The New Challenges for Advanced Packaging Technologies

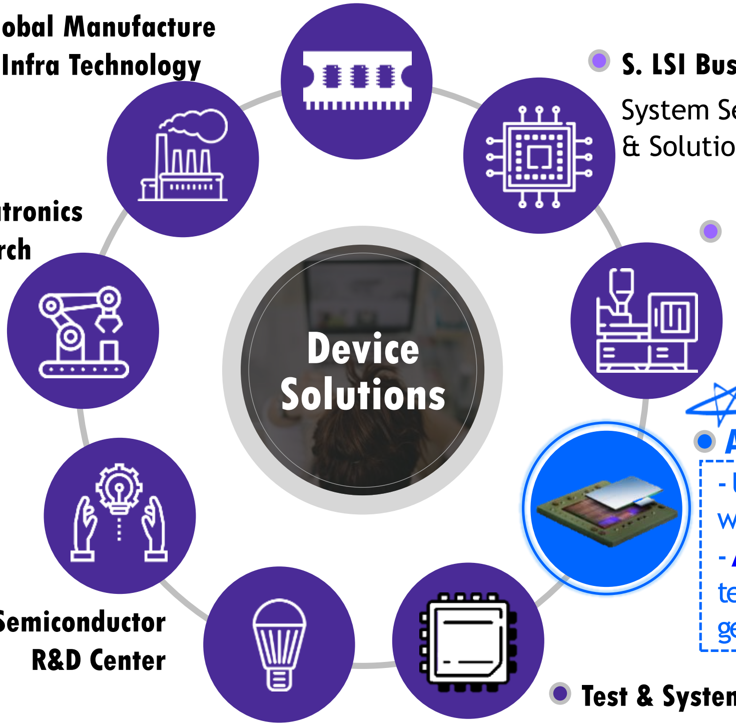
Dae-Woo Kim

May 30 – June 2, 2023

AVP TD Team, AVP Business Team

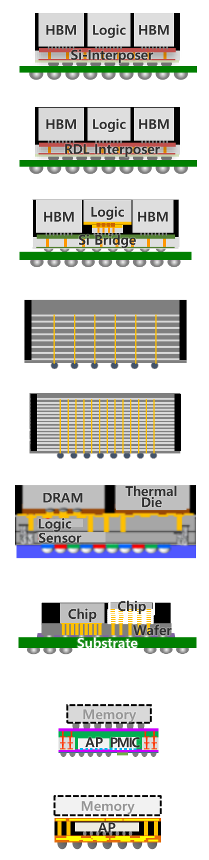
AVP(Advanced Package) Business Team

Ultimate System-in-Package Provider with Flexible Service and Synergy Platform



- **Memory Business Unit**
  DRAM, NAND Flash, Solution Production
- **S. LSI Business Unit**
  System Semiconductor IP, IC Design & Solution Development
- **Foundry Business Unit**
  Foundry Solution for Fabless(Design) Customer
- **AVP Business Team**
  - Ultimate system-in-package provider with flexible service and synergy platform
  - AVP TD team is working on the new technology development to maximize next generation product values.
- **Test & System Package**
  Conventional Package
- **LED Business Team**
- **Semiconductor R&D Center**
- **Mechatronics Research**
- **Global Manufacture & Infra Technology**

Advanced PKG Architecture		
2.xD	2.5D Si Interposer	
	Organic Interposer	
	Si Bridge (I-CubeE)	
3D	TC Bonding	
	Hybrid Cu Bonding	
	Wafer on Wafer	
3.5D		
FOPKG	PLP	
	WLP	

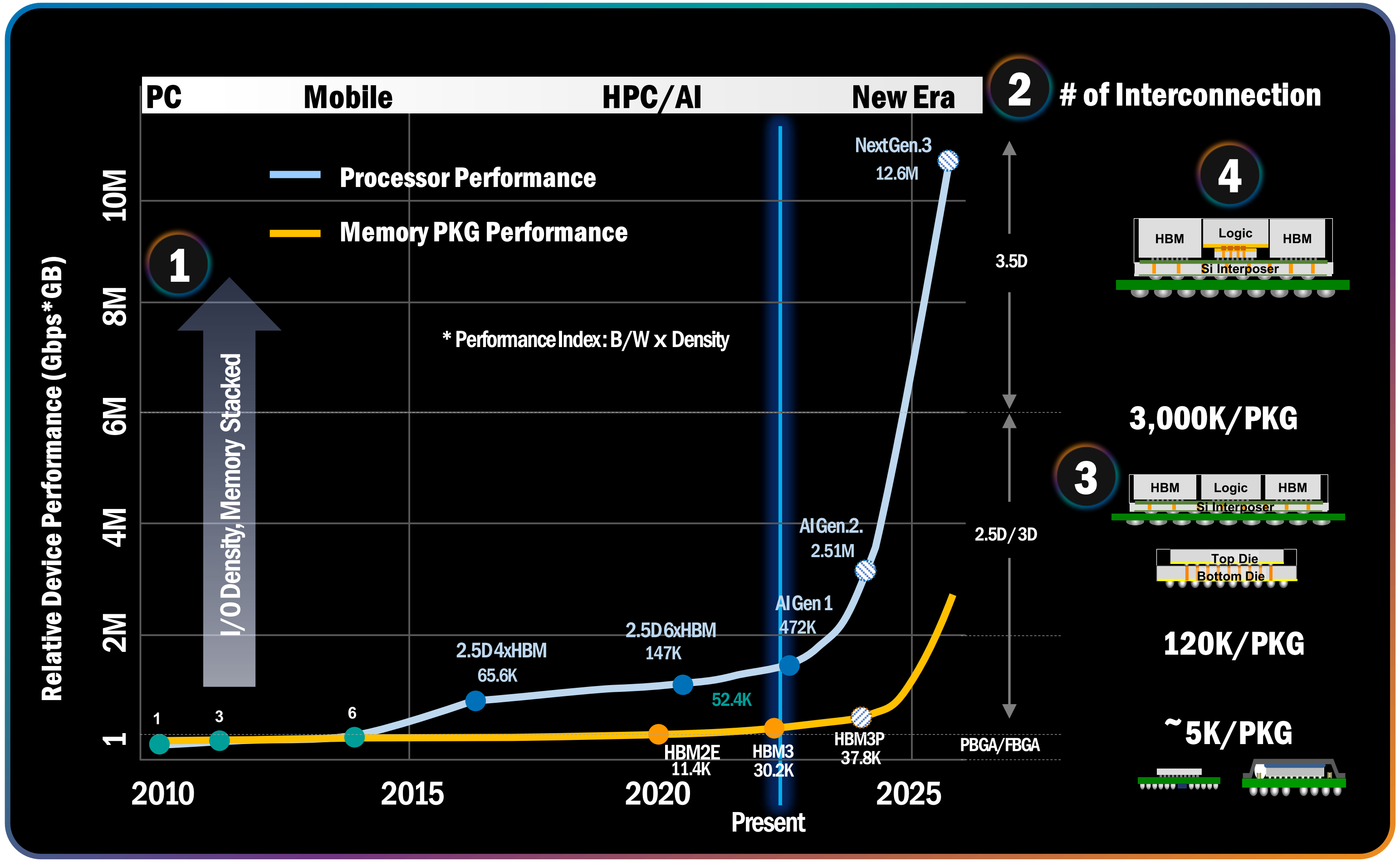


Value & Challenges

1. Thickness
2. Area
3. High Density
4. Reliability
5. Performance
6. Cost
7. Long TAT
8. Si Validation

The New Challenges for Adv. PKG Technology

More-than-Moore accelerated by Package Solutions



1 Improved SiP Performance (BW x Density)

- '10~'18 270x, '18~'26 ~50,000x
- 1Gbps·GB ('10)→269Gbps·GB ('18)→12.6MGbps·GB ('26)

2 Increased PKG Interconnection

- '10~'18 1.2x, '18~'26 50x
- 5.1K ('10) → 6.2K ('18) → 3.2M ('26)

3 Finer Interconnection Pitch

- '10~'18 2.0x, '18~'26 22x
- 150㎛ ('10) → 90㎛ ('18) → 4㎛ ('26)

4 Emerging Chiplet Integration

- Cost saving with chip Split
- Above 150㎟ die@advanced node

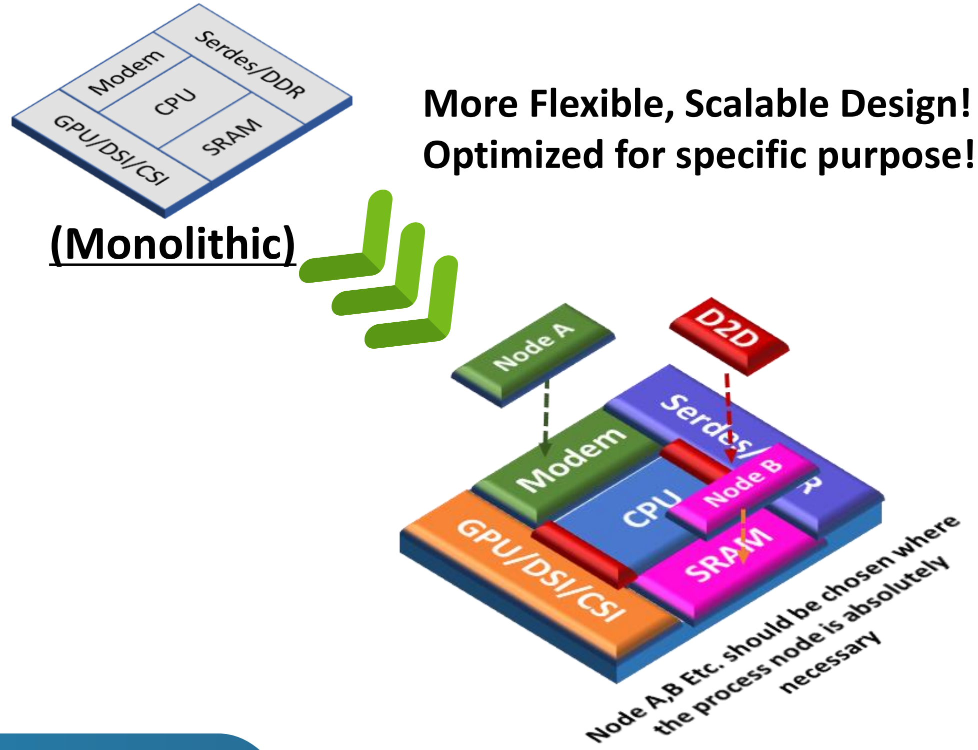
Advanced Packaging for harsh environments

- Chiplet for Open Platform requires heterogeneous integration, standardization, SCM
- Chiplet challenges : technology convergence, high infra & PKG cost, long development time, reliability

Chiplet for Open Platform

like Lego blocks! like Shopping!

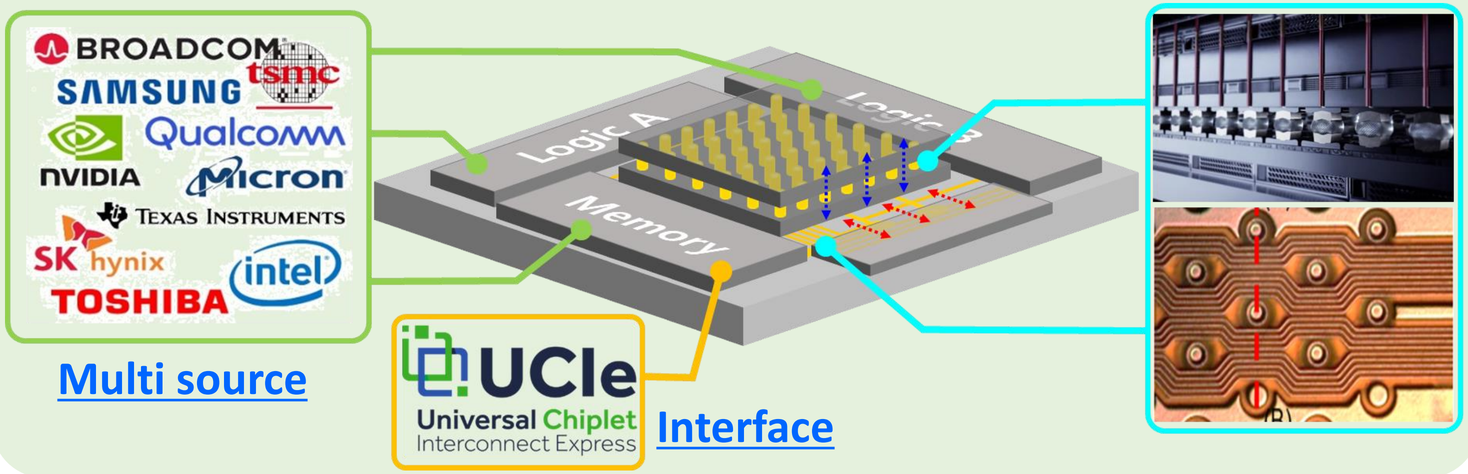
More Flexible, Scalable Design!
Optimized for specific purpose!



(Monolithic)

(Chiplet like Lego blocks)

Requirements..!



Interconnection

Multi source

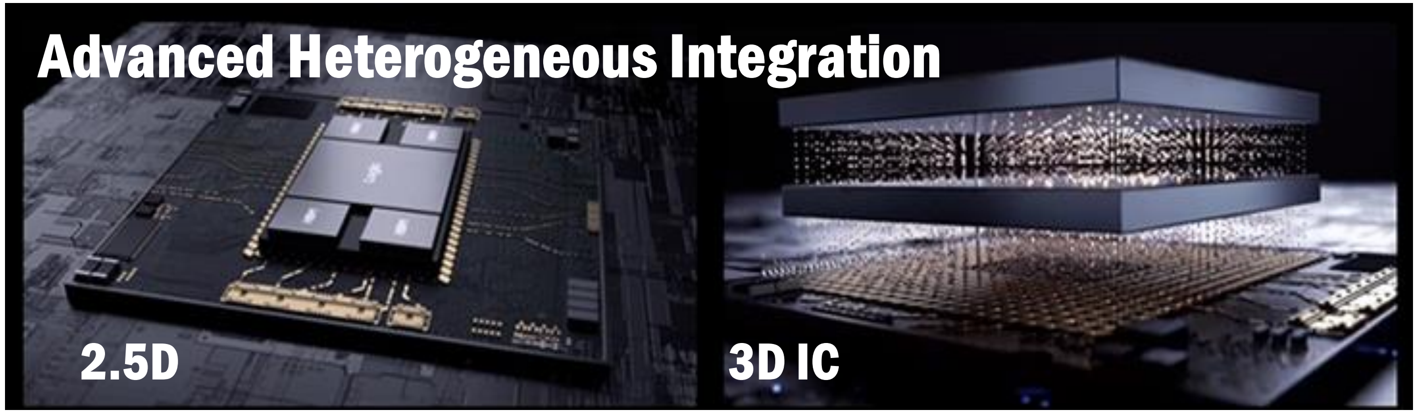
Interface

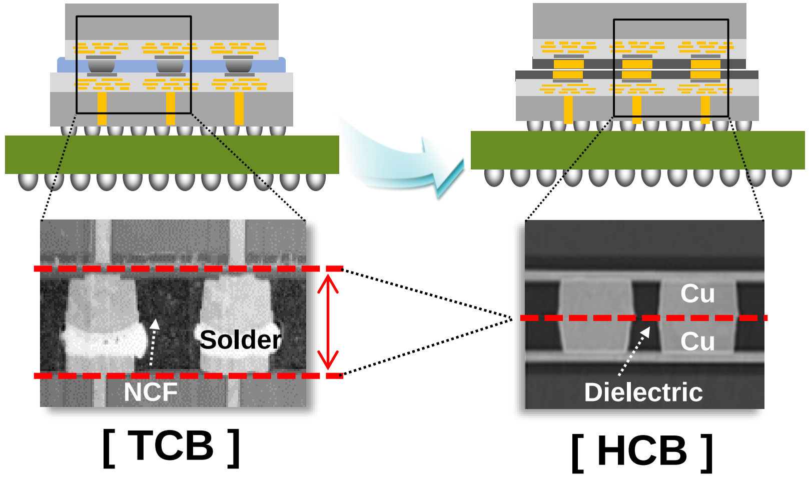
Challenges..!

Adv. Technology..! | High Cost..! | Long TAT..! | High Reliability..!

Summary

- **Heterogeneous integration would be the key driver for advanced package technology**
  - Co-package design, synergy platform (Memory+Logic), SI/PI optimization, mechanical Simulation etc.
- **Chiplet technology for open platform need to define "Standardization"**
  - High infra cost & package cost, longer development time and assembly TAT.
  - Advanced package need to adopt Si FAB technology for higher interconnection.
  - Higher reliability requirement for system level integration and harsh use conditions.





Advanced Packaging and Heterogeneous Integration Roadmap for Harsh Environment – Current Status and Opportunities

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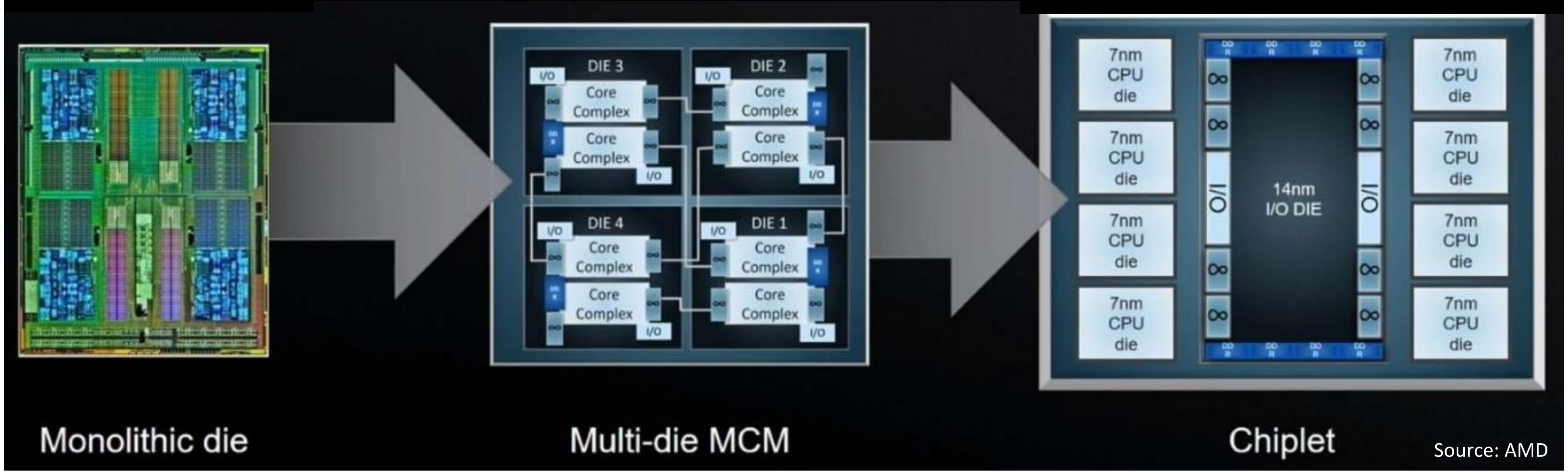
The Chiplet Revolution: A Key Enabler?

- Increasing processing power & functional density
- Digital & memory devices require advanced technology nodes

System defined at package level through chiplet-enabled HI

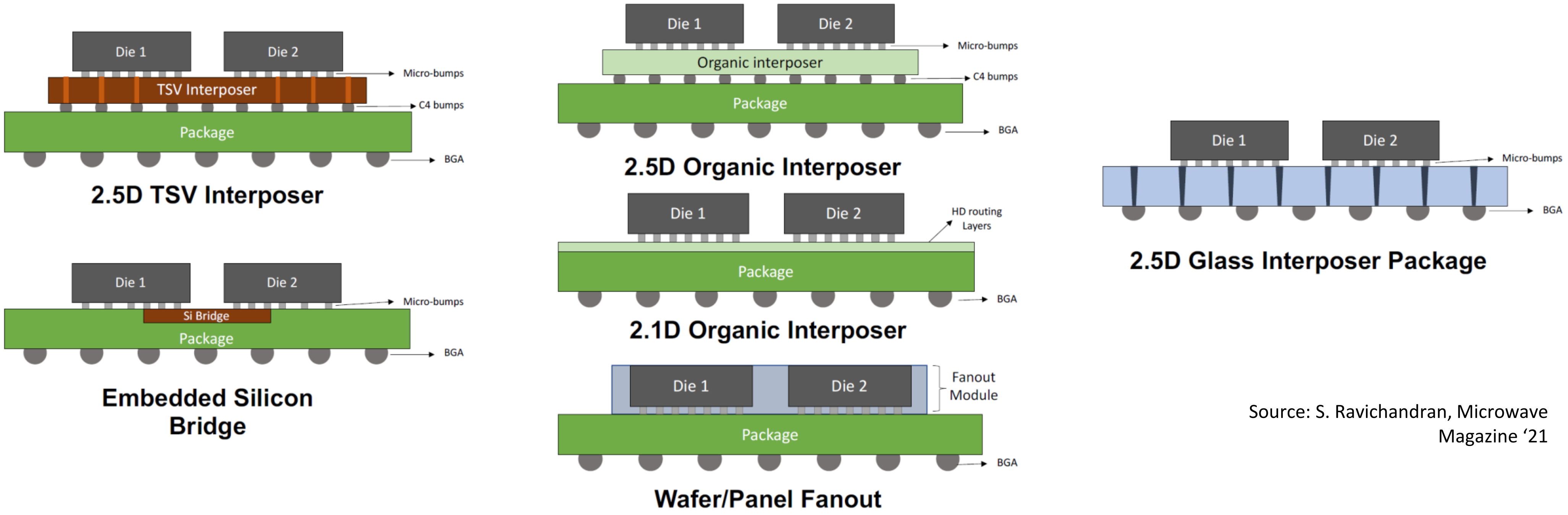
Difficult to reuse & source | vs. | Flexibility / modularity Plug-and-play



Source: AMD

Many Integration Platforms to Pick from

- Rapid diversification of architectures in 2D, 2.5D and 3D, some more 'proven' than others in harsh environments
- Trade-offs in cost, feature scaling and reliability to be analyzed

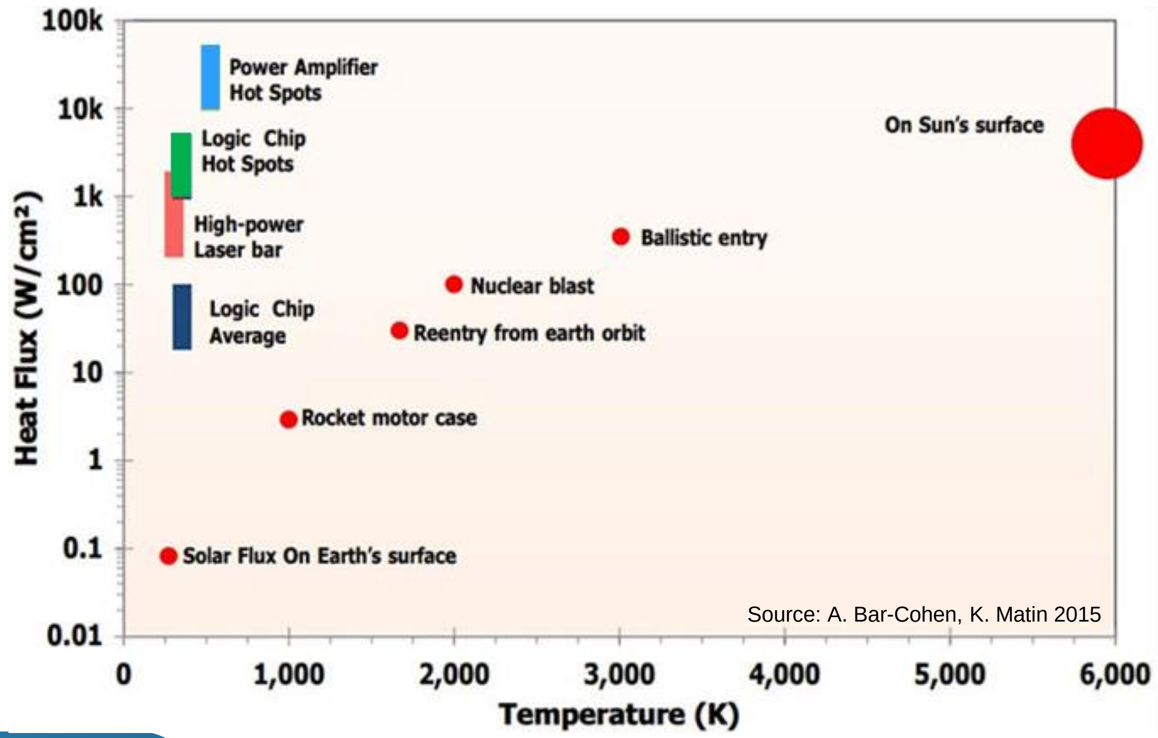


Source: S. Ravichandran, Microwave Magazine '21

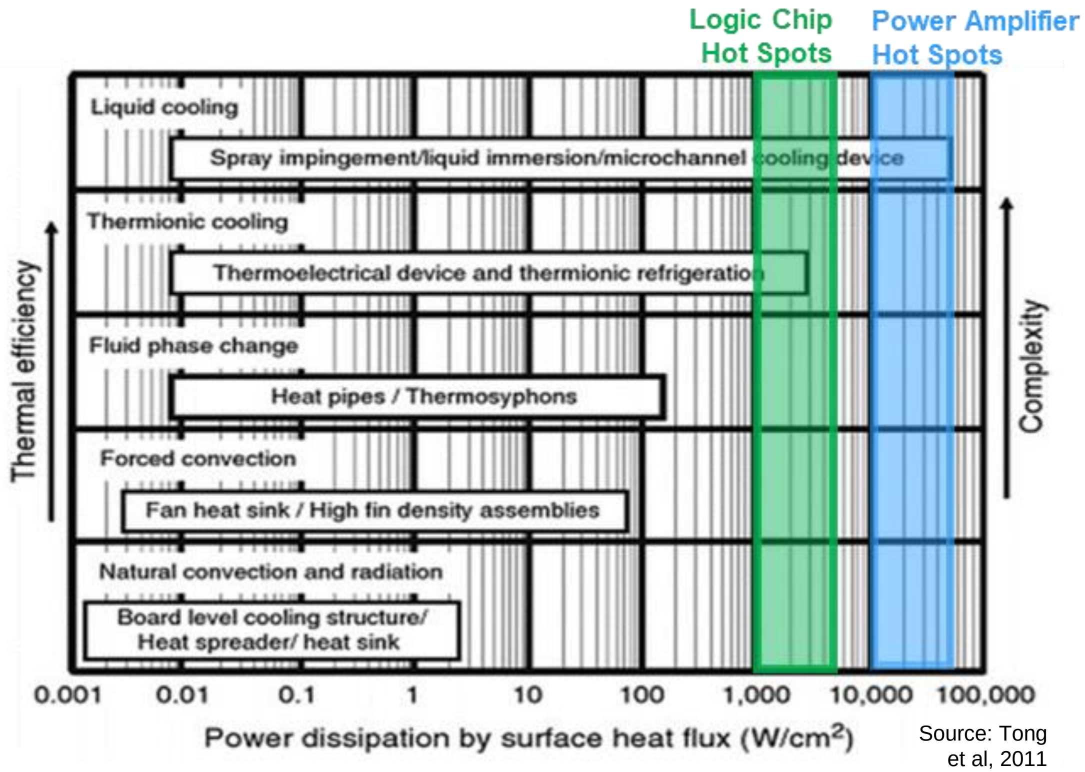
How do we quickly adopt these advanced integration nodes?

The Thermal Challenge – A Key Bottleneck

- Thermal densification at both device and package level
- Multi-scale thermal management for heat spreading & removal



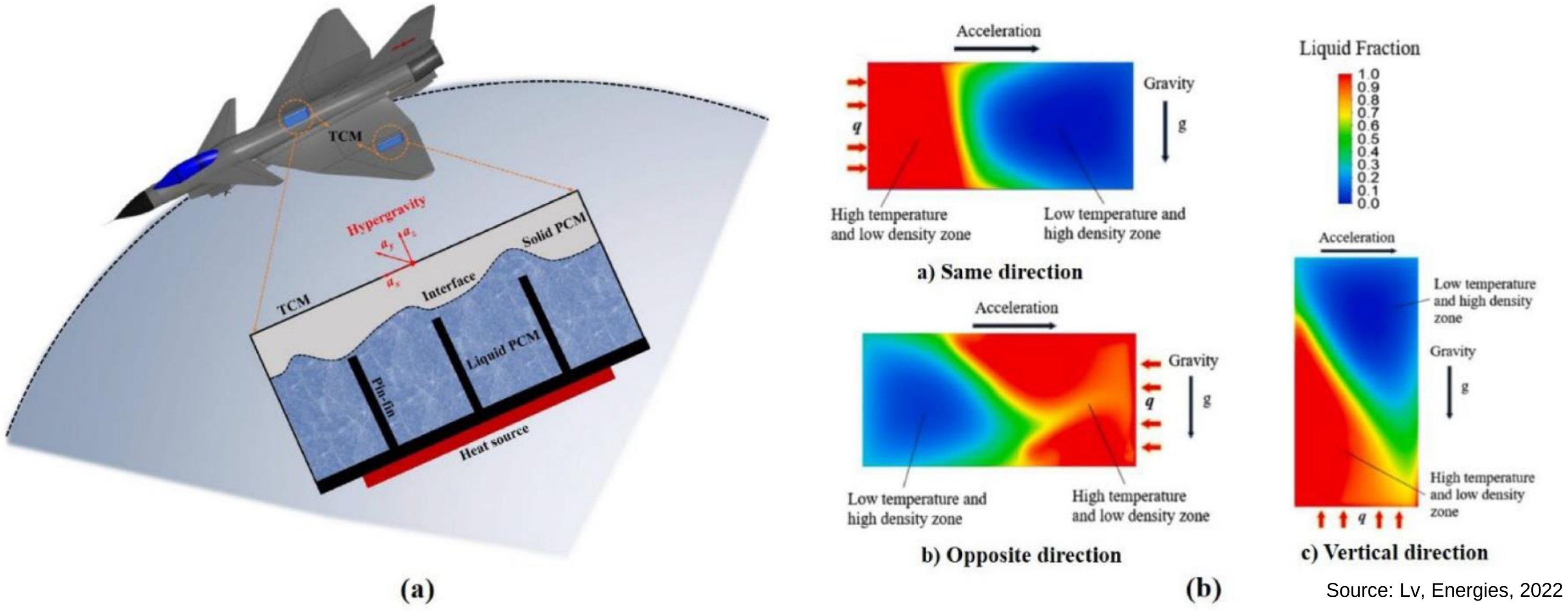
Source: A. Bar-Cohen, K. Matin 2015



Source: Tong et al, 2011

The Thermal Challenge – A Key Botteneck

- Most 'classic' solutions cannot be directly applied to automotive, e-aviation or space applications



Source: Lv, Energies, 2022

Schematic of (a) the PCM device on board aircraft under hypergravity condition and (b) PCM melting process in different acceleration directions

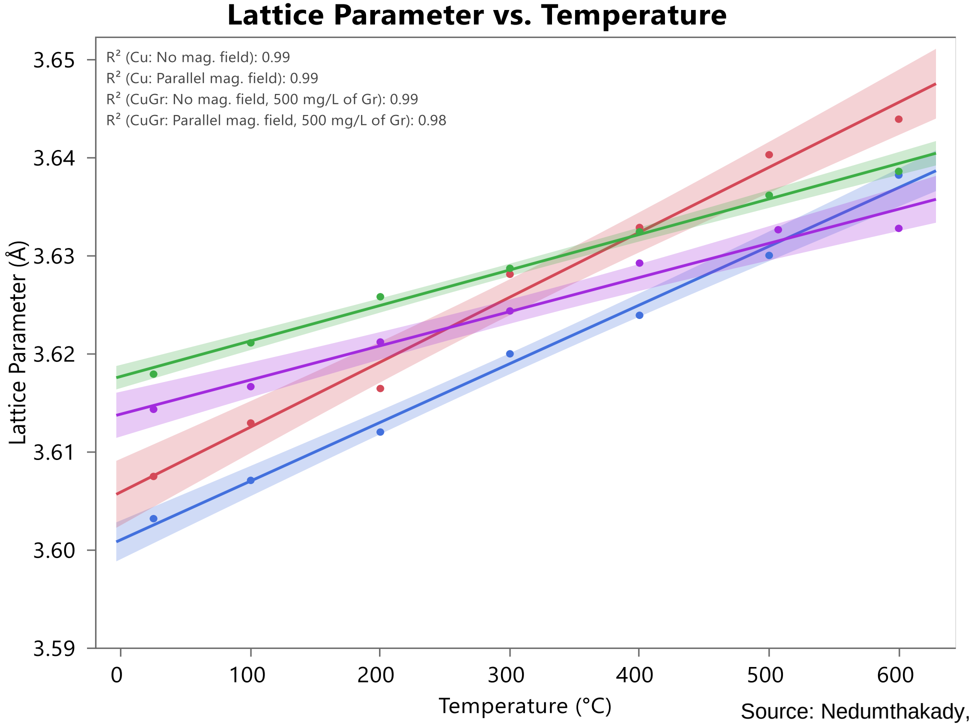
- Environmental influences:
  - Vibrations and shock
  - Gravity
  - Acceleration
  - High (Venus) / low (Moon) temperatures
- Research needs:
  - Working fluids
  - Reliable fluid / vapor confinement
  - Dry out…

Outlook on Reliability Prediction & Test Methods

- Re-qualification for use in harsh environments
  - Complex / new mission profiles
  - Interaction between stress loadings
  - New failure mechanisms
  - Test sequence
- Stretching already stretched-out integration platforms
  - Materials pushed to their limits
  - System-level reliability and yield already difficult to achieve by consumer standards
- Introduction of new technologies
  - Interconnection solution – solder or else
  - Nanomaterials → cross-scale effects?
  - CTE-matched architectures

AI-driven design for reliability, performance and SWaP

CTE reduction with Gr reinforcement of electrodeposited Cu



Source: Nedumthakady, ECTC, 2023

Next Gen Software-Defined Vehicles & Automated Driving Systems

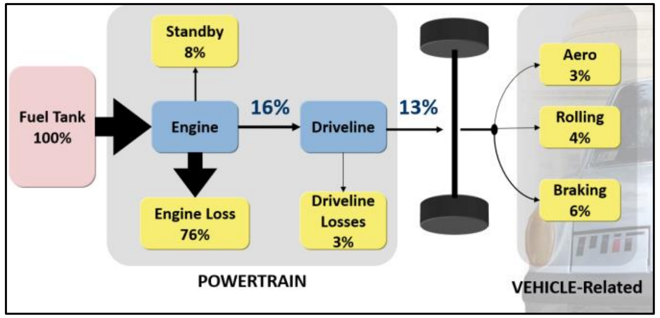
Ramesh S
General Motors R&D
Warren, MI
USA

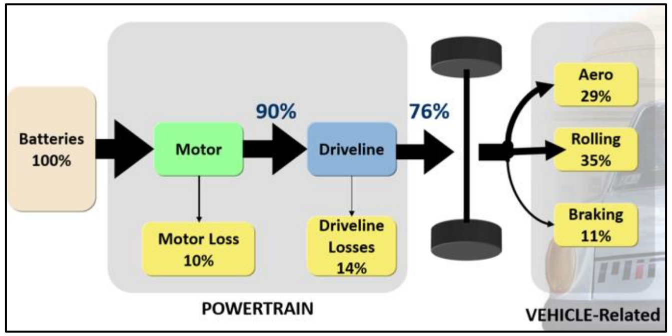
General Disclaimer

- Based upon my observations
- Not the Opinion of GM
- Tried my best to quote the original source of diagrams wherever possible

ICE to EV

- Significantly improved energy efficiency: 13% vs 76%
- In the last 3-4 years, almost all the major OEMs announced plans for major expansion in BEV portfolio
  - OEMs catered to the needs of customers and the government mandates on emissions
  - Several European countries have government set target dates to phase out ICE passenger vehicles
- EVs redefine the computations needs in automobiles with the addition of battery management (for safety and efficiency), infotainment, connectivity and autonomous driving!





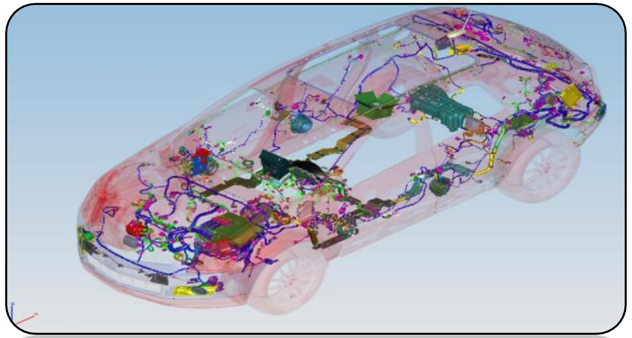
BEV Truck: 3-motors

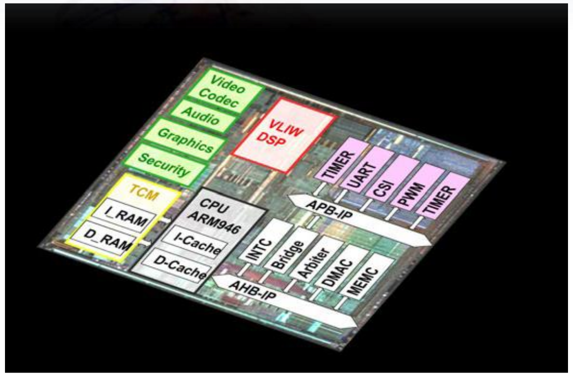
Your Company Logo

HW Architecture Evolution

- First Embedded Controllers
  - 1977 – First GM production automotive microcontroller
    - Electronic spark timing
  - 1981 – All GM North American vehicles use microcontroller-based engine controls
    - 3.9M vehicles total, 22K ECMs per day manufacturing rate
    - 50,000 lines of assembly code,   MC6800 – 8-bit, 2 MHz

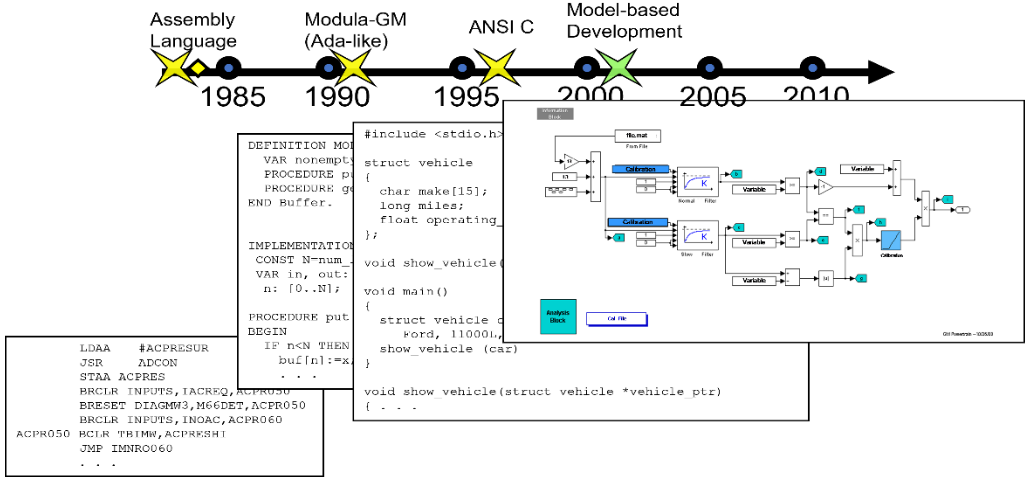
- Today, high end cars with advanced technology like Advanced Driver Assist System (ADAS) may contain up to 150 ECUs or more and > 150 million lines of code.
- Multidomain integrated ECUs & High-Performance Centralized Compute platforms enabled by powerful SoCs



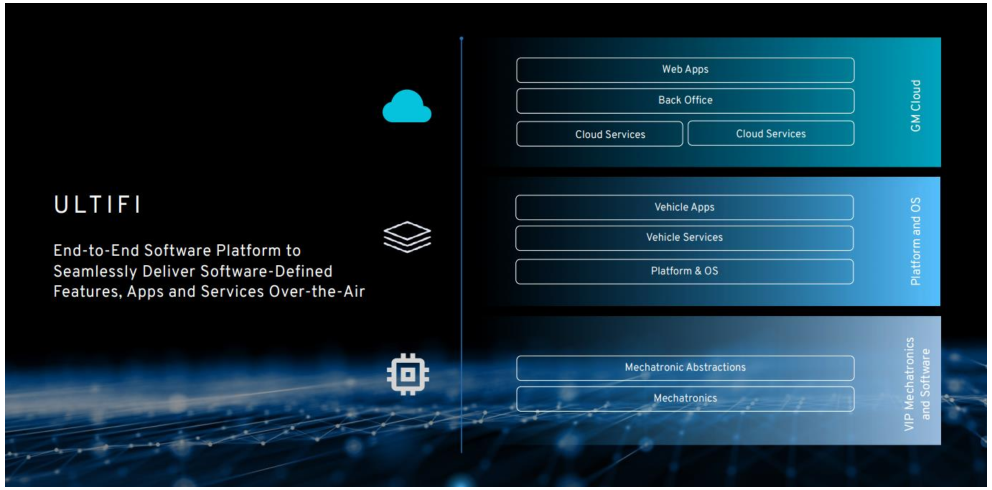


SW Architecture evolution

- Centralized to distributed back to centralized architecture
- Middleware based architecture
- Platform based architecture
  - SW apps and services



	AUTOSAR Classical Platfrom	AUTOSAR Adaptive Platfrom
Operating System	OSEK OS	POSIX specification
Communication Protocols	Signal-based Communication (CAN, FlexRay, Most)	Service- Oriented Communication (SOME/IP)
Scheduling Mechanisms	Fixed task configuration	Dynamic scheduling strategies
Memory Management	Same address space for applications (MPU)	Virtual address space for each application (MMU)

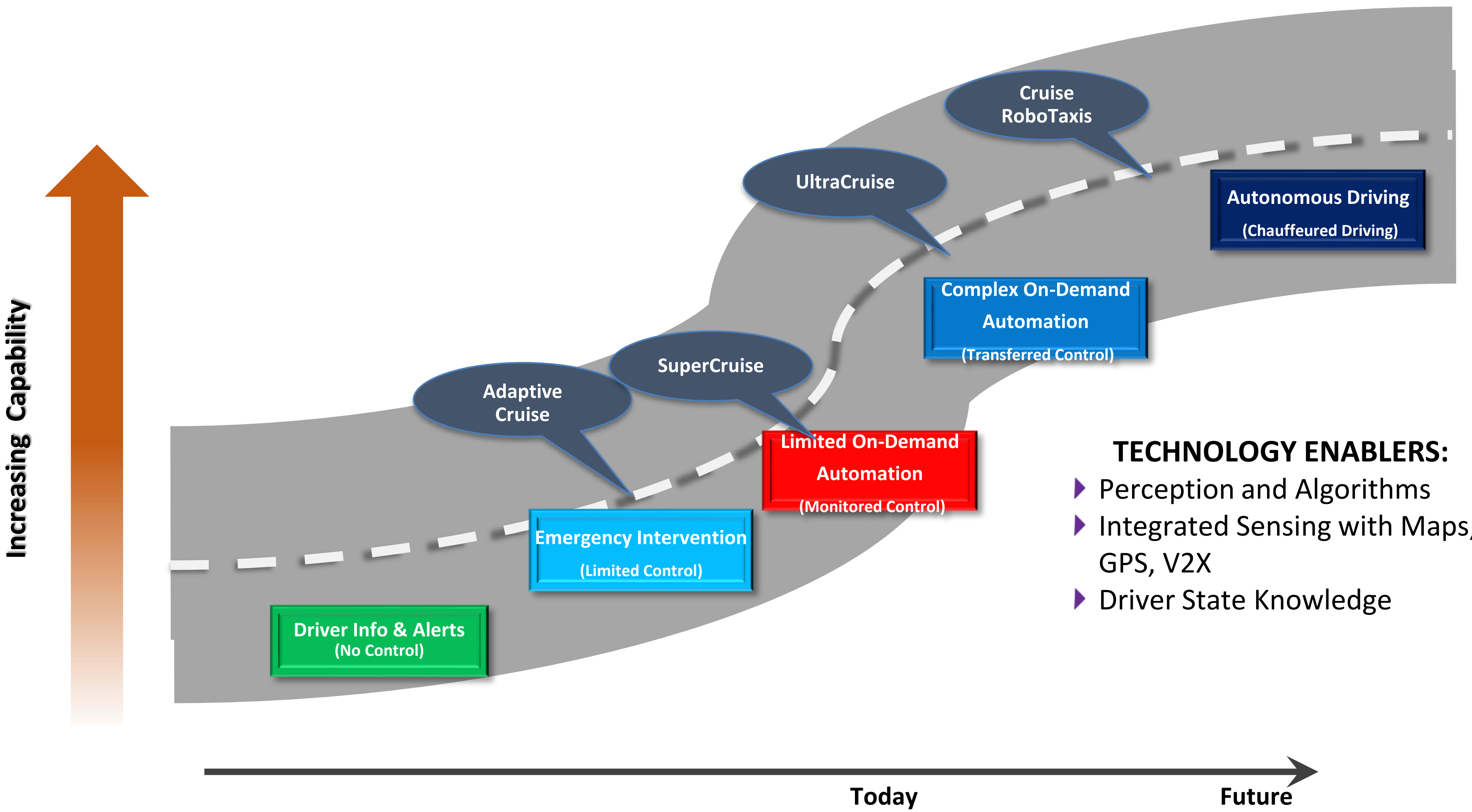


Levels of Automation in Vehicles

- SAE definition identifies 5 levels
  - Increasing degrees of automation
  - Decreasing levels of human role
- Concept of Operational Design Domain (ODD), Dynamic Driving Tasks (DDTs)
- Level 2 - 5: Increasing range of ODDs and DDTs
- Level 5 unlimited ODD and probably beyond all DDTs
- Industry focus has been primarily on Level 2 - 4

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
Human driver **monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
Automated driving system **("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

A- Z of Cruises: Road to Autonomy

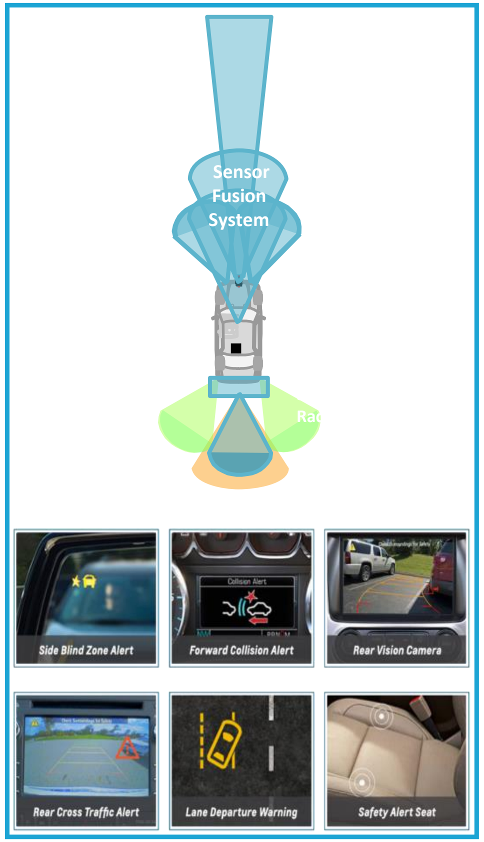


TECHNOLOGY ENABLERS:

- Perception and Algorithms
- Integrated Sensing with Maps, GPS, V2X
- Driver State Knowledge

Super Cruise – Hands Free Driving Feature

ACTIVE SAFETY



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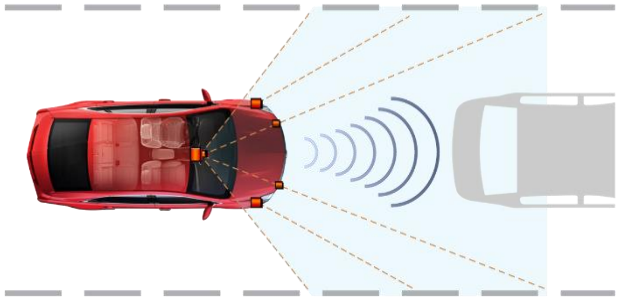
STEERING



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IT

LANE FOLLOWING: Using a combination of GPS and optical cameras, Super Cruise watches the road ahead and adjusts steering to keep the car in the middle of its lane.

COLLISION AVOIDANCE: A long-distance radar system detects vehicles more than 300 ft. ahead. The vehicle will automatically accelerate or apply the brakes to maintain a preset following distance.

Prevents 10 K deaths, Saves 250 Billion Dollars – Boston Consulting Co.

Level 2+ Features

- Shift in Functionality
  - From Traditional Control System Paradigm
    - Sense – Control – Actuate
  - To Robotics Paradigm
    - Perceive – Plan - Act
- Perception & Planning tasks involve AI/ML components
  - Lane and Traffic Signal Detection, 3D Object Classification
  - Path planning

Takeaways

- Large amount of Variety Electronic Assets
  - Centralized Compute Platform powered by SoC
  - Multiplicity of CPU and GPU cores
  - Variety of Sensors
    - Long and Short Range Radars
    - Number of external and in-cabin cameras
    - Lidars
    - Ultrasonic sensors
  - Interconnect Networks
    - Ethernet backbone, CAN Buses
  - Various Connectivity devices – In-cabin, V2C, V2E, V2V
    - GPS, Bluetooth, In-cabin WiFi, LTE, 5G

2023 Special Session / Panel Discussion
“Advanced Packaging and Heterogeneous Integration Roadmap for Harsh Environment – Current Status and Opportunities”

Ram K. Trichur, Global Head of Semiconductor Packaging

Henkel Corporation

May 30, 2023

Brief Overview: Henkel Corporation

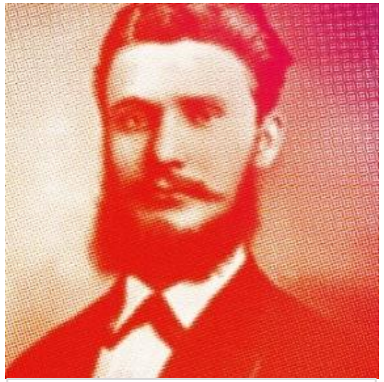
Overview

- Founded in 1876. HQ in Dusseldorf. Now 146 years old.
- 2 Businesses – Adhesive Technologies & Consumer Brands
- 22.4B€ revenue in 2022.
- 53000 employees from more than 124 countries.
- Active in 78 countries. 174 production sites world wide.

Our brands

LOCTITE, Schwarzkopf, Persil, TECHNOMELT, Dial, syoss, Schwarzkopf got2b, Pattex, Pritt

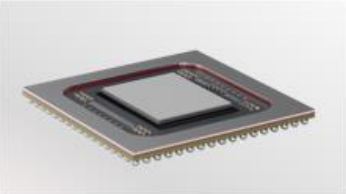
Founder



Fritz Henkel

Our fields of expertise in electronics materials

SEMICONDUCTOR PACKAGING MATERIALS

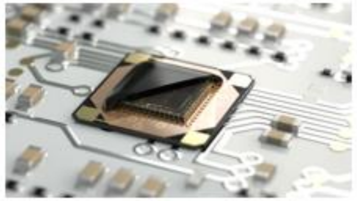


- Semiconductor Pastes
- Semiconductor Films
- Semiconductor Encapsulants
- Semiconductor Underfills

COMPONENT ASSEMBLY MATERIALS

- Component Assembly Adhesives
- Inks & Coatings

BOARD-LEVEL ENCAPSULANTS

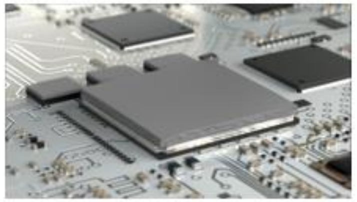


- Board Level Encapsulants
- Board Level Underfills
- Conformal Coatings

DEVICE ASSEMBLY MATERIALS

- Dispensing Equipment
- Electronics Cleaners
- Electronics Structural Adhesives
- Instant Adhesives
- Sealants and Gasketing Materials
- Surface Treatment Solutions

THERMAL MANAGEMENT MATERIALS

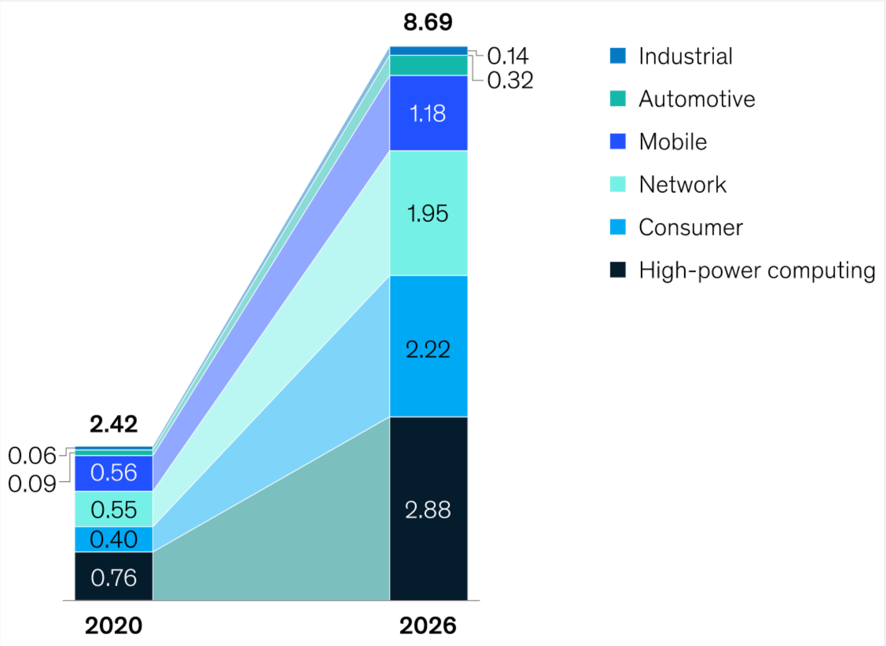


- Gap Pads / Sil Pads
- Gels
- Greases
- Liquid Gap Fillers
- Phase Change Materials
- Thermally Conductive Adhesives

Market Trends & Outlook for Adv. Pkg in Automotive

Advanced Packaging Sales by End Application ($B)

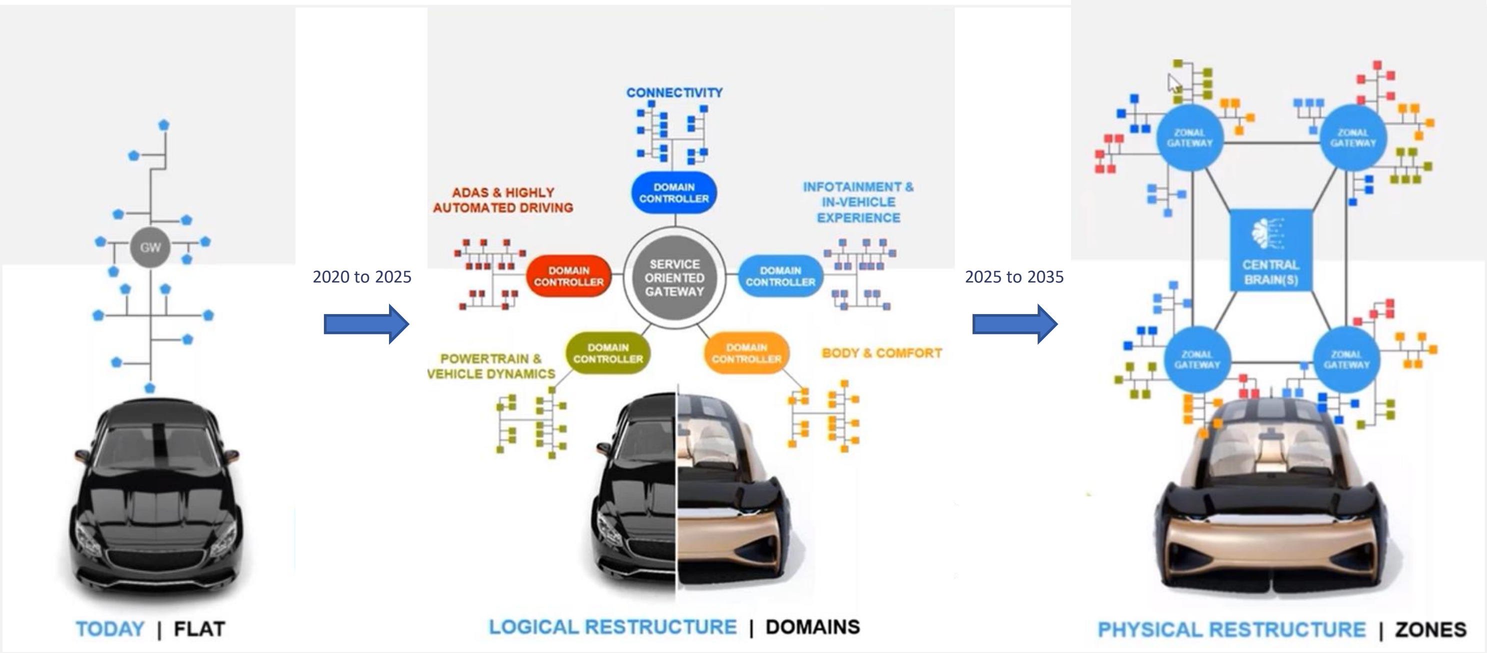
Source: McKinsey, 2023



- Overall end application revenue grows to 8.69B by 2026.
- Largest volume driver for adv. Packaging is HPC, consumer electronics & network devices.
- One of the highest growth comes from Automotive applications. CAGR$_{'20\text{-}'26}$ is 24%.

Vehicle Architecture Transformation

Source: NXP

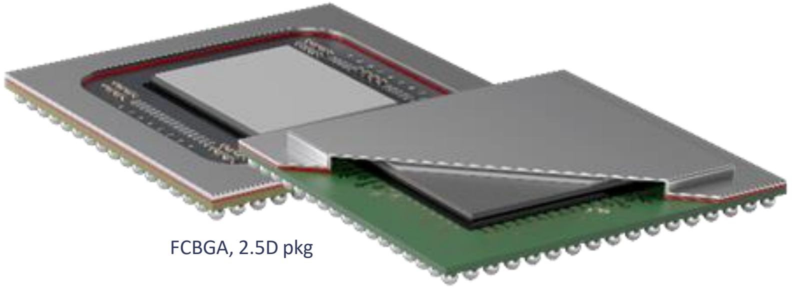


Distributed ECU → Distributed - Domain → Centralized - Domain → Centralized Zonal – Domain Controller → Centralized Zonal – Central Computer

- Vehicle architecture transforming from distributed ECU based framework to domain/ zonal architecture to eventually central computing architecture.
- Domain cockpit controllers: With same SoC manages several displays in the car, low-level ADAS (parking, driver monitoring), comfort applications and future vehicles also new cockpit trends to include gaming.
- Central computers: Advanced HPC SoC for handling full autonomy, infotainment, networking.

Adv. Pkg Automotive Component Trends & Rel. std

Processors (Zonal / Central)



FCBGA, 2.5D pkg

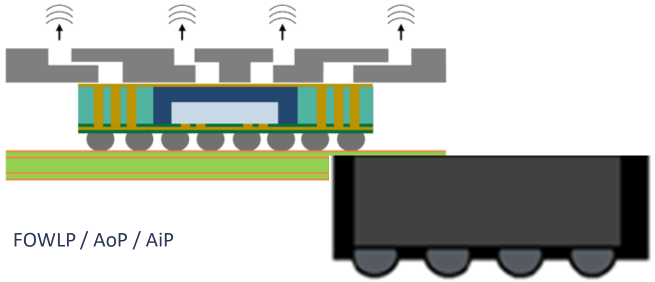
Package trends
- Heterogeneous integration, chiplet style packaging, and 3D integration.
- High I/O density. Larger chip and larger body architectures

Connectivity / ADAS / Comfort (SiP, QFN)

SiP pkg

Package trends
- SiP - Increased integration for RF front end, Higher frequency, wide band gap ICs, more heat dissipation. Higher Power, High reliability
- QFN - Cu wire, Cu LF packages.

Sensors (Radar / Camera)



FOWLP / AoP / AiP

Package trends
- Fan-out pkg requires more integration (incl. antenna in/on package) for Radar. High reliability.
- Lower cost wafer level processing techniques for scaling for CMOS image sensors.

Automotive reliability grade and mapping

Grade	Operating temp range	Component / Operating locations
0	-40 to +150 °C	Close to engine, on engine
1	-40 to +125 °C	Under the hood or critical component
2	-40 to +105 °C	ADAS, Chassis
3	-40 to +85 °C	Infotainment, comfort, body electronics

Accelerated Environmental Stress Tests

Grade	Temp cycling conditions	High temp storage
0	-55 to +150 °C / 2000 cycles	175 °C for 1000 hrs / 150 °C for 2000 hrs
1	-55 to +150 °C / 1000 cycles	175 °C for 500 hrs / 150 °C for 1000 hrs
2	-55 to +125 °C / 1000 cycles	150 °C for 500 hrs / 125 °C for 1000 hrs
3	-55 to +150 °C / 500 cycles	150 °C for 500 hrs / 125 °C for 1000 hrs

Material Requirements & Challenges

Material	Package Requirements & Challenges (For FCBGA, 2.5D, 3D, FOWLP, SiP, QFN)
Capillary Underfill (CUF)	Needs fast flow for large die. High toughness, Low CTE for reliability. Enhanced adhesion to multiple surfaces. High thermal fillers for heat dissipation.
Lid / Stiffener attach	High adhesion to SS, Ni, SR, substrate, etc. Optimization of Modulus & Tg to enhance reliability.
Thermal Interface Materials	Higher thermal conductivity, low modulus, thinner bond lines, lower thermal resistance.
Wafer-level Encapsulation	Finer filler capability to enable fine-line RDL; Low CoO enabler like printable materials; Cu-plateable mold materials to enable AoP & passives integration.
Die Attach	Enhanced adhesion to bare Cu surfaces. Alternative fillers to mitigate dendritic growth.

Testing Challenges: In order to reduce the time required for rel. tests, special accelerated testing require materials to pass even more stringent environmental & operation conditions beyond intended use.

THANK YOU!

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henkel-adhesives.com/us/en/industries/electronics