IMAPS – Device Packaging

Scottsdale, March 10-13 2014 – *Keynote Automotive Market*

Present and **Future Applications** of **MEMS** for **Automotive Industry**

001851

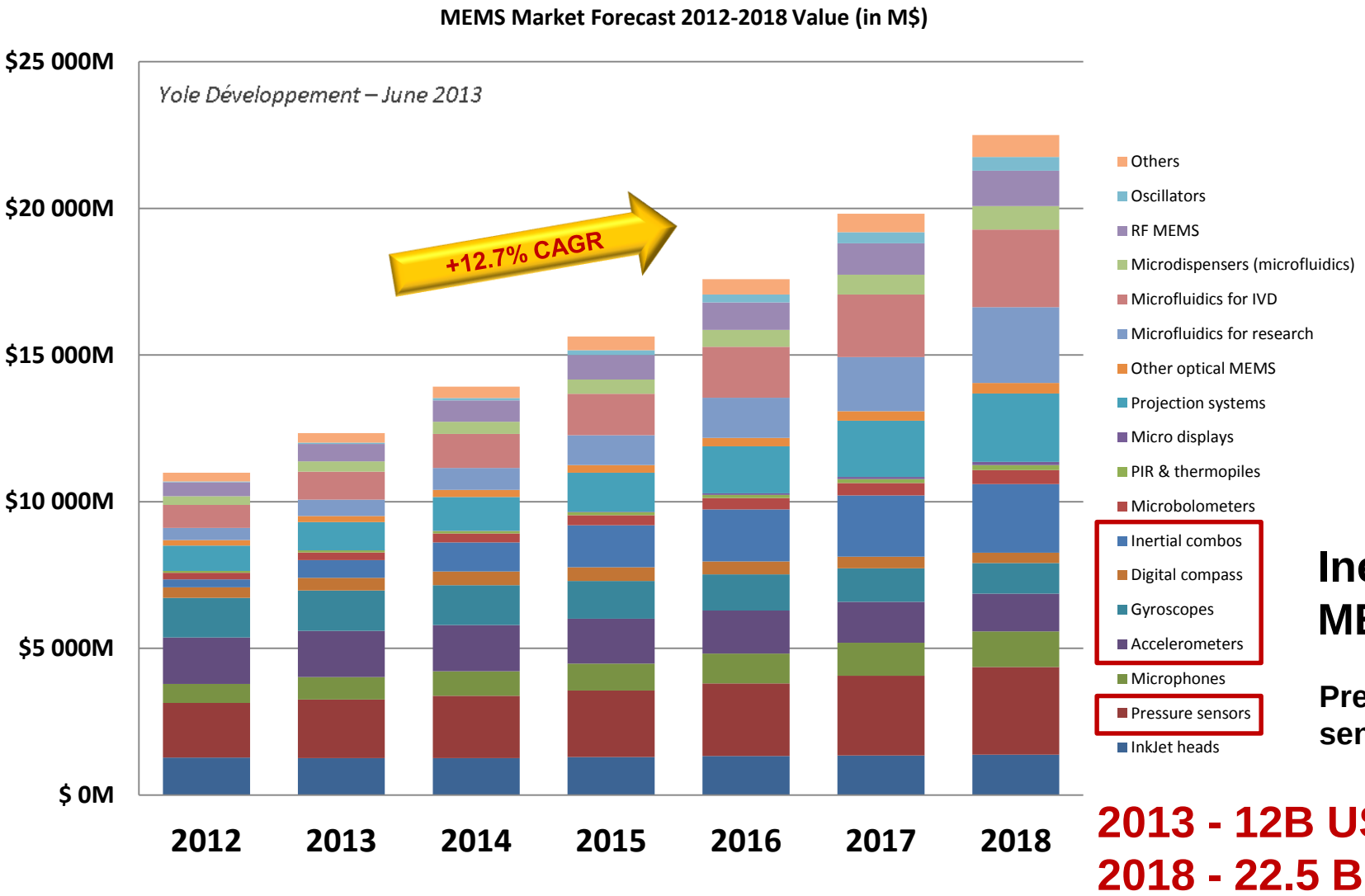
YOLE Développement

Presentation Outline

- MEMS Forecast & Applications
- MEMS in Automotive
- Focus on
  - Advanced Driver Assistance Systems
  - Pressure Sensors
  - Inertial MEMS
  - Microphones
- Reverse Engineering
- Conclusion

Market Forecast & Applications

2012-2018 MEMS Markets in US$M



Inertial MEMS

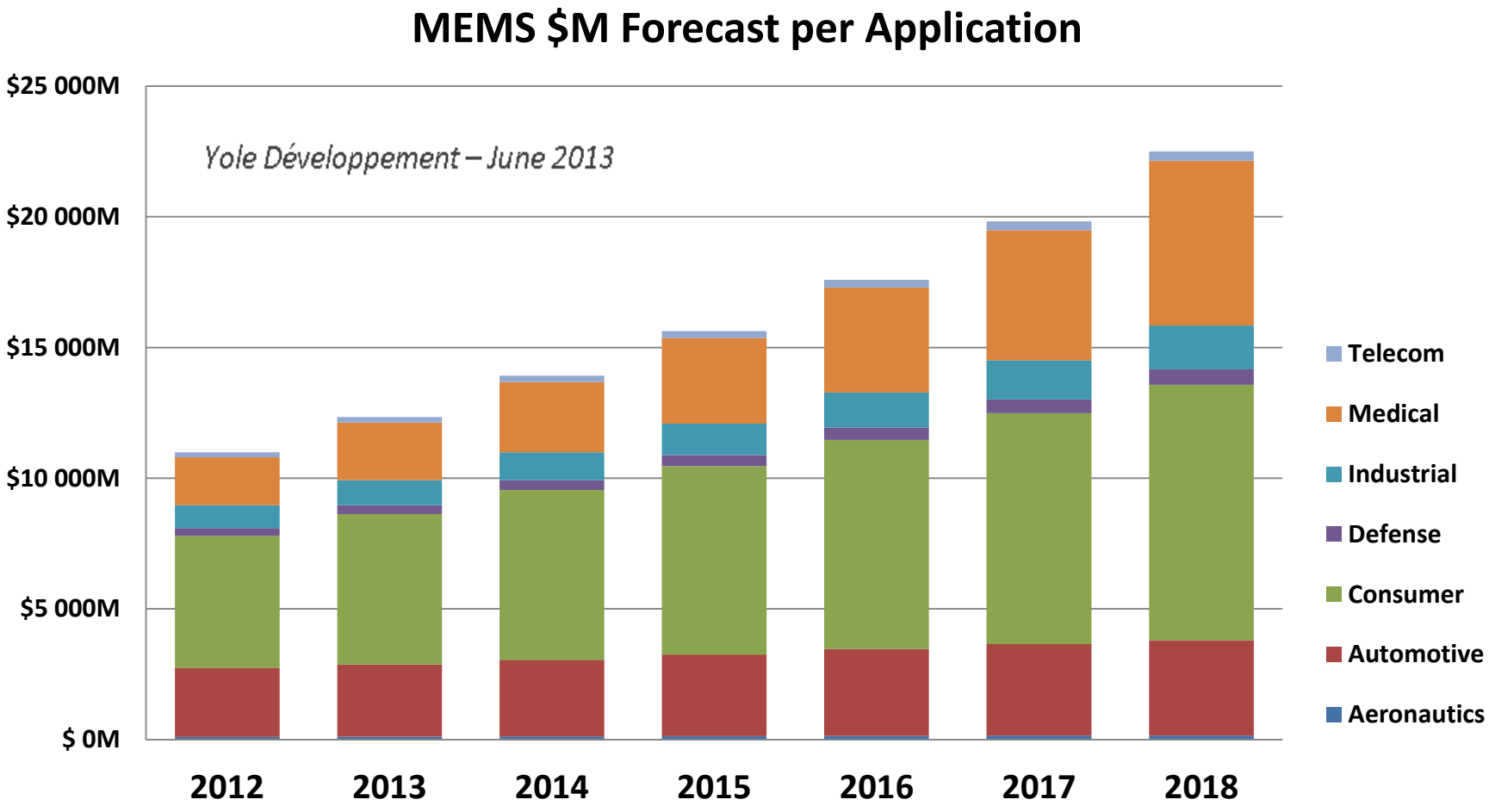
Pressure sensors

2013 - 12B US$

2018 - 22.5 BUS$

001854

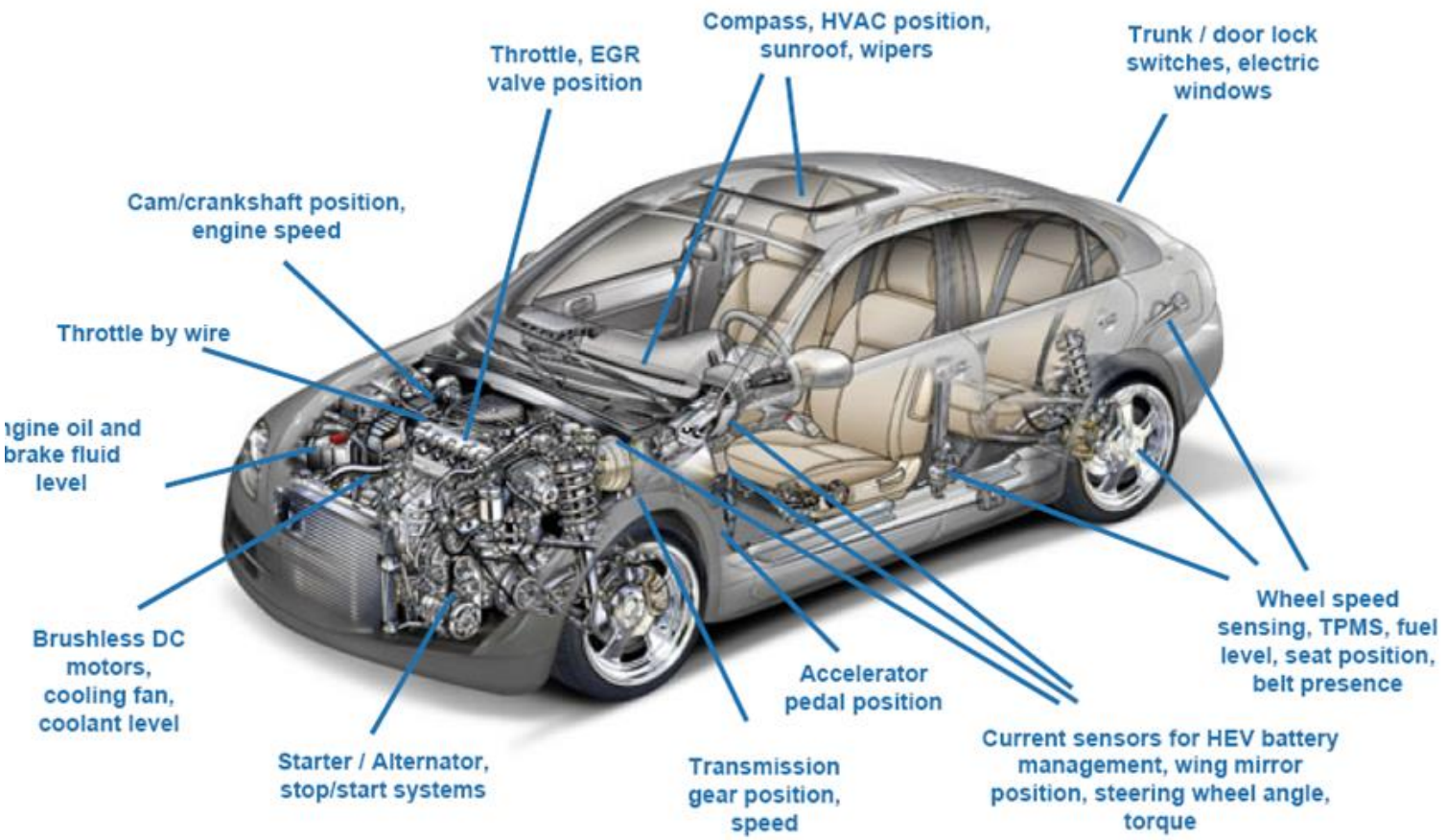
MEMS Markets by Application (in US$M)



- **Automotive will have a slight growth in the coming years**
  - **Telecom and consumer will grow faster**

2013 – 2,7B US$
2018 – 3,6 BUS$

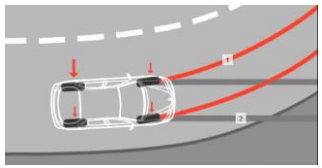
MEMS in Automotive



Infineon source

MEMS for Automotive

Overview



ESP

ABS

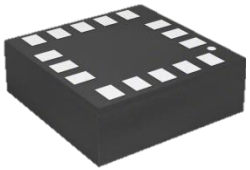
Inertial devices

Microphones

Pressure sensors

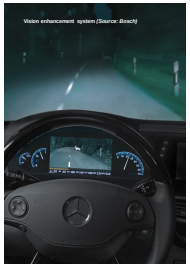
TPMS

Side airbags, Seat occupancy

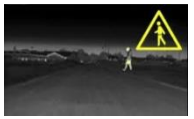


MEMS Sensors

Uncooled IR detectors

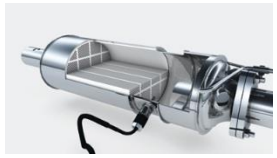


Active Safety



Night vision

HVAC



Particle filter

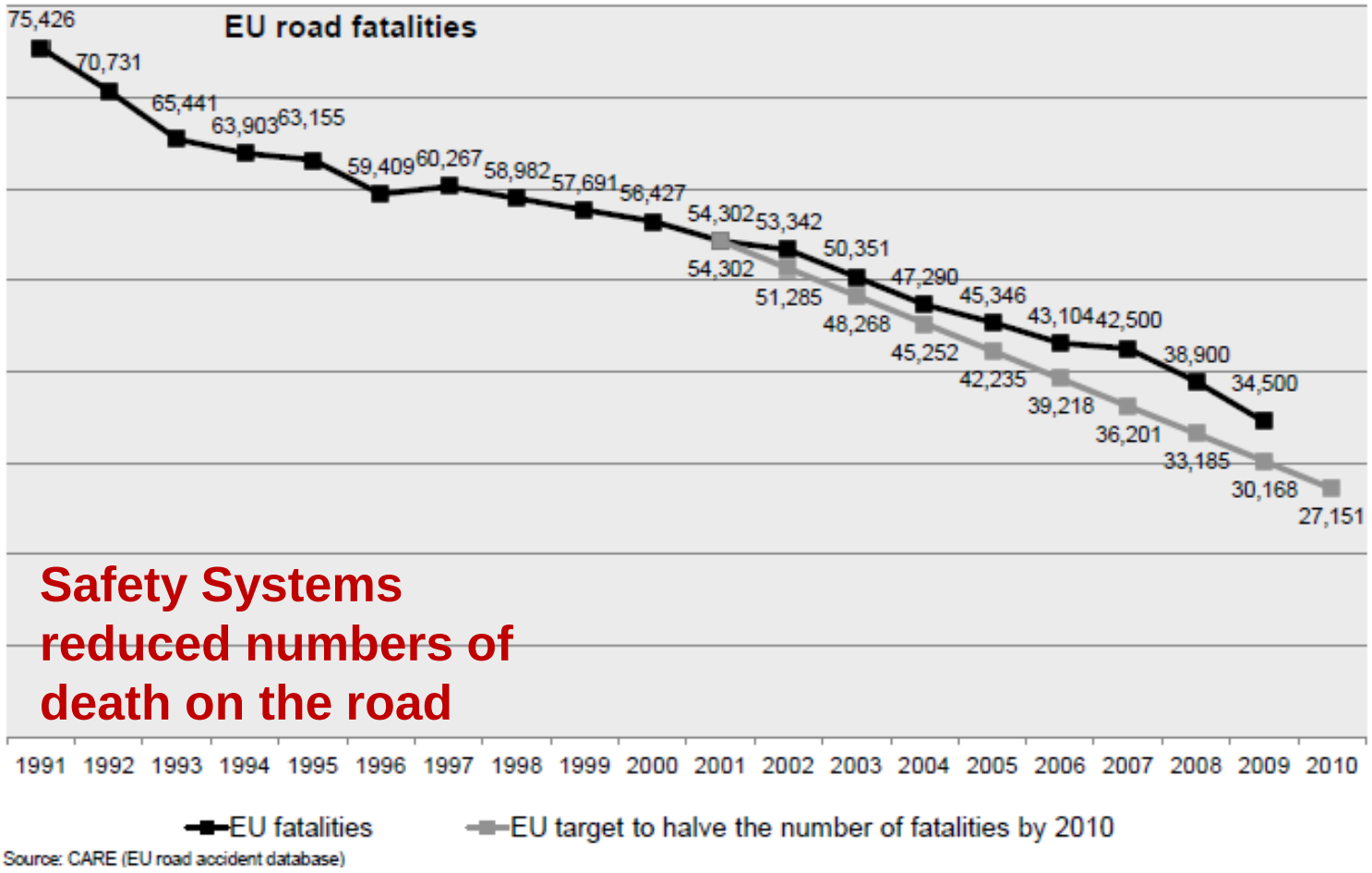
Micro-mirors & pico projectors

Head-up displays

Advanced Driver Assistance Systems ADAS

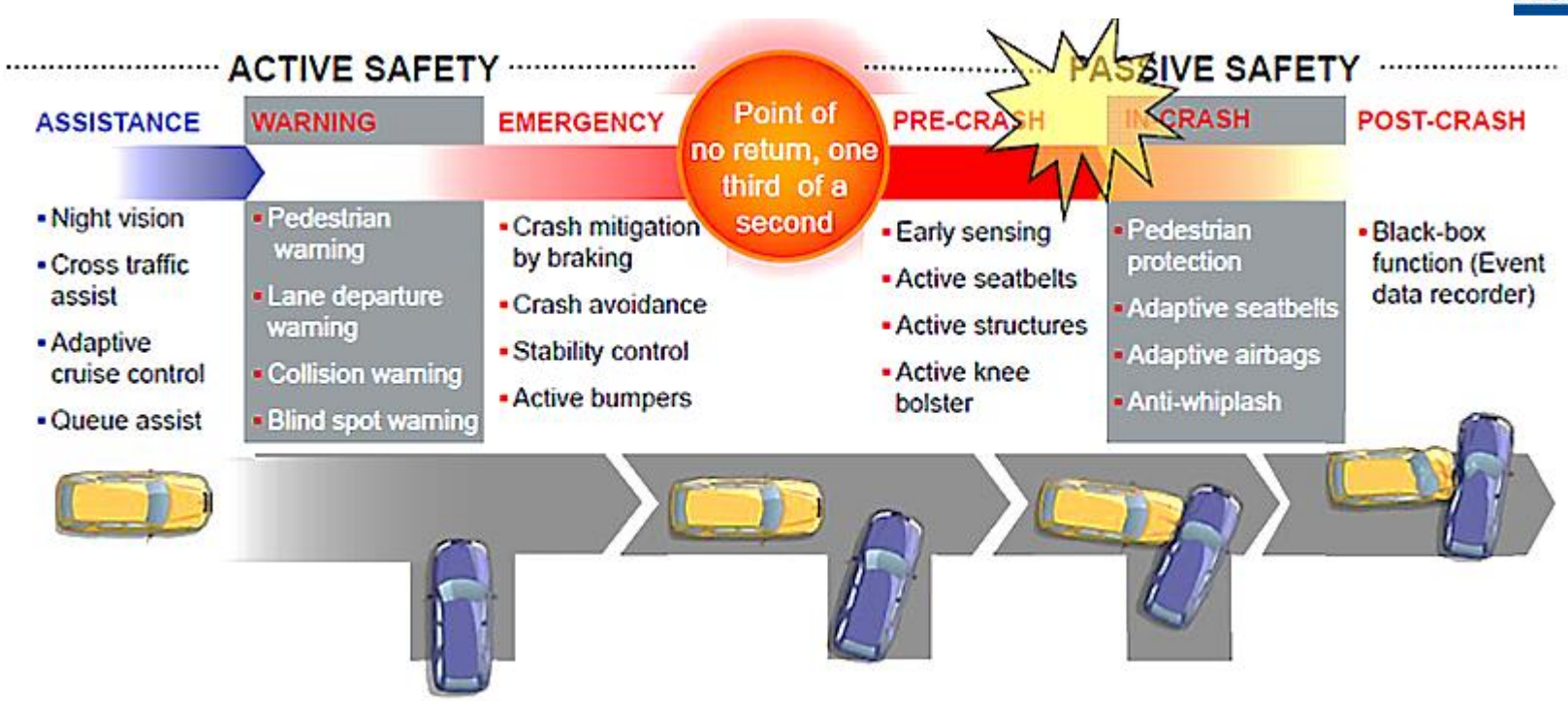
001858

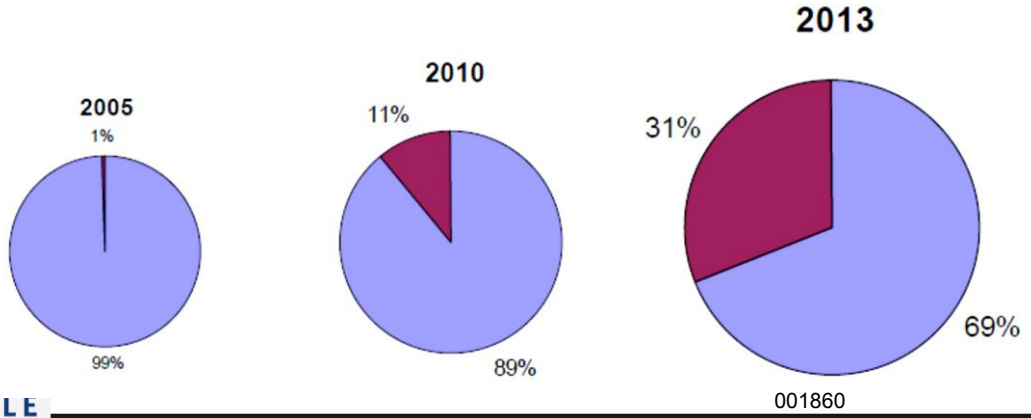
Fewer Deaths Due to Safety Systems



Transition from Passive to Active Safety

Autoliv example



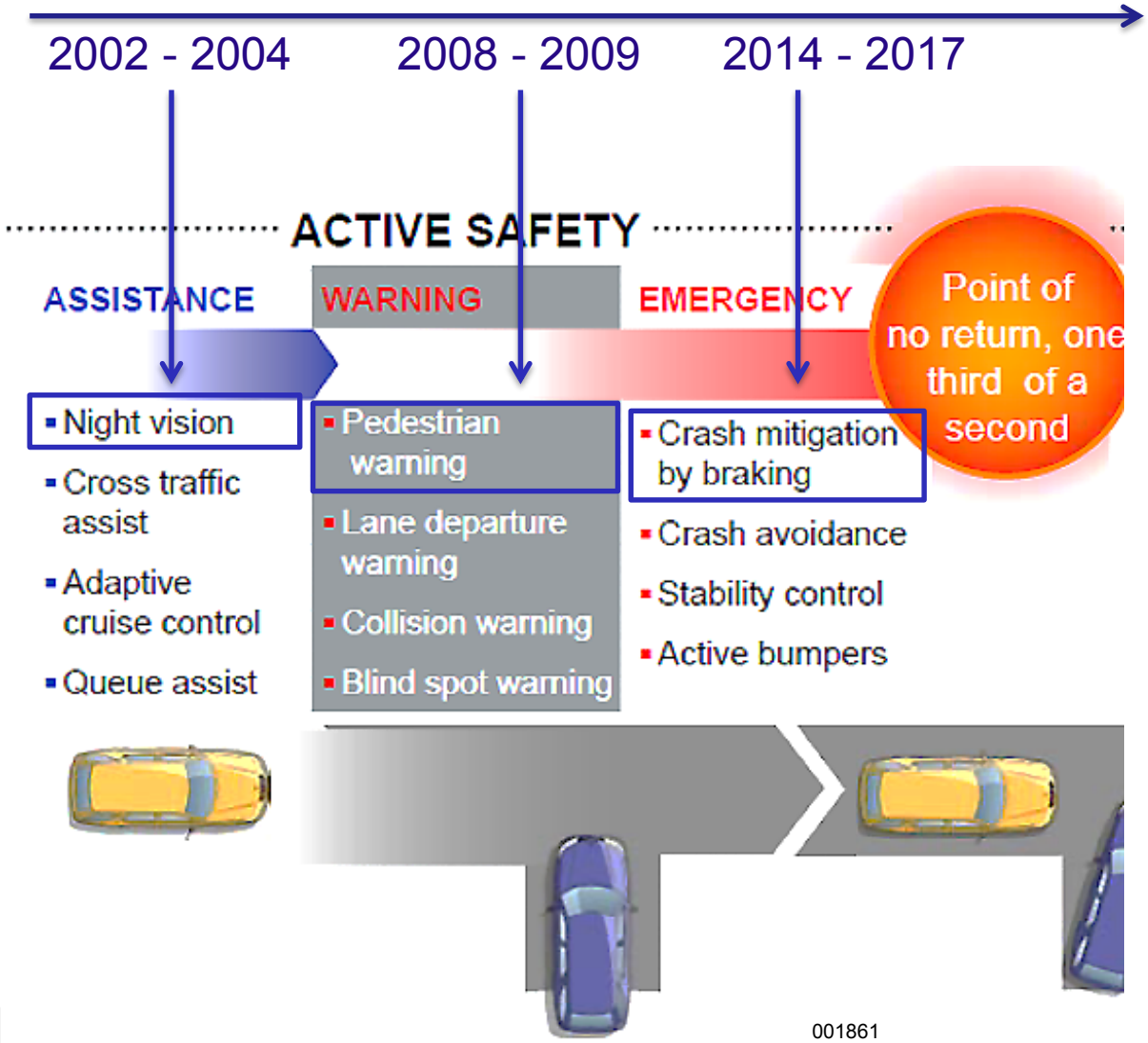


Active Safety
1% in 2005
31% in 2013

001860

Night Vision Functions Evolve Towards Pedestrian Collision Mitigation

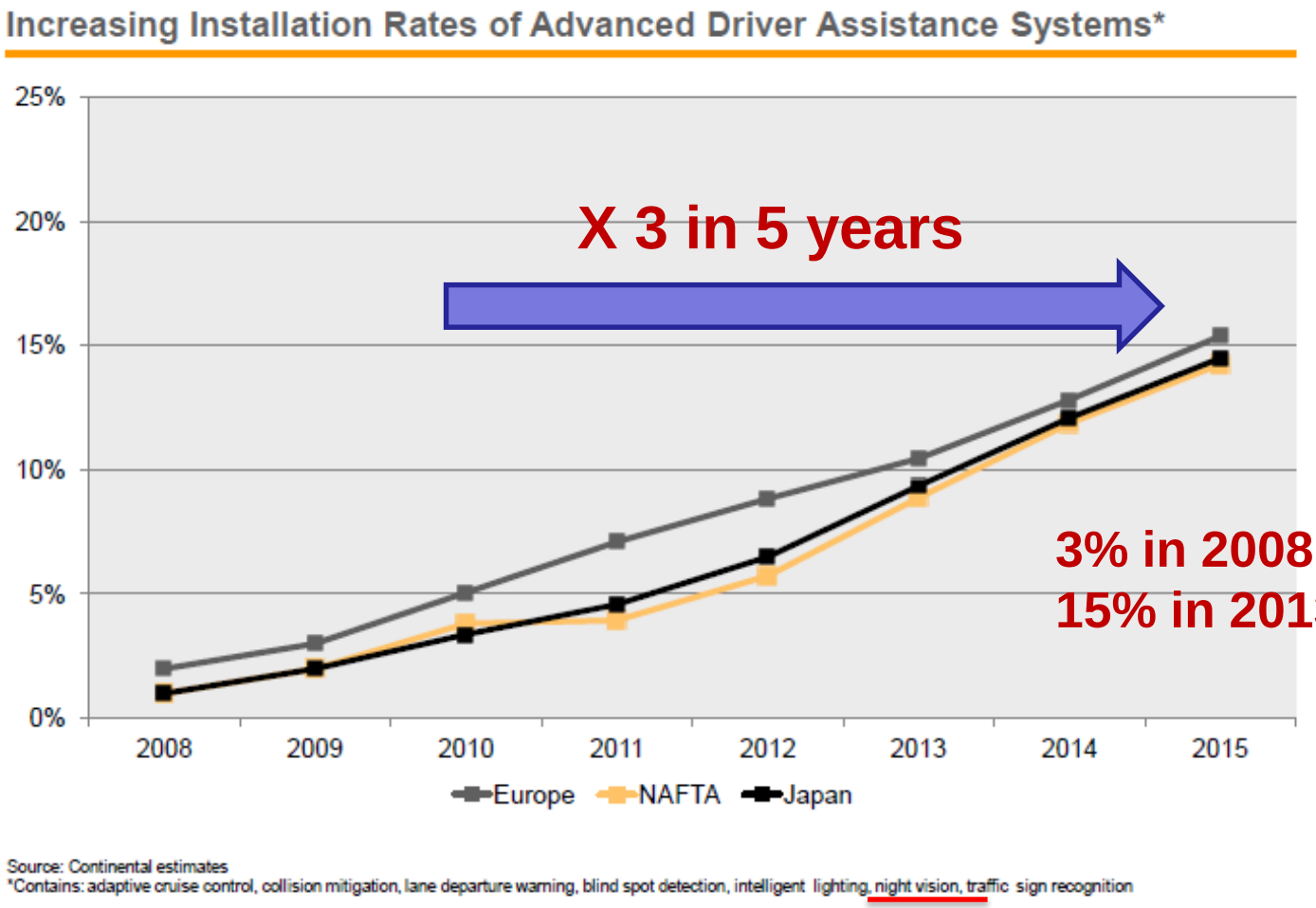
The most useful reason for night vision



- **Radar + vision camera fusion system to prevent false alarm**

Global Advanced Driver Assistance Systems

Market expected to grow



Source: Continental estimates
*Contains: adaptive cruise control, collision mitigation, lane departure warning, blind spot detection, intelligent lighting, night vision, traffic sign recognition

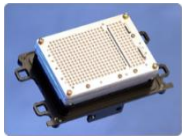
Vision cameras and radar are the most popular ADAS technologies.

Advanced Driver Assistance Systems
(Also called active safety systems)

- **Advanced Driver Assistance Systems, or ADAS, are systems to assist with driving. ADAS are also called Active Safety systems.**
- **ADAS includes a wide variety of functions based on several detection technologies :**
  - **Visible and NIR cameras :**



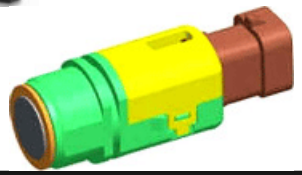
  - **Radar**



  - **Thermal FIR cameras**

µbolometers

  - **Others : Ultrasonic, LIDAR (laser)**



001863

Automotive Visible CMOS Cameras

Main applications

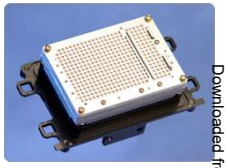



	Front-View Camera	Side & Rear-Side View Camera	Inside-Car Camera	Rear-View Camera
"Vision-based" sensors **=> Image restitution for the driver**		**→ Blind-spot detection (BSD)** **→ Assisted passing**		**→ Parking assistance** **→ Rear-view & back-up cameras**
"Signal processing" analytical sensors **=> No image. Only imager function**	**→ Intelligent head-light control (IHC)** **→ Traffic signals recognition (TSR)** **→ Lane Departure Warning (LDW)** **→ Pedestrian detection**		**→ Driver drowsiness monitoring** **→ Intelligent airbag deployment**	

Prevention

Vision cameras provide a wide variety of functions for a limited cost (less than $100).

Main Functions of Radar



Adaptive Cruise Control (ACC)

ACC follows the flow of traffic ahead of the vehicle, even if its forward progress is stop-and-go. Uses **Long Range (> 200m) Radar (LRR).**

Emergency Brake Assist (EBA) or Pre Crash Braking (PCB)

Emergency Brake Assist detects critical traffic situations and ensures optimum braking.
Uses Long Range (>200 m) Radar (LRR).

Blind Spot Detection (BSD)

Blind Spot Detection warns the driver when there are vehicles in the blind spot of the side-view mirror.
Uses Short Range (30-50 m) Radar (SRR).

Radar is increasingly used even if the cost is higher (up to $260) than vision cameras. (Radar $ > Imager $)

Automotive Vision Enhancement

NIR vs FIR detection

- FIR (far Infrared) systems are passive IR systems based on Long Wavelength IR microbolometers.
- NIR (Near Infrared) systems are active IR systems using a Near Infrared light source (about 0.8 microns)
- Both introduced in cars since 2000 but their use is limited by their high cost
  - retail price is more than $2,000.
- Today generally used to display an image to the driver, and can also detect pedestrians and warn the driver (Mercedes, Honda) .

NIR sytem

FIR sytem

NIR active Driver Assistance System
(Bosch example)

Vision enhancement system *(Source: Bosch)*

In-car video camera *(Source: Bosch)*

001867

FIR Passive Driver Assistance System

Autoliv - BMW example

Autoliv's night vision generation 2 system launched in 2009 includes an automatic pedestrian detection warning.

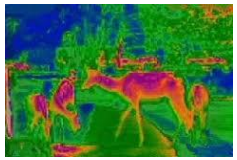
001868

Autoliv FIR Night Vision Roadmap

Additional functions and cost reduction

2009 2010 2011 2012 2013 2014 2015 2017 2017

37 premium models contracted for 2015



Autoliv

Generation 2:
- Pedestrian detection
- About $800 camera
- Less than $500 imager
- 25 micron imager

- 30 %

Generation 3:
- Pedestrian + animal detection
- About $600 camera
- Less than $350 imager
- 17 micron imager

Generation 4:
- Fusion NIR-FIR ?
- About $325 camera
- Less than $100 imager
- 12-17 micron imager

- 50 %

Pressure Sensors

Pressure Sensor for Automotive Applications

Key applications

Higher Volume Applications (tens of millions of units)	• **Air Intake Sensors for Engine Controls (MAP/BAP/Boost)** • **TPMS** • **HVAC**
Other Applications	• **Fuel Common Rail** *(100% of Diesel Engines, Also needed for Gasoline Direct Injection)* • **Oil Pressure, Brake, Suspension, Steering** • **Side Airbags** • **Particulate** • **Mass Air Flow Sensors** • **Seat occupancy** • **Fuel Vapor (saturated)**
Application Market Dynamics	• **TPMS sensors over 15% CAGR in Sensor Demand** • **Most of others from 5% to 10% CAGR in Sensor Demand**

Pressure Sensor for Automotive Applications

TPMS examples

- **A tire pressure monitoring system (TPMS) is an electronic system designed to monitor the air pressure inside the pneumatic tires on various types of vehicles.**
- **Infineon is one of the leaders in TPMS and pressure sensor for TPMS manufacturing**
  - **Infineon SP37 TPMS**
- **Other products examples:**

Infineon SP37 Tire pressure sensor for TPMS

Melexis MLX91801 Tire Pressure Monitoring Sensor

Freescale MPXY8300 for TPMS

Pressure sensors' positon for TPMS, source: Infineon

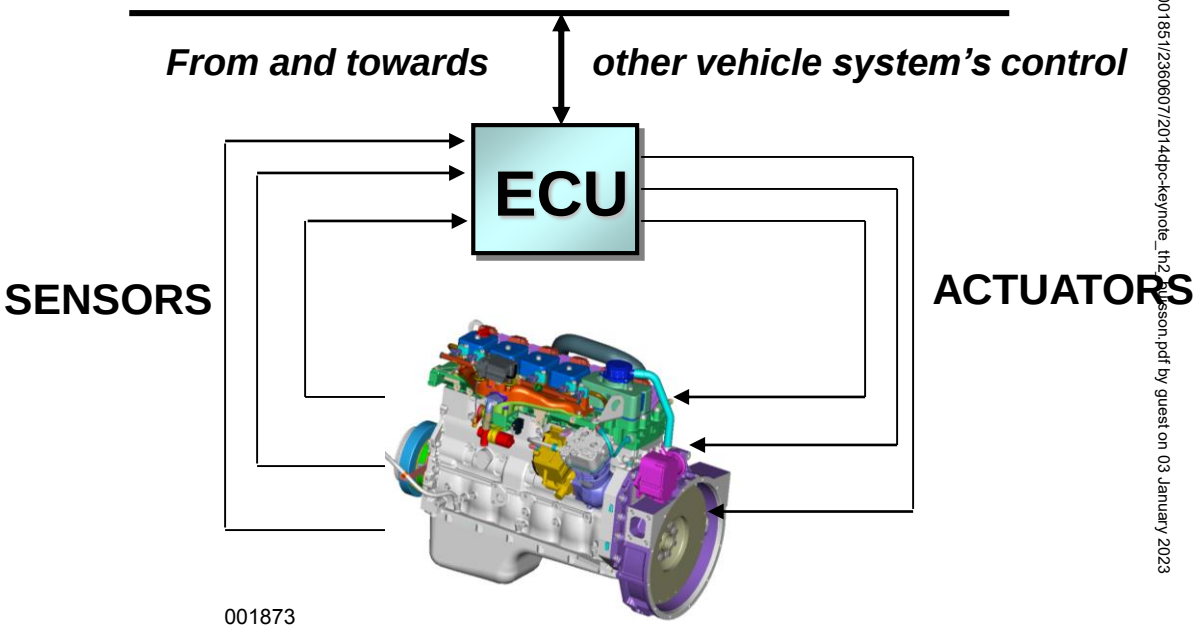
001872

Pressure Sensor for Automotive Applications

Engine management system (EMS) - MAP

- An engine management system (EMS) is used to keep combustion engine
- The EMS is a type of electronic control unit (ECU) that determines the amount of fuel, ignition timing and other parameters.
- The pressure inside the manifold is measured by the manifold absolute pressure sensor (MAP).

Continental MAP module with an Infineon KP21x sensor inside

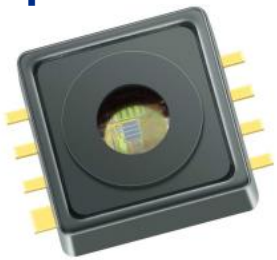


001873

Pressure Sensor for Automotive Applications

Engine management system (EMS) - MAP

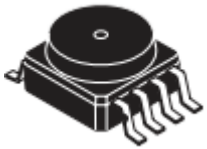
- Manifold absolute pressure sensor (MAP sensor) is one of the very first pressure sensors developed for automotive applications.
- The MAP is an important parameter to compute the air/fuel ratio provided to the engine for lower emission due to better combustion and increased efficiency.
- There are a lot of MAP products on the market. Most main automotive pressure sensor manufacturers can supply such basic sensors.



Infineon
KP229E3518

Bosch
MAP module

Delphi
MAP module

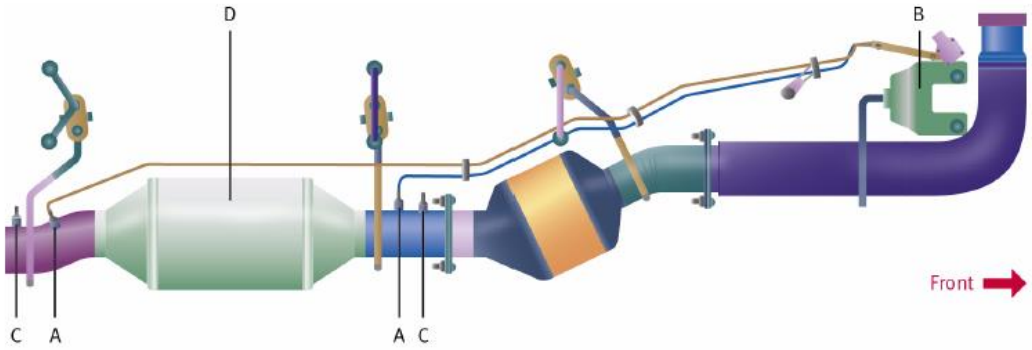


Freescale
MPXA4250A6U

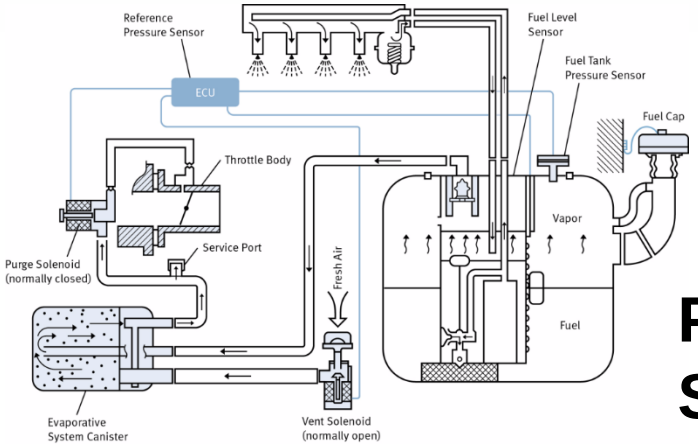
001874

And much more!

Particles filters for Diesel Engines

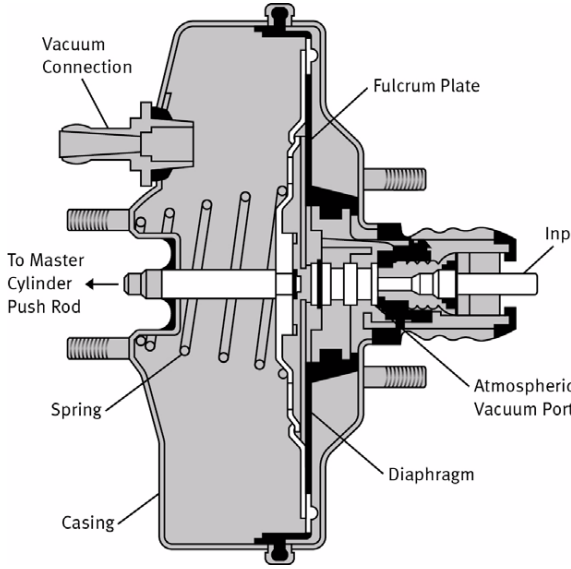


A Pressure sensor
B Exhaust differential pressure sensor
C Temperature sensor
D Particulate filter



Pressure sensor and fuel vapor control system, Source: Infineon

Brake booster



A typical brake booster, source: Infineon

Pressure Sensor & fuel vapor control system

001875

Pressure Sensor for Automotive

Conclusions

- **Automotive applications dominate the MEMS pressure sensor market.**
  - **Current applications are numerous: MAP, Boost, Fuel Rail, Vacuum Boost Stop and Start, Oil Pressure, Particle Filter, Oil Transmission, Fuel Vapor (Tank), Brake & ESP, Suspension, Side Airbags, TPMS, HVAC fans, Seat Occupancy (Weight)…**

- **MEMS pressure sensors still have a very bright future in the automotive industry.**
  - **Promising applications: MAP, TPMS…**
  - **New applications appearing: In-cylinder pressure sensing, EGR…**

- **This segment will continue growing over the next several years with the expectation of new functionalities or higher performance**

MEMS Microphone Applications Automotive application

MEMS microphone for automotive application

- **Interesting applications identified**
  - Three different applications are distinguished
    1. Hands free solution for Mobile phone
    2. Acoustic crash sensor
    3. Noise cancellation to monitor car indoor noise level and for remote voice control features
  - Acoustic shock detection sensors detect the chassis sound when crashing

MEMS microphone for automotive application

- **Integration of MEMS Microphone in Automotive market is still a challenge because:**
  - **Miniaturization and strong integration is not a key issue in Automotive cockpit**
  - **Price of ECM are really competing with MEMS Microphones.**
  - **Opportunity for Digital MEMS Microphones is immunity of these devices from Automotive electromagnetic environment compared to ECM and Analog MEMS Microphones.**

Example of possible Microphone integration in a car belt

- **Microphones can provide active noise cancellation features for indoor car environment.**

INERTIAL Automotive applications

Inertial MEMS in Automotive

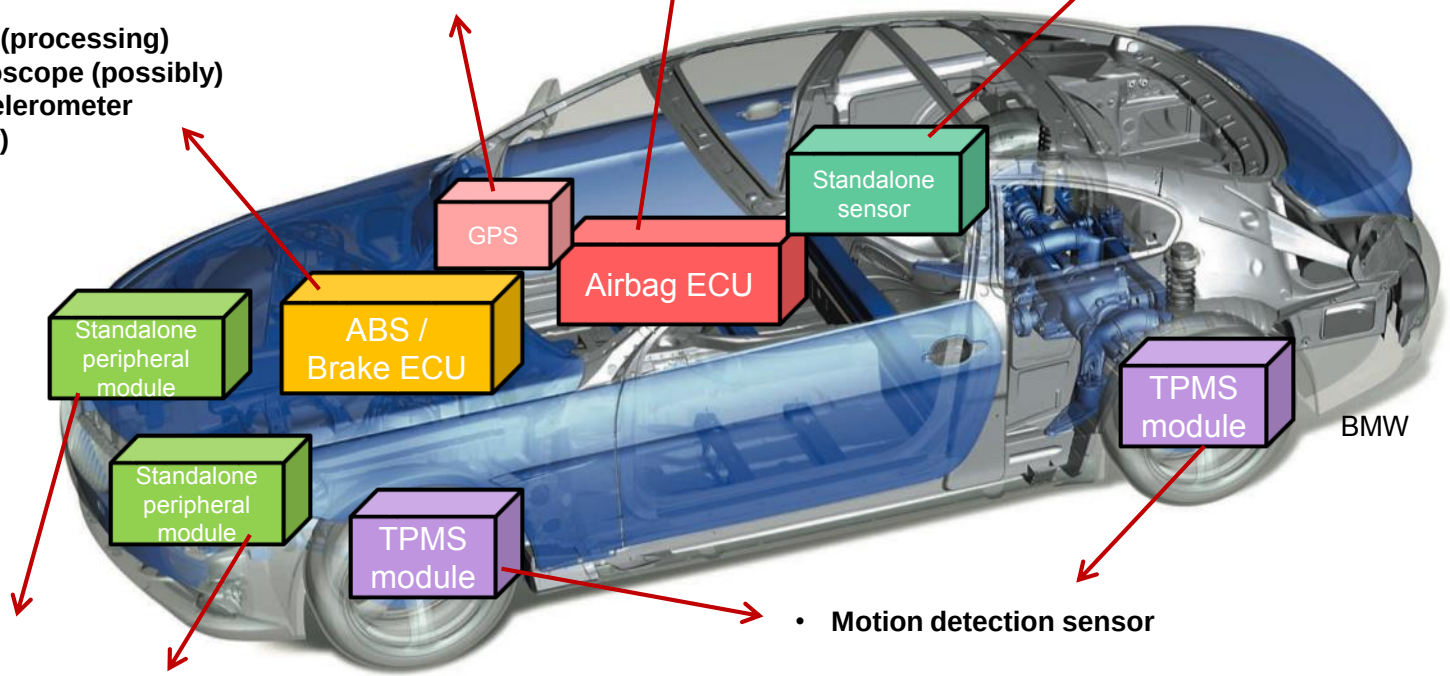
Structure of passenger vehicles with current integration of inertial sensors

- Front crash sensor
- Rollover sensors
- ESC accelerometer
- ESC gyro (possibly)

Standalone sensor
- ESC gyro (possibly)

- Navigation gyroscope

- ESC unit (processing)
- ESC gyroscope (possibly)
- ESC accelerometer (possibly)



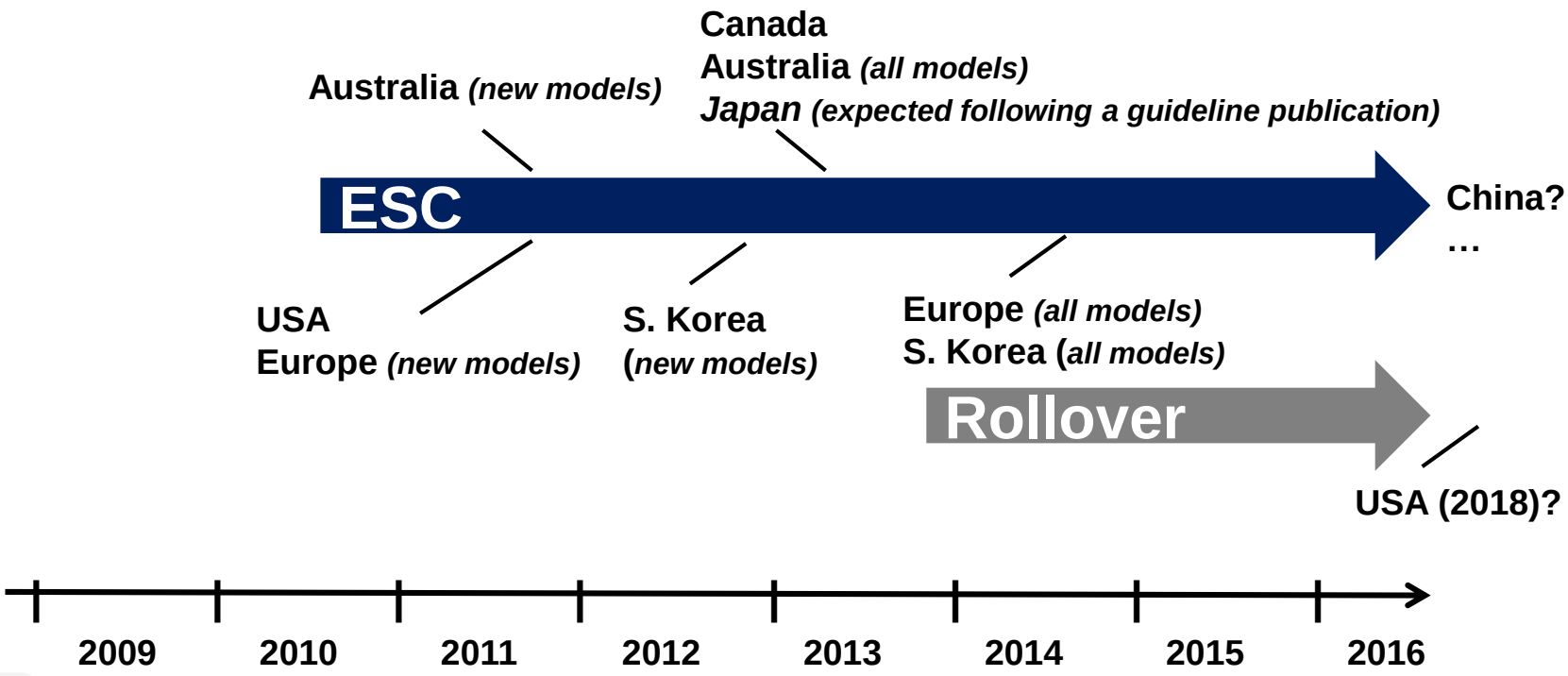
- Motion detection sensor

Standalone peripheral module
- Satellite crash sensors

Inertial MEMS in Automotive

Mandates – currently announced

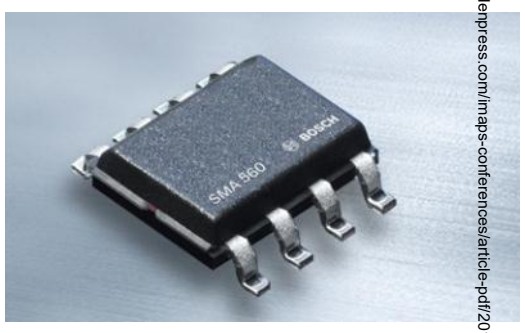
- **Electronic Stability Control (ESC) is an electronic safety technology that can help a driver maintain control of his vehicle**
- **An increasing number of new cars are equipped (47% in 2011)**



001882

Main ECU Airbag Sensor

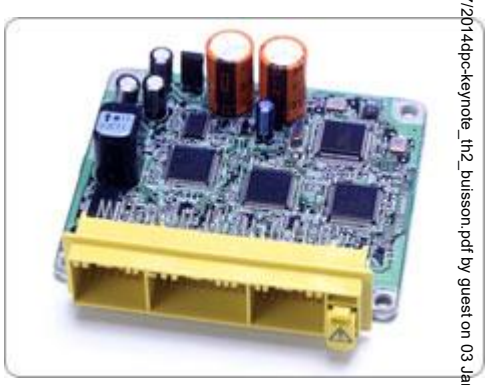
- **Current trend is to use 2-axis sensors for main ECU airbag**
  - **90% adoption for 2-axis solutions today**
  - **1-axis solutions are still used but less often:**
    - **in China 1-axis solutions are often sufficient**



Bosch BMA550

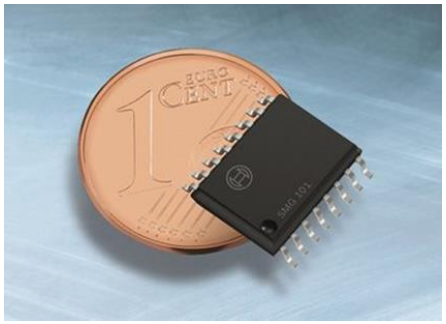
- **Evolution of packaging is a key technical evolution**
  - **Driven by footprint reduction**

- **Measurement range and frequency resonance depend on each model**
  - **High g accelerometers are used: +/- 35 to 100g**
  - **No clear roadmap on the measurement range and sensor frequency resonance**
  - **Those parameters are still very dependent on the vehicle**


Denso airbag ECU

Rollover Sensors

- **The popular SUVs in the 2000's have generalized the use of curtain airbags**
  - **Anti-rollover systems provide protection against car roll accidents**
  - **Curtain airbags open and remain inflated for six or more seconds, covering the side windows: Shock protection + Prevent out of the car ejection**
- **This market is mostly limited to North America**
  - **SUVs are not a widespread type of car in other areas**
- **Rollover function needs both a gyroscope and an accelerometer**
  - **Accelerometer: low-g**
  - **Gyroscope: 300°/s range**



Bosch SMG10x-series 3rd generation rollover gyro

ESC Accelerometer

- **Low-g accelerometers are used to measure lateral acceleration**
  - **2 to 5g devices**
  - **Transition from 1-axis detection to 2-axis is underway**

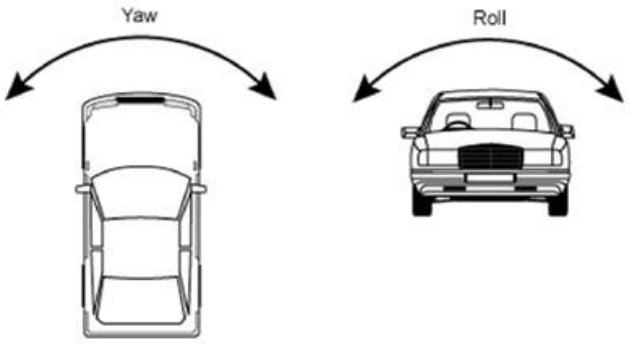
Freescale MMA6900

- **Leading ESC accelerometer players are Murata and Bosch**
  - **Freescale is a newcomer in ESC accelerometers**
    - **Low-g ESC accelerometer has been qualified in 2010**

ESC Gyroscope

- **Requirements for ESC gyroscope depends on the location:**
  - **For installation in engine room: ABS ECU → ESC unit**
    - **-40 → +125°C operating temperature**
    - **150°/s range**
  - **For installation in Airbag ECU:**
    - **-40 → +105°C operating temperature**
    - **300°/s range**
  - **Different mounting direction depending on the location**
- **Leading ESC gyroscope players are Panasonic and Bosch**
  - **Challengers: Maxim, Murata …**
  - **Epson is a newcomer in ESC gyroscope**

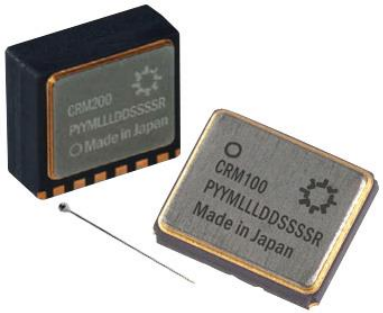
Epson Toyocom XV-9000 series of gyro-sensors for ESC or Rollover



Auto Navigation Sensors

- **MEMS gyroscopes can be use for dead reckoning**
  - **Ex: Renault Carminat TomTom, available in May 2009 in select Renault models**
  - **1-axis gyroscopes with >50Hz bandwidth**
  - **Car-integrated GPS does not use accelerometers to get information on speed**
- **Leading players are Murata, Epson and Panasonic**
  - **Murata supplies 1-axis silicon gyros for this market**
  - **Epson Toyocom is involved in Auto car navigation since 2008**
  - **New players still appear in car navigation (Silicon Sensing…)**
  - **Bosch decided to exit this market**

Carminat TomTom



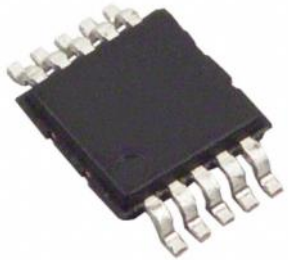
SSS Pintpoint in-plane and out of plane gyroscopes

Epson Toyocom XV-8000CV gyroscope for car navigation

001887

Magnetometers

- **Magnetometers have been widely used in passenger vehicles for years**
  - **Used to provide a compass function**
  - **Mostly a US market**
- **2-axis magnetometers are used in automotive**
  - **No need for a 3rd axis**
- **These magnetometers are used as indicators**
  - **show digital indication of the direction (e.g. “65°N”)**
  - **typically used as a dashboard digital indicator or integrated in the rearview mirror**
- **Level of integration is very basic**
  - **Like temperature sensors…**
  - **No integration with the car electronics → no impact from inertial combo sensors**



Honeywell 2-axis magnetometer for compassing

Inertial MEMS in Auto

Conclusions

- High-g MEMS accelerometers are growing because of the increasing integration of peripheral sensors in addition to front car sensors, in countries where car safety regulation drives fast growth of inertial sensors
- Low-g accelerometer, TPMS devices and gyroscopes are driven by regulations in USA and in Europe, rapidly spreading to other countries
- Magnetometer for compass is rather small market in automotive
- Combo sensors started to emerge with ESC combos

Summary & Conclusions

The Future of MEMS in Automotive Industry

- MEMS are getting broadly adopted in the automotive industry, making cars more safe, comfortable, economic…

- Some devices such as intertial devices and pressure sensors are now mature. Although their market growth gets related to the overall automotive market, these can still be boosted by changes in regulation (e.g. ESC in USA)

- Next to that, new applications are slowly growing to improve active safety, such as Night Vision and Head-up displays.

Thank-You!

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001892