Benefits of Jointly Funded Research in Packaging

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75 billion devices by 2030 : Coverage across many industries

Ecosystem Investment

Cost Sensitive

CLOUD
Data Centers

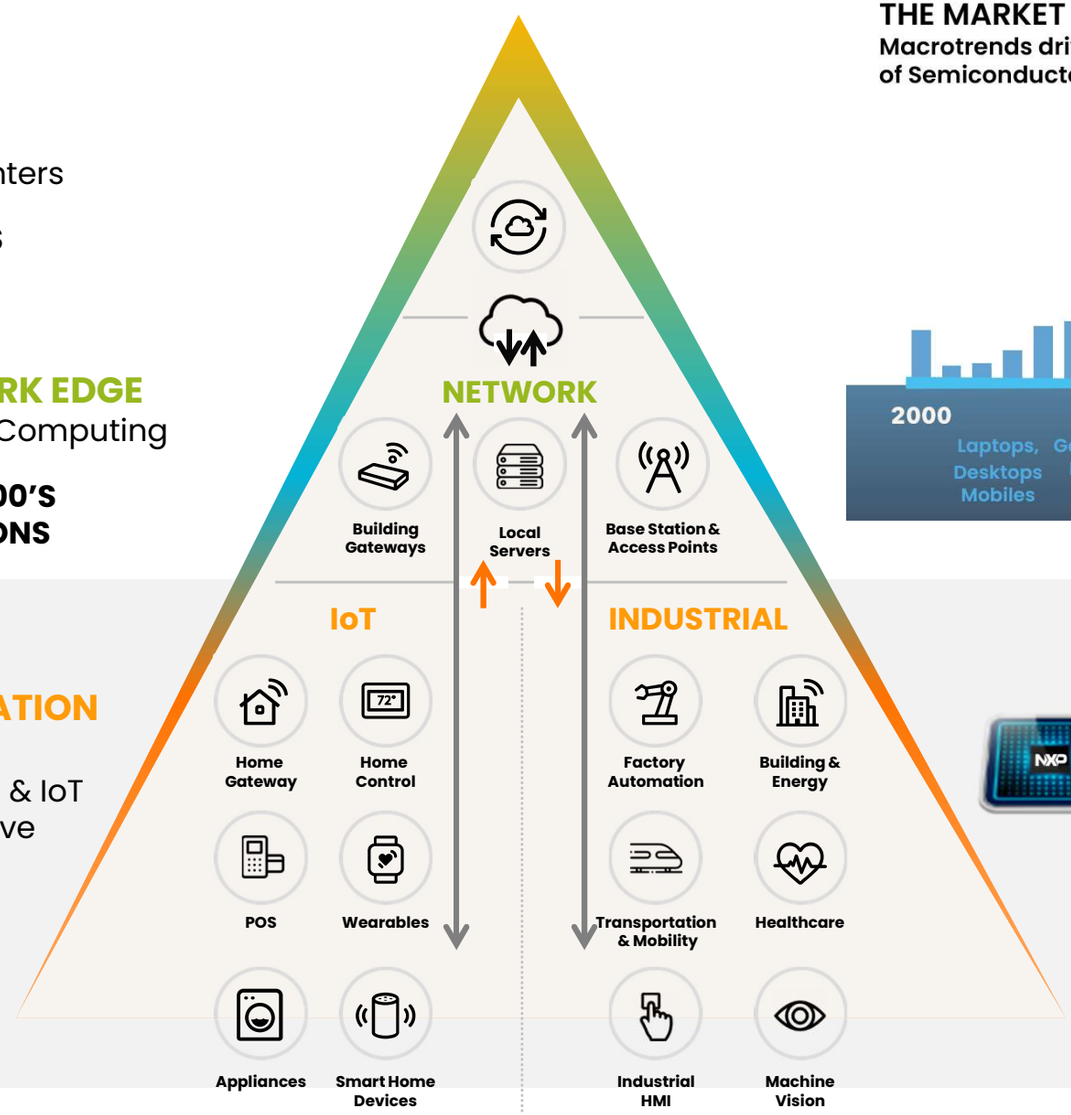
MILLIONS

NETWORK EDGE
Network Computing

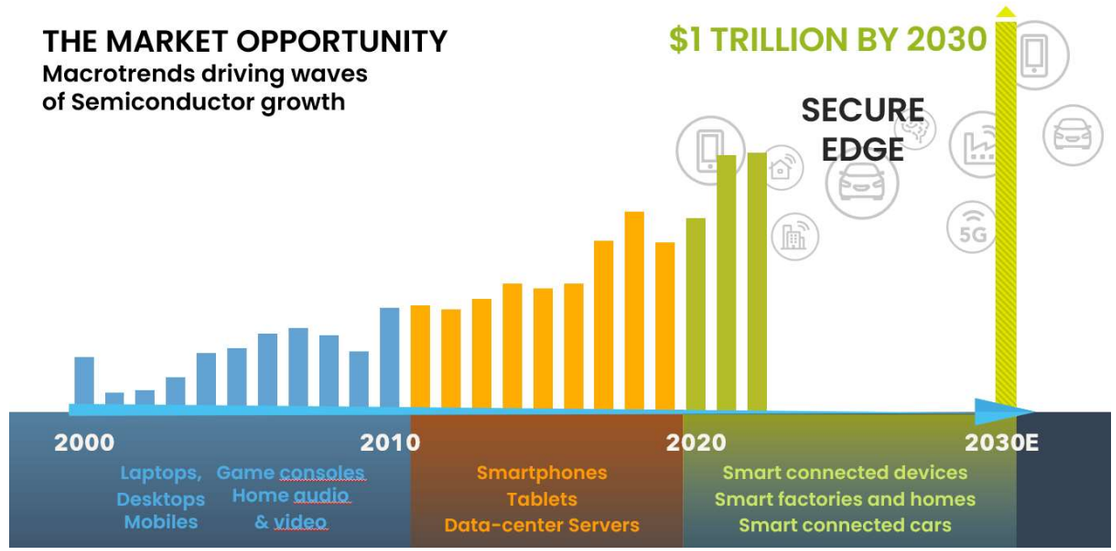
10'S TO 100'S OF MILLIONS

APPLICATION EDGE
Industrial & IoT
Automotive

BILLIONS



THE MARKET OPPORTUNITY
Macrotrends driving waves of Semiconductor growth



NXP: Leading supplier of edge processors including Automotive, Industrial, IoT

Industry Market Trends: R&D Drivers

	Application Class	Compute/Memory Bandwidth Limited	Interconnect Limited	Reliability Needs	Key Metrics	
HIGH PERF. COMPUTE	**AI training/inference Cloud graphics/XR Engineering Simulation**	High	High	Low-Med	Perf./Power	
MOBILE	**Handheld Devices**	High	High	Low	Perf./Power	
COM INFRA	**5G/6G**	High	High	High	Perf./Cost	
AUTOMOTIVE	**ADAS, Entertainment, Networking, Automation**	High	Med	High	Perf./Power /Cost	
	Electrification	Low	Low	High		
IOT/EDGE	**Smart Home Consumer Devices**	Low	Med	Med	Power/ Cost	
MEMS/SENSOR	**Medical Devices Chemical Sensors Optical Sensors**	Low	Med	Low	Power/ Cost	

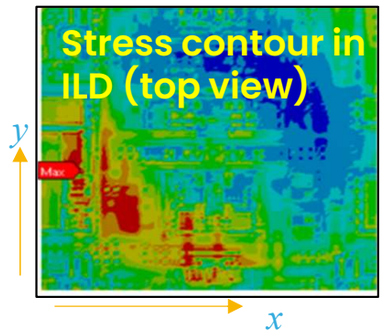
MAPT Roadmap: Table 1.1 Future Requirements for Application Drivers (Extract)

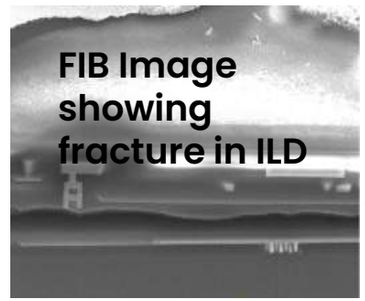
- Common R&D challenges across market segments
- Broad industry use cases to enable **R&D reuse**
- Focused efforts to extend technology into adjacent markets: e.g. HPC to Auto Reliability, Cost
- Consortia R&D expands **thought leadership**

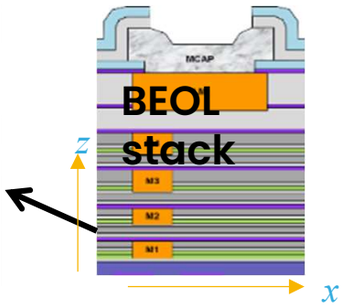
Virtual Prototyping for Total Quality/First Time Right

Virtual experiments for new device configurations to:

- Predict safe operating areas
- Identify critical use conditions
- Develop optimized design solutions







Building Blocks:

Modeling

Package and system level
ECAD-MCAD interfaces
Multiple length scales
Coupled fields

Material Characterization

new packaging material
viscoelasticity, plasticity, creep
temperature and humidity

Overstress Criteria

Stress exceeds critical value causing instantaneous failure: EMC delamination, Si fracture.

Fatigue Criteria

Cyclic stress below critical values is causing damage accumulation and finally failure after a certain number of cycles: solder joint fatigue, RDL trace fatigue

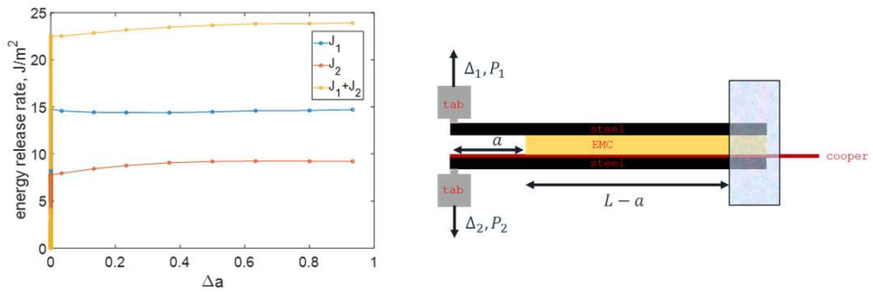
Project Highlights: Maximizing R&D Value

- **Millimeter Wave Packaging Research - Antenna in Package**
  Prof. Rashaunda Henderson-UT Dallas
  - Antennas on mold compound in QFN packaging technology (90-220GHz): Frequency, temperature dependence.
  - Material Characterization (DK/DF) performed from 90-325 GHz both frequency and temperature dependency.

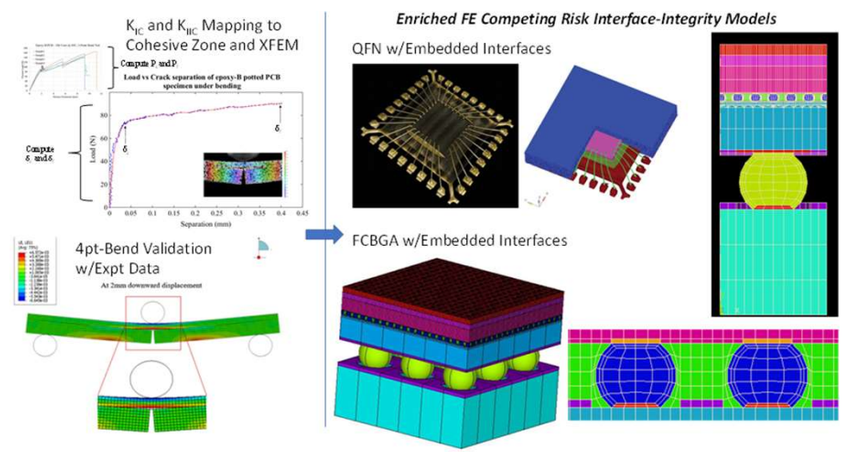
- **Characterization of Interfacial Adhesion under Cyclic Loading**
  Prof. Rui Huang and Prof. Kenneth M. Liechti, University of Texas at Austin
  - Novel method: Interfacial adhesion strength under cyclic loading (mechanical and thermal cycles)
  - New cohesive zone model: interfacial adhesion and fracture.
  - Improves package reliability prediction (e.g. EMC, Cu interface)

- **Predictive-Models and Characterization - Interfaces under Sustained High-Temp/ High-Humidity Operation in Auto Environments**
  Prof. Pradeep Lall-Auburn University
  - Material interface characterization/ predictive model tools
  - Study of interfacial fracture toughness with aging
  - Damage Model development to capture the aged material behavior

Interface Adhesion Test Method(UT)



Interfacial Fracture Toughness vs. Aging (Auburn)



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