

# Bosch Sensortec - Consumer MEMS Technology



## Consumer MEMS – A Technology Play

Frank Melzer, CEO Bosch Sensortec

Bosch Sensortec

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# Bosch Sensortec - Consumer MEMS Technology

## 2011 key figures

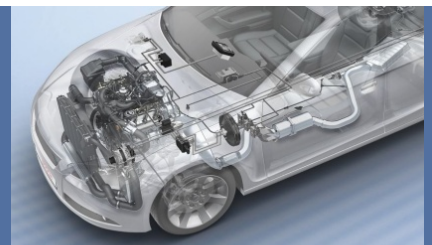
**Bosch Group**

- 51.4 billion euros in sales
- 303,200 associates including 38,750 in research and development



**Automotive Technology**

- 59% share of sales
- World's largest supplier of cutting-edge automotive technology



**Industrial Technology**

- 14% share of sales
- World's leading manufacturer of large gearboxes and of powertrain, packaging, and process technology



**Consumer Goods and Building Technology**

- 27% share of sales
- World's largest power tool manufacturer, leading the field in household appliances, heating and cooling, and security systems



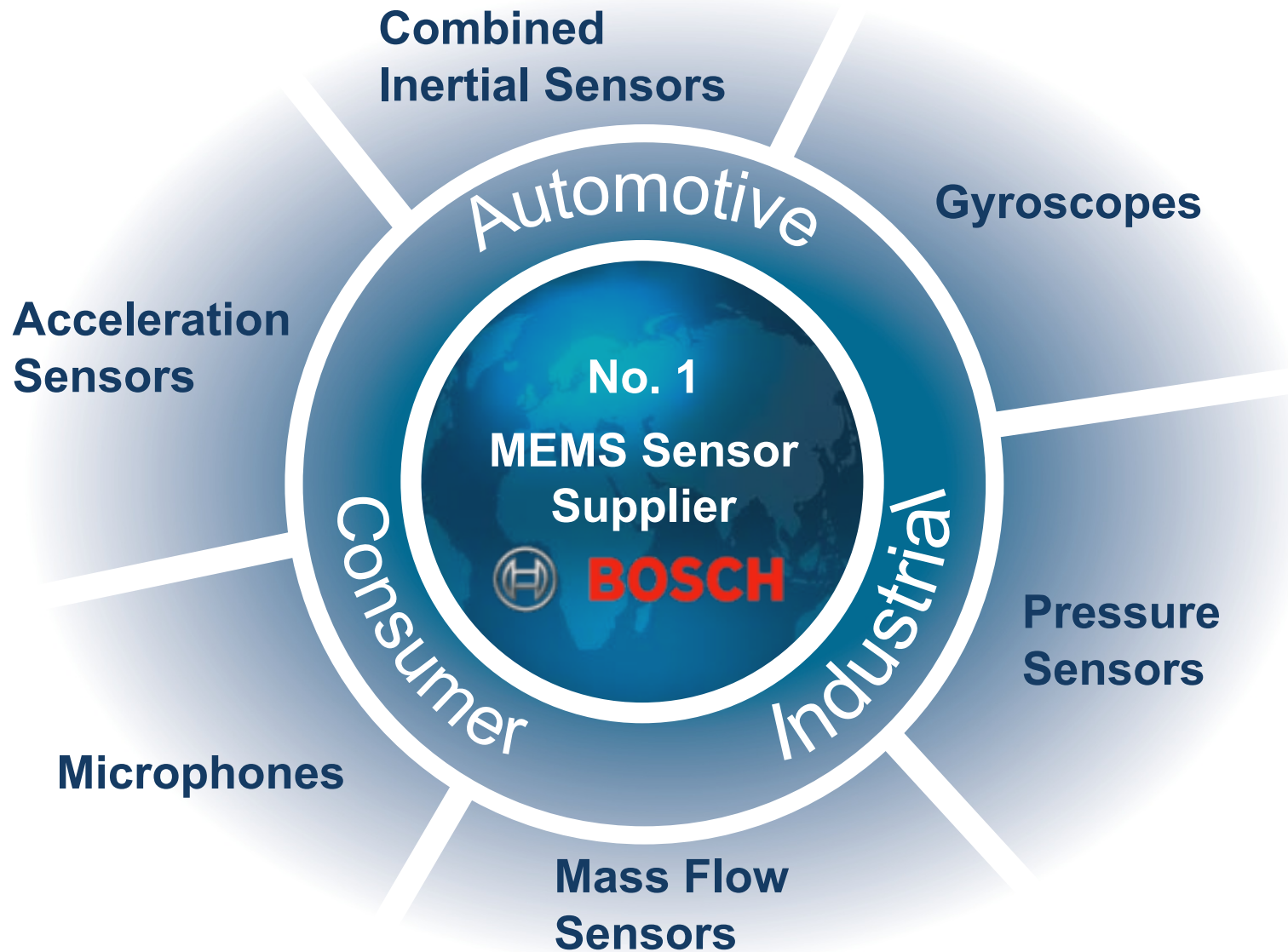
<sup>1</sup> Including other segments

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# Bosch Sensortec - Consumer MEMS Technology





# Bosch Sensortec - Consumer MEMS Technology

## Bosch the global MEMS sensor leader

### Bosch: No. 1 global supplier of MEMS sensors

#### MEMS for automotive applications

##### Automotive Electronics



- Acceleration, angular rate, pressure, mass flow, torque and CO<sub>2</sub> sensors
- Headquartered in Reutlingen near Stuttgart, Germany

#### MEMS for consumer applications

##### Bosch Sensortec



- Acceleration, magnetic, gyroscope and pressure sensors
- Headquartered in Reutlingen

##### Akustica



- MEMS microphones
- Headquartered in Pittsburgh, PA, USA

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## A multitude of markets for MEMS



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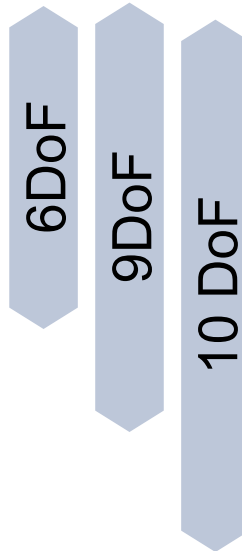
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## Smartphones & tablets – the technology drivers

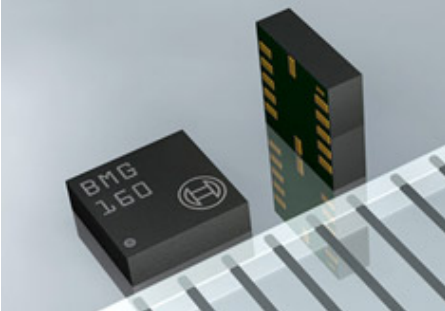
- Geomagnetic sensors
- Acceleration sensors
- Gyroscopes
- Pressure sensors



### The HW & SW Integration Challenge

## Today's Smartphone Sensors

### Gyroscopes



- Very small LGA packages (3x3)
- Low power consumption
- Smallest IMU

### Acceleration sensors



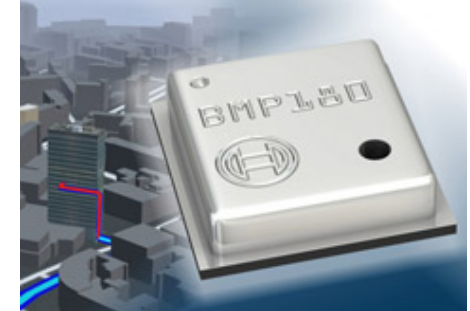
- 2x2 LGA is the industry standard
- Lowest power consumption
- Use case optimized

### eCompass



- A typical mid-end Smartphone solution
- 3-axis geomagnetic sensor + 3-axis accelerometer

### Pressure sensors







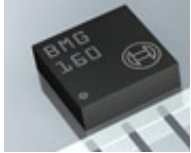



- Ultra low power
- High resolution
- Low TCO (stability)

**Sensor data-fusion software provides the functional tie**

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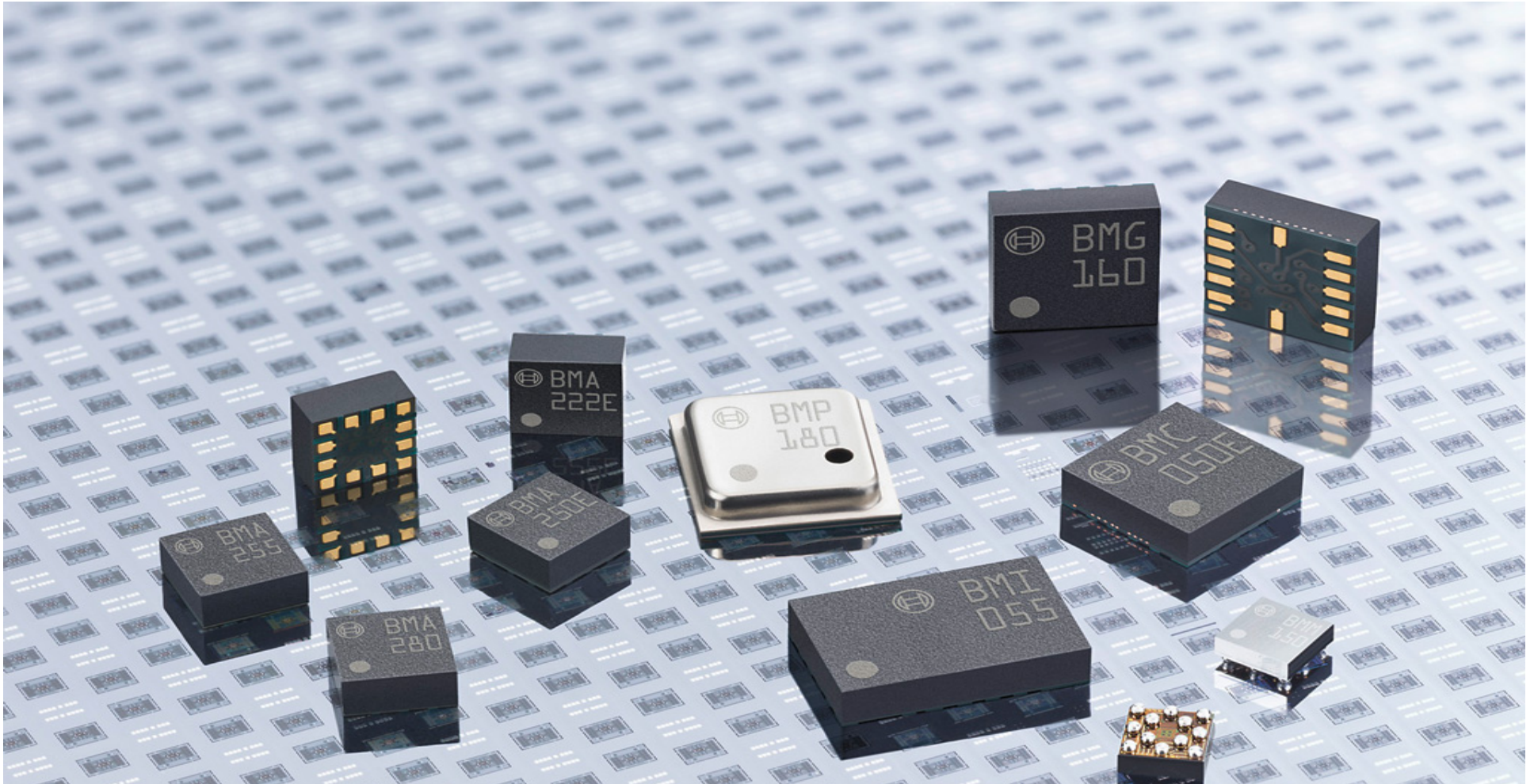
## Consumer MEMS driven by small packages

2005	2006	2007	2008	2010	2011	2012	
							
First triaxial acceleration sensor in 4x4 package	World's smallest digital pressure sensor	World's first 3x3 digital acceleration sensor	Full portfolio of acceleration and pressure sensors	First 2x2 mm acceleration sensor	6DoF eCompass in 3x3	World's smallest triaxial gyroscope in 3x3	World's smallest IMU in 3x4.5





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## Key Success Factor - Technology

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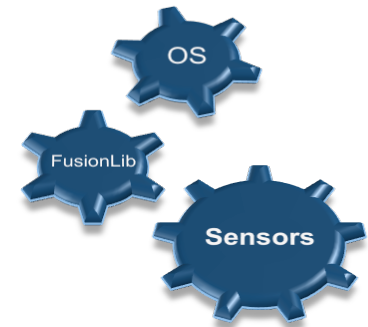


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## Consumer MEMS – the solution challenge

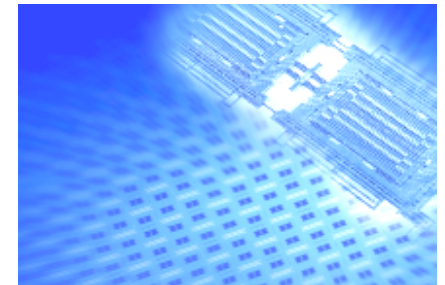
### → Sensor Fusion Software

- 10 DoF solution available today (FusionLib)



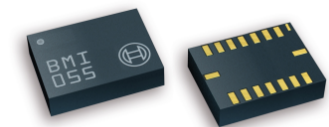
### → MEMS sensor – in-house – technologies required

- Accelerometers
- Magnetometers
- Gyroscopes
- Barometers



### → HW Integrating Components on the rise

- 6DoF: eCompass & IMU
- 9DoF: Accel+Gyro+Geomag

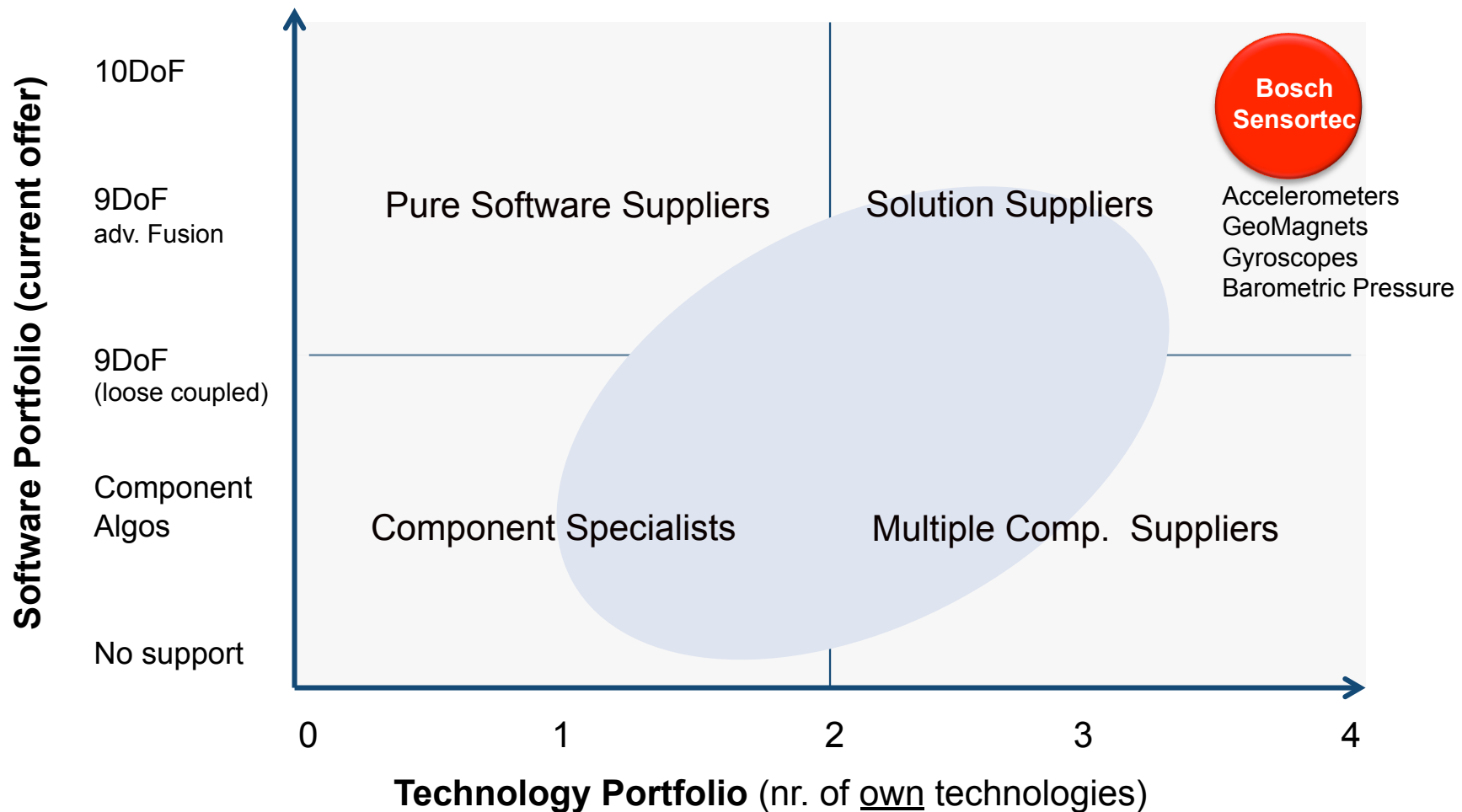


# Contradictory market requirements?

- 1. Accelerometers market requirements:**  
full performance range (8 – 14 bits) & small 2x2 package
- 2. Gyroscopes market requirements:**  
Low noise & low power modes
- 3. Geomagnetic Sensors:**  
high range & high resolution  
Right combination of technologies is the key
- 4. Barometric Pressure sensors:**  
high resolution & high accuracy

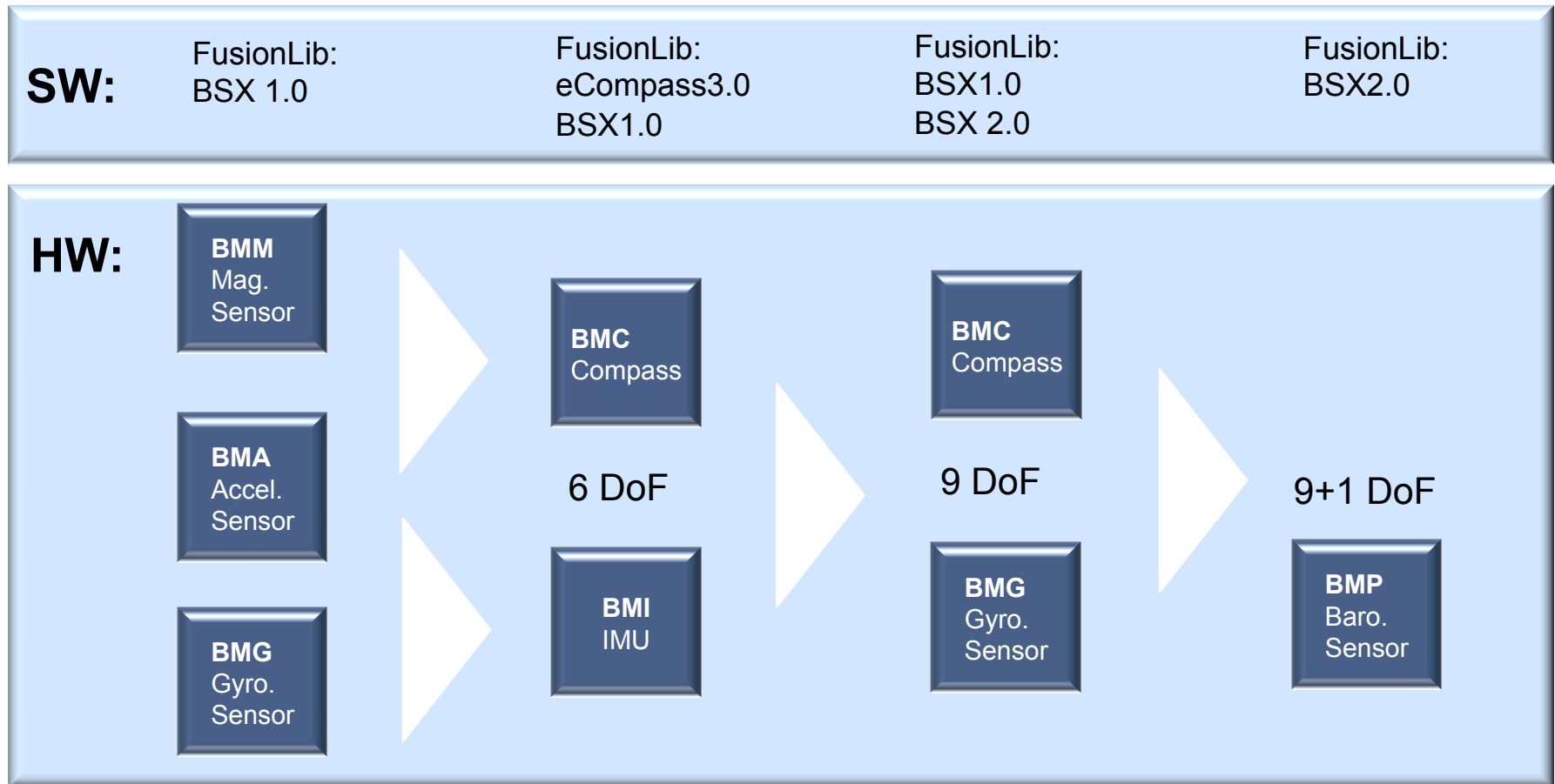


## MEMS Supplier positioning



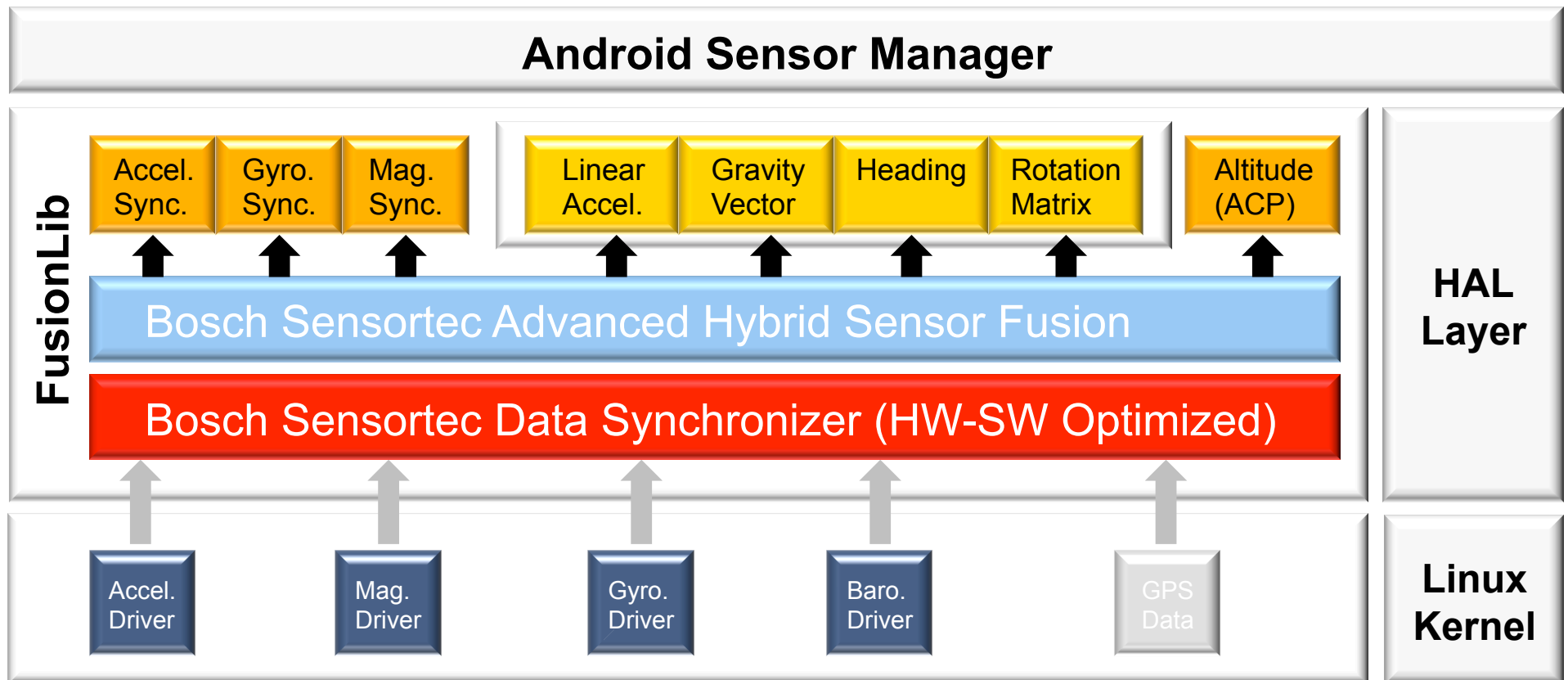


## Hardware Integration paths



**SW needs to be compatible to all HW combinations.**

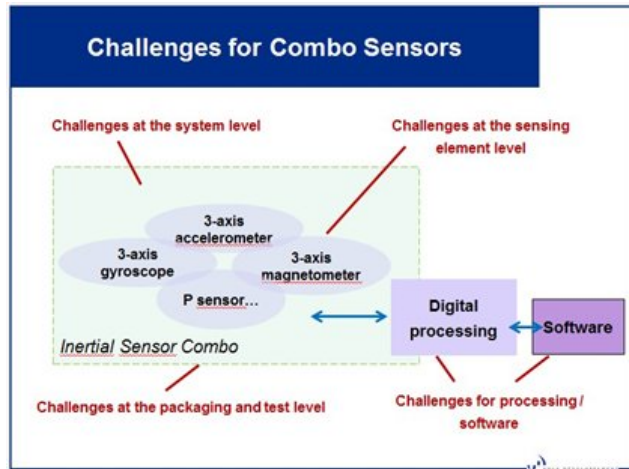
## State of the art 10DoF Solution – Android example



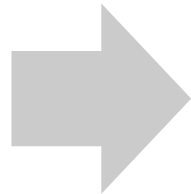
**Customers requirements go well beyond standard HAL definition**

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## 9DoF Sensor Data Fusion Challenges

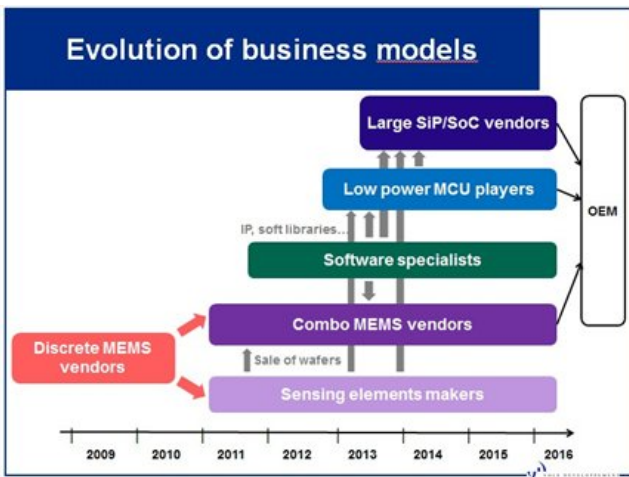


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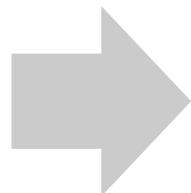


### Technical Problems:

- Sensor Incompatibility
- HW to SW match
- Data synchronization



\*



### Quality & Logistics:

- delivery capabilities ?
- overall quality ?
- overall performance ?

\* As seen by Yole Développement

# Sensor Fusion Challenge - Some Facts

- **Matching Sensor Data: not all sensors work together**
  - Sensor **Performance matching** is key
  - Sensor **data timing matching is crucial** but HW specific
  
- **Geomagnetic sensor integration is the most complex task**
  - Component integration requires **Tools & Experience**
  - SW integration requires **specific Know-How**
  
- **Gyroscope and Barometric sensor implementation is uncritical**
  - As long as out of one hand solution (Ex. FusionLib)



**Best sensor fusion approach by “out of one hand technologies”**



# How to get sensor fusion right

### → Use the right SW approach

- Power & performance optimized (is usually HW specific)
- Compiled and proven libraries

### → Use matched (right) components

- Allow no HW Incompatibility – Interface but also timing problems
- Watch for matched performance – performance grades

### → Choose a supplier with all sensor technology know-how

- Geomagnetic sensor capability is key
- Do not accept patchwork solutions



# Accelerometer Requirements for 10DoF

→ **Accelerometers:** High Resolution & High Accuracy requirement

- Requirement for **single range operation** mode: allows various apps running in parallel while no range switching is required (and possible)
- **Stable accelerometer operation** also during temperature changes (TCO's are a significant performance deterioration)
- Accelerometers contribute to all fused sensors output (Quaternion, heading & linear acceleration)

**Accelerometer performance is key for overall performance**



# Magnetometer Requirements for 10DoF

- **Magnetometers:** Balanced Power / Resolution factor @ high Range
  - Getting **high effective** measurement **ranges & good power per resolution factors** – is the industry dilemma – not for BMC's
  - **SW algorithms** provide ~ 50% of perceived performance. Due to the strongly HW dependency **HW manufacturers need to supply SW.**
  - **Patchwork Combos:** (eCompass & 9DoF from different suppliers) are “**compromise solutions**”.

**Magnetometers are a key component for 9DoF systems**



# Gyroscope Requirements for 10DoF

- **Gyroscope:** low noise and low power requirement
  - Gyroscope is the most power consuming sensor – thus **power management is key**. Fast turn-on and turn-off times are a conventional but effective way for reducing overall power dissipation (fast power up modes are required)
  - Gyroscope technology is the **most complex technology** (compared to magnetometers and accelerometers)
  - But Gyroscope system integration is an easy task...

**Gyroscope size is a limiting factor for 9DoF package integration size**





## Technology enablers (some figures)

### → Robust and cost effective structures

- Based on technology and implementation experience
- Shrinking is a major challenge for MEMS structures

### → Driving at the (controlled) technical limit

- amplitude change in micromechanical structure

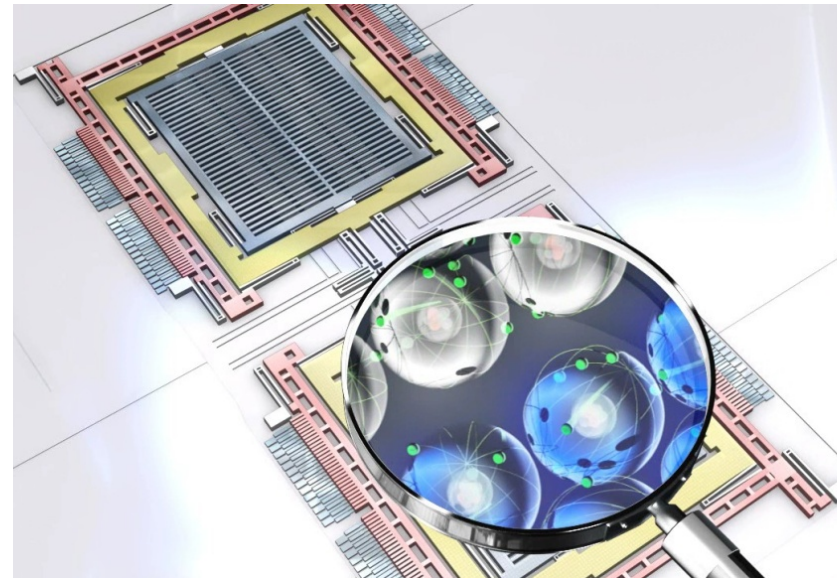
**~4 fm**

(compares to ~0.00001 x Si-Si distance  
or ~ radius of atomic nucleus)

- capacitance change **~2 zF**

( $\mu$  - n - p - f - a - z)  
 $10^{-6}$   $10^{-21}$

(compares to charge variation of  
~0.06 electrons (at 5V))



# Barometer Requirements for 10DoF

### → Barometric pressure sensor (barometer):

- **Resolution is key** it defines the ability to distinguish very small altitude changes. This measurement can not be corrected or backed by another sensor signal
- TCO (temperature coefficient): a low **TCO guarantees the stability** of the altitude measurement.

**High performance barometers are the enablers for indoor navigation**

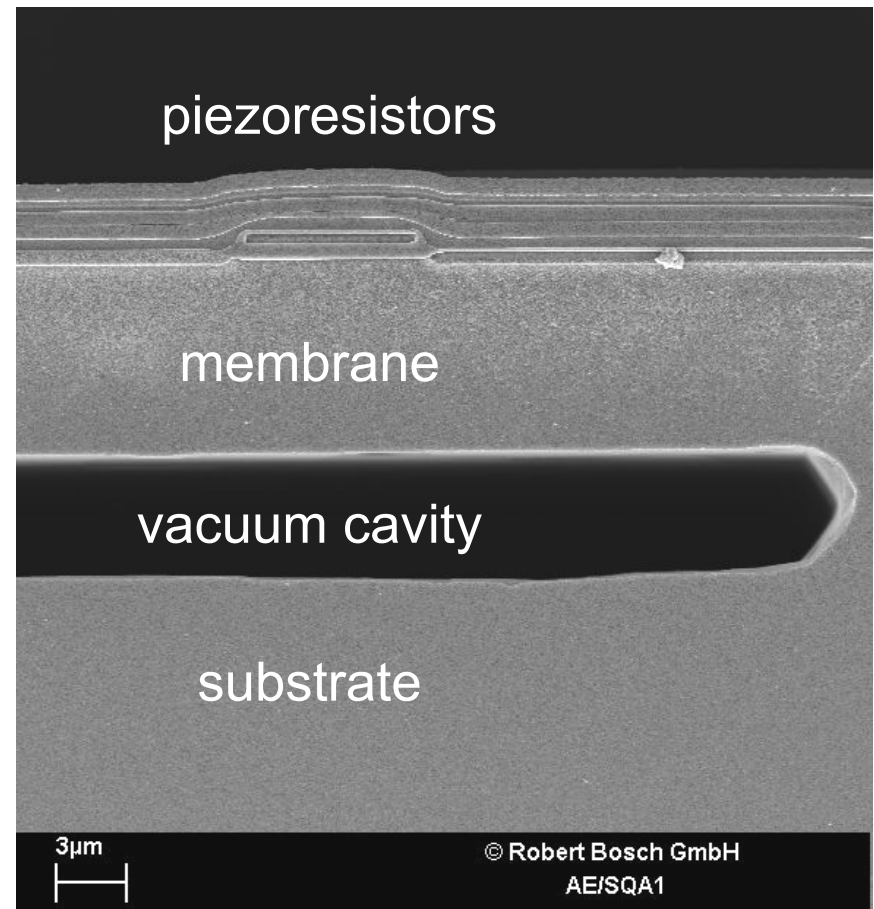
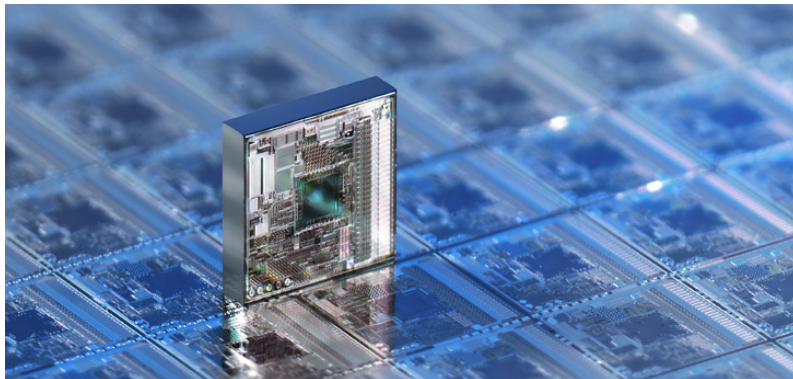


## MEMS technology – surface micromachining

→ **APSM technology (Advanced porous silicon membrane)**

Performance enabler:

A specific technology



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## MEMS Sensor fab in Reutlingen (biggest globally)

Employees	2 758
Production area	34 300 sqm
Minifactories	Wafer fab, sensor frontend, sensor backend, test center
Products	IC, power S/C (chip and packaged), sensors (packaged, customer specific mold package)



### 150 mm module

4 100 sqm  
1 500 wafers/day  
Technologies:  
BCD1, 2, 3, 3s, 4, 4s  
CMOS, Bipolar, PSC bipolar, MOS  
Pressure sensors  
Inertial sensors  
Process:  $\geq 0.5 \mu\text{m}$

### 200 mm module

4 600 sqm  
800 wafers/day  
Technologies:  
BCD4, 4s, 6, 6sCu  
Advanced CMOS, HVCMOS  
Pressure sensors  
Inertial sensors  
Process  $\geq 0.18 \mu\text{m}$





# Bosch Sensortec - Consumer MEMS Technology

## Test Center in Reutlingen



**Highest installed MEMS test capacity globally**

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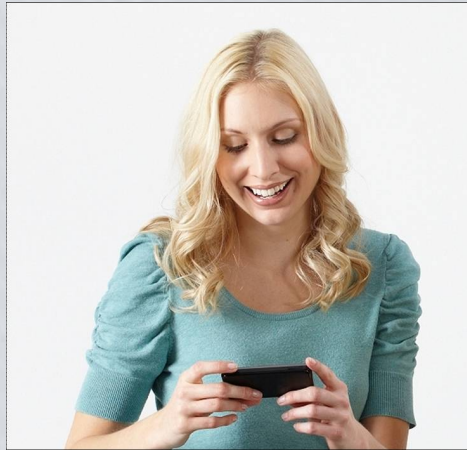
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## Thank you!



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