MEMS Sensors and Passive Safety Applications

► Automotive Electronics and Electrical Systems Forum, 6th May 2008

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Summary

- Automotive Safety Market Trends
- Freescale Technology Capabilities
- MEMS content in Airbag Application
- Airbag Satellite Communication comparison (DSI/PSI5)
- Airbag Future MEMS Integration Trends

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Automotive Safety Market Forces

More than

1.2 Million people

are killed on the world's roads every year !

Safety

Regulation key to mass penetration

- US legislation requiring front and passenger airbag, crash data retention, smart occupant sensing
- No specific airbag legislation in Europe, Japan and Asia Pacific
- China is introducing front and side airbag legislation
- European pedestrian impact legislation may drive pedestrian airbag, although other solutions can be used
- US NHTSA: ESP mandatory for all cars sold in the US by 2012, Europe could follow
- E-call expected to be mandatory in Europe by 2010

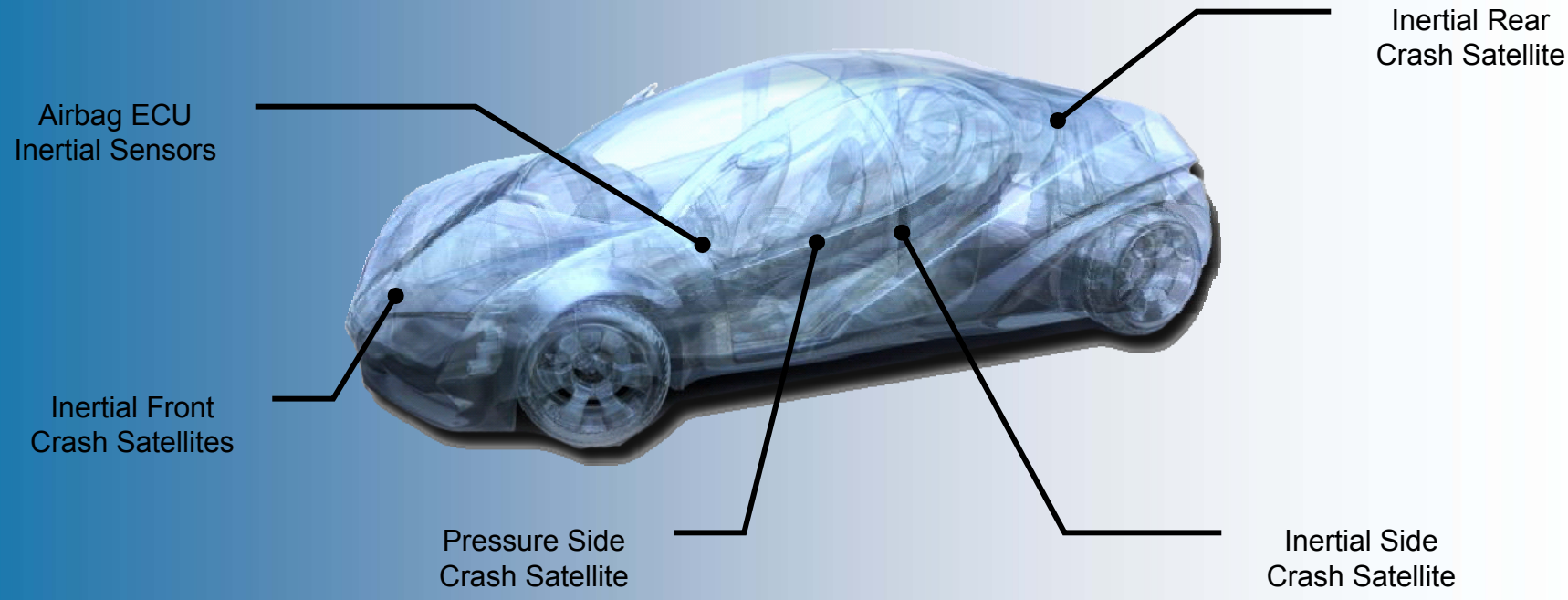
Consumer demand driving the most advanced systems

- According to Chinese CCID consulting agency, Airbag fit rate in 2006 reached 80% on homemade cars
- 2005 survey by European NCAP showed that "safety" was the most important aspect influencing car choice
- Severe crash testing in Europe (front and side) is forcing a 100% fit rate

Airbag MEMS Sensors

- **Front airbag penetration fueled airbag ECU growth in the last decade**
- **Fit rate is close to 100% in most of the world with gains coming from China and India**
- **Europe leads the way for side impact and head airbag**
- **Side and head airbag fuels growth in satellite sensors**

- **Up to 9 MEMS based sensors in High End vehicles used for crash detection**



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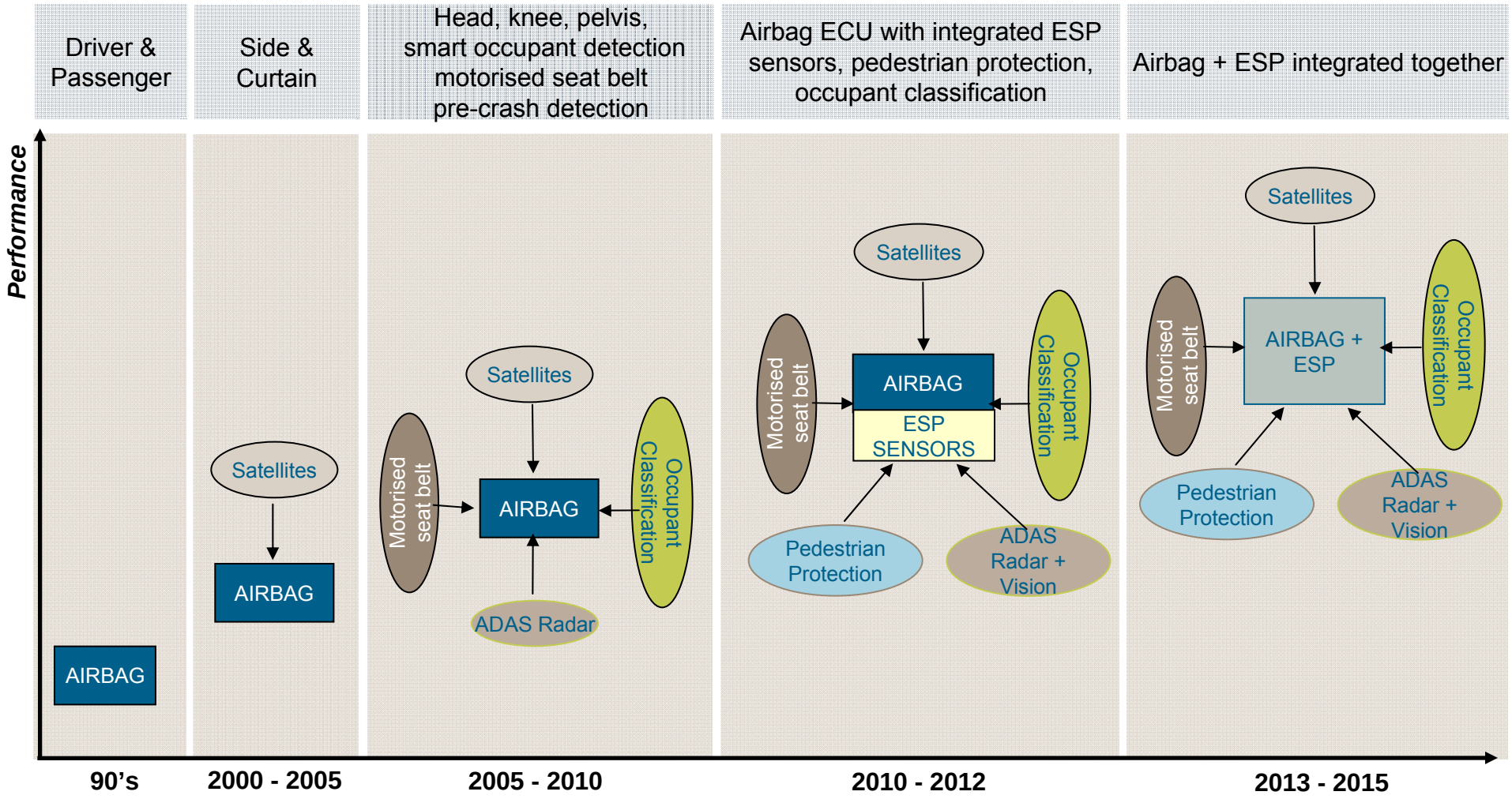
Airbag Integration Trends



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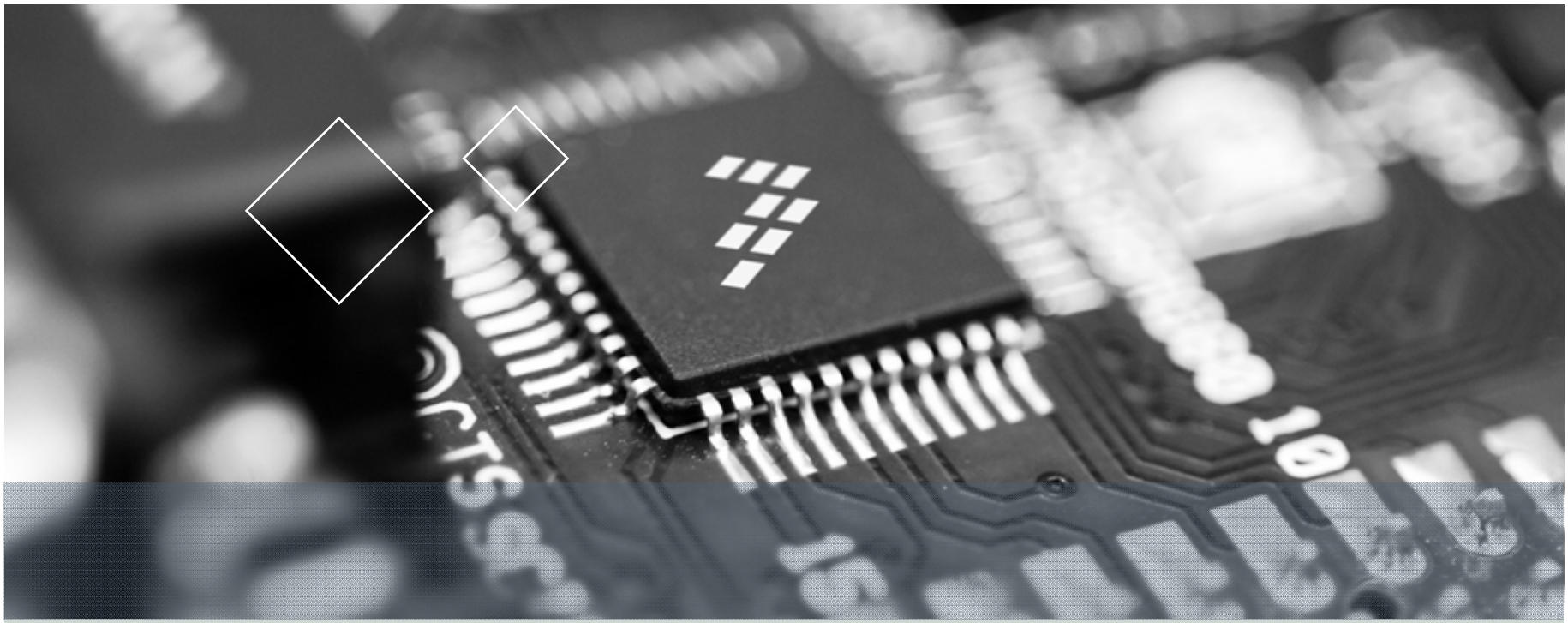

Technology and Product offering

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Freescale commitment to Automotive and MEMS

Global Leadership

Freescale is the world's leading provider of semiconductors to the automotive market.

Long-term Presence

We know what it takes to meet the unique requirements of the automotive market, and we've been delivering since the 1970s.

Quality

Focused on achieving Zero Defect performance.

MEMS based Sensors:

- Freescale passed the **300 million units acceleration sensors** in custom safety automotive applications
- Since 1980, Freescale shipped over **500 million pressure sensors**




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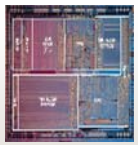
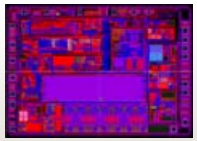
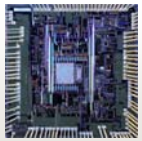
Integration Capability

Proven IP Portfolio: SoC

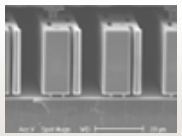

Embedded Control/Memory

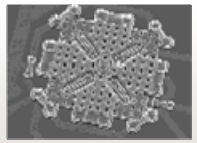

Hi-Performance Analog

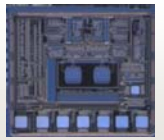

Power Management


Connectivity

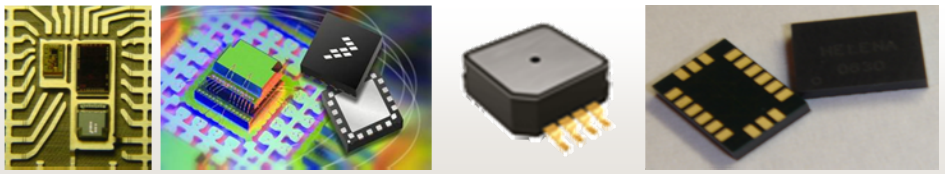
Diverse MEMS Sensing Technologies


High Aspect Ratio


Surface Poly


CMOS Surface Poly


Integrated Bulk



Flexibility in Proven ASSP/ASIC and SiP/SoC Techniques Enables Fast and Low Risk Time to Market

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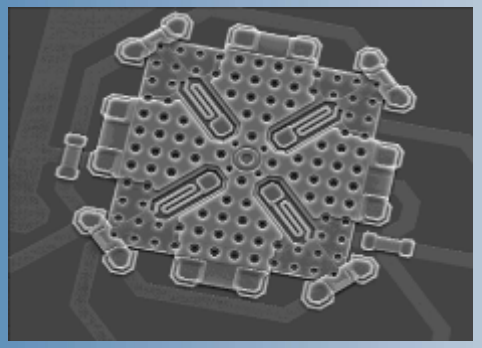
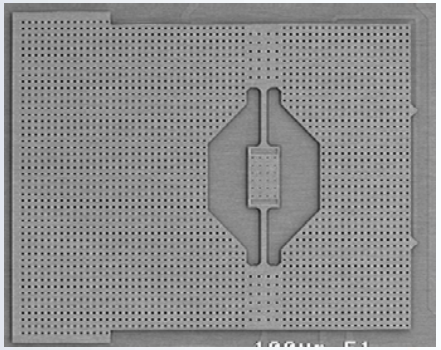
Example of Automotive Inertial Sensing Elements

Z axis Elements

Poly Silicon, Folded Beam Z-Axis Sensing

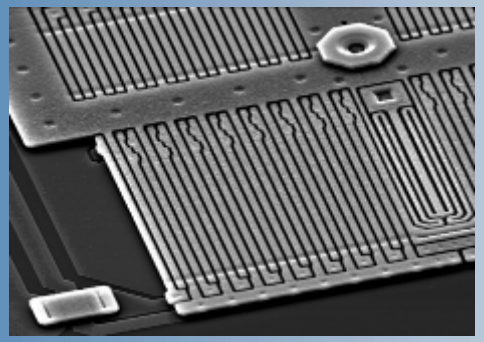


Poly Silicon, Torsional Beam Z-Axis Sensing

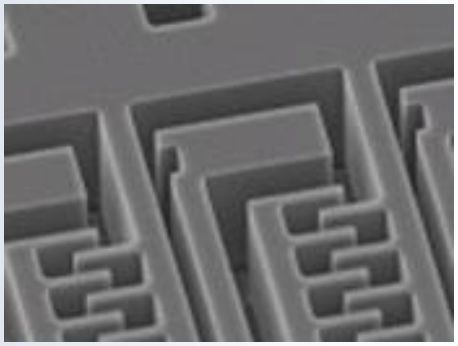


X axis Elements

Poly Silicon, Interdigitated X and XY-Axis Sensing



Harmems, Interdigitated X and XY Sensing



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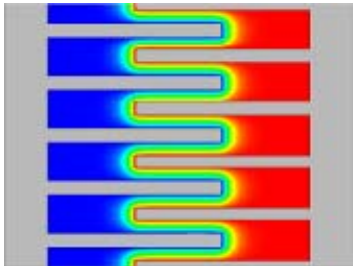
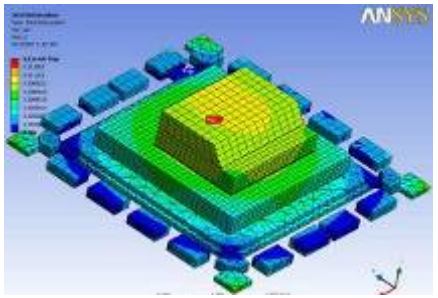
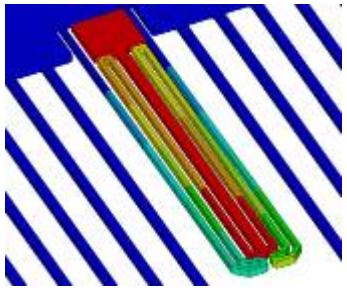
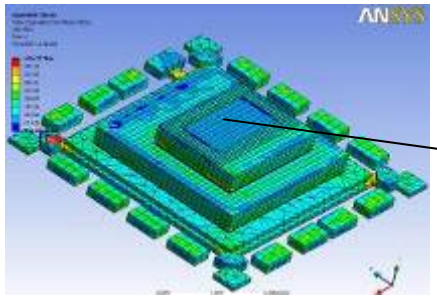
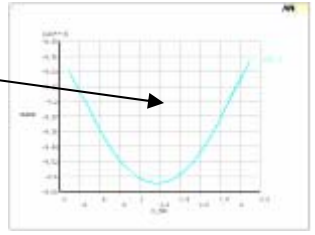
Simulation and Modeling Capabilities











- Use FEA to respond to the “Multiphysics” challenge of MEMS design: Mechanics, Electrostatics and Fluidics.
- Use analysis to study TCO (Temp Coefficient Offset) behavior in various package.
- Use analysis to study vertical and lateral deformation of the g-cell
- Model package deformations over temperature and extract surface curvature where transducer sits.

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Special Automotive Tests Capabilities

Mechanical Drop Tower

Ball Drop Test

- **Mechanical drop tower mounted along orthogonal sensing axes.**
- **The drop tower could apply shock pulses predicted to elicit a failure mechanism**

- **Ball drop test can produce high g amplitudes at high frequencies assumed comparable to those seen during crash test.**
- **If the output reproduces itself during several ball drop test runs, this means the device is performing in a controlled manner.**

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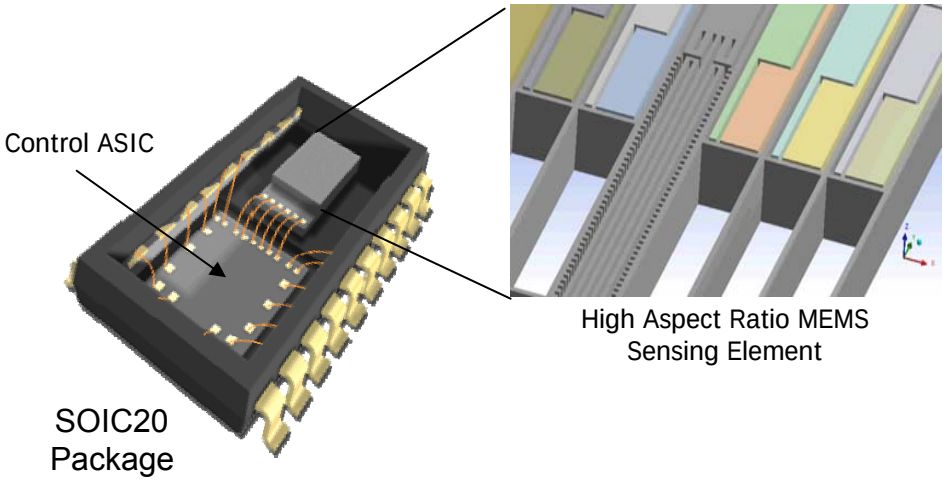
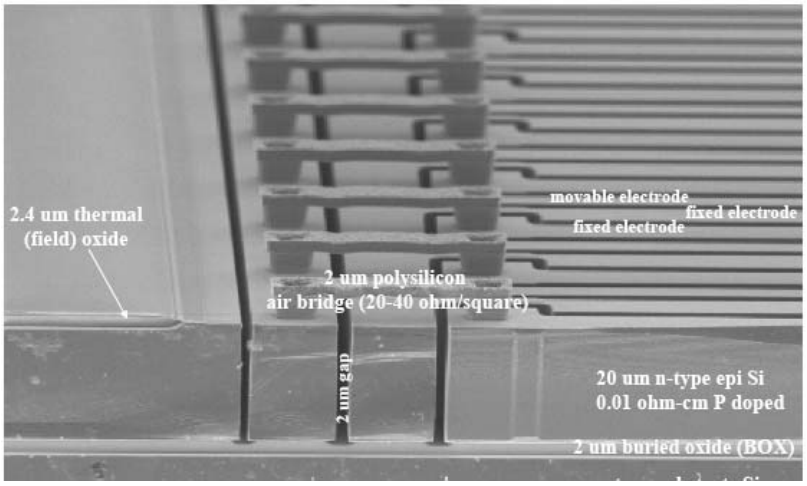
New Main ECU Airbag Sensors

- Dual axis Sensors with fully digital signal processing:
  - Overdamped Inertial sensing element
  - Analog or Digital output
  - 3.3V or 5V Power Supply
  - Bidectional Self-test
  - Programmability (filters, ...)

Front Airbags



High Aspect Ratio MEMS
Sensing Element



World market: > 60 Mu units / year

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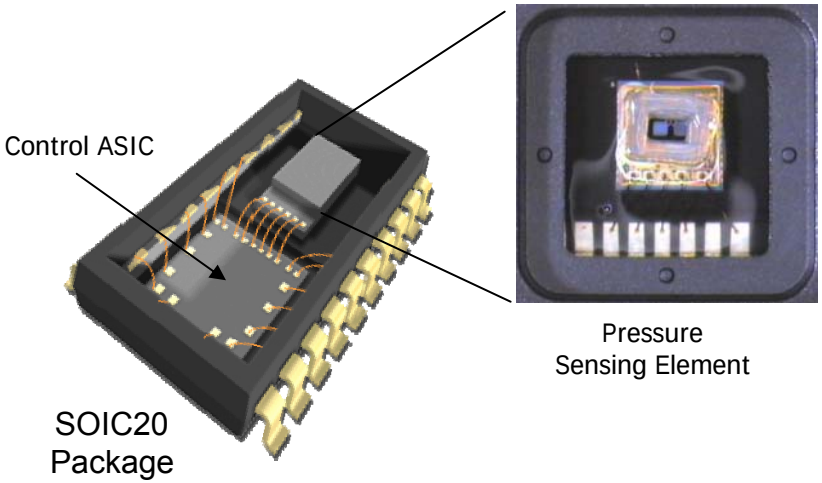
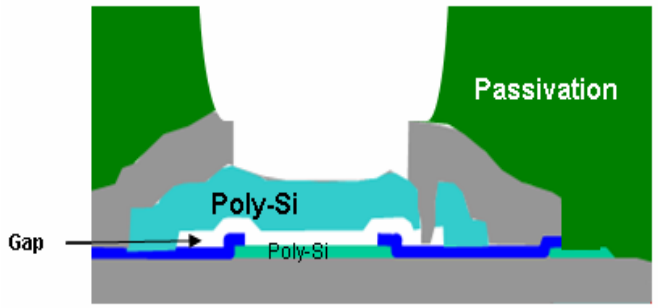
New Integrated Airbag Satellite Sensors

- System-in-Package (SiP) solution integrates board-level functionality in a single package:
  - Pressure sensing element
  - State Machine
  - Power supply
  - Communication protocols (PSI5 or DSI)

Side Airbag Curtains





CMOS Pressure cell

World market: > 20 Mu units / year

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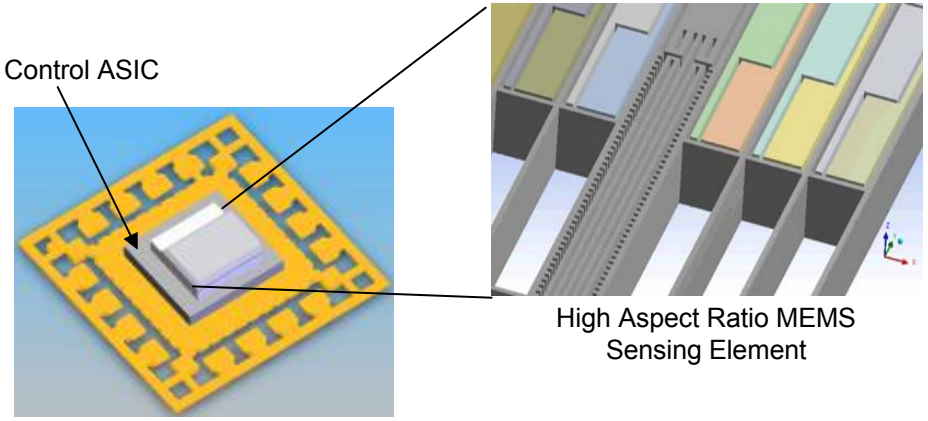
New Integrated Airbag Satellite Sensors

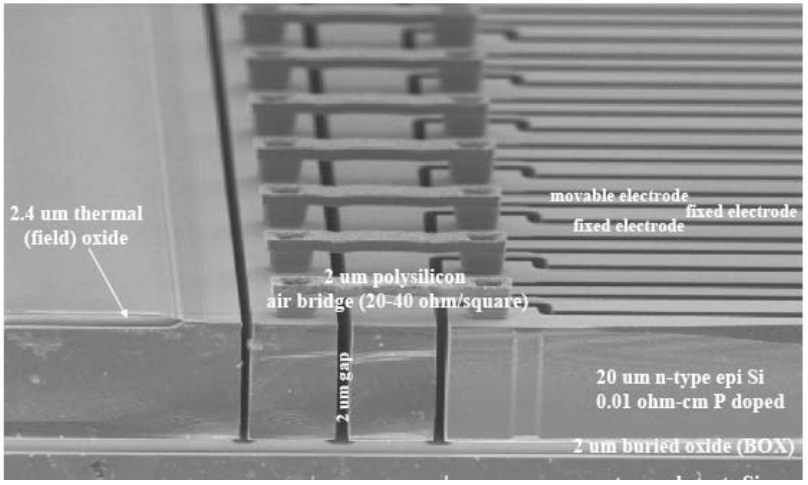
- System-in-Package (SiP) solution integrates board-level functionality in a single package:
  - Inertial sensing element
  - State Machine
  - Power supply
  - Communication protocols (PSI5 or DSI)

Side Airbag Curtains



QFN Package

High Aspect Ratio MEMS Sensing Element



World market: > 150 Mu units / year

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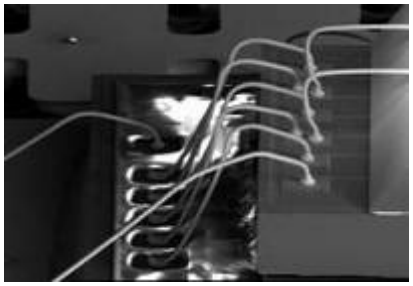
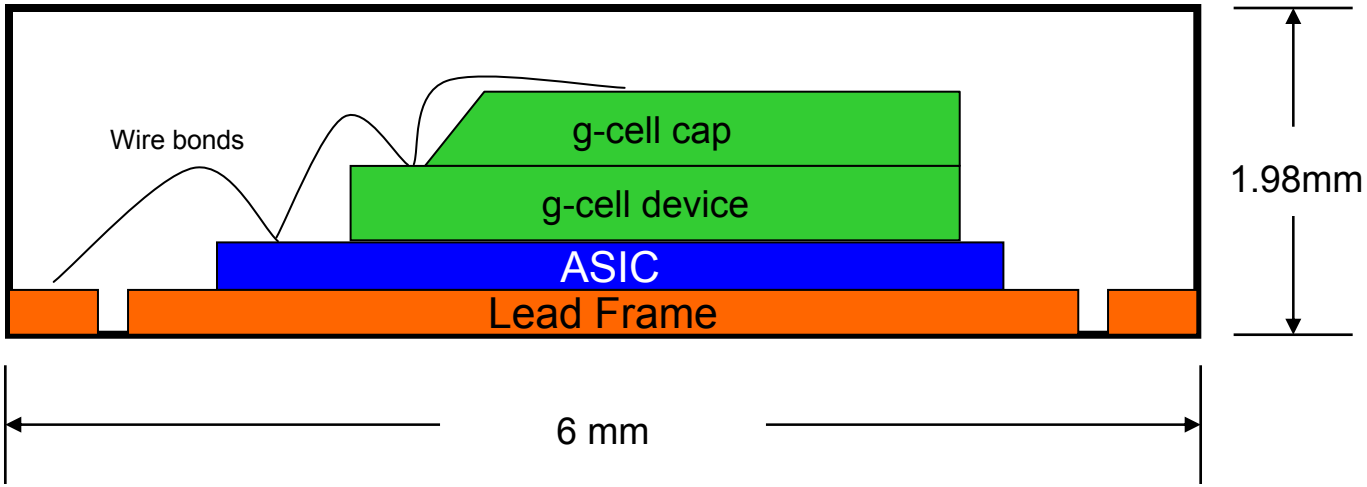
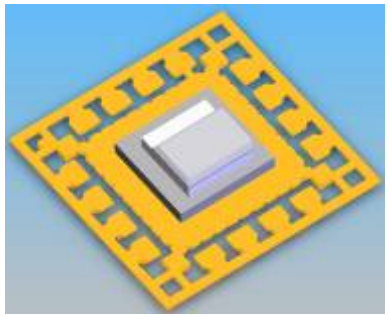
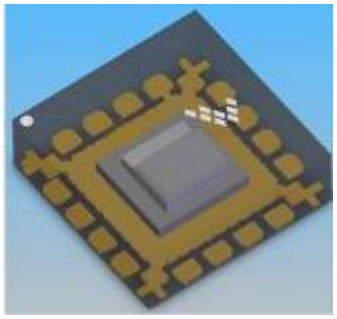
QFN Package Cross Section

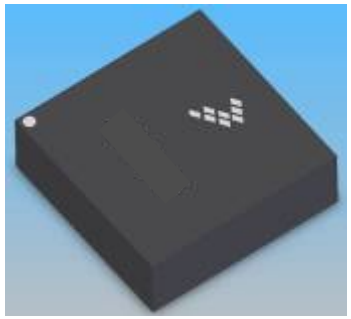


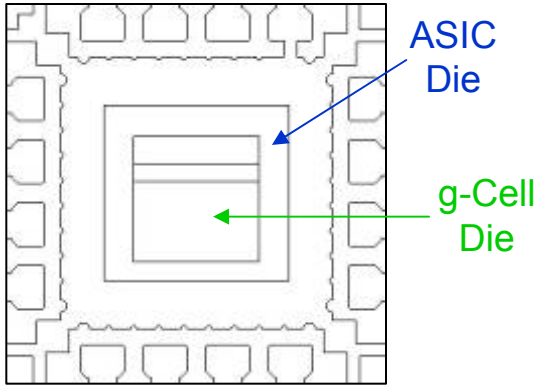


Automotive Qualified Package:
In production since 2006









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Airbag Satellite Communication

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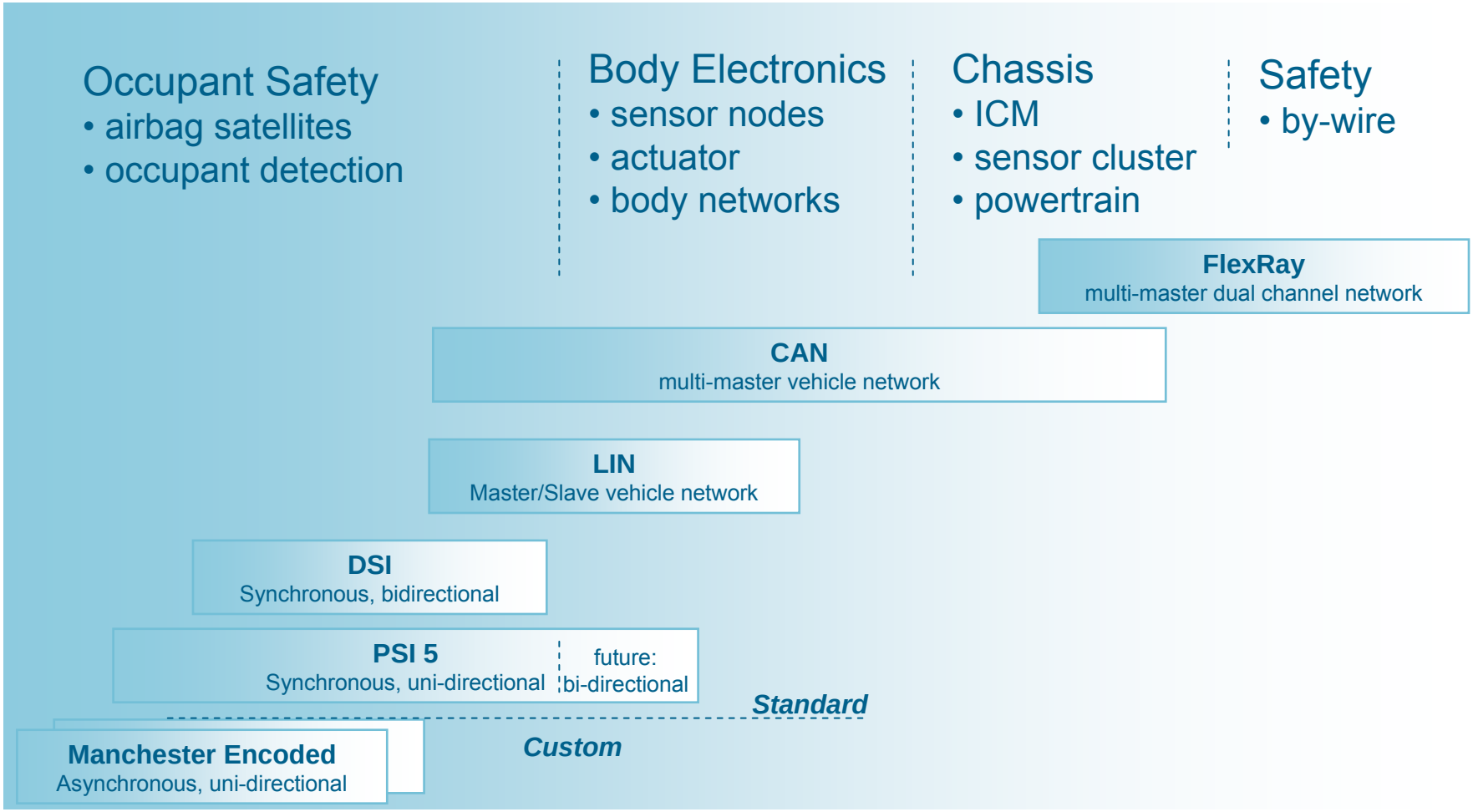
Comparison – PSI5 and DSI/DBUS in the vehicle network heirarchy



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Comparison – summary

Feature	PSI5 (V1.2)	DSI/ DBUS	Comment
• maximum data rate	189kbit/s	150kbit/s (200kbit/s)	DSI/DBUS higher data rate in development
• bi-directional data	no	duplex	PSI5 bi-directional data (not duplex) expected in next version of specification (Q3 2008)
• differential data	no	yes	
• bus architecture	parallel (daisy-chain)	daisy-chain	PSI5 daisy-chain option expected in next version of specification (Q3 2008)
• number of sensors	5 (max) 3 typical	15 (max) 3-4 typical	

Comparison – system features

Feature	PSI5	DSI/ DBUS	Comment
• software complexity	low	low/high	Without use of DSI/DBUS loopback, fault tolerance and re-configuration features, software overhead comparable with PSI5
• scalability	no	good	PSI5 requires complete re-configuration of network to add a sensor. DSI/DBUS can add sensor easily, but bandwidth is shared, leading to reduction in sample rate when sensor added.
• power consumption	low	high	PSI5 I_{LIMIT}= 65mA per interface DSI I_{LIMIT}= 150mA per interface DBUS I_{LIMIT}= 250mA per interface
• cost	low	low / moderate	DSI/DBUS feature richness leads to higher cost (when used)
• availability	2009	now	

Passive and Active Safety Integration Trend

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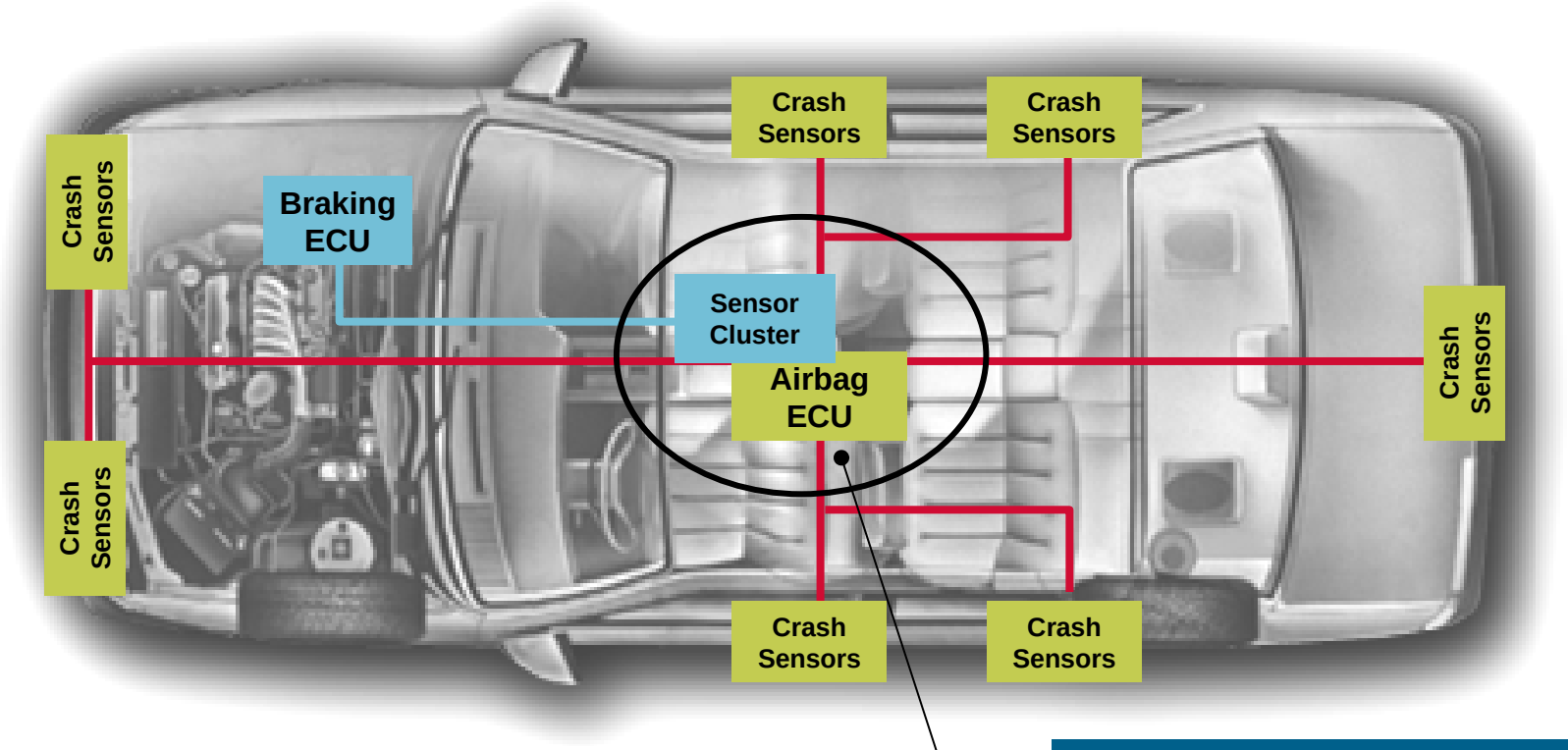
The Passive and Active Sensor Network



Multiple modules sharing the same spot!
Possibility for optimization and cost reductions

CAN bus

Dedicated Airbag bus (DSI for example)

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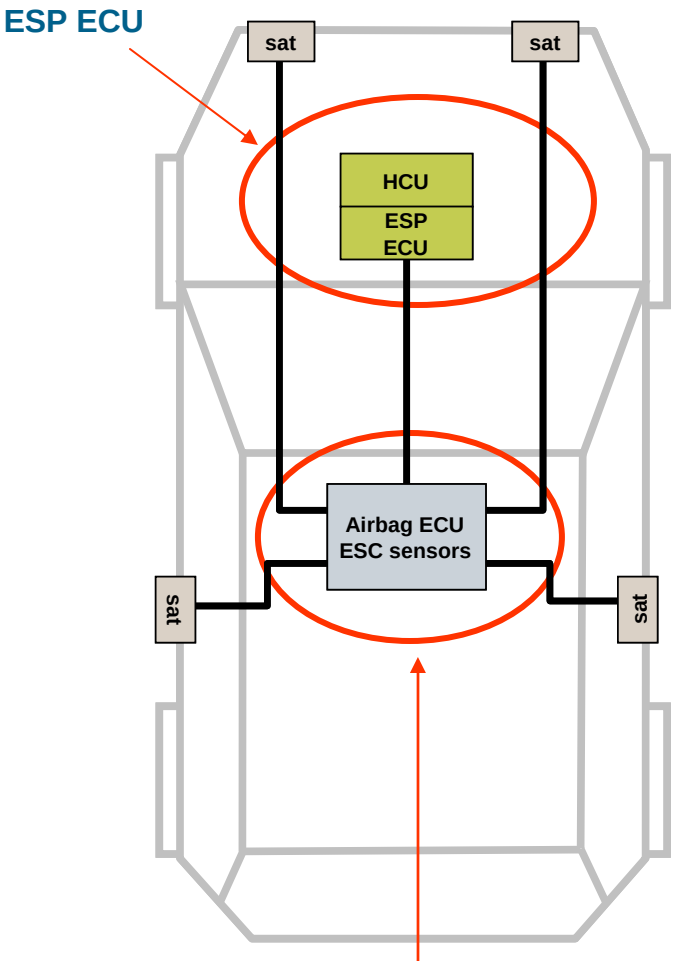
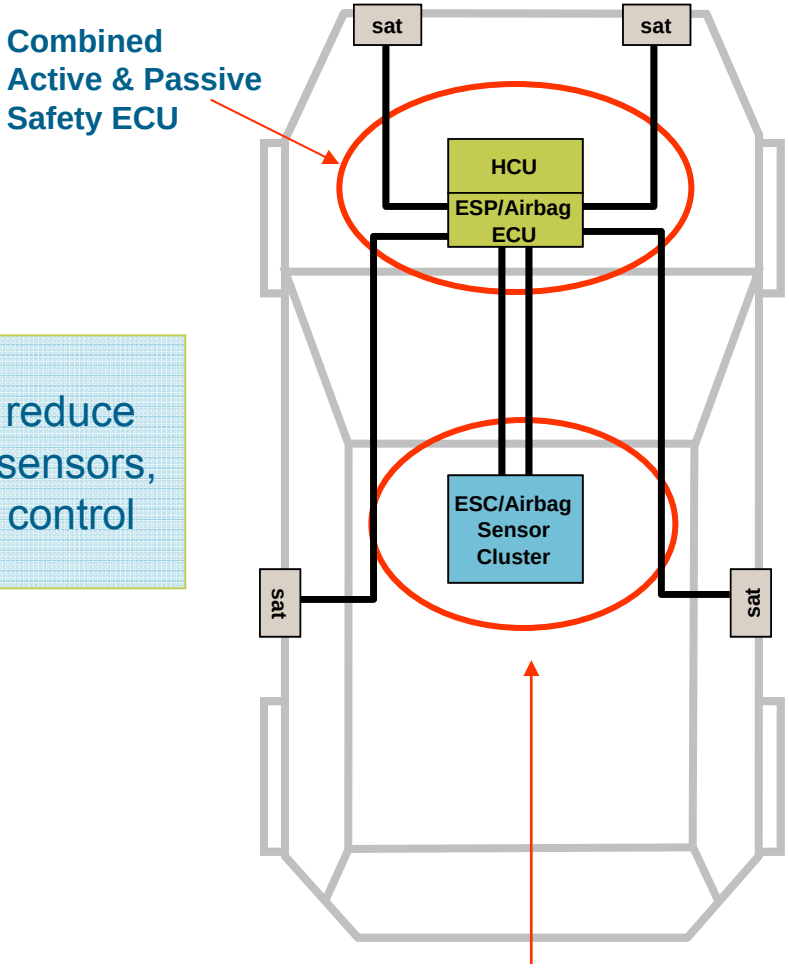
Airbag Possible New Architectures



Airbag ECU and ESP sensor cluster merge together

Goal is to reduce number of sensors, centralise control

OR



Centralized Airbag & ESP sensor cluster

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Possible Integration Scheme Summary

Traditional Architecture	Braking ECU Alternative	Airbag ECU Alternative	Sensor Fusion Alternative
Plus ► Known architecture ► Flexibility in placement inside the vehicle	Plus ► "All in one" braking solution ► Saving one housing and associated wirings, connectors, costs ► Component cost savings (MCU and Analog)	Plus ► Ideal position in the car ► Saving one housing and associated wirings, costs ► Component cost savings (MCU and Analog) ► Potential for sensor data sharing (roll over)	Plus ► True sensor fusion ► Plausibility check ► Ideal solution for sophisticated chassis management algorithm ► Flexibility of mounting if a 6 Degree of Freedom unit is used
Minus ► Dedicated module (cost) ► Wiring between the sensor cluster and the braking ECU ► Ideal position in the car is usually also used by the Airbag ECU	Minus ► Very harsh environment for Inertial Sensors ► Temperature, vibration, electromagnetic interferences	Minus ► Available space inside the airbag ECU	Minus ► Cost ► Mainly targeted to high end, complex chassis management solutions ► Airbag sensors must be on a dedicated bus for autarchy reasons

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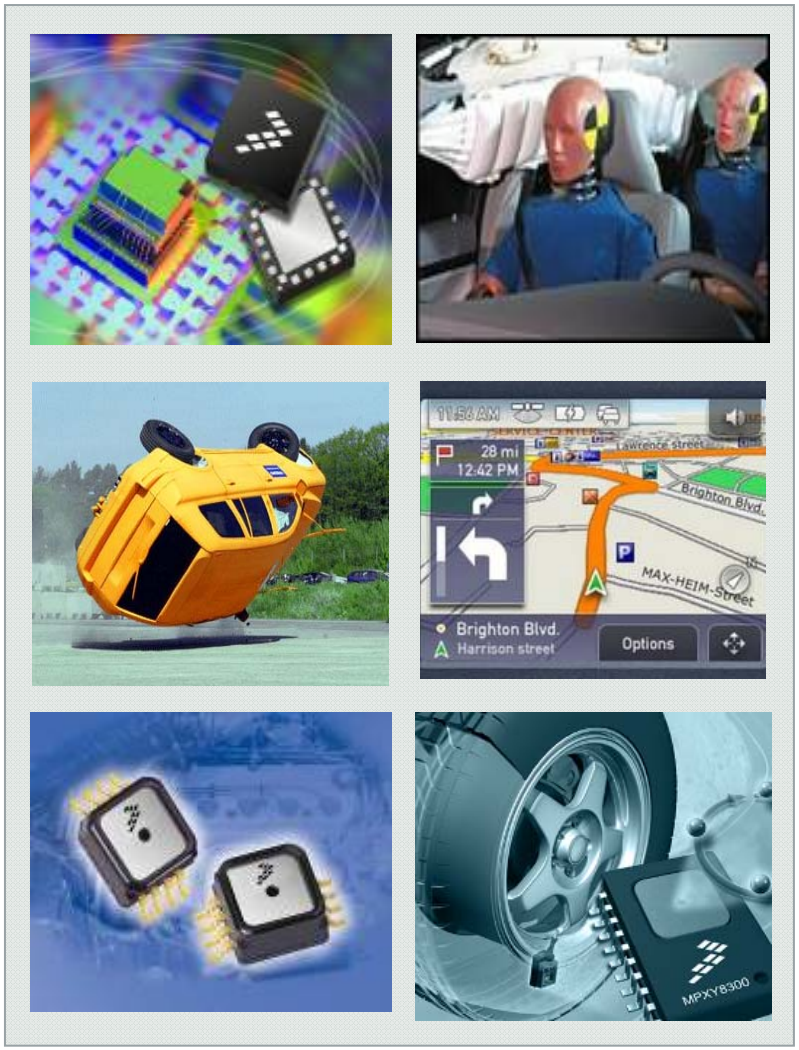
Conclusion

- Automotive trend is towards more Safety: with Airbag and now Vehicle Dynamic Control (VDC)
- Freescale is a key player in MEMS market and for Airbag Sensors
- Simulation & Modelling tools are key to develop the next generation of devices
- FSL has solution for both PSI5 and DSI Satellite Communication
- Airbag and VDC modules are merging together
- Long term Vision: Complete System Integration like VDC and/or airbag



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