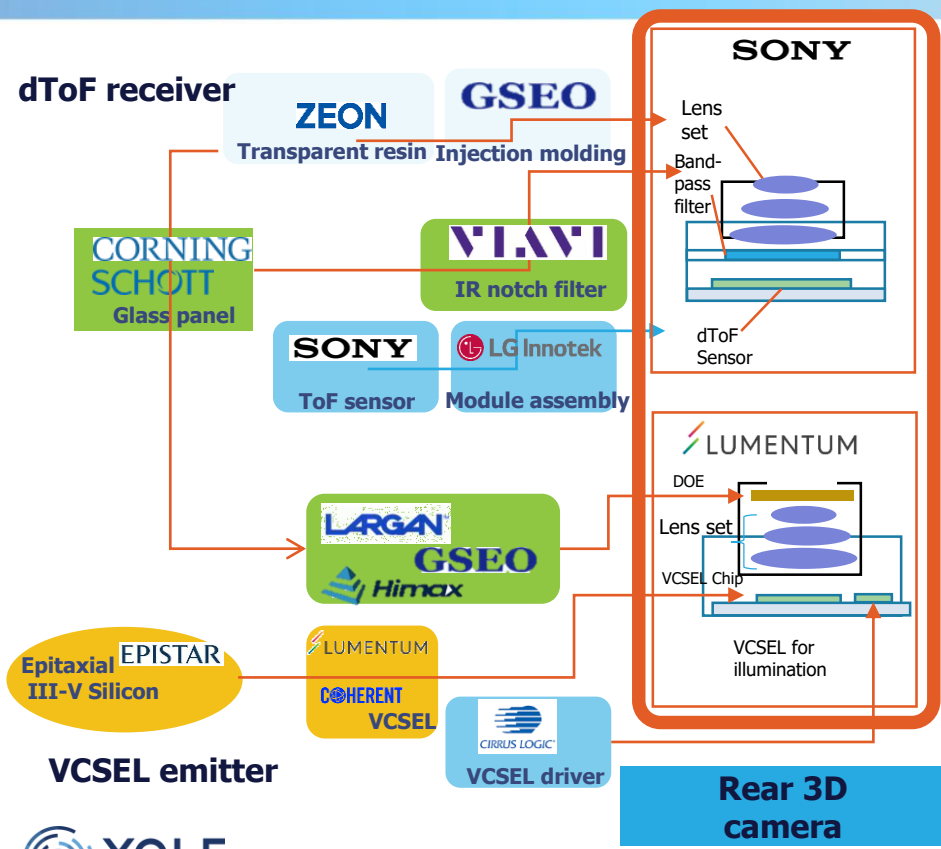


# A roadmap proposal for emerging technologies



# Industry and supply chain

# Supply chain for rear 3D camera iPhone Pro "LiDAR"



**Estimated  
ASP: \$12**

Courtesy of LG Innotek

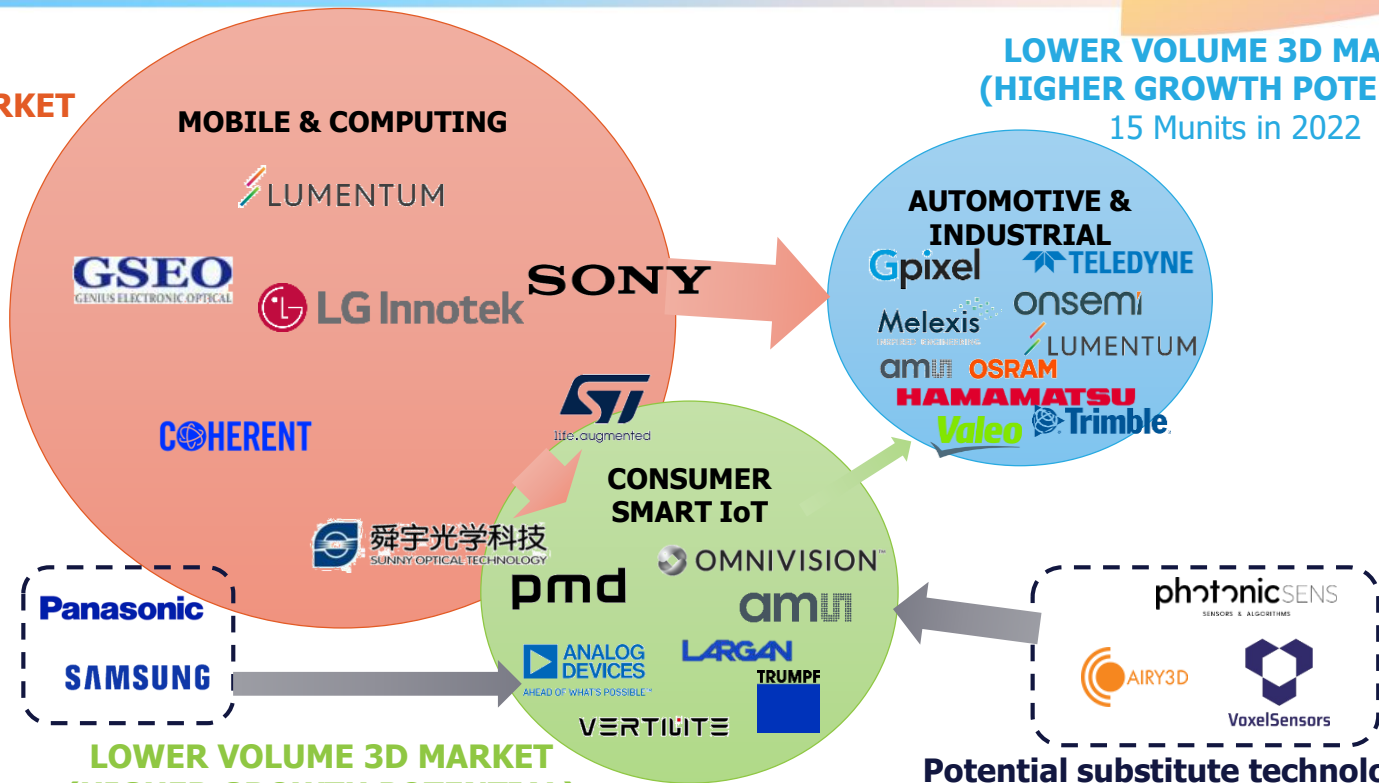
- SPAD array sensors, for direct time-of-flight technology, have superior range and accuracy vs. indirect time-of-flight (used in Android phones), but the module is about 30% more expensive.

# Supply chain dynamics between different markets

**HIGH VOLUME 3D MARKET  
(ESTABLISHED)**  
371 Munits in 2022

**LOWER VOLUME 3D MARKET  
(HIGHER GROWTH POTENTIAL)**  
15 Munits in 2022

*Non-exhaustive list  
of players*



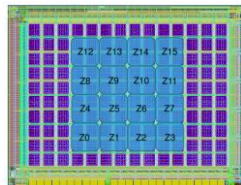
**Past suppliers  
coming back?\***

*\*Had supplied mobile  
iToF products*

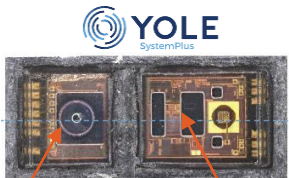
**Potential substitute technologies  
(non-exhaustive)**

**LOWER VOLUME 3D MARKET  
(HIGHER GROWTH POTENTIAL)**  
23 Munits in 2022

# Time of Flight (ToF) sensor ecosystem

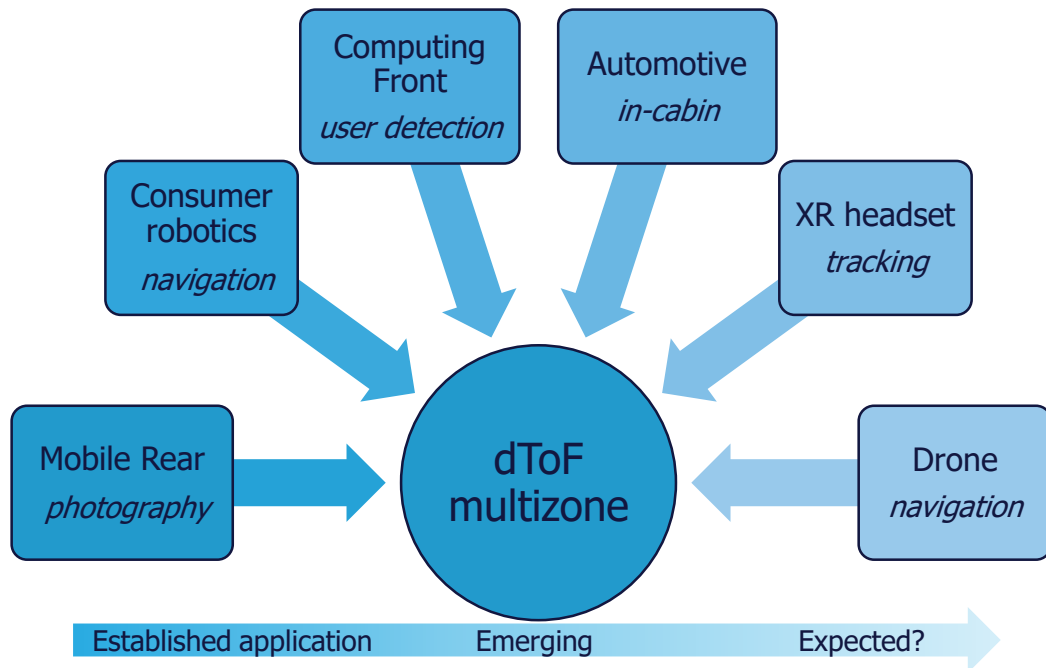


Example of 4x4 zones configuration  
Source: STMicroelectronics



Receiving dToF SPAD array      Emitting VCSEL

Samsung S22 Ultra  
dToF Autofocus

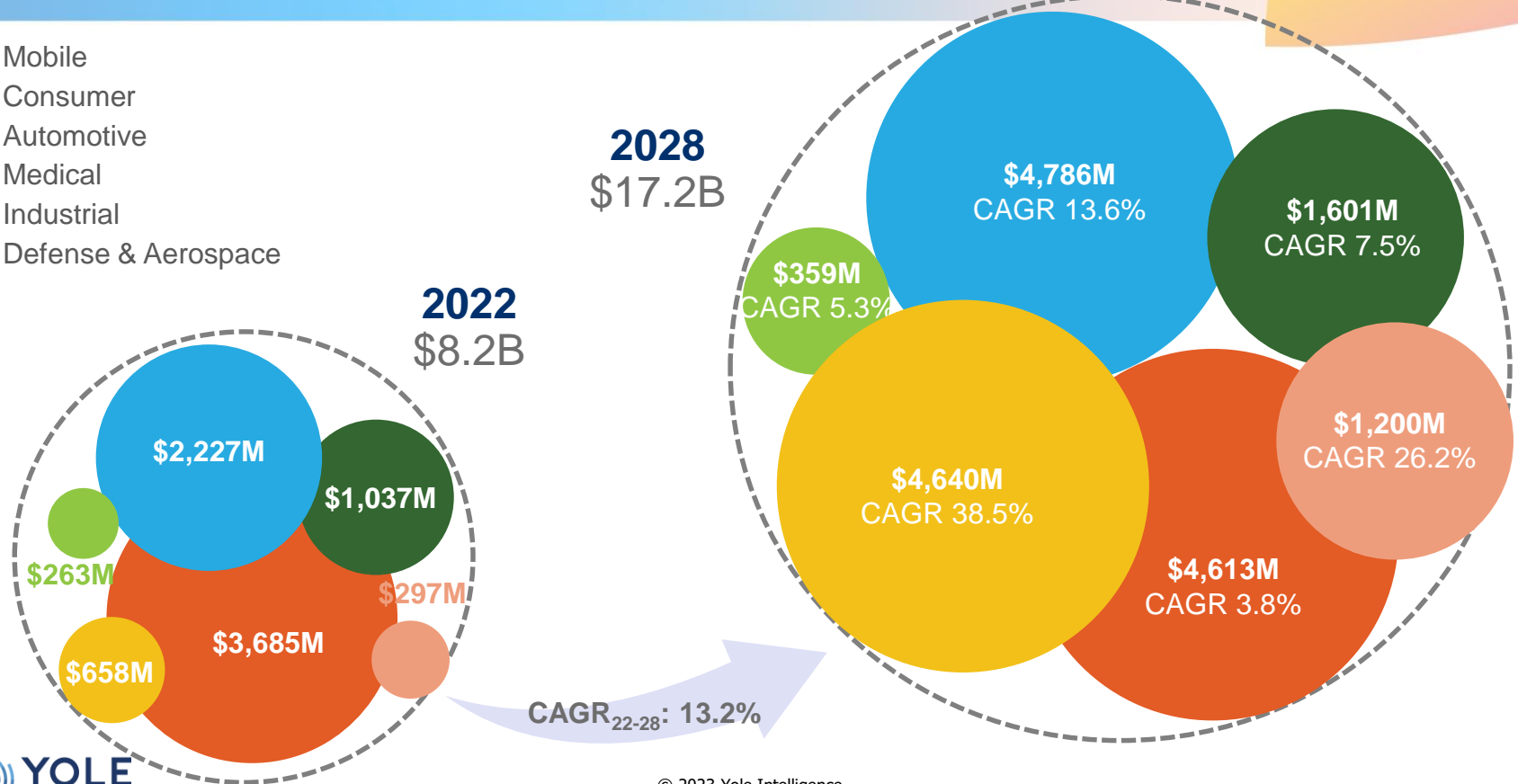


# 3D sensing market forecasts



# 3D imaging and sensing market forecast

- Mobile
- Consumer
- Automotive
- Medical
- Industrial
- Defense & Aerospace



# Conclusion and outlook

- After reaching \$8.2B in 2022, the 3D imaging and sensing market is expected to more than double by 2028, to reach \$17.2B.
  - 409 million units were shipped, the majority of which were for the mobile market (>88%).
- Beyond mobile, 3D sensing is expanding to the other markets: consumer, automotive, medical, industrial, defense and aerospace.
- ToF technologies, both indirect and direct, are expected to expand further and represent 66% of 3D sensing revenues by 2028.
- Intense research and development to unlock new opportunities:
  - Smaller pixels, in pixel hybrid stacking, SWIR, FMCW LiDARs, metasurfaces, event-based sensing, single-camera technologies,...

## Yole Group resources

3D Imaging and Sensing 2023

<https://www.yolegroup.com/product/report/3d-imaging--sensing-2023/>

SWIR Imaging 2023

<https://www.yolegroup.com/product/report/swir-imaging-2023/>

Status of CMOS Image Sensor Industry 2022

<https://www.yolegroup.com/product/report/status-of-cis-industry-2022/>

Yole Group other related products

<https://www.yolegroup.com/products>



## 2023 Embedded Vision Summit

“LiDAR Technologies and Markets: What’s Changing?” (Talk)

Business Insights, Wednesday, 11:25 am