MEMS and Sensor Integration TWG

HIR
HETEROGENEOUS INTEGRATION ROADMAP

Mary Ann Maher, PhD., Co-Chair

- Mary Ann currently serves as CEO of SoftMEMS
- She received her PhD from Caltech in 1989.
- She has over 30 years of experience in the area of electronic design automation (EDA) for MEMS, sensors, and analog circuits

Shafi Saiyed, PhD., Co-Chair

- Shafi leads package development team at Analog Devices
- Shafi received his PhD in Systems Science from SUNY Binghamton in 2005.

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Defining Scope for MEMS & Sensor Integration

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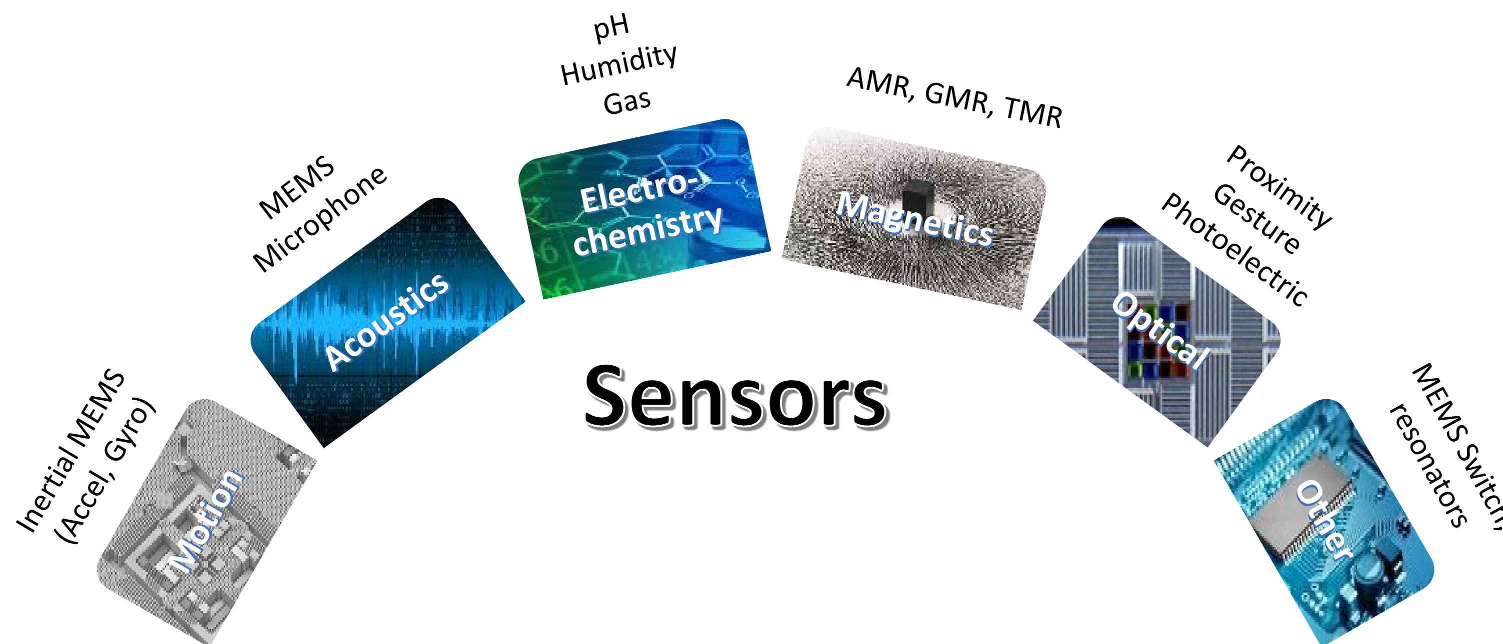
- **Sensors interact with the outside world**
- Real (analog) world requires different sensing modes
- Each sensing mode has different set of requirements and manufacturing approaches
- **Working principle (physics) drives packaging**
- No Moore's law or lithography-based roadmap



Integration Upward on Signal Chain

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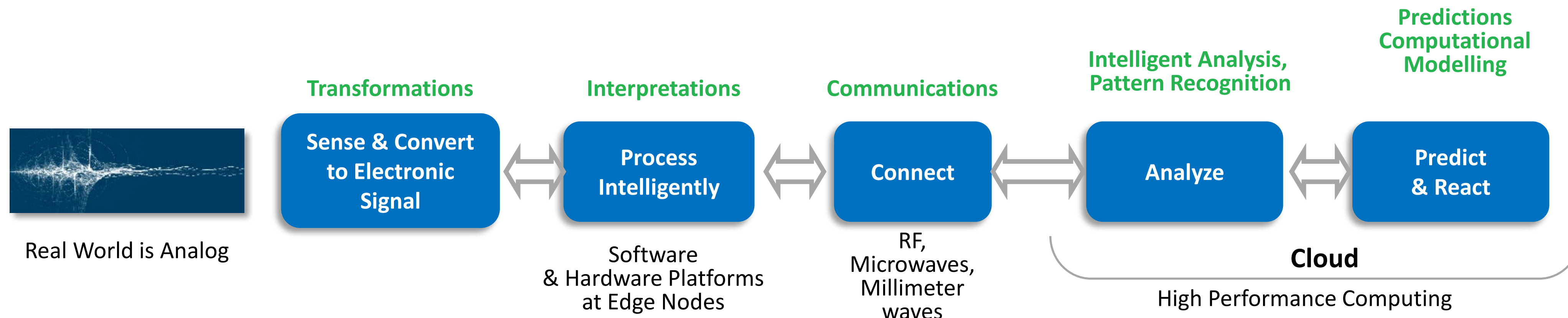
- **Across any application domain, the basic signal chain from real world-to-cloud remains common**



- **Challenge: How to Integrate components that require different fabrication processes, materials, designs**
  - with other sensors, ASICs, passives, antenna, power sources, etc, in the same advanced integrated packages
- **Challenge:** How to integrate diverse components up the signal chain (keeping sensor performance and signal integrity)?

End Applications Drive Different Integration Path

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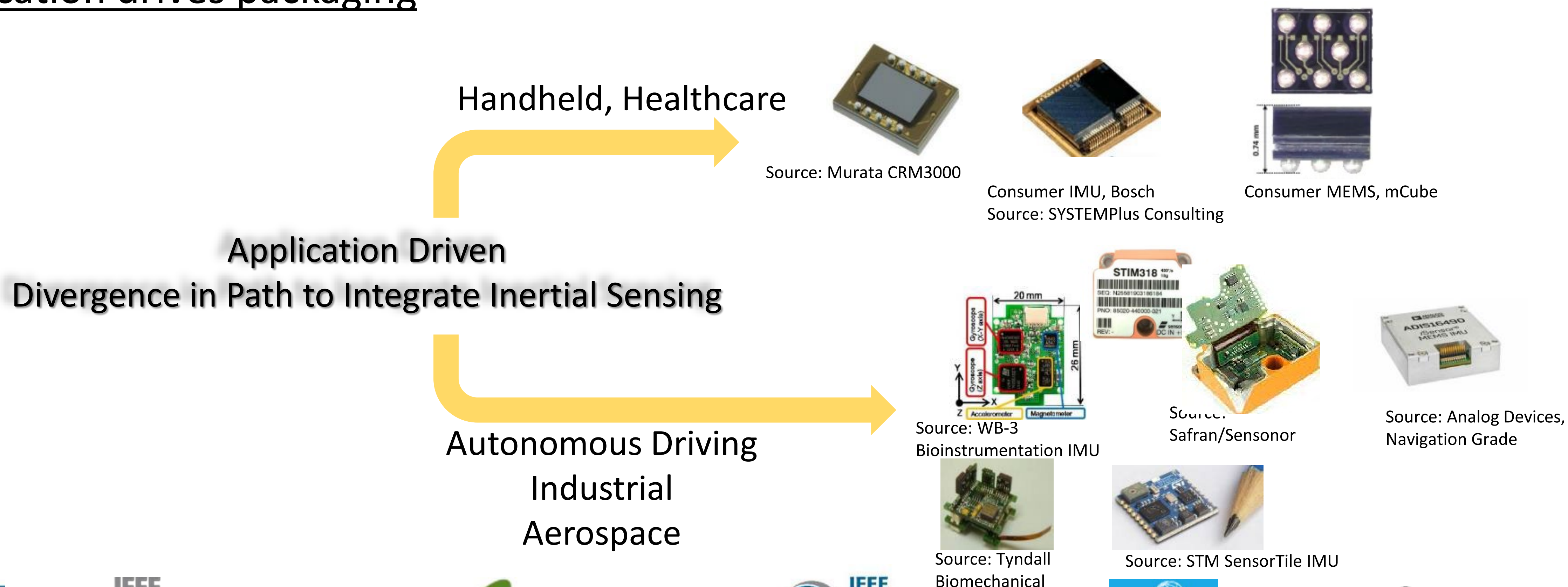
- Diverging path to integrate Inertial MEMS sensors with other components of the signal chain
- Application drives packaging



Inertial MEMS Landscape

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BEAM
MOVABLE PLATE
FIXED PLATES
ANCHOR
TETHER
ANALOG DEVICES
InvenSense TDK
BOSCH
DENSO
ST
freescale NXP
muRata
Cap
VIA
MEMS
CMOS
mCube
Kionix
ROHM

Central anchoring mass
Torsion axis
Torsion spring
P1
Bottom electrode

- Example z-axis accelerometer
- Movable mass, fixed electrodes

Challenge: Sensitive to substrate bending

d_1
d_2

Offset error if d1 ≠ d2

Courtesy Bosch, keynote 2022 iMAPS

MEMS Development Flow

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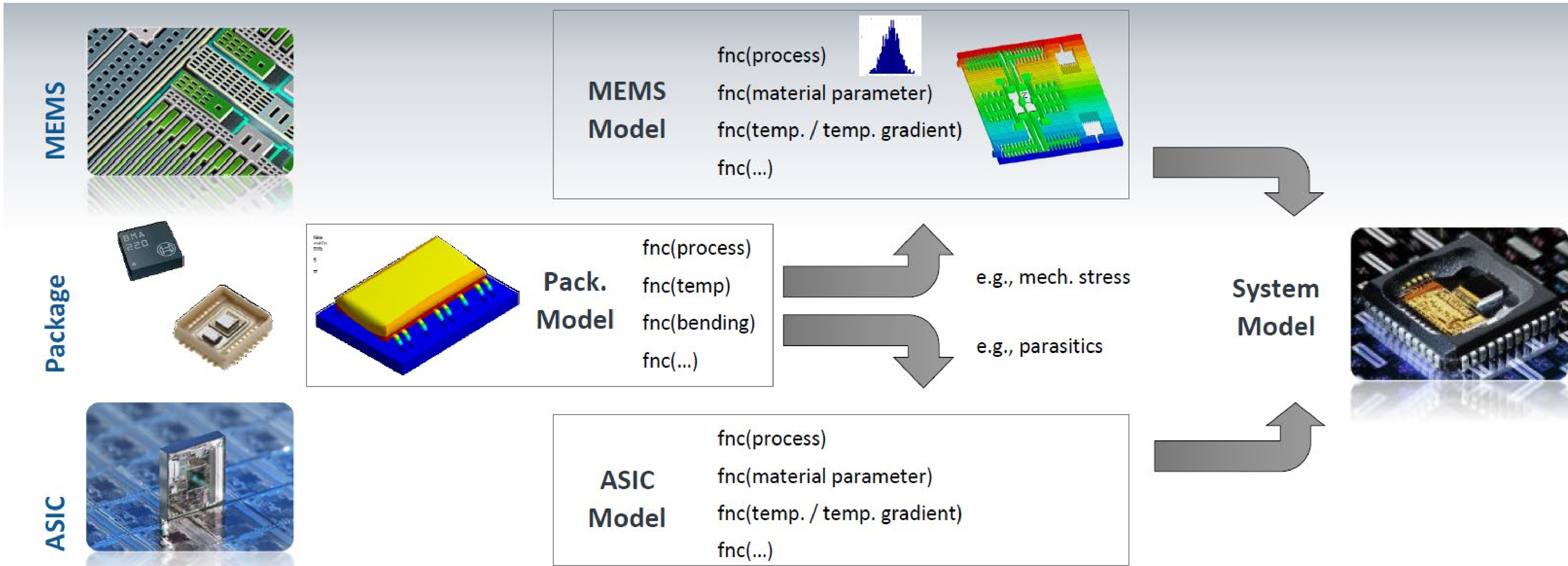

Courtesy Bosch, keynote 2022 iMAPS

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Applications & Packaging

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	Current State-of-Art		5, 10 years & beyond	
	Application Areas	**Packaging**	**Emerging Application Areas**	**Packaging**
Mobile / Consumer	• Tilt • Navigation • Gaming	• Traditional low density LGA • Thick sensors	• Tilt • Navigation • Gaming	• Size reduction, **WLP** • **Thin sensors** • Integration with µProcessor • **EMI shielding**
Medical & Health	Not pervasive	Traditional plastic on rigid organic substrates	• Implantable • Concussion monitoring • Vital Signs monitoring • Telemetry	• **Flexible substrates** • Thin profiles, **WLP** • **Biocompatibility**
Automotive	• Air bag crash sensors • Rollover • Stability control	• Traditional large body SOIC / QFN	• Navigation grade IMUs • ADAS • Acoustic noise cancellation • Adaptive headlights • Vision correction • Condition monitoring	• **SiP based modules** • Substrate technology • Integration of µProcessor for intelligent processing • **Integration of RF for communication**
Aerospace & Defense	Not pervasive	• FOG and/or RLG • Traditional ceramic substrate based modules	• Machine Health • Attitude & Heading • Navigation • Stability	• **SiP based modules** • Substrate technology • Integration of µProcessor for intelligent processing • **Integration of RF for communication**

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Important Collaborations with other chapters

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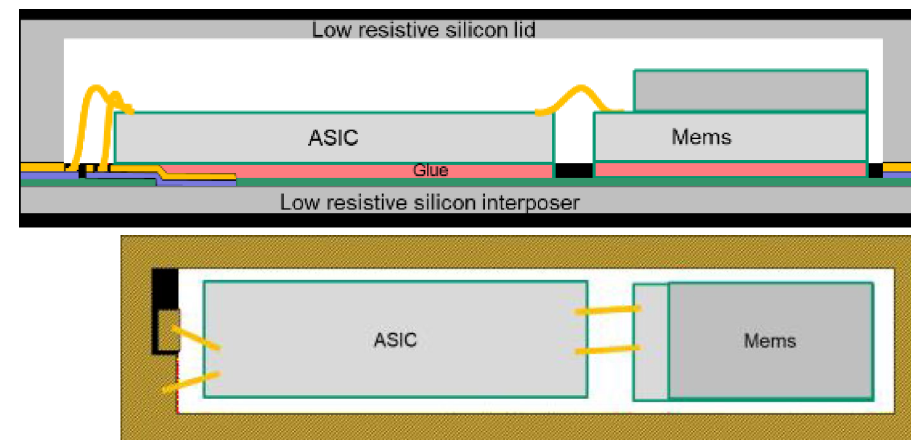
- **MEMS interacts with almost all other chapters**
- **Discuss requirements and remove overlaps with:**
  - Automotive, IoT, Medical Health and Wearables
  - To be done in future: Mobile, Aerospace and Defense, Reliability,
- **Key linkages for this year:**
  - Review: Simulation and modeling, co-design, thermal and materials
  - New: security, reliability and test, onshoring



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Current Status of Chapter

- **What you will find:**
  - MEMS specific integration requirements
  - MEMS specific integration methods- overview
  - MEMS Application specific requirements and roadmaps for integration for
    - Automotive, Health/Wearables, Consumer
    - Materials
    - MEMS specific CAD
- **What we need to do :**
  - Address reviewer's comments on references etc
  - Make 5, 10, 15 year predictions more explicit

2024 and beyond, TWG continuing to work on …

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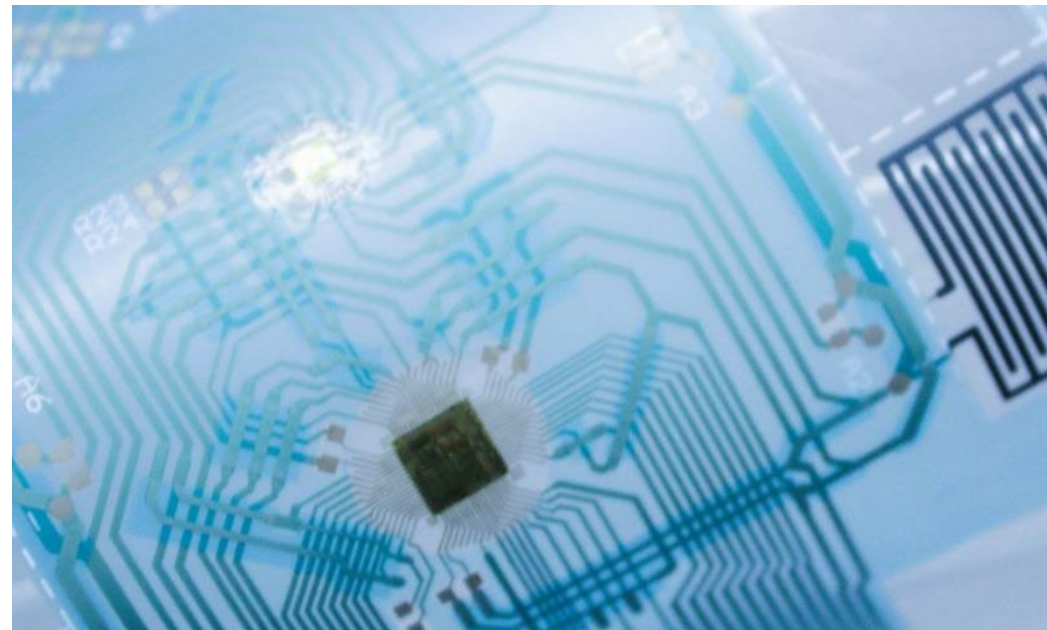
- **Additional Foundational Technologies to be considered**
  - AI + MEMS- TInyML
  - MEMS on Flexible substrates
- **Important topic areas:**
  - Manufacturing and supply chain issues for regional manufacturing
  - Chips Act impact
- **Expand applications areas:**
  - Integration of chemical/environmental sensors
  - MEMS + Photonics



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- Team Members
  - Mary Ann Maher, PhD (SoftMEMS), Co-Chair
  - Shafi Saiyed, PhD (Analog Devices), Co-Chair
  - Jean-Charles Souriau (CEA LETI)
  - Benson Chan (IEEC, Binghamton University)
  - Philippe Robert (CEA LETI)
  - Andrew Fung, PhD (AM Fitzgerald)
  - William Chen, PhD (ASE and HIR Chair)
  - Looking for industry volunteers to helps us with gas sensing, optical sensing
  - Looking for academics to join us……