# Modelling & Simulation Chapter
# Chapter 14

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# Highlights from M&S

- State of the art
  - High Fidelity Models: FEA, CFD, FDTD
  - Lower Fidelity Models: Compact models…
  - Point analysis tools
- Example of Challenges
  - Electrical – SI/PI die-die coupling, parasitics.
  - Thermal & Mechanical – Hot spots, Warpage..
  - Multi-physics – Mobility shifts, Migration
  - System-Level models – fast/accurate models
  - Reliability – Physics of Failure
  - Materials – Stochastic behavior

Chapter 14: Modeling and Simulation

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# Modelling and Simulation Techniques

- Electrical analysis
- Thermal & thermomechanical
- Mechanics & multiphysics modeling
- Multi-scale modeling
- Machine learning/AI
- System-level modeling
- Material characterization

nonlinear analysis
linear analysis
BC transfer

Electron Wind
Stress Gradient
Atomic Transport
Concentration Gradient
Temperature Gradient
Stress-migration
Self-diffusion
Thermomigration

Machine Learning Algorithms

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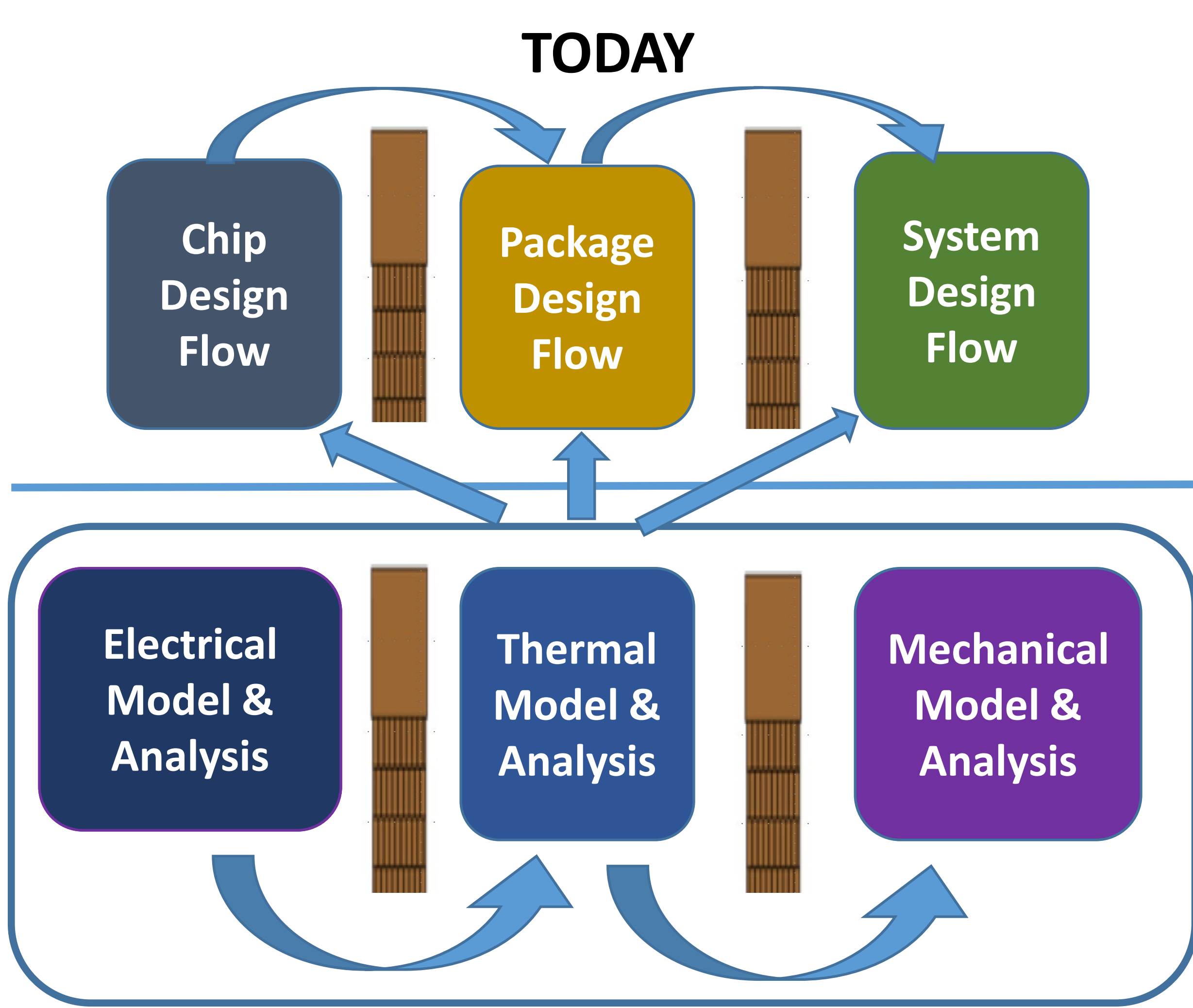
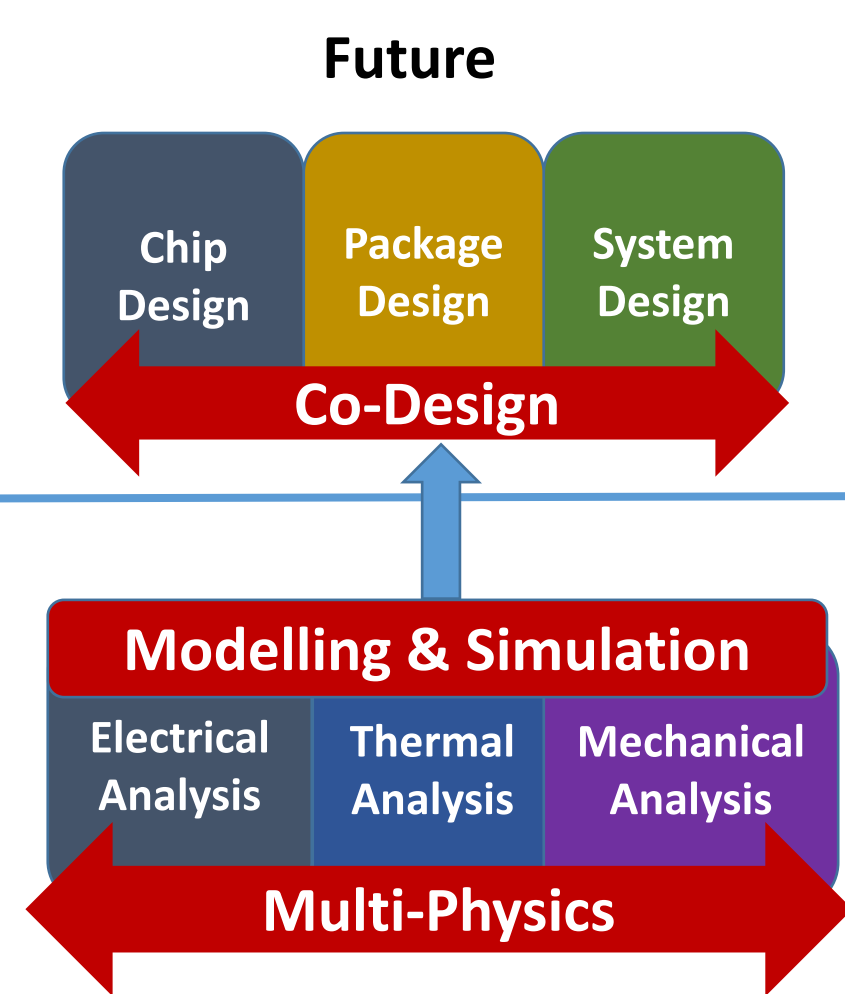
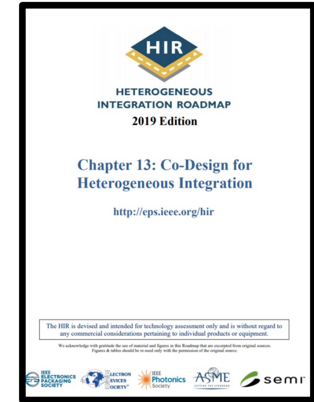
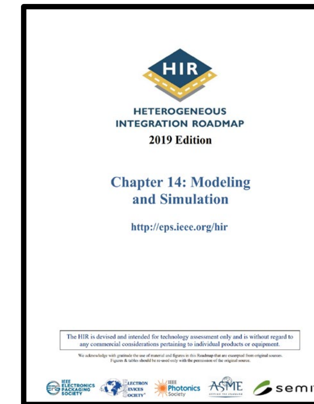
# Moving towards a New Paradigm



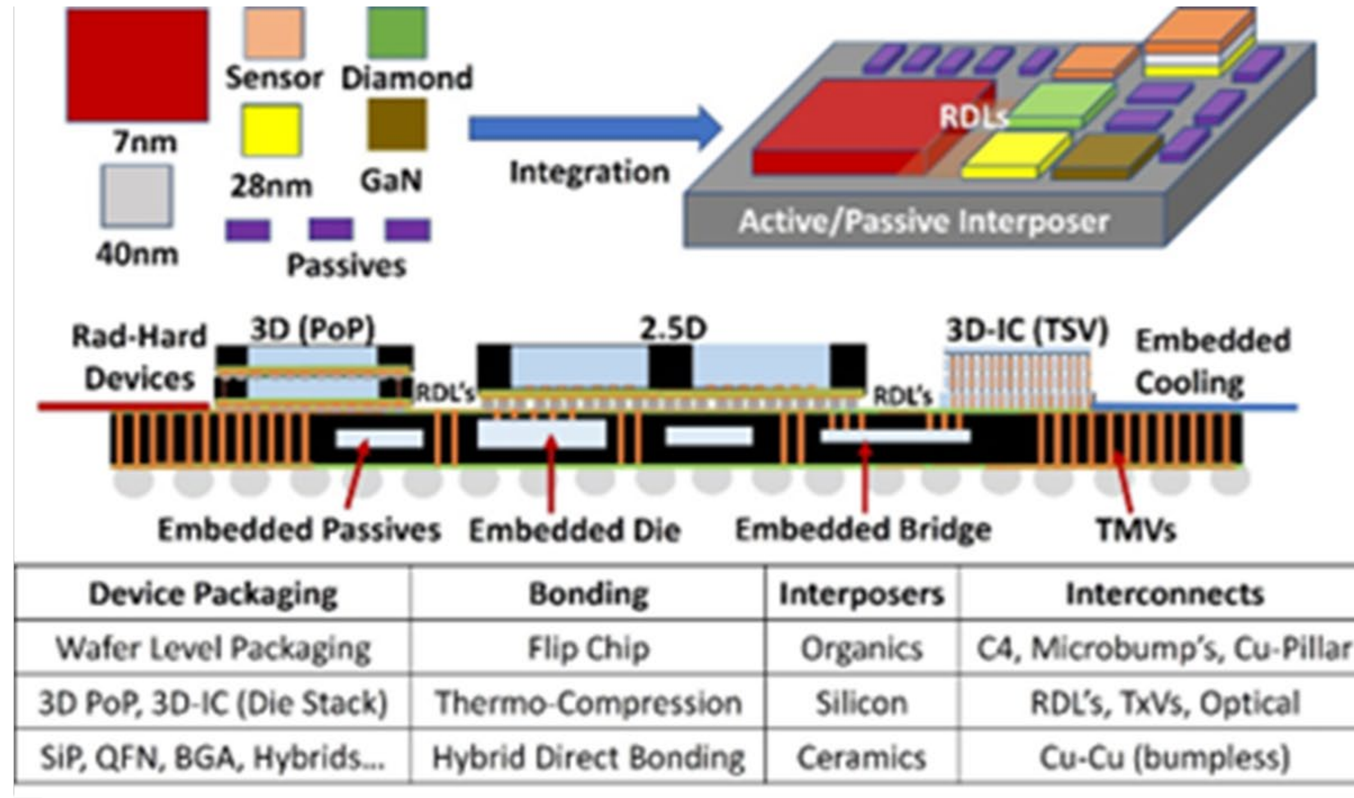
# Moving towards chiplets

Design

Materials

Processes

Environments




| Device Packaging | Bonding | Interposers | Interconnects |
|---|---|---|---|
| Wafer Level Packaging | Flip Chip | Organics | C4, Microbump's, Cu-Pillar |
| 3D PoP, 3D-IC (Die Stack) | Thermo-Compression | Silicon | RDL's, TxVs, Optical |
| SiP, QFN, BGA, Hybrids... | Hybrid Direct Bonding | Ceramics | Cu-Cu (bumpless) |

Electrical

Performance

Thermal

Mechanical

Reliability

- **Multi-domain/co-simulation requirements**
- **Large design space for multi-objective optimization**

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ASME SETTING THE STANDARD

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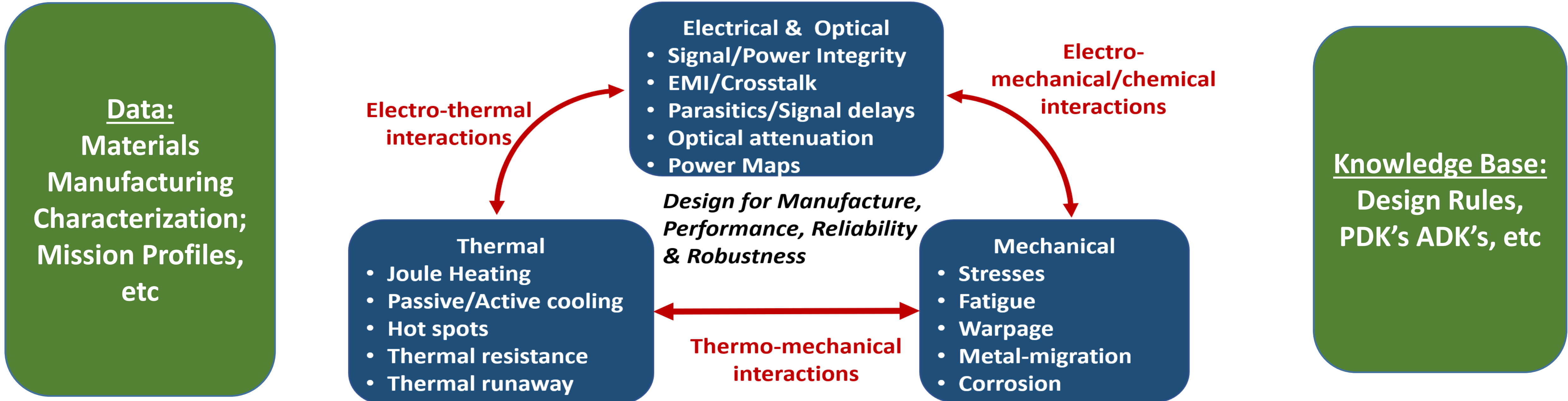
# Modeling & Simulation

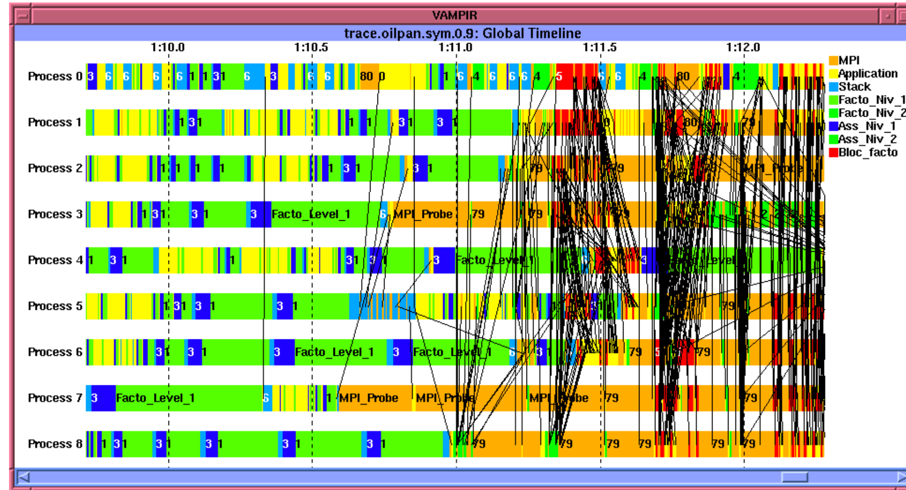
**Scale:** Devices (nm) Packages(um-mm) Boards (mm-cm) Systems (cm-m)

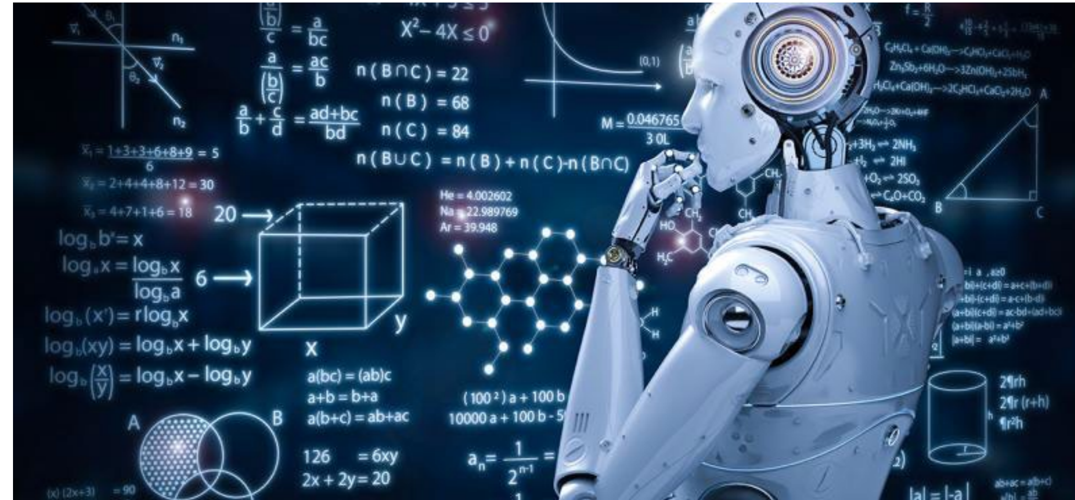



**Model Fidelity:** Analytical Circuit/Network Compact/Response Surface MOR MD/FEA/CFD

**Model based Optimization; Big Data Analytics; Physics of Failure Models; Prognostics; etc.**

# Potential Solutions

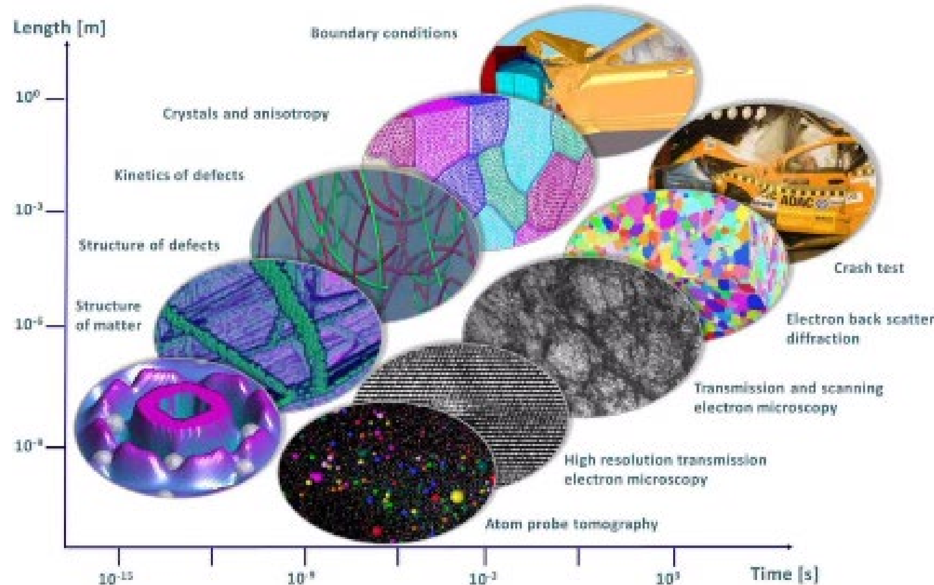


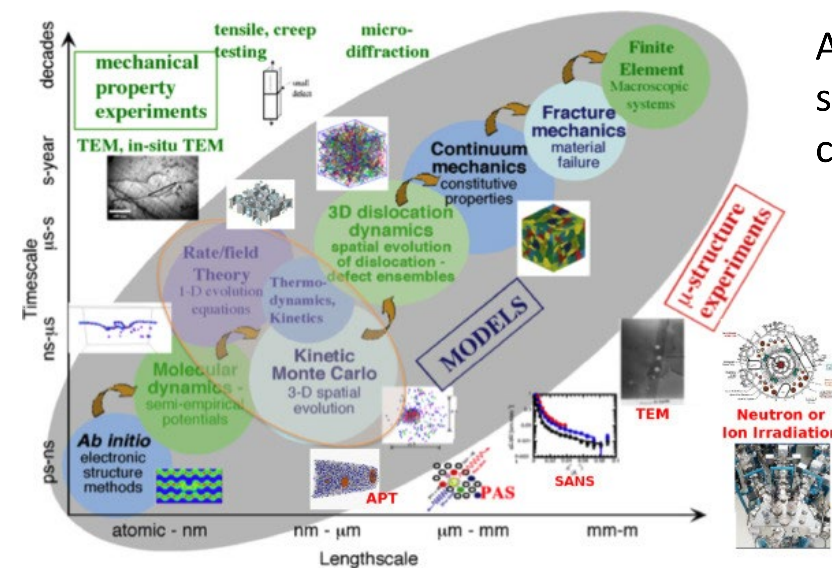



AI/ML applications

Advanced solvers (CPU, CPU-GPU, Cloud AWS, and DSA).

Multi-scale modeling

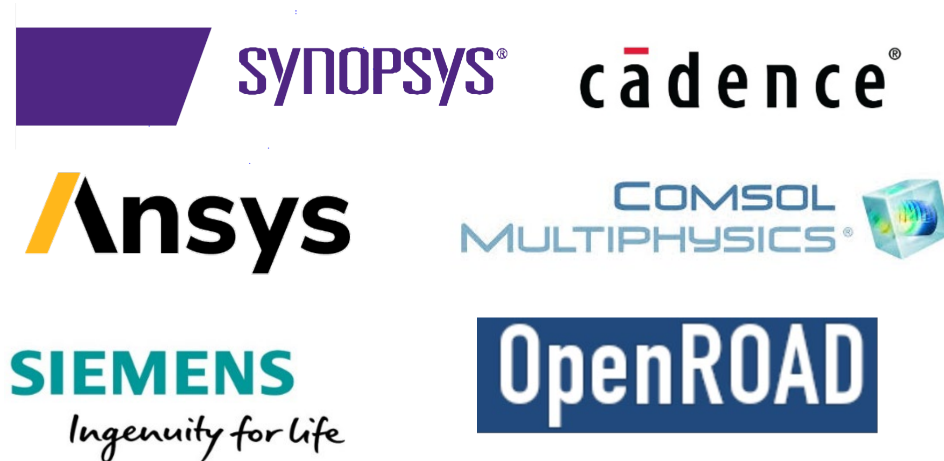



Advanced multi-scale material characterization.

# Potential Solutions - Tools

## EDA suppliers are enabling multiphysics and system co-design solutions through on-going developments:



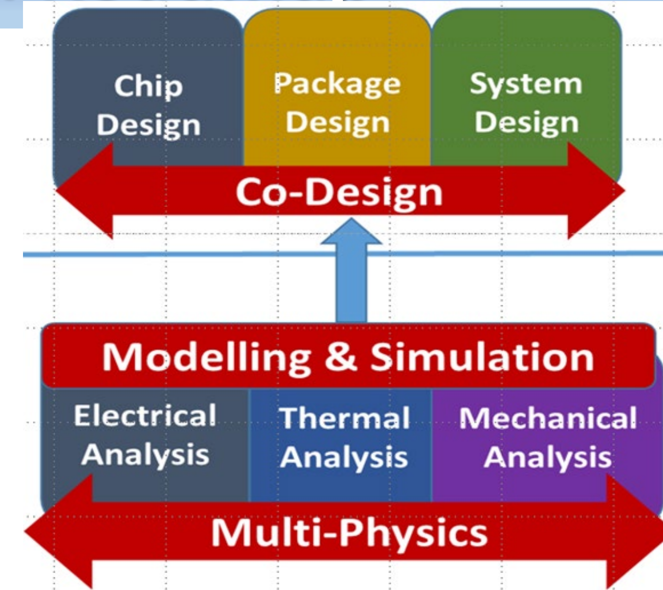
- **No single tool can do it all.**
- **Modular architecture to 3rd party simulation tools**
- **Open access data formats**
- **3D-ADK's**

Rajen Murugan (Texas Instruments, EuroSimE 2021, HIR Panel

# Heterogeneous Integration Roadmap



- Chip-package-board interactions
  - Floor planning, Shielding
  - TxV locations
  - Design of cooling structures
  - Chip-package interactions
  - Package Board interactions
- Multi-physics aware design
  - Electro-thermal
  - Thermo-mechanical
  - Physics of Failure
- AI enhanced design space exploration



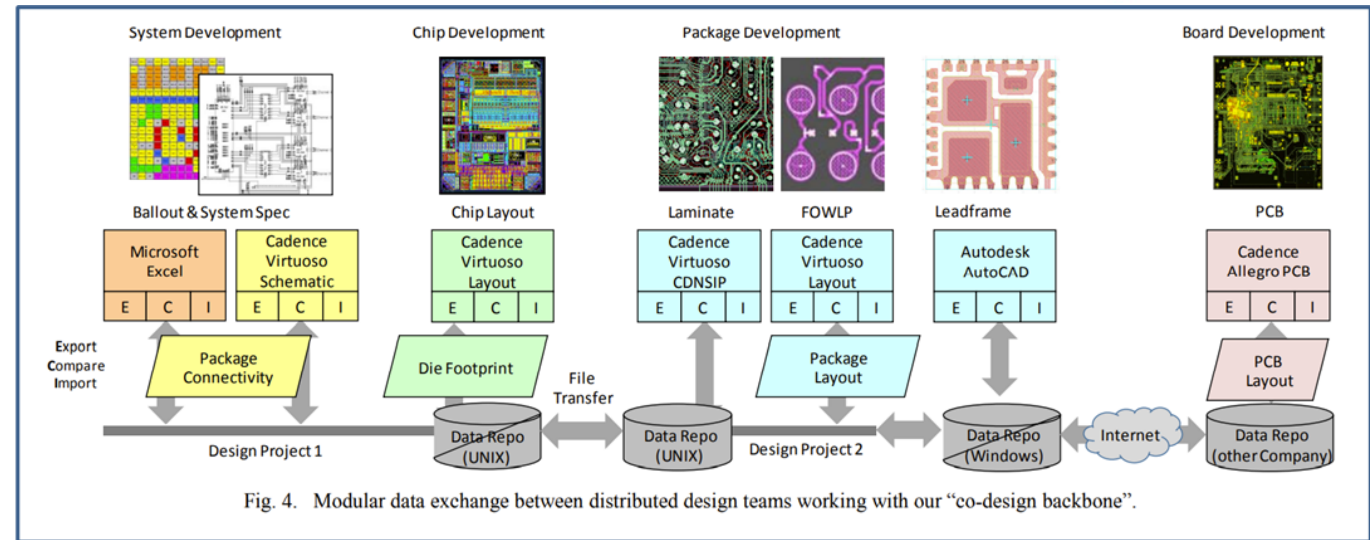
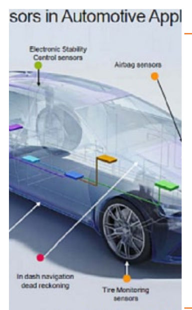




Fig. 4. Modular data exchange between distributed design teams working with our “co-design backbone”.

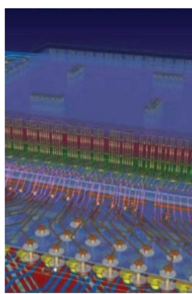
T. Brandtner et-al, "Chip/Package/Board Co-Design Methodology Applied to Full-Custom Heterogeneous Integration," ECTC, 2020

# Applications

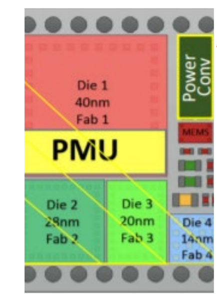



MEMS

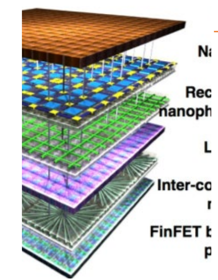
Reliability



Manufacturing Process



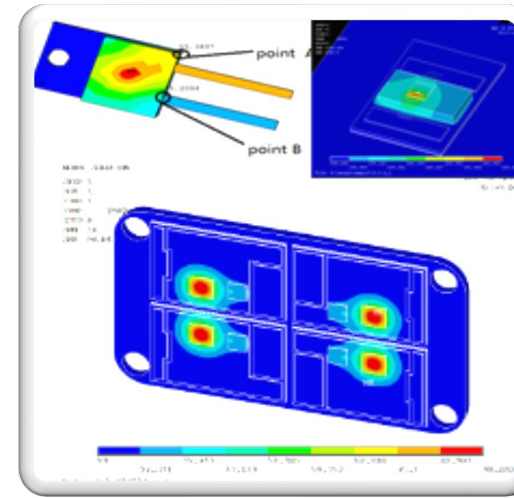

Composite Materials



Digital Twin

# Digital Twin

In-situ Data-monitoring and updating



Virtual world

Physical world

Adaptive Design, Plan, Decision and Strategy Feedback

- Digital Twin is the ultimate aim of product design, reliability and lifetime management.
- Modeling and Simulation plays a vital role in digital twin realization.

# Plans for next edition

- Plans for nest edition
  - Expand/revise current sections
  - Strong theme for Chiplets
  - New section on photonics
  - New Section on Process Modelling
- Current linkages with TWG's
  - Co-Design (Need for fast analysis)
  - Single and Multi-Chip
  - Automotive
  - Mems and Sensors
  - Reliability
  - Thermal
  - Supply Chains

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# Ensuring Roadmaps Align

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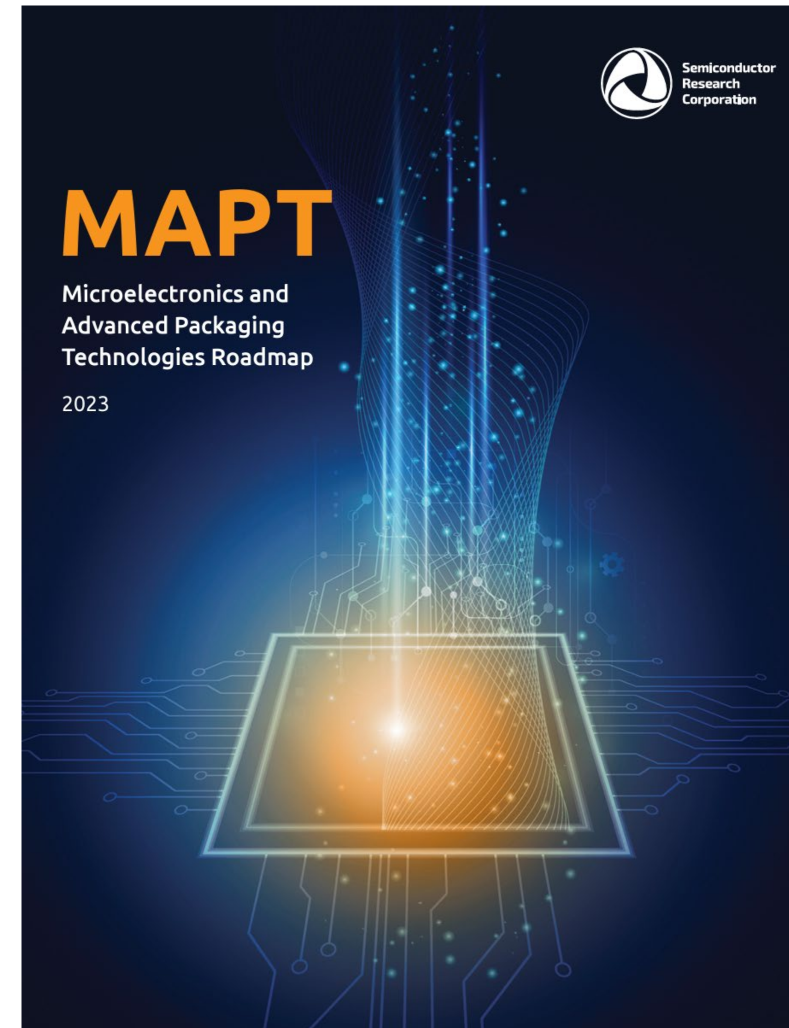


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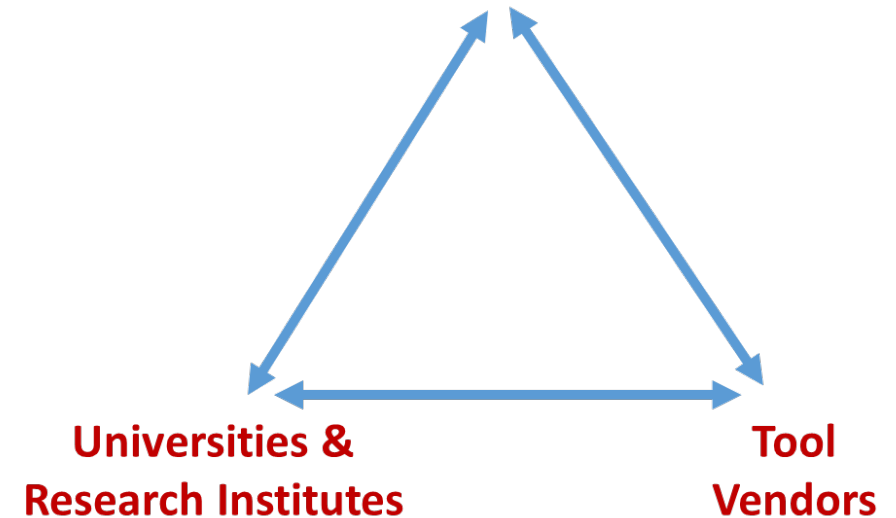
# Thank You

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- Rajen Murugan (Texas Instruments)
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