

Small Form Factor MEMS Packages

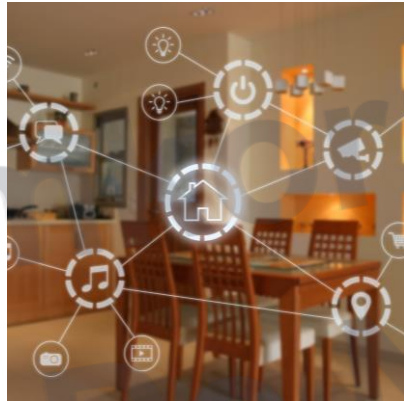
Lawrence Natan | Sr Manager,
MEMS & Sensors

Agenda

- 1 MEMS All Around Us: The Megatrends Adoption
- 2 Understanding the Challenges
- 3 Solutions for Small Form Factor MEMS Packages
- 4 Summary

MEMS, All Around Us: The Megatrends Adoption

MEMS: All Around Us



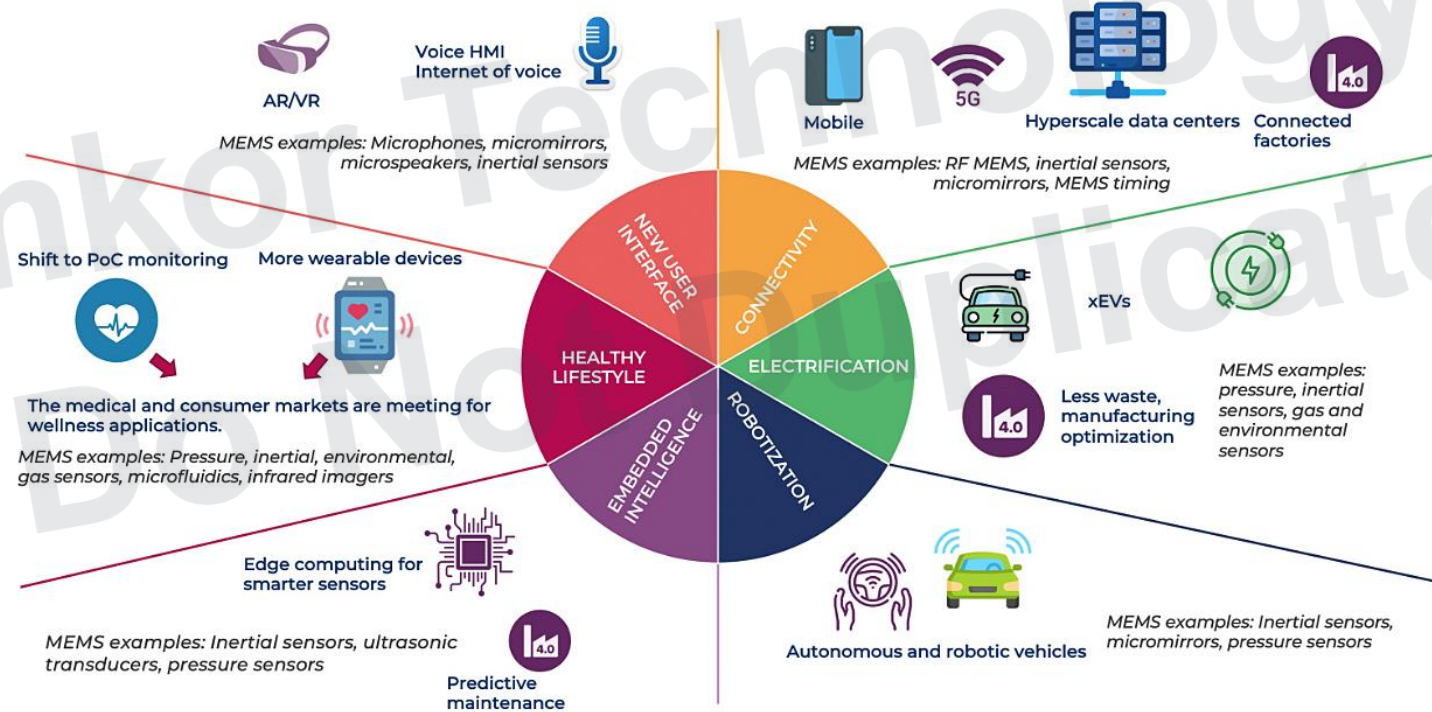
Courtesy Sandia National Laboratories
Summit™ Technologies MEMS.sandia.gov



Industry Megatrends Adoption

MEGATRENDS RELATED TO MEMS ADOPTION

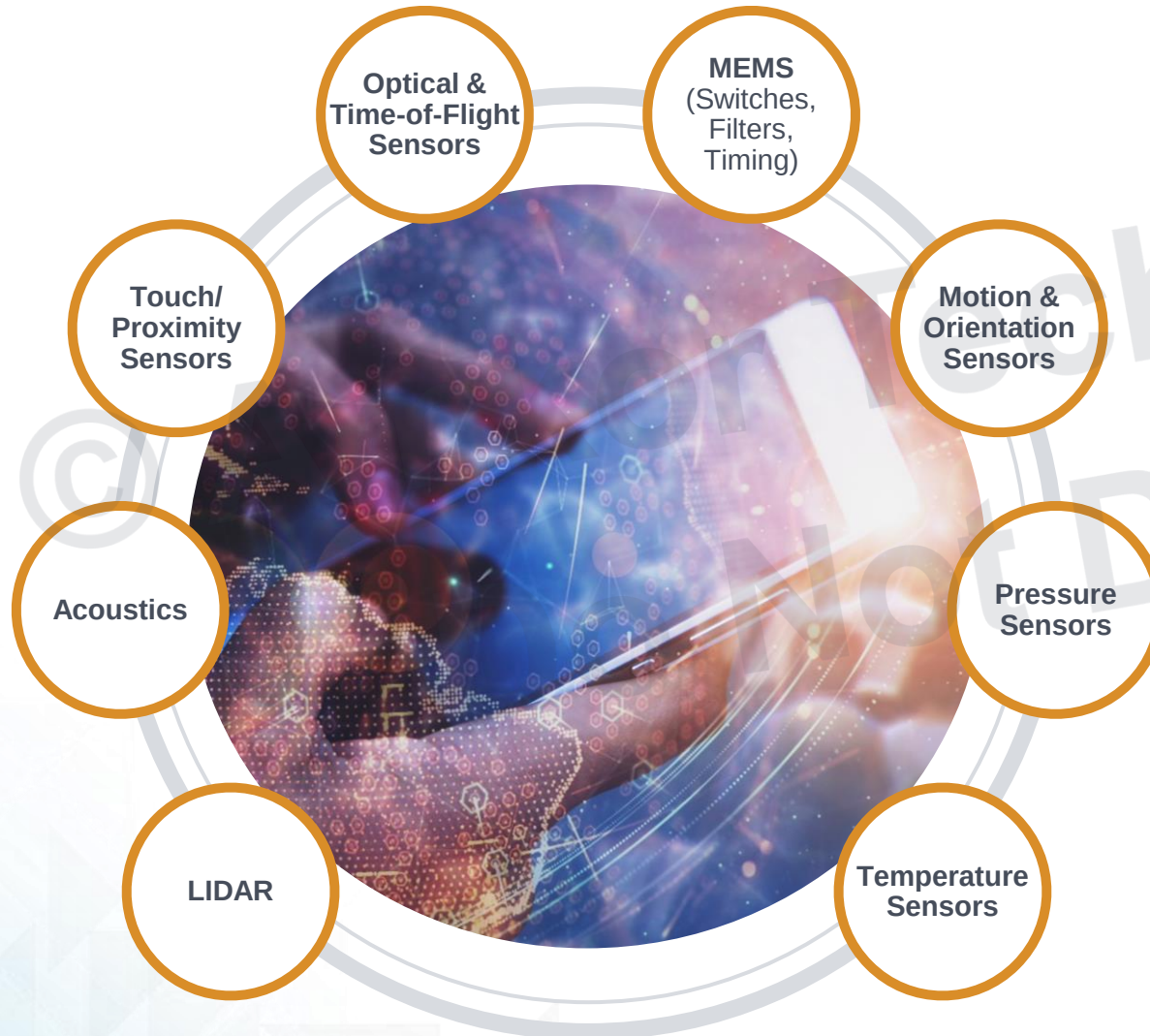
Source: Status of the MEMS Industry report, Yole Intelligence, 2024



Source: Yole Intelligence 2024

Communications

Amkor Provides Package Solutions for MEMS & Sensors in a Smartphone



Sensor Applications

- ✓ Enhancing performance & connectivity
- ✓ Improved identification & security
- ✓ More immersive & personalized experience

Consumer Products

Amkor Enables Smarter Sensors for IoT Through Innovative Package Solutions

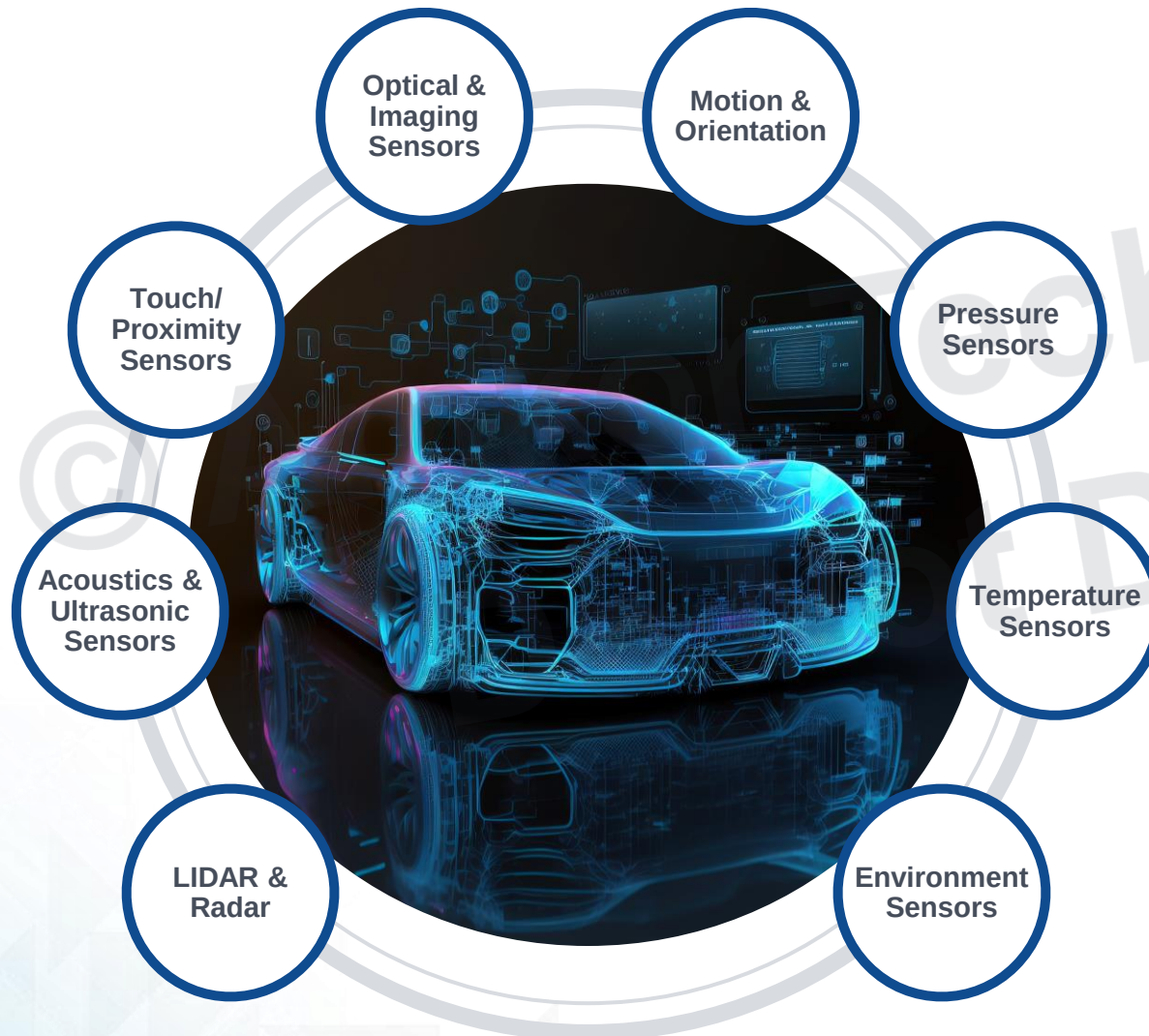


Sensor Applications

- ✓ Fitness & activity tracking
- ✓ Health monitoring
- ✓ Immersive experience in AR/VR through gesture recognition

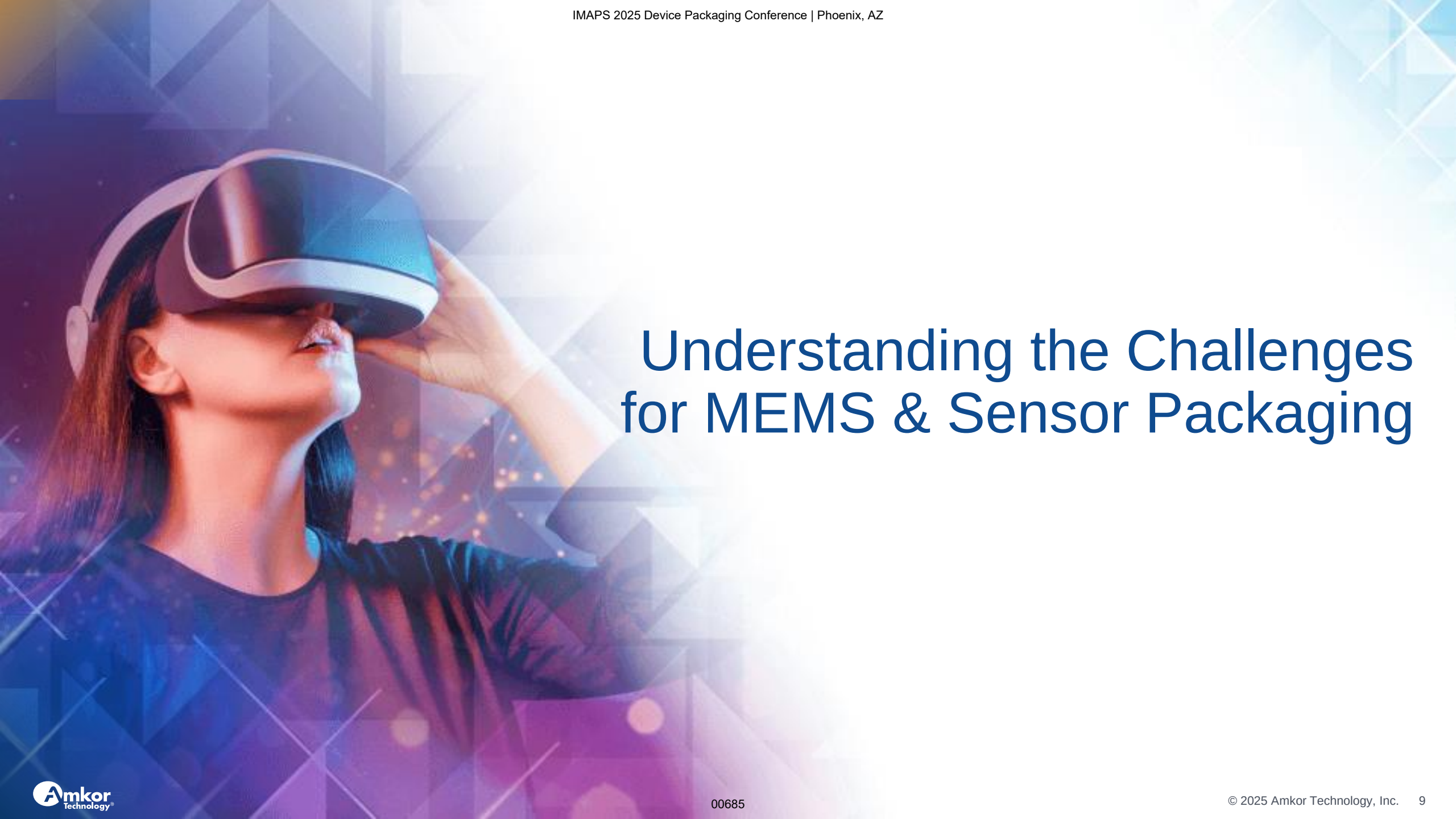
Automotive & Industrial

Amkor is the Leading Automotive OSAT



Sensor Applications

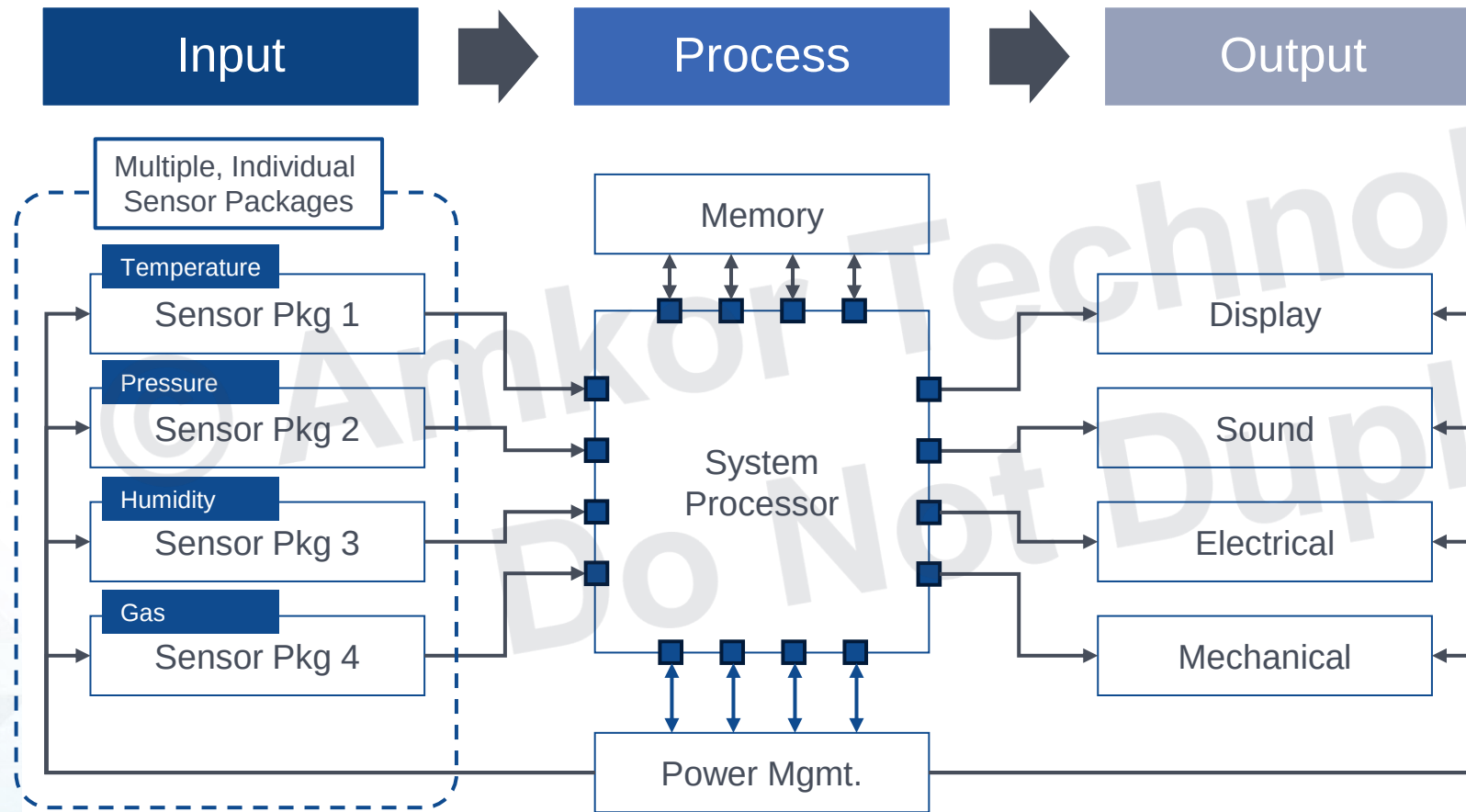
- ✓ Advanced Driver Assistance Systems (ADAS), autonomous functionality
- ✓ Infotainment, telematics, digital cockpit, passenger comfort
- ✓ Improving vehicle safety



Understanding the Challenges for MEMS & Sensor Packaging

Basic System Framework

Input – Process – Output (IPO) Model, using Individual Sensor Packages

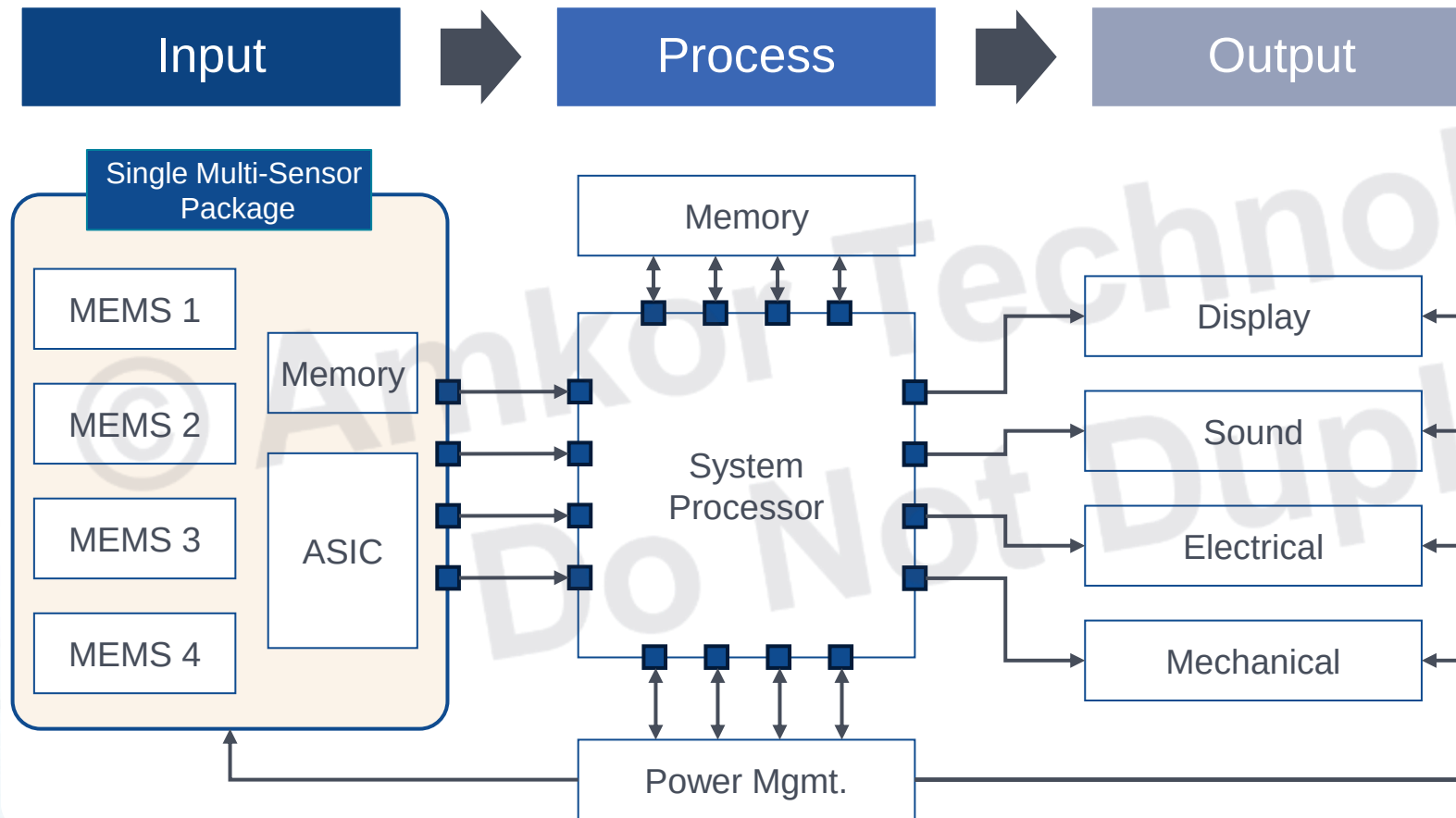


System Challenges

- Thermal Issues
- Latency Issues
- Inefficient Power Delivery
- Large system footprint
- More parts, more potential failure points

Basic System Framework

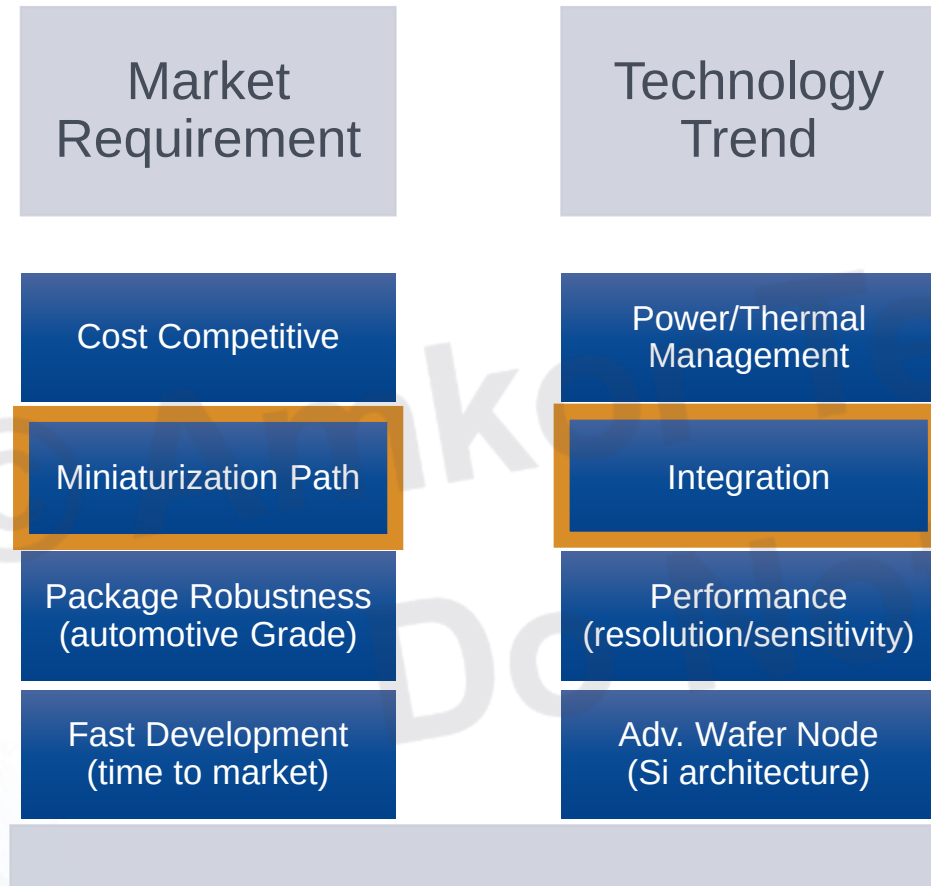
Input – Process – Output (IPO) Model, using Single Multi-Sensor Package



System Benefits

- ✓ Improve Thermals
- ✓ Better Latency
- ✓ Low-Power Operation
- ✓ Miniaturization Path
- ✓ Less Parts, reduced failure points

MEMS & Sensor Packaging Challenge



Package Solution

- ▶ Supports standardization
- ▶ Lower development cost
- ▶ Faster time-to-market
- ▶ Flexible for new technologies

FORM FACTOR

A critical influence for package solutions

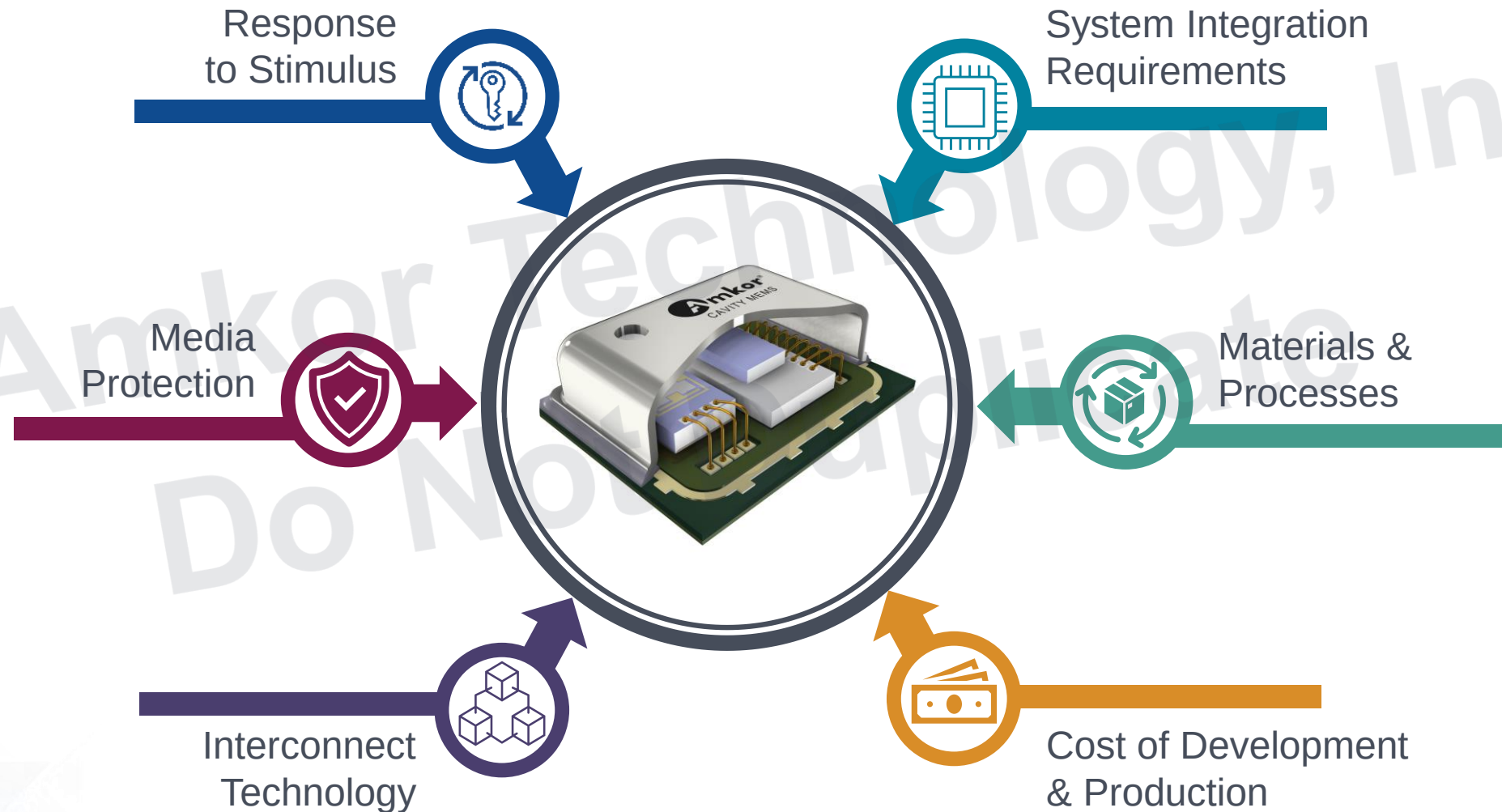
Solutions for Small Form Factor MEMS Packages

What is Form Factor?

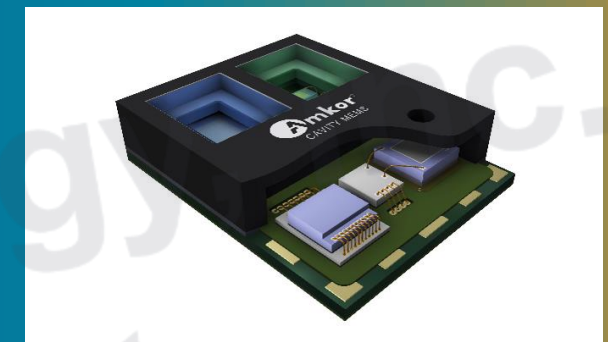
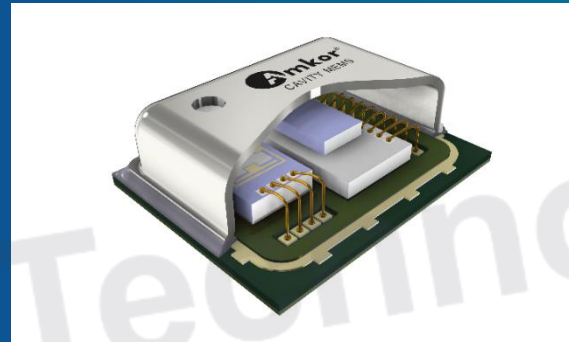
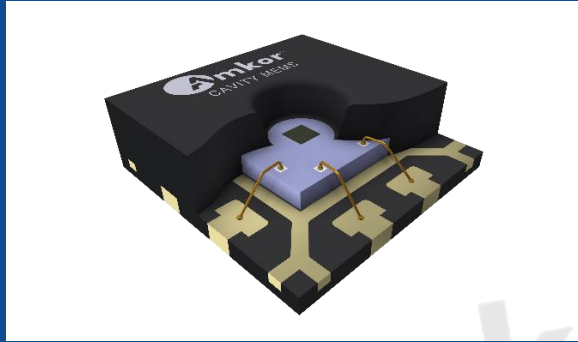


Design attribute referring to **size, shape** and **physical form** of a device, that determines the **function & interaction with other components** of the system

Form Factor Impact In MEMS Packaging



Amkor's Strategy: Transition to SiP (Sensor-in-Package)



Customized Solutions

- ▶ Application specific/performance driven
- ▶ Costly custom tooling's & process flows
- ▶ Supply chain vulnerabilities

Standardized Platforms

- ▶ Faster development cycles
- ▶ Manufacturing efficiency = lower cost & easier to scale
- ▶ Supply chain flexibility

Integrated Architecture

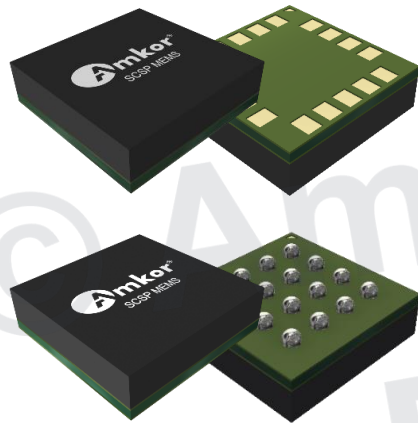
- ▶ Enable system-level solutions
- ▶ Miniaturization paths & modular designs
- ▶ Extended supply chain compatibility

MEMS & Sensors Packages

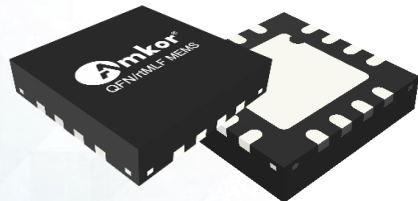
By Form Factor (Influenced by Stimulus Response & Media Protection)

Overmolded Packages

Laminate BGA/LGA

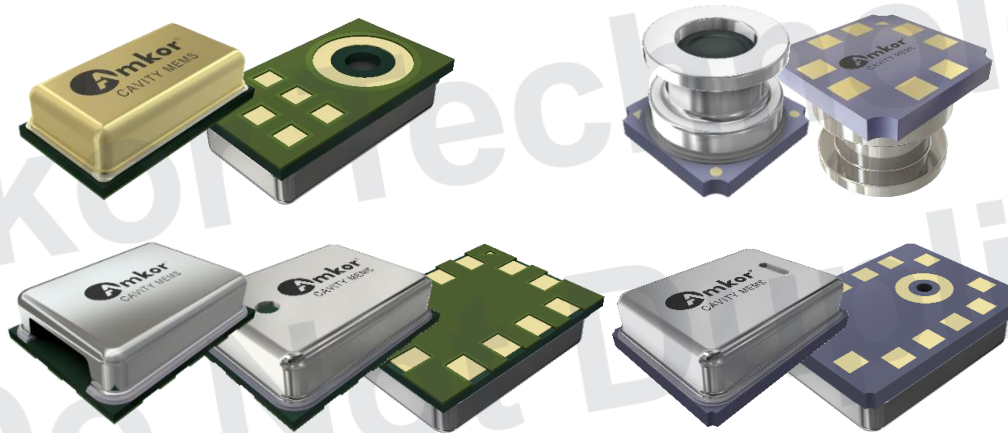


QFN/rtMLF™ package



Cavity Packages

Lid cavity/ceramic cavity

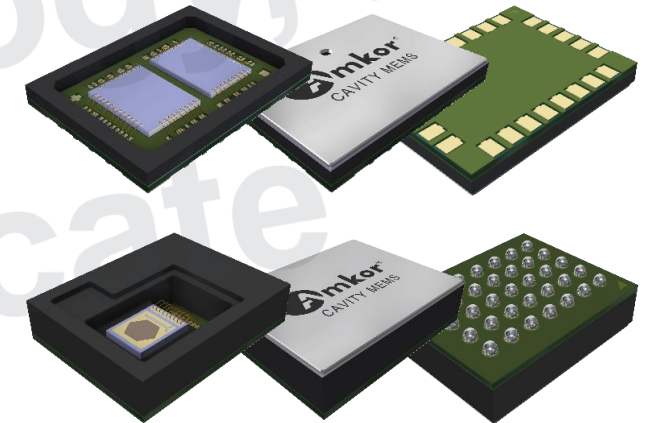


Substrate cavity/ceramic cavity

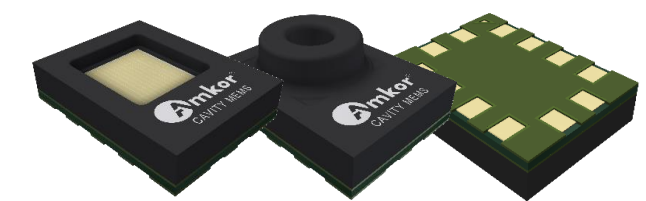


Molded Cavity Packages

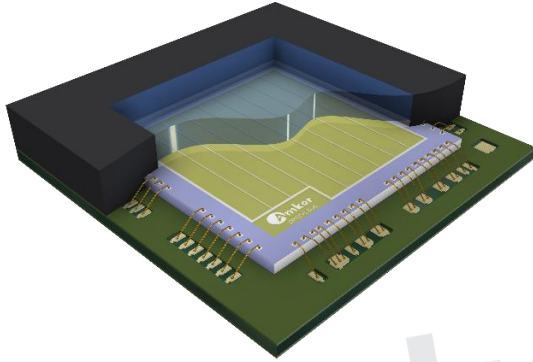
Standard cavity molding



Film assisted molding



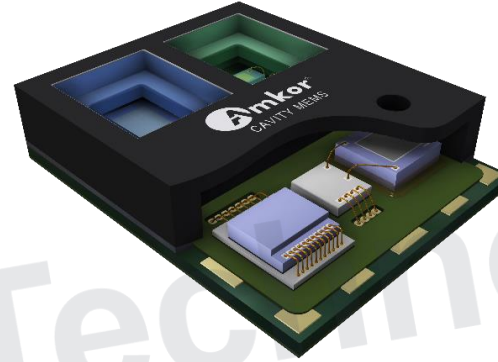
Optical MEMS & Sensor Packages



Overmolded Packages

Glass-on-Die

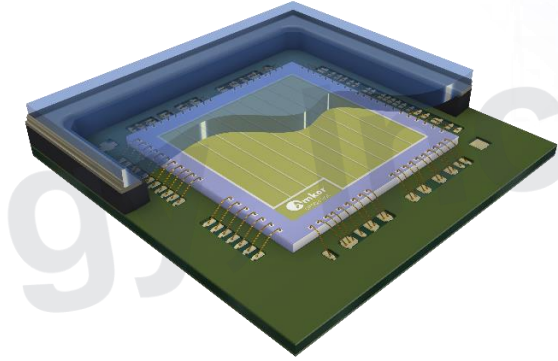
- ▶ Glass attached on die
- ▶ No air cavity interface
- ▶ Use DAF with high transmittance ($>90\%$, λ : 400-700 nm)
- ▶ Single/Multi-die stacking



Cavity Packages

Glass-on-Top

- ▶ Air cavity created by LCP or substrate
- ▶ Single/Multi-die stacking



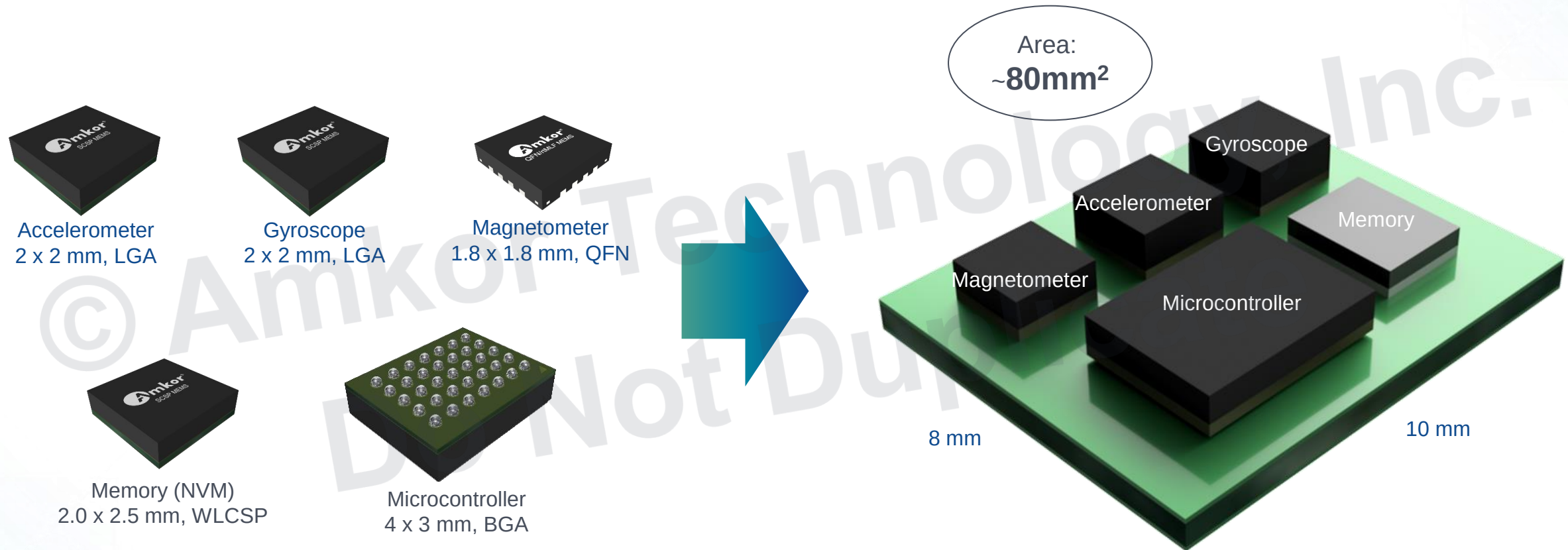
Molded Cavity Packages

Glass-on-Top

- ▶ Air cavity created by mold process
- ▶ Compatible for standard cavity & film assisted molding
- ▶ Single/Multi-die stacking

Form Factor for Overmolded Packages

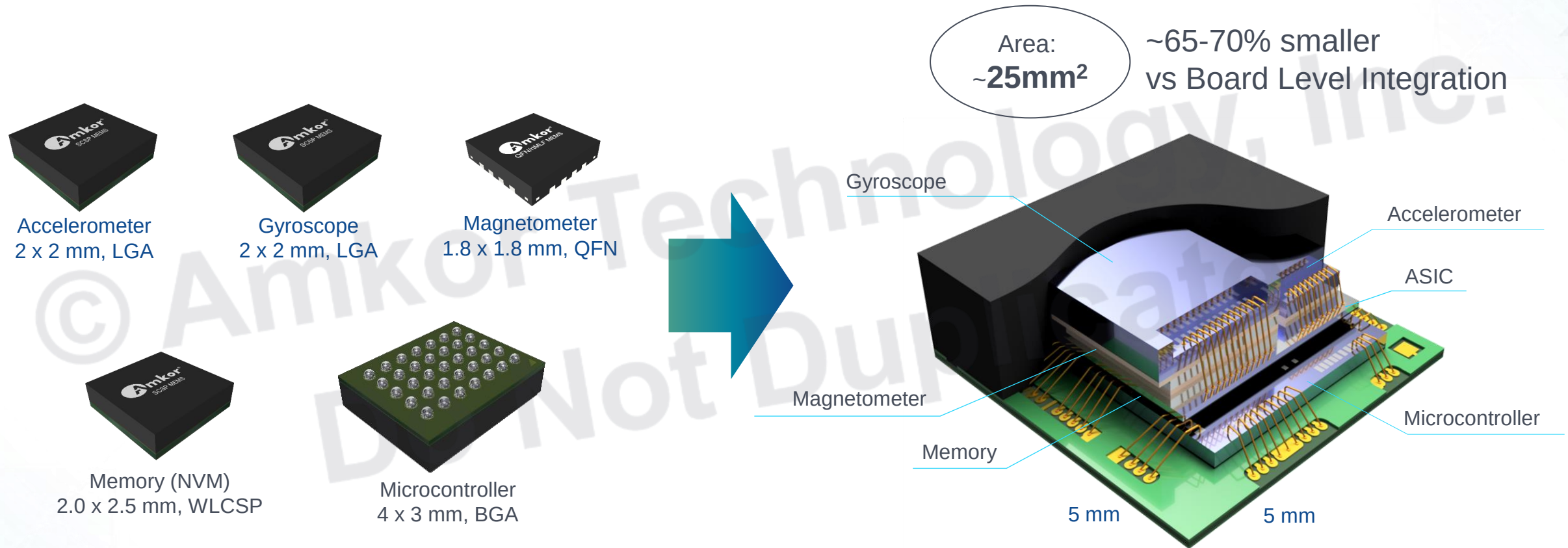
Example: Motion/Orientation Sensors for consumer



Layout simulations, using IPC-2222 & IPC-7351 guidelines,
(PMICs and other sub-system components are **not** Included)

Miniaturization for Overmolded Packages

Example: Motion/Orientation Sensors, using Package Level Integration



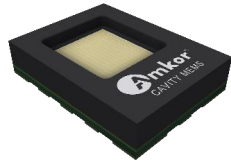
Layout simulation, using Amkor MEMS PKG Design Rules
5 x 5 mm MEMS-SCSP package

Form Factor for Cavity Packages

Example: Environment Sensors for Smart Thermostats/HVACs



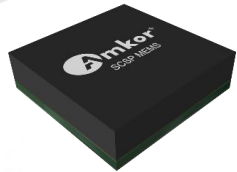
Gas Sensor
2.5 x 2 mm, LGA



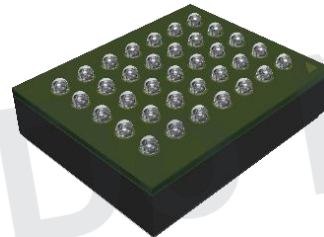
rH,Temp Sensor
3 x 2 mm, LGA



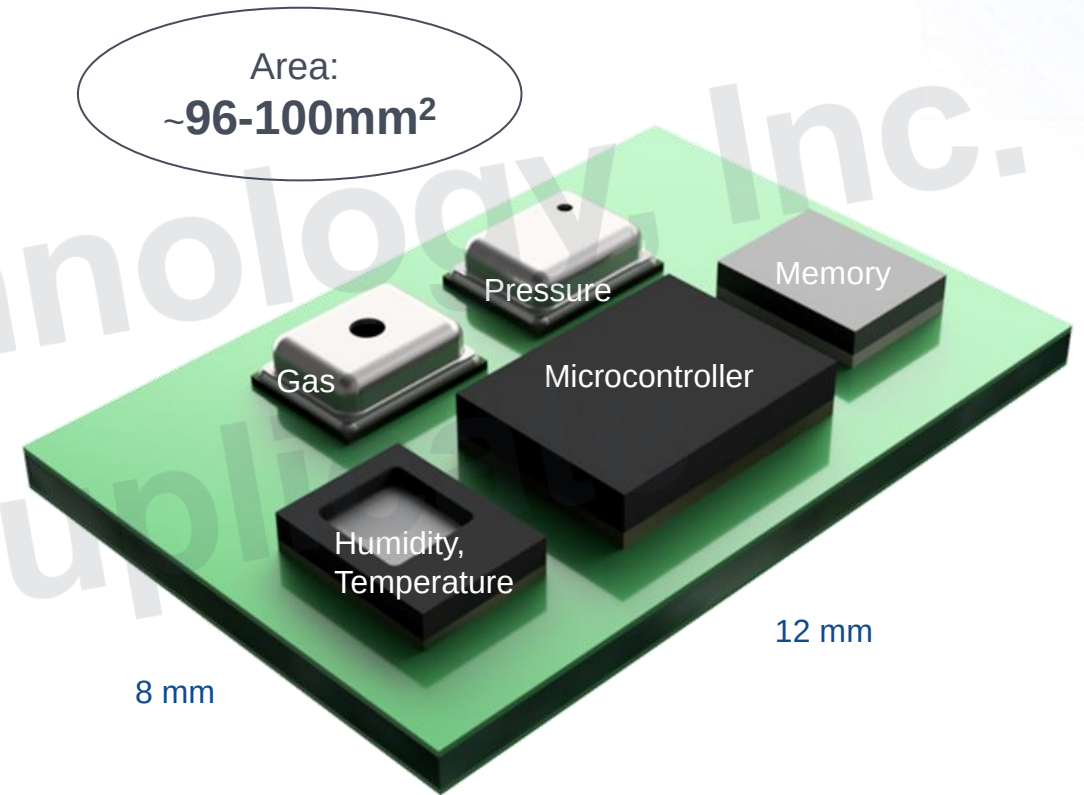
Barometer
2.5 x 2.0 mm, LGA



Memory (NVM)
2.0 x 2.5 mm, WLCSP



Microcontroller
4 x 3 mm, BGA



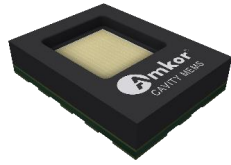
Layout simulations, using IPC-2222 & IPC-7351 guidelines,
(PMICs and other sub-system components are **not** Included)

Miniaturization for Cavity Packages

Example: Environment Sensors for Smart Thermostats/HVAC, using Package Level Integration



Gas Sensor
2.5 x 2 mm, LGA



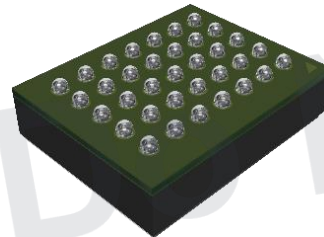
rH,Temp Sensor
3 x 2 mm, LGA



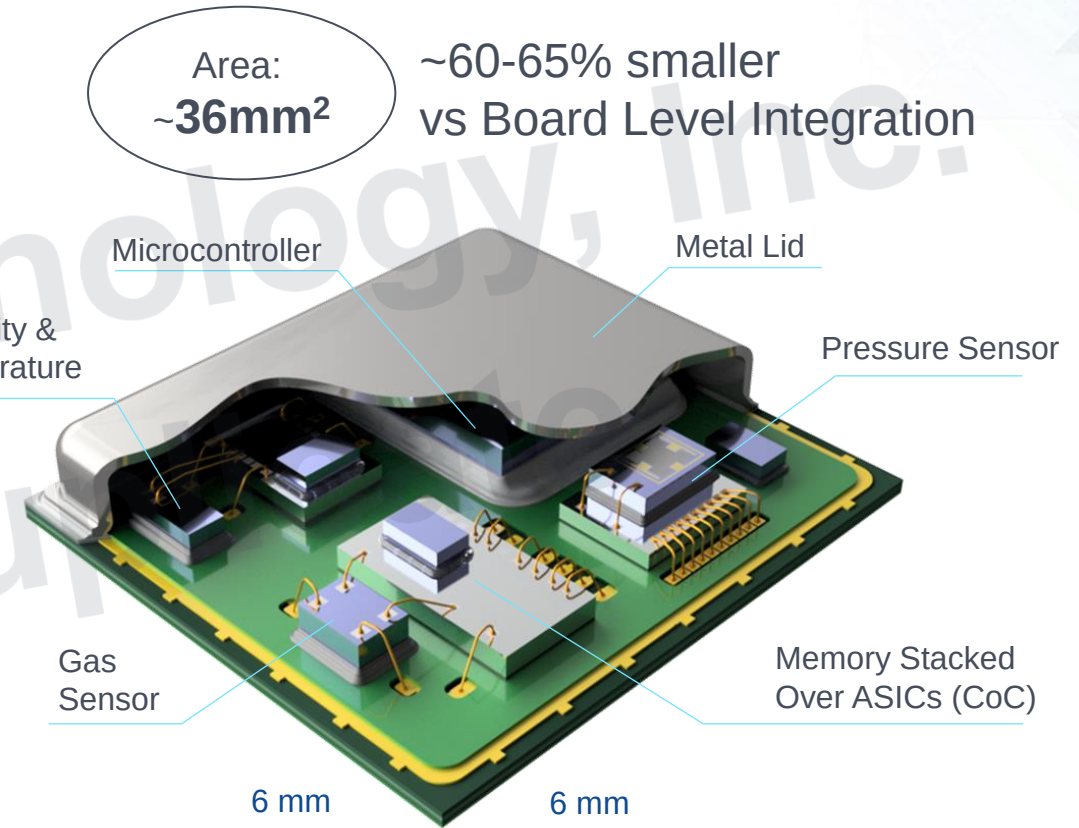
Barometer
2.5 x 2.0 mm, LGA



Memory (NVM)
2.0 x 2.5 mm, WLCSP



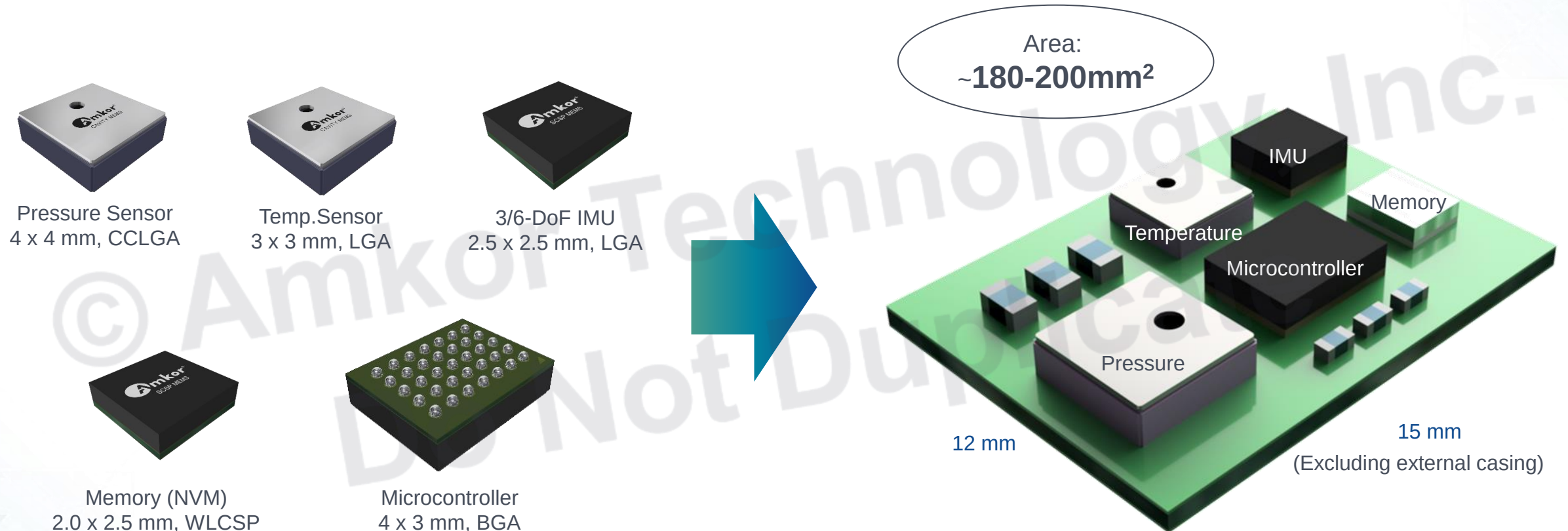
Microcontroller
4 x 3 mm, BGA



Layout simulation, using Amkor MEMS PKG Design Rules
6 x 6 mm Lidded Cavity package

Form Factor for Molded Cavity Packages

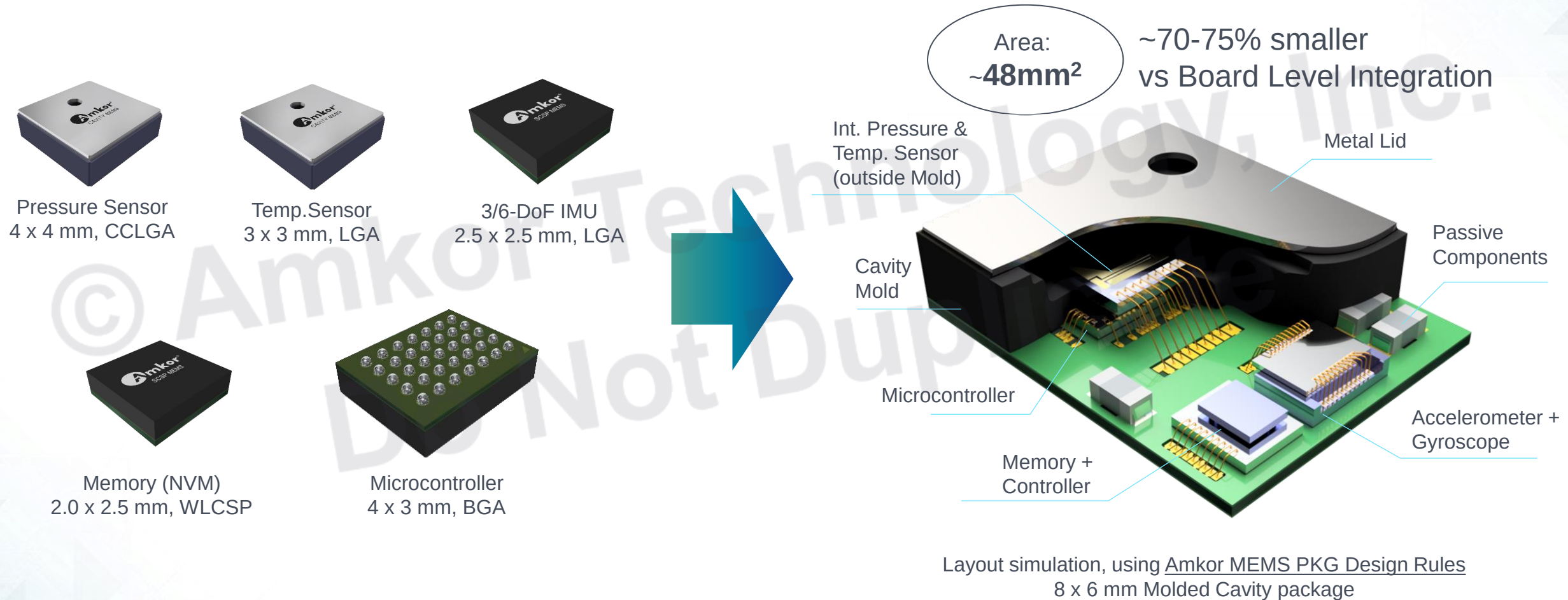
Example: Advanced TPMS for Automotive



Layout simulations, using IPC-2222 & IPC-7351 guidelines,
(PMICs and other sub-system components are **not** Included)

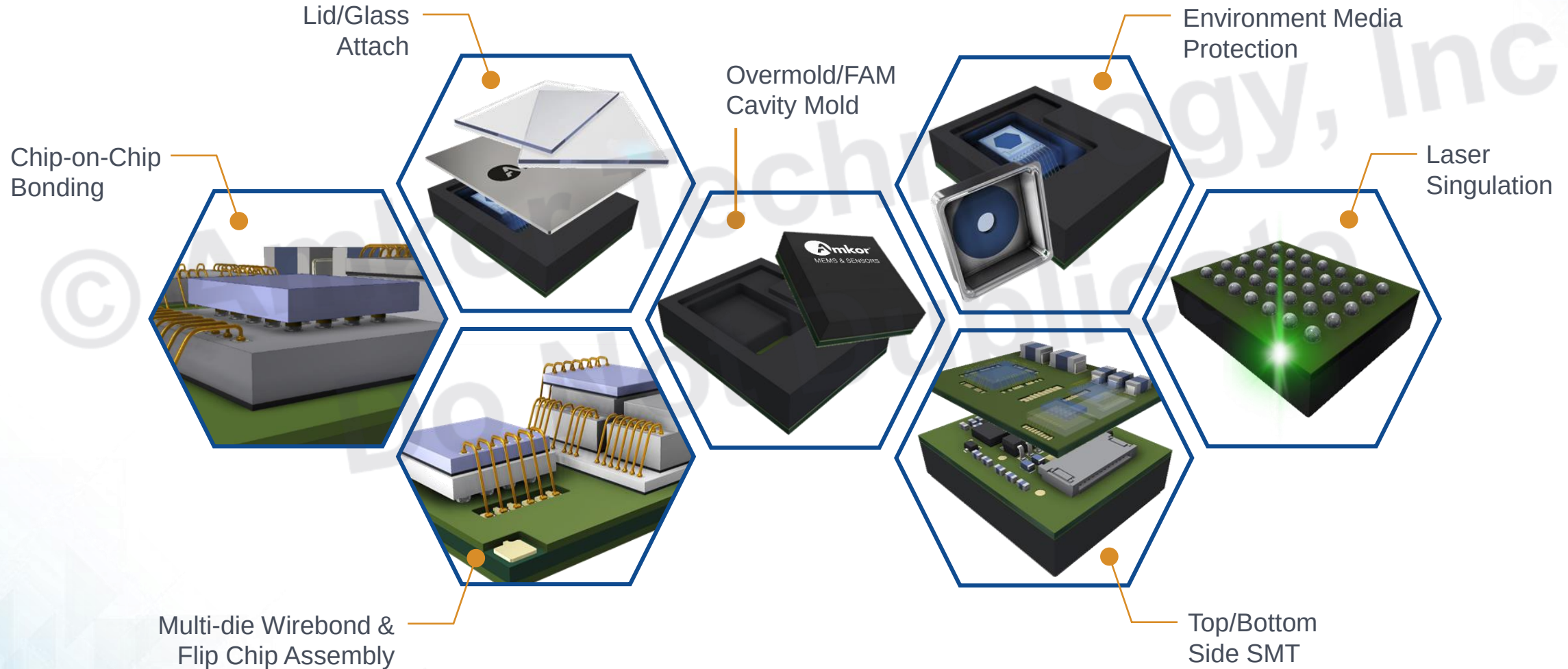
Miniaturization for Molded Cavity Packages

Example: Advanced TPMS for Automotive, using Package Level Integration



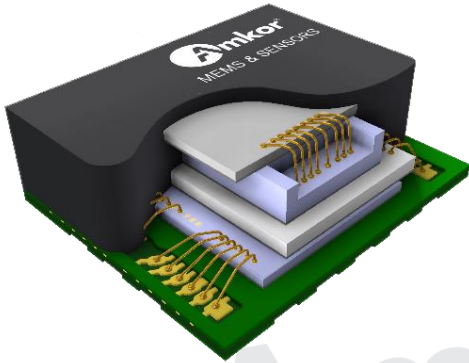
Matured Technologies Available

To Enable Heterogeneous Packaging for Small Form Factor MEMS Devices



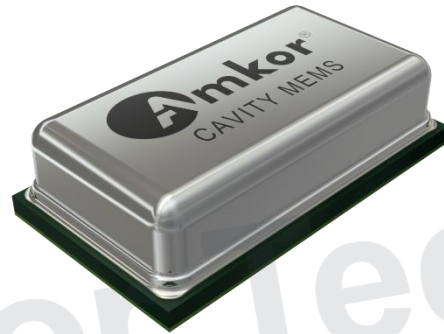
MEMS & Sensor Package Toolbox

Environment Media Protection



Overmolding

- ▶ Standard package format
- ▶ Very high-volume packaging



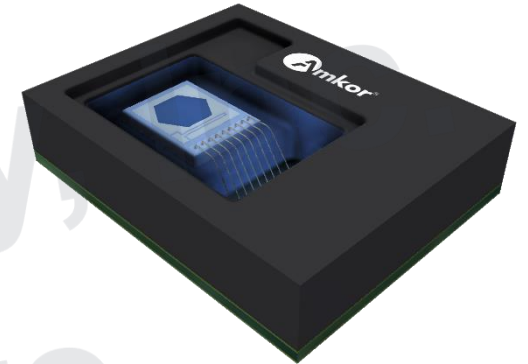
Laser Drilled Hole

- ▶ Achieve IP4X & IP5X rating (protection against water splashes & droplets only)
- ▶ Multi-position flexibility (for tight keep out zones)



ePTFE Membrane

- ▶ Achieve IP6X rating
- ▶ Attach as standard lid (no special tooling required)

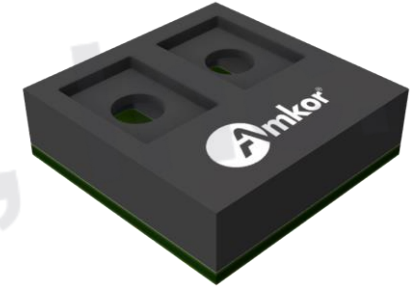
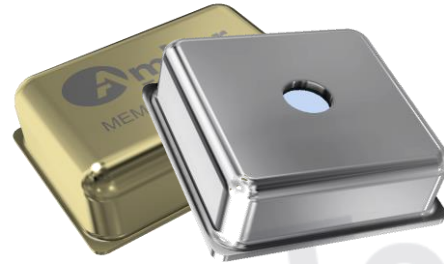


Gel Filling

- ▶ Low-stress encapsulation
- ▶ Excellent sealing

MEMS & Sensor Package Toolbox

Lid Designs



Flat (Blanked) Lids

- ▶ Designed to cap the package cavity
- ▶ Achieves uniform thickness & tight flatness requirements
- ▶ Hardened stainless steel

Stamped Lids

- ▶ Creates package cavity
- ▶ Design rules available for narrow-flange & deep-draw design
- ▶ Stainless steel & Cu-alloys

Machined Lids

- ▶ Barrel-type cavity
- ▶ Tolerance control achieved by precision machining (milling)
- ▶ SS316L recommended for machineability

LCP Lids

- ▶ Designed for precision injection molding
- ▶ Supports multi-aperture/ cavity designs
- ▶ Mostly used for optical sensors

Summary

Summary

► Growth in MEMS & Sensors

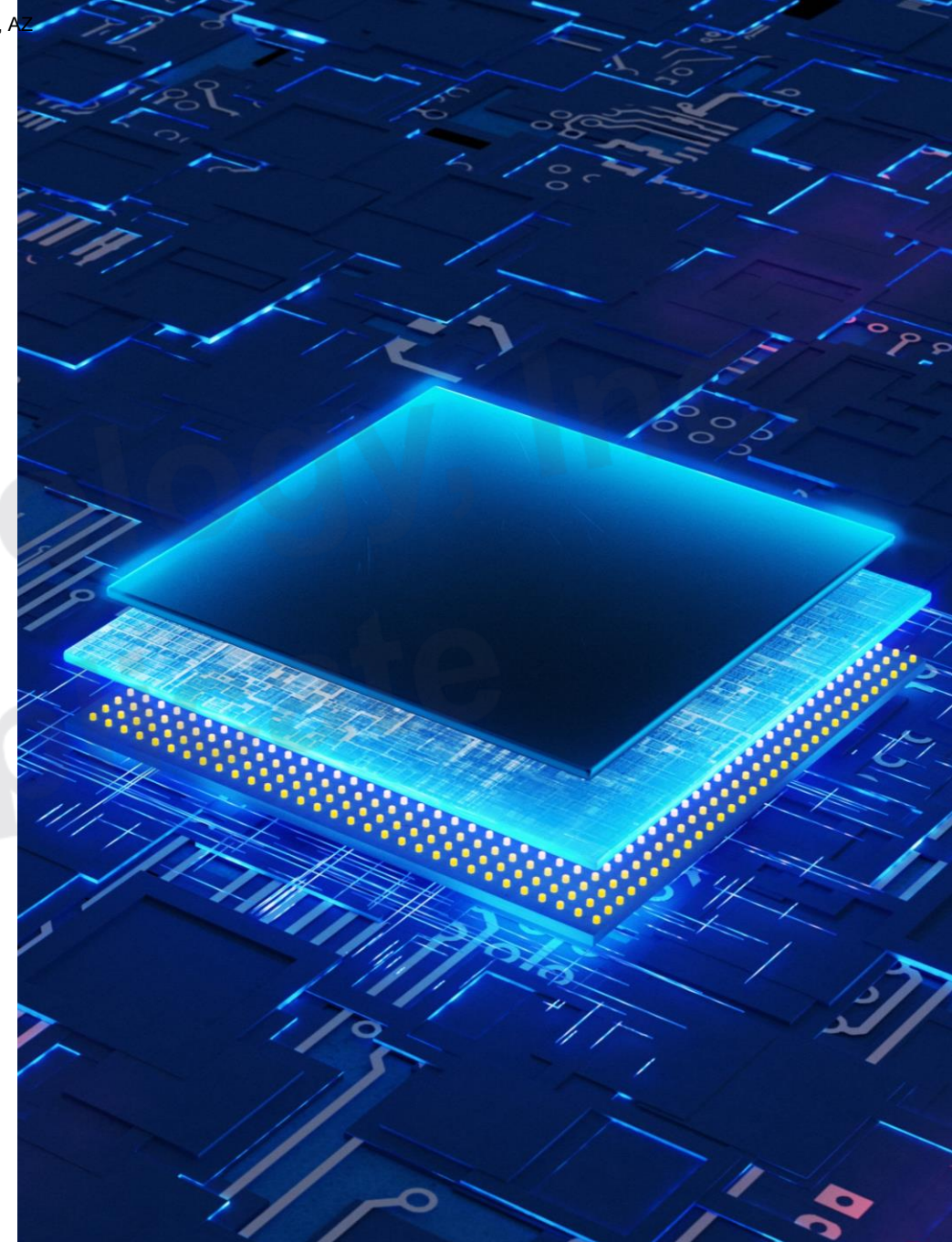
- ▷ Increased adoption & proliferation fueling megatrends
- ▷ Demand for smarter sensors & more autonomous functionalities enabling the bridge to the digital world

► Creation of New Opportunities

- ▷ Miniaturization & integration drives innovation in package form factor
- ▷ Availability of matured technologies to support packaging solutions enabling faster development & scalability

► Next Steps

- ▷ Advance Known-Good-Die (KGD) solutions for defect management
- ▷ Development of multi-stimulus test solutions



In Closing



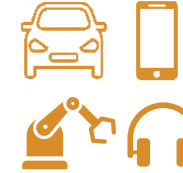
25+ Years of Experience

MEMS & Sensors
Assembly and Test



8+ Billion Units

MEMS & Sensors
shipped



End Markets

Automotive, Communication,
Industrial & Consumer



Dedicated Team

RnD, Engineering
& Manufacturing



Global Footprint

In 5 countries

- ▶ Amkor provides comprehensive package solutions to create opportunities and enable future technologies.
- ▶ Early collaboration is key!





ENABLING the FUTURE

Thank You

