

How 3D Time-of-Flight enable differentiating features for the smart car

Martin Lass
Head of Time-of-Flight Business

Agenda

1. Introduction – What is 3D Time-of-Flight
2. Incabin Sensing – Motivation, Use-Cases & Technologies
3. Detailed Use-Case Discussion –
   Car Access, Driver Monitoring, Occupant Monitoring, Gestures, Smart Airbag
4. Infineon REAL3™ Product Portfolio & Partner Ecosystem

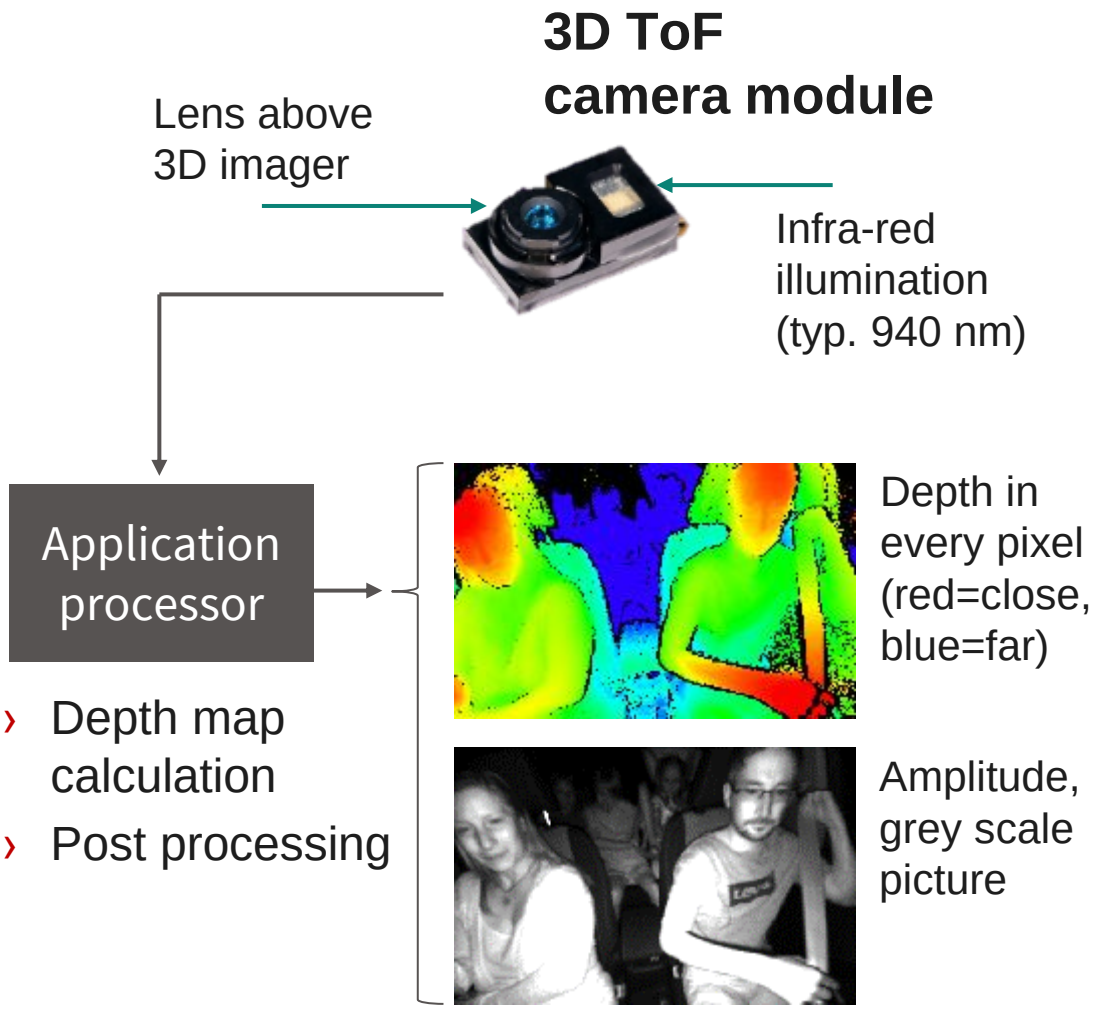
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1

Introduction –
What is 3D Time-of-Flight

3D ToF provides most powerful data of the surrounding

Distance measurement and 2D-IR image simultaneously



Time-of-Flight in a nutshell:

- Camera based technology
- Sending out active infrared light (VCSEL)
- Comparing transmitted with reflected signal
- Depth map is calculated out of the phase shift

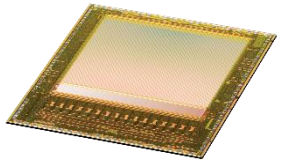
What do I get?

- High resolution depth map of the environment
- Distance information in every pixel and grey scale picture simultaneously
- In darkness and strong sunlight

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REAL3™ Time-of-Flight

Long history of successful product launches in multiple markets



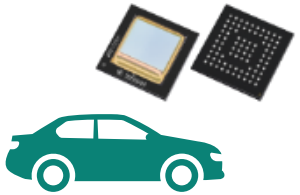
REAL3™ by Infineon



Security



AR



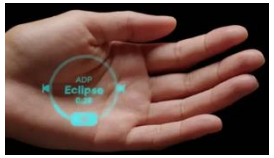
Automotive



Vacuum Cleaner



Smart lock





AI Pin



hToF

2013 — 2015 — 2016 — 2018 — 2020 — 2021 — 2022 — 2023 — 2024

Infineon and **pmd** jointly developing ToF imager since 2013













Smart Phones (rear & front)

>25 million imager sold // 6th generation of pixel design

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Incabin Sensing – Motivation, Use-Cases & Technologies

Market Drivers for Incabin Monitoring Systems (ICMS)

Regulations + High level of automatization + OEM brand differentiation



Meet NCAP rating

Meet regulations

Passenger safety

Increasing level of automatization

Well-being

Seamless connectivity

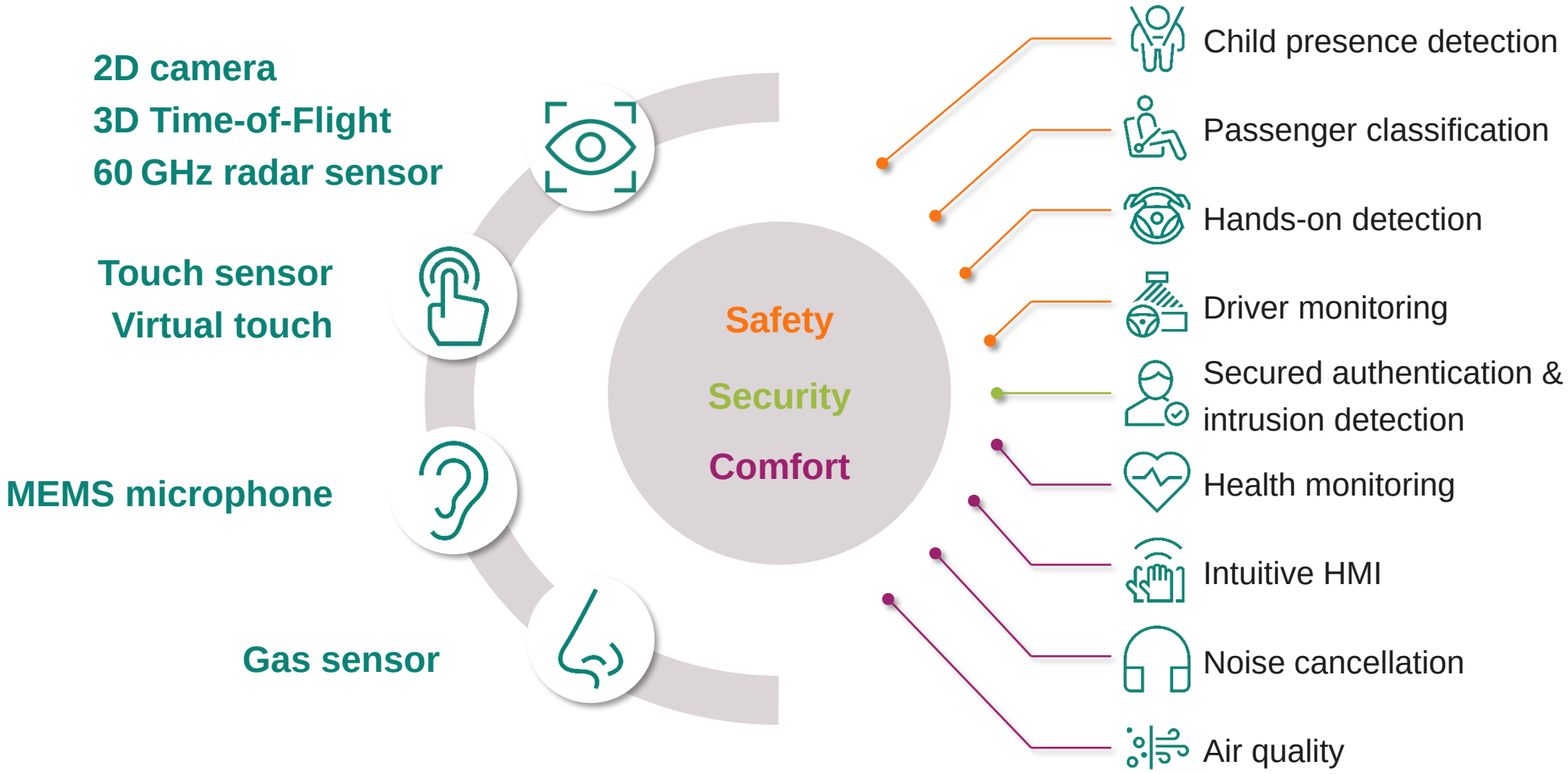
Intuitive interaction

Personalized settings & services

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Sense the car like a human

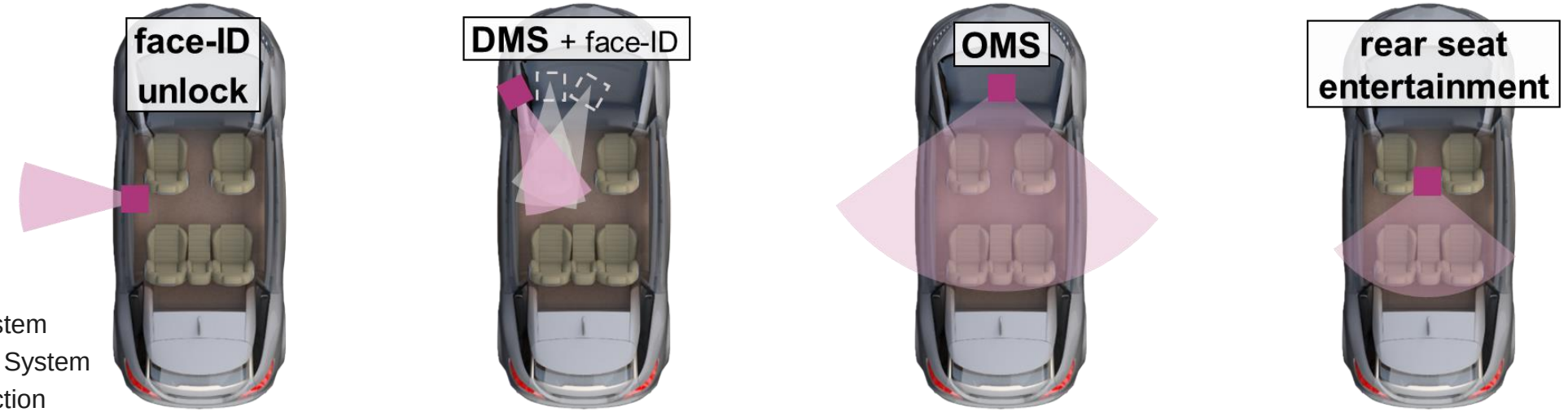
Different sensor technologies to realize different ICMS use-cases



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3D ToF In-cabin monitoring

Favorite camera placements per use-case



DMS: Driver Monitoring System
OMS: Occupant Monitoring System
CPD: Child Presence Detection

	face-ID Car Access	DMS + face-ID	OMS	Rear Seat Entertainment
Camera placement	**B-pillar**	**A-pillar** steering wheel Rear mirror area	**Rear mirror** area **Center console**	At **display** or in **ceiling**
hFoV	40° to 65°	40° to 65°	up to 120°	up to 120°
focus use case	**Face tracking:** Handsfree car access, Personalization	**Face tracking:** 3D face-ID, DMS features, HUD optimization	**Body & hand tracking**: Gestures, Object detection, Smart Airbag, Fusion with 2D (video) and or Radar (CPD)	**Hand & finger tracking:** Gestures for display control/ interaction and more, Supporting CPD

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Detailed Use-Case Discussion

- Car Access by secure face-ID
- Driver Monitoring + secure face-ID
- Occupant Monitoring + gestures
- Occupant Monitoring + smart airbags

Face-ID Car Access

3D data for most robust and secure face authentication



Application benefits

- Handsfree car access
- Personalization is already initiated while entering

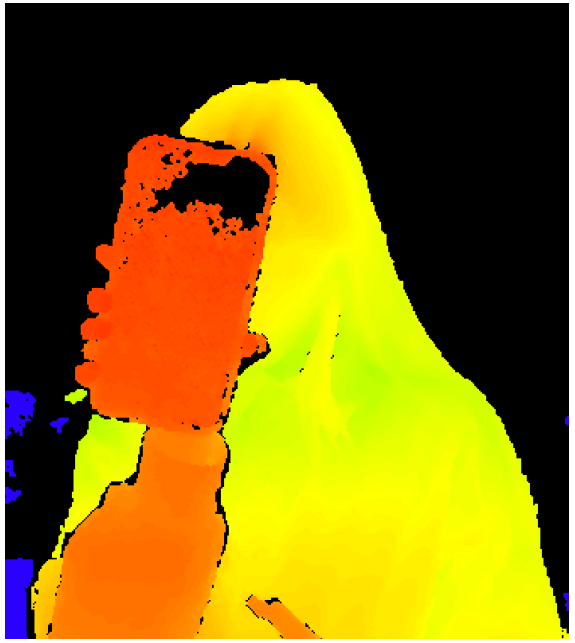
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Face-ID Car Access

Real world 3D ToF data: all data available simultaneously



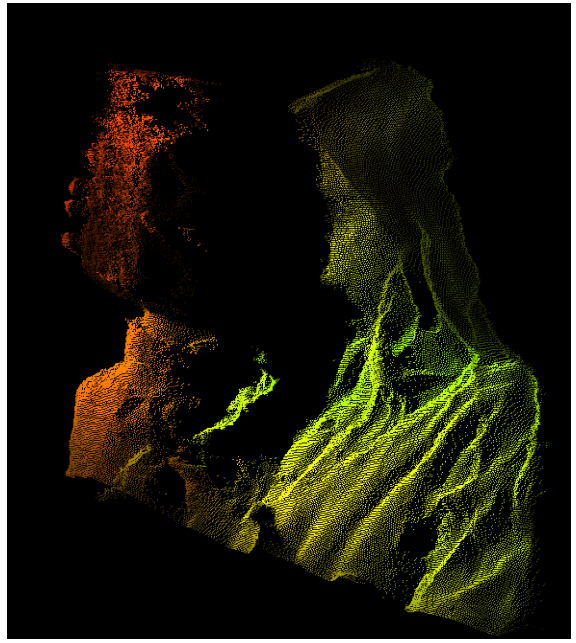
IR amplitude image



depth image



overlay: amplitude + depth



rotated 3D point cloud

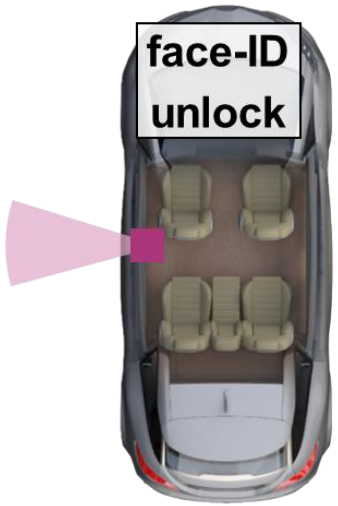
3D ToF benefits

- Absolute sunlight robust IR amplitude image for face identification (based on ToF data, modulated IR light)
- Measured 3D data ensuring anti-spoofing
- 3D ToF meets highest face-ID security standards, e.g. from GooglePay and Alipay

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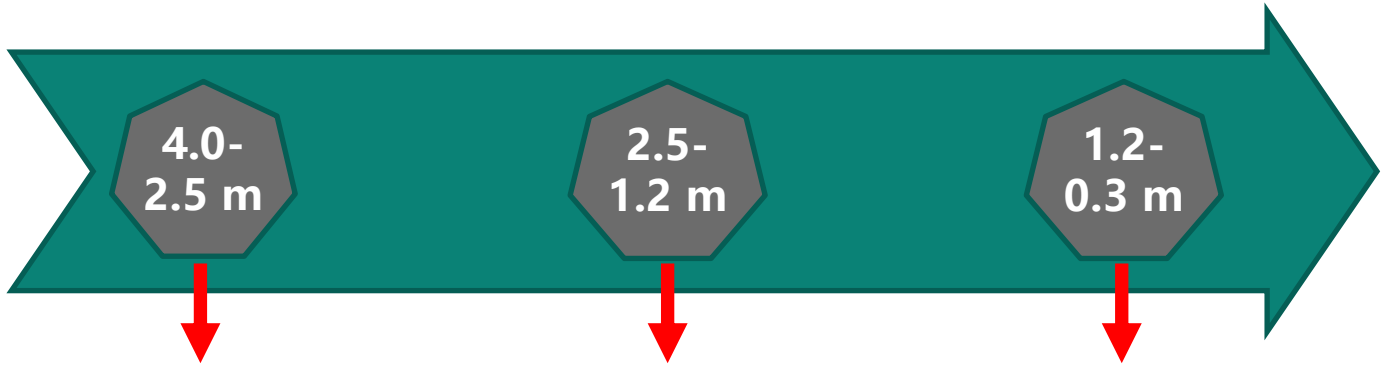
Face-ID Car Access

Solution example by Ofilm



- Direct facing camera
- 40-65° hFoV

- Complete Car Access solution based on REAL3™ ToF imager
- Wake-up based on Radar and low power IR camera



Always on Radar
1) liveness detection
2) Wake up ULPC

ULPC (ultra low power camera)
3) Head posture detection
4) Wake up ToF camera

ToF camera
5) Secure Authentication
6) Unlock

- Door open <1 sec
- Secure and spoofing robust authentication based on ToF camera
  - Fake Accept Rate: FAR < 1/1,000,000
  - False Rejection Rate: FRR < 1%

Solution example



Complete embedded 3D face-ID car access solution example (behind B-pillar glas)

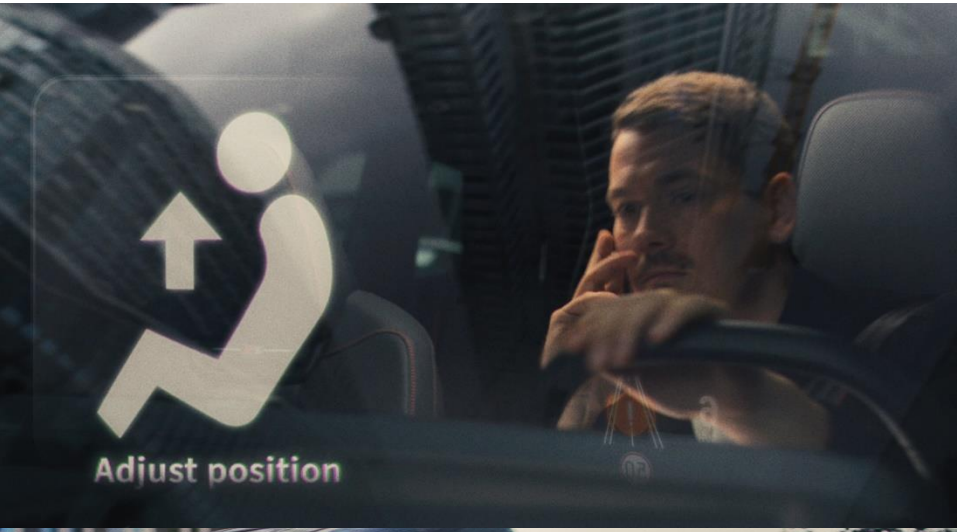
福耀集团 Fuyao Group

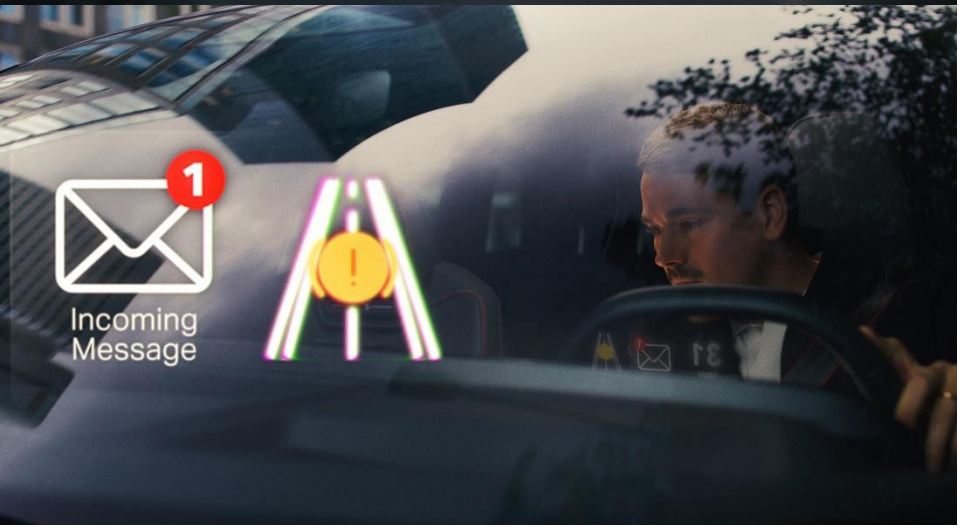
OFILM

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Driver Monitoring (DMS)

One 3D ToF camera for DMS tasks + secure face-ID





Application benefits

- Standard DMS tasks: driver attention/distraction, fatigue detection
  - Head tracking
  - Eye closure detection
  - Gaze area segmentation
- Personalized settings
- Secure face-ID: Seamless connectivity, whenever you need secure authentication
  - Get access to private data & services
  - OEM can offer paid services
- Optimized Head-up display (exact eye-origin known)
- Automated mirror positioning
- Wellbeing & Safety:
  - Automatic head rest adjustment
  - Healthy seating position

3D data

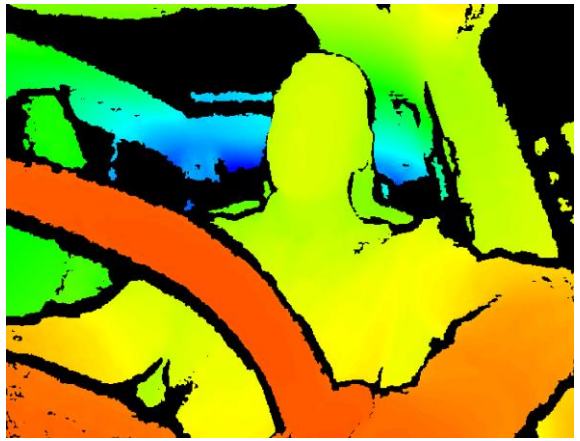
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Driver Monitoring (DMS)

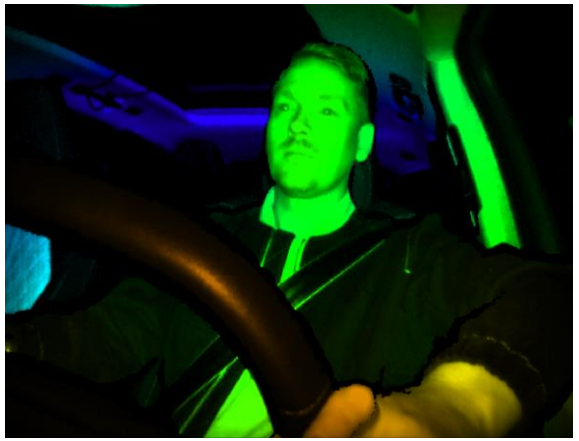
Real world 3D ToF data: all data available simultaneously



IR amplitude image



depth image



overlay: amplitude + depth



rotated 3D point cloud



3D ToF benefits

- Measured 3D data ensuring anti-spoofing
- 3D ToF meets highest face-ID security standards, e.g. from GooglePay and Alipay
- Exact eye position to optimize projections
- One camera for basic DMS features, adding secure face authentication, HUD optimization

Solution examples

AITO

BAIC

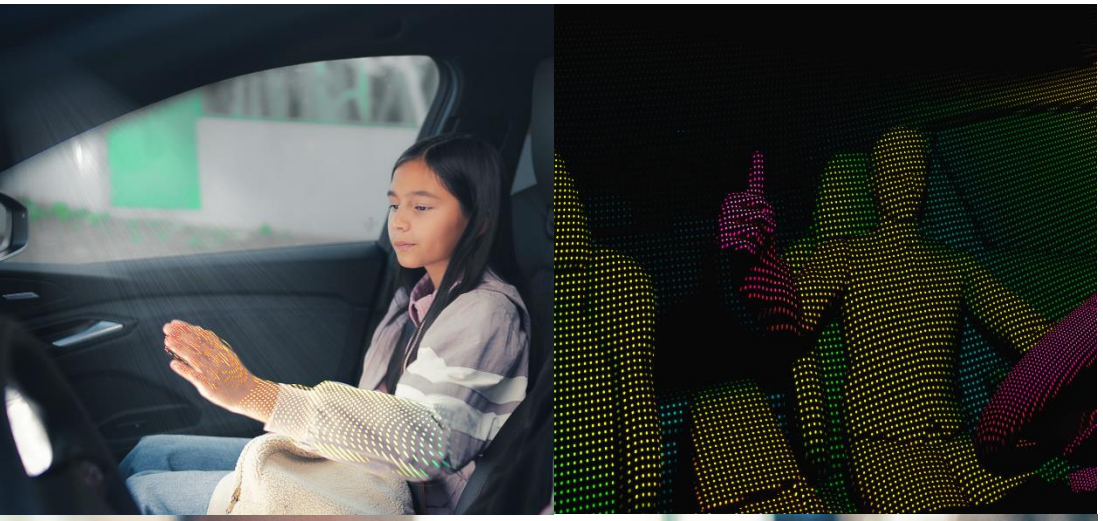
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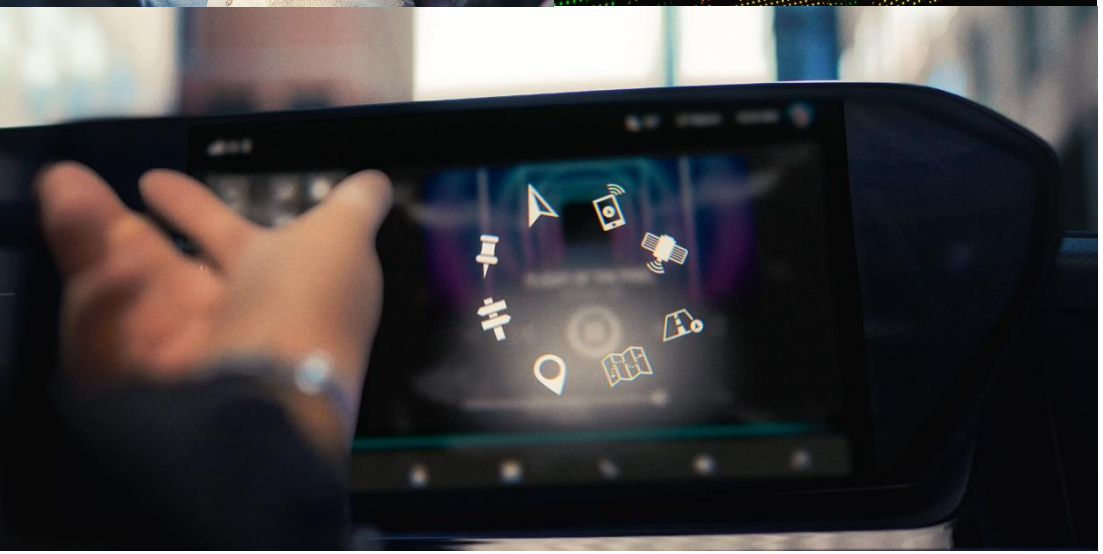


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Occupant Monitoring (OMS) – Gestures

Real time hand & finger tracking for intuitive gesture control

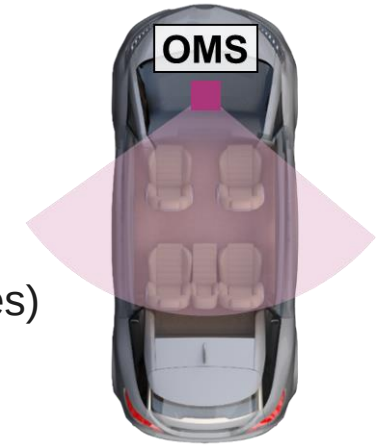




Application benefits

- Intuitive interaction: dynamic & static gesture
  e.g. simple accept/decline, “short cut gesture” with personally assigned function
- Interaction with projections (HUD, smart surfaces)

→ *Gestures for driver must be intuitive in order not to be distractive*



Rear seat entertainment

- Gesture controlled rear seat entertainment screen
- Entertainment: gesture-based video games
- Interior lighting control
- Supporting child presence detection (CPD)



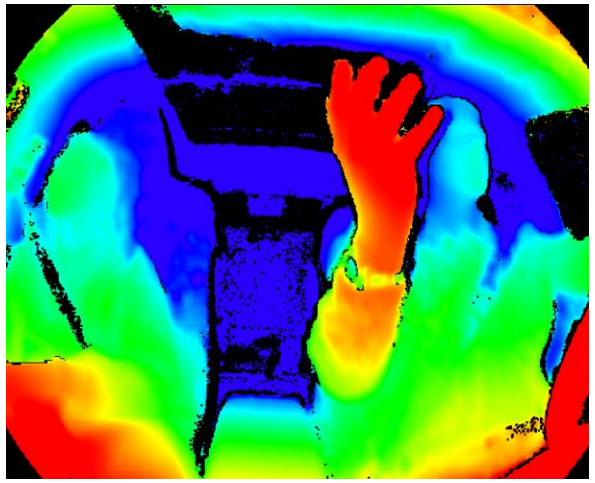
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Occupant Monitoring (OMS) – Gestures

Robust 3D data used by several SW and solution partners



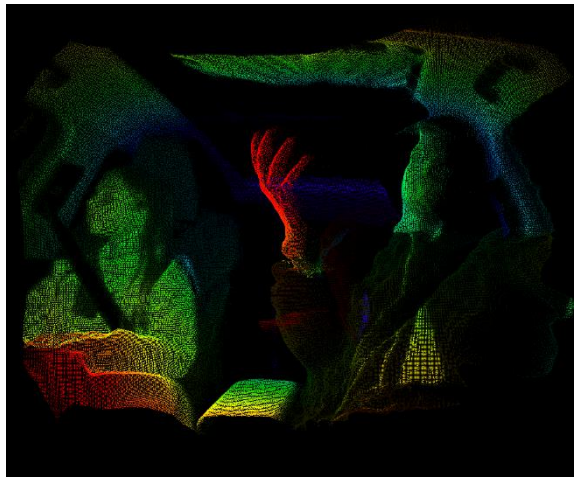
IR amplitude image



depth image



overlay: amplitude + depth



rotated 3D point cloud

3D ToF benefits

- Most accurate hand & finger tracking by measured 3D data in real time // sunlight-robust
- Reduced processing efforts compared to 2D solutions
- Precise static and dynamic gestures
- Gestures as add-on to other OMS use-cases

Solution examples

- REAL3™ ToF based gesture control



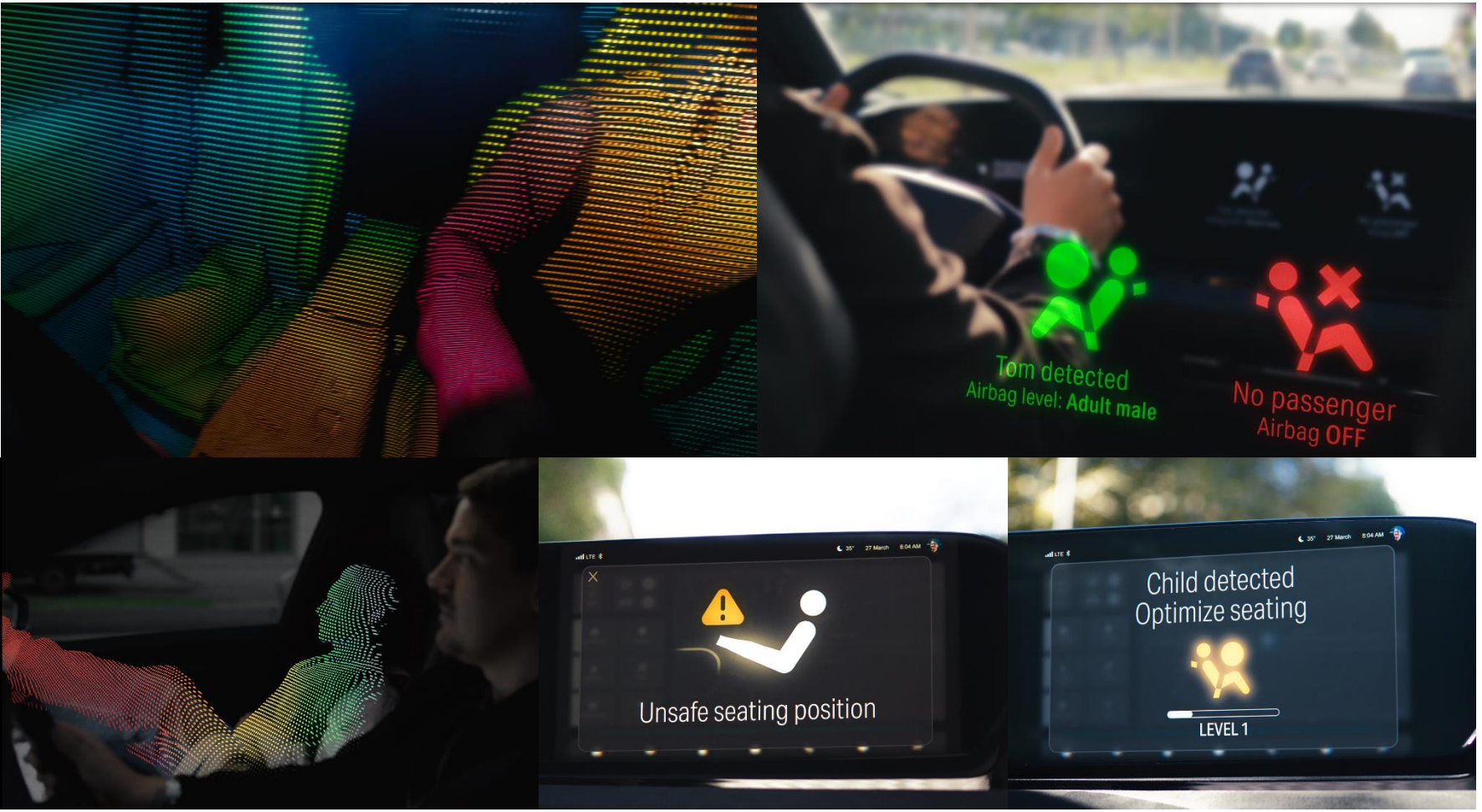
in cooperation with ArcSoft

More solution partner: G-PULSE 金脉 OFILM

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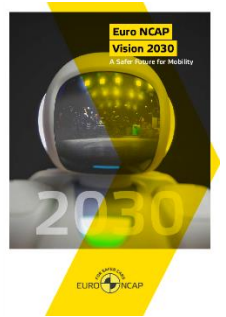
Occupant Monitoring (OMS) – Smart Airbags

3D body model & object classification – in real time



Application benefits

- Automatic airbag switch off
  - Unused seat
  - Rear facing baby seat
  - “feet on dashboard”
- Optimized airbag deployment
  - Depending on passenger and seat positioning

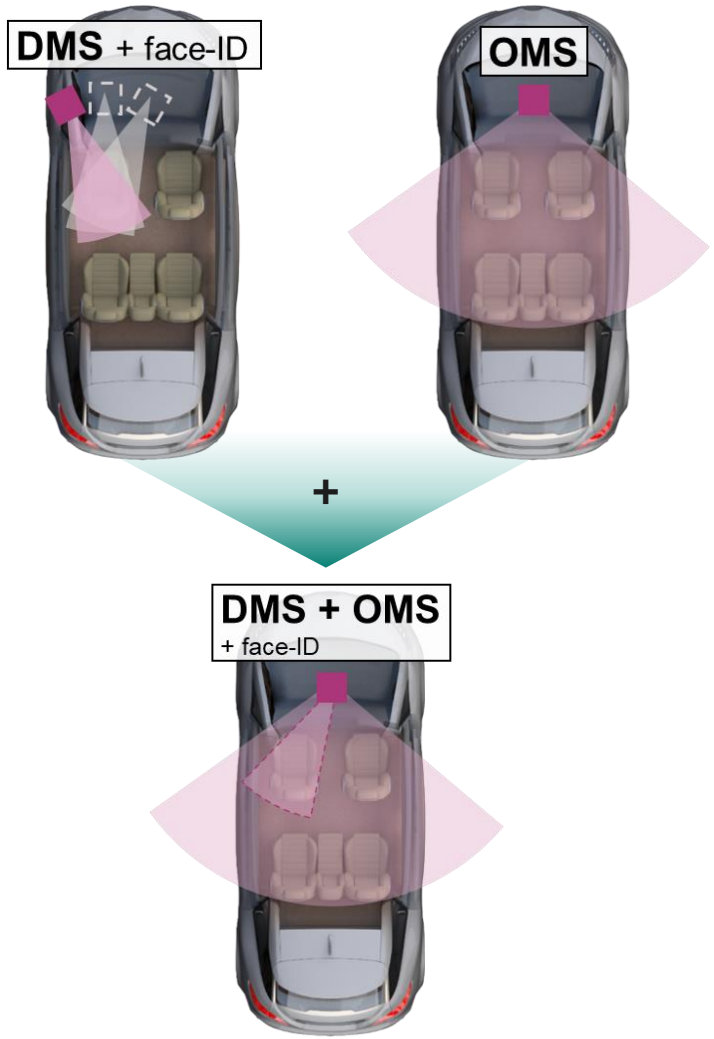


EuroNCAP Vision2030

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In-Cabin Camera solutions

Trend to one central camera combining DMS & OMS



2D camera

Benefits

- High resolution (2-8Mpxl)
- Strong SW ecosystem, availability of AI algorithms

- *Gaze tracking, DMS*
- *wide FoV cameras*
- *Visualization use-cases:*
  e.g video call, cabin picture

Challenges

- SW relies on estimations only, high processing demand to estimate depth

3D ToF

Benefits

- Measured distance data
- 3D body model
- Working in all light conditions

- *Best size & weight estimates*
- *Smart Airbags*
- *Secure authentication*
- *Gestures*

Challenges

- Low 2D resolution (resolution for depth use-cases sufficient)

2D and 3D ToF complement each other

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In-Cabin Camera solutions

Trend to camera fusion of 2D and 3D

2D + 3D fusion (RGB-D camera)



DMS: Driver Monitoring System
OMS: Occupant Monitoring System

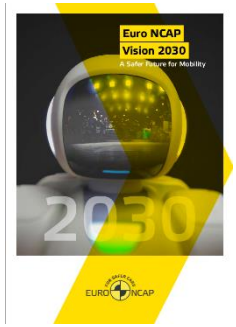
One camera to address wide FoV for combined DMS + OMS features

2-8 Mpxl RGB-NIR imager + VGA ToF imager

Combine high resolution 2D with the value of 3D

3D ToF benefits

- Depth for 3D body model
- Depth for best size & weight estimates
- Depth for real time body & hand tracking
- Depth for verification & robustness of 2D AI algorithms
- Depth for security (e.g. anti spoofing)
- Depth for functional safety features



Meet increasing requirements towards Level3 and Smart Airbags

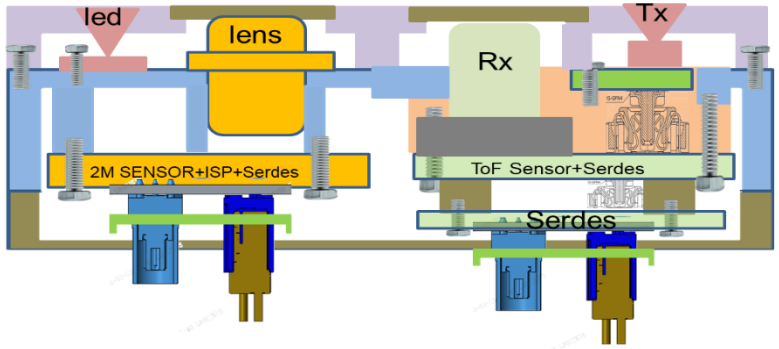
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Optimized ToF camera solutions in the market with innovation roadmap of 2D + 3D camera fusion in place

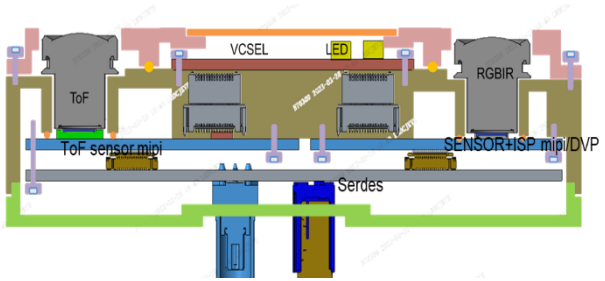
- ToF is mature and proven with optimized solutions in the market
  - ToF camera module cost scaled down by volume
  - Key components available (lens, VCSEL)
  - Most BOM cost optimized ToF solution from Infineon available:
    - REAL3™ imager + *new* VCSEL driver IC
    - Future proof: ISO26262 compliant imager



- RGB-D demo cameras available by partners // cost down roadmap already in place



First RGB-D demo available



Optimized camera in development

RGB-D camera example by OFILM

- 2.3Mpxl RGB-IR imager (5M or 8M possible)
- REAL3™ VGA ToF imager (IRS2877A)
- 2D+3D fusion: 1 ToF / 6 RGB pixel upscaling
- Target FOV: up to 120 x 90°
- Optimized PCB & mechanical design
- One SERDES I/F
- In evaluation: one shared illumination

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4

Infineon REAL3™ Product Portfolio & Partner Ecosystem

New product launch: automotive grade VCSEL driver IC

Optimizing REAL3™ ToF camera modules for Automotive

REAL3™ IRS9103A

Automotive grade laser driver IC

optimized for 3D Time-of-Flight

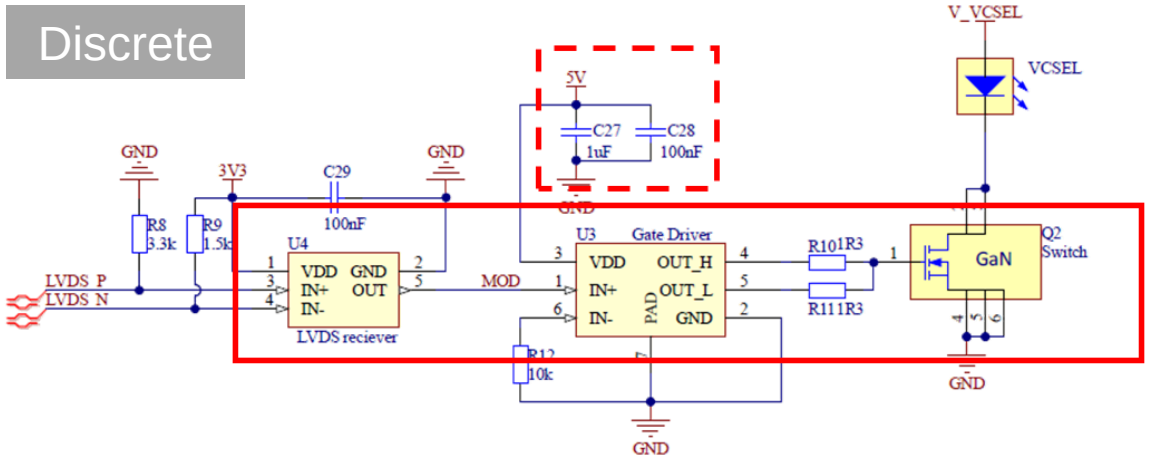


- Driving up to two triple-junction VCSEL (Vertical Cavity Surface Emitting Laser) 14A / 10V / 130MHz
- On-chip over temperature & under voltage protection / pulse width limiter
- Tiny 1.35 x 1.35 mm² PG-WFWLB-9 package
- AEC-Q100 grade 2

Discrete driver solution require 4 key components:
LVDS receiver, Gate driver, 5V power supply, GaN switch

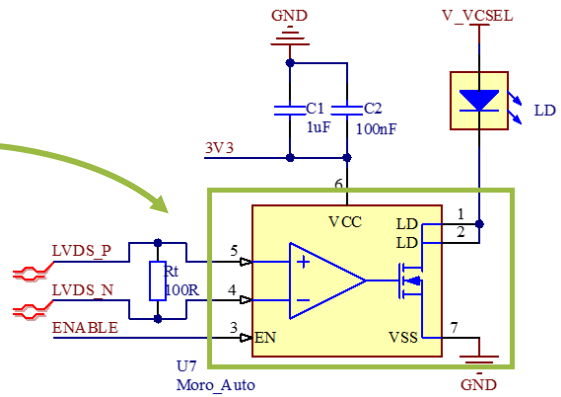
IRS9103A has all key components integrated:
Fully powered from existing 3.3V power

Discrete



4-in-1

IRS9103A



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New product launch: automotive grade VCSEL driver IC

Optimizing REAL3™ ToF camera modules for Automotive

REAL3™ IRS9103A

Automotive grade laser driver IC

optimized for 3D Time-of-Flight



- Driving up to two triple-junction VCSEL (Vertical Cavity Surface Emitting Laser) 14A / 10V / 130MHz
- On-chip over temperature & under voltage protection / pulse width limiter
- Tiny 1.35 x 1.35 mm² PG-WFWLB-9 package
- AEC-Q100 grade 2

Benefits

- Only 1 instead of 4 key components
- Cost down of driver circuit by >50%
- Driver circuitry PCB area down by >80%
- Reduced tolerances
- Simplified design

Most optimized Time-of-Flight solution for automotive:

IRS2877A(S) + **IRS9103A**

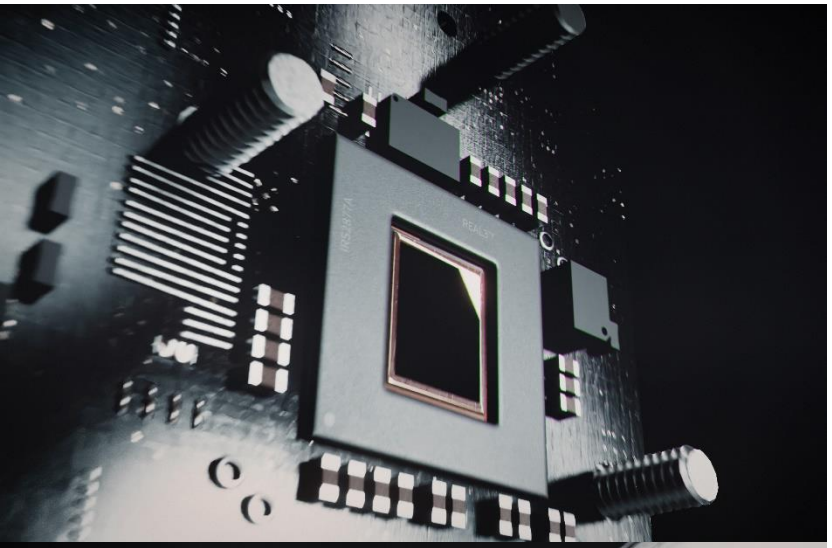
REAL3™ ToF imager | REAL3™ VCSEL driver

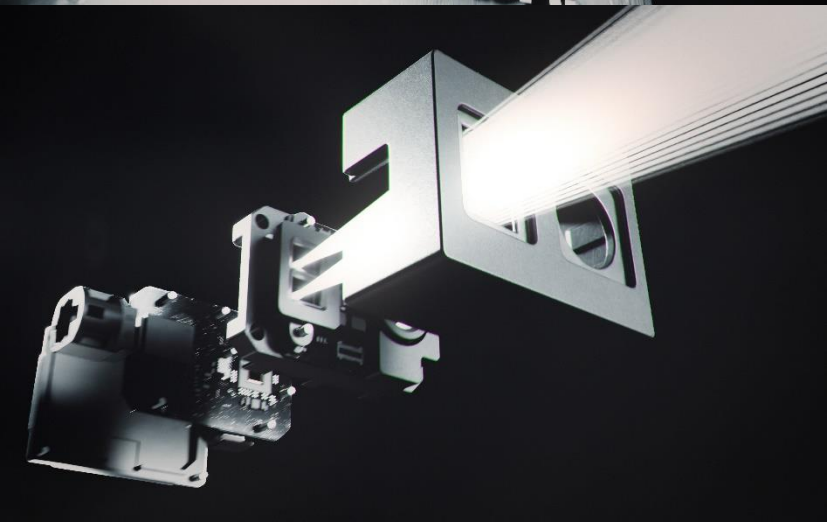
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REAL3™ Time-of-Flight for Automotive

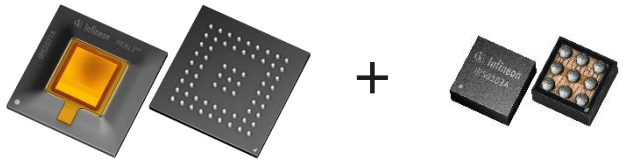
Best performance at smallest size





- VGA system resolution (640 x 320) @ 4mm image circle (1/4”)
- Lowest BOM cost
  - Small sized lens
  - Integrated eye safety circuitry
  - Optimized VCSEL driver IC
  - 2 standard supply rails only (1.8V, 3.3V)
- Outstanding performance
  - Minimized pixel crosstalk
  - Suppression of Background Illumination (SBI) circuitry in every pixel
- Proven solution
  - AEC Q100 qualified BGA package – standard soldering and no thermal constraints: no ceramic or underfiller material required
  - Most efficient mass production calibration
- Future proof: World’s first ISO26262 ASIL-B compliant 3D ToF imager

Most optimized ToF bundle in the market:



IRS2877A(S) + IRS9103A

ISO 26262 compliant

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Why not higher resolution ToF?

Keep ToF affordable and focus on 2D+3D fusion on system level

What does high resolution ToF mean:

- Smaller pixel → reduced performance, or
- Increased image circle → bigger lens
- Higher depth processing demand (adding dedicated ISP)
  - ➢ **Higher cost + higher processing + increased power consumption**
- Increased resolution is always too little to replace 2D camera and to meet high resolution features (>2Mpxl)
- High resolution ToF has not been adopted by other markets (e.g. smartphones)
  - ➢ **Too less volume to enable competitive cost**

Infineon's solution:

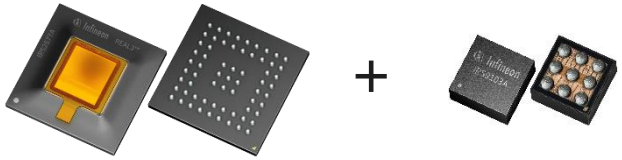
VGA is best performance @ lowest system cost

- VGA is sufficient resolution for all depth features
- Existing ToF solution is mature and highly cost optimized

Sensor fusion: Combine 2D features with 3D benefits to offer "all data" needed

- Future proof: address all in-cabin use-cases meeting Level3 and Smart Airbag requirements

Most optimized ToF bundle in the market:



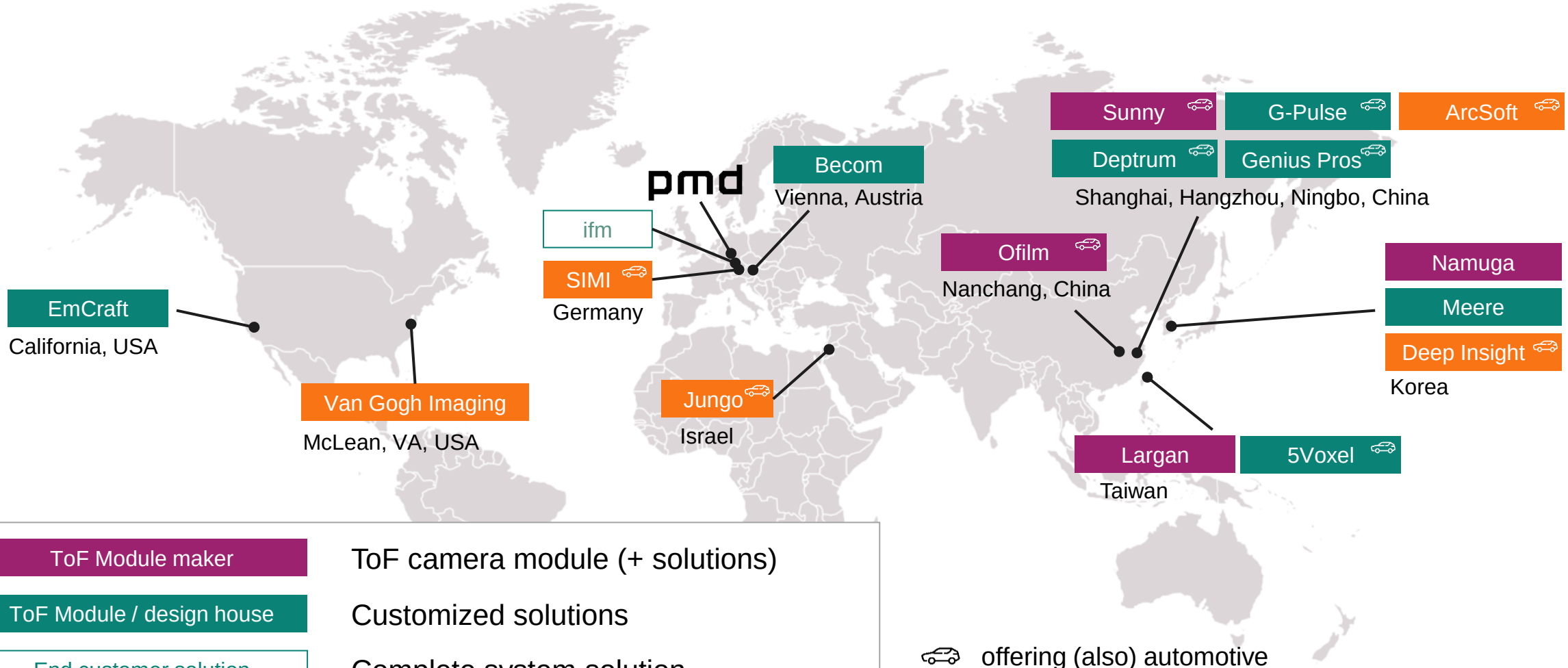
IRS2877A(S) + IRS9103A

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ToF Partner Network for Robotics, IoT and Automotive

Ease of integration with experienced partners



ToF Module maker	ToF camera module (+ solutions)
ToF Module / design house	Customized solutions
End customer solution	Complete system solution
Software	Application Software for REAL3™ ToF

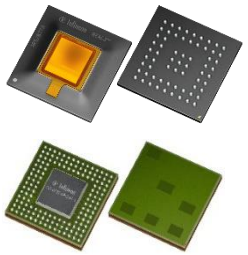
offering (also) automotive

Note: some module maker can also offer complete solutions for certain applications

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Sense the car like a human

Infineon offers a broad sensor portfolio to address all major in-cabin use cases



3D Time-of-Flight

60 GHz radar sensor

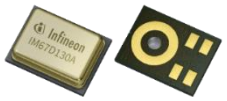


Touch sensor (CMUT)



MEMS mirror

MEMS microphone



Gas sensor



Safety

Security

Comfort

- Child presence detection
- Passenger classification
- Hands-on detection
- Driver monitoring
- Secured authentication & intrusion detection
- Health monitoring
- Intuitive HMI
- Noise cancellation
- Air quality

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Infineon 3D Time-of-Flight enables the smart car

1. 3D data enables differentiation and new services through smart features while supporting regulations
2. IRS2877A(S) is most size & cost optimized (VGA @ 4mm image circle)
   New autograde VCSEL driver for further system cost down
3. Single ISO26262 compliant ToF imager in the market
4. Market proven and strong system partner ecosystem
5. Unique in-cabin sensing portfolio:
   3D ToF / 60GHz Radar / silicon microphones and more

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