



Driving Adoption of Advanced IC Packaging in Automotive Applications

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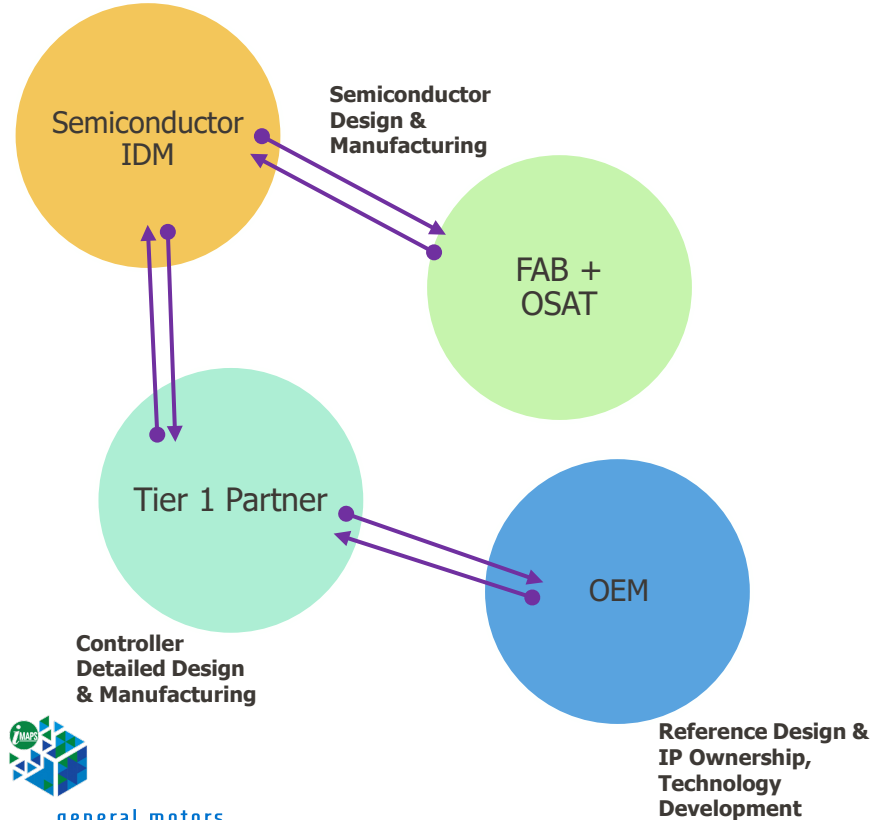


- Shift in Automotive Semiconductor Sourcing
- Importance of Manufacturing On-shoring
- Drivers for Increased Compute Power – ADAS, SDV, & IVI
- Drivers and Pain Points of Advanced Packaging
- Standardization of Chiplets and Advanced Packaging

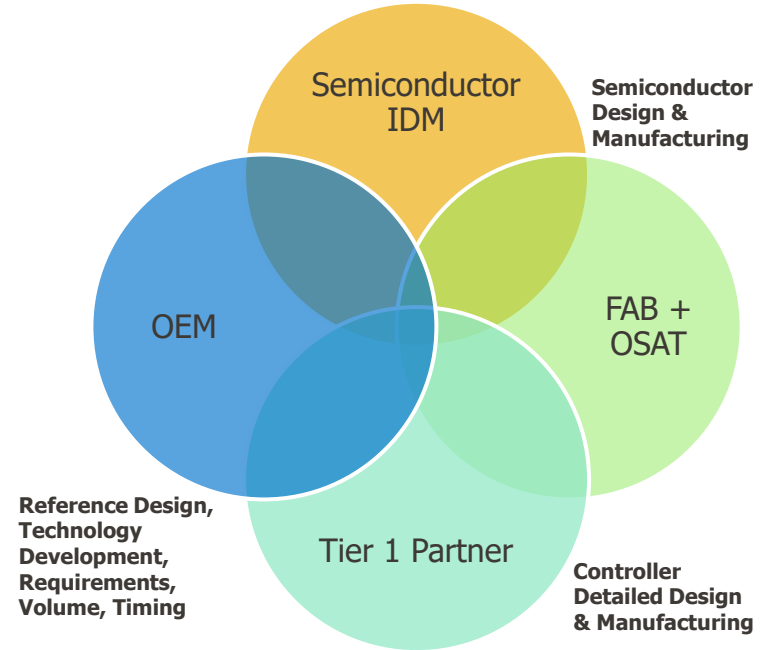




Current State of Sourcing – Linear Relationships



Target End State – Fully Integrated Partnerships

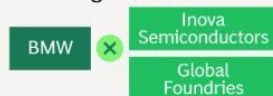




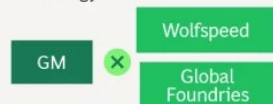
Automotive OEMs are implementing new semiconductor engagement models

Engagement models

Direct agreements



Direct supply agreements with microchip developer Inova Semiconductors and Global Foundries for smart LED technology



Strategic supplier agreement with Wolfspeed for SiC power devices



Strategic partnership with STMicroelectronics to ensure supply of power electronics for xEVs.

Focus locally



Denso (part of Toyota Group) invested of \$350 million in JASM, TSMC's majority-owned manufacturing subsidiary in Japan



Collaboration to boost manufacturing and R&D in the US

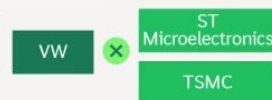


Collaboration with seven suppliers to redesign and standardize new families of MCUs in North America

Planning ahead



Cooperation with Qualcomm and Nvidia, respectively, to codevelop autonomous driving software solutions coupled with SoCs



Codevelopment of CARIAD semiconductors with STMicroelectronics and TSMC



Cooperation with Foxconn to develop standardized chip families

Own it yourself



Development of proprietary Full Self-Driving chipset and intensive cooperation with TSMC and Samsung foundry



Development of in-house semiconductors, especially MCUs and power ICs by Hyundai Mobis



Vertical integration in high-power semiconductors with in-house fabrication project

But a targeted approach is needed to secure supply for chip types and processes at the highest risk of persistent shortages

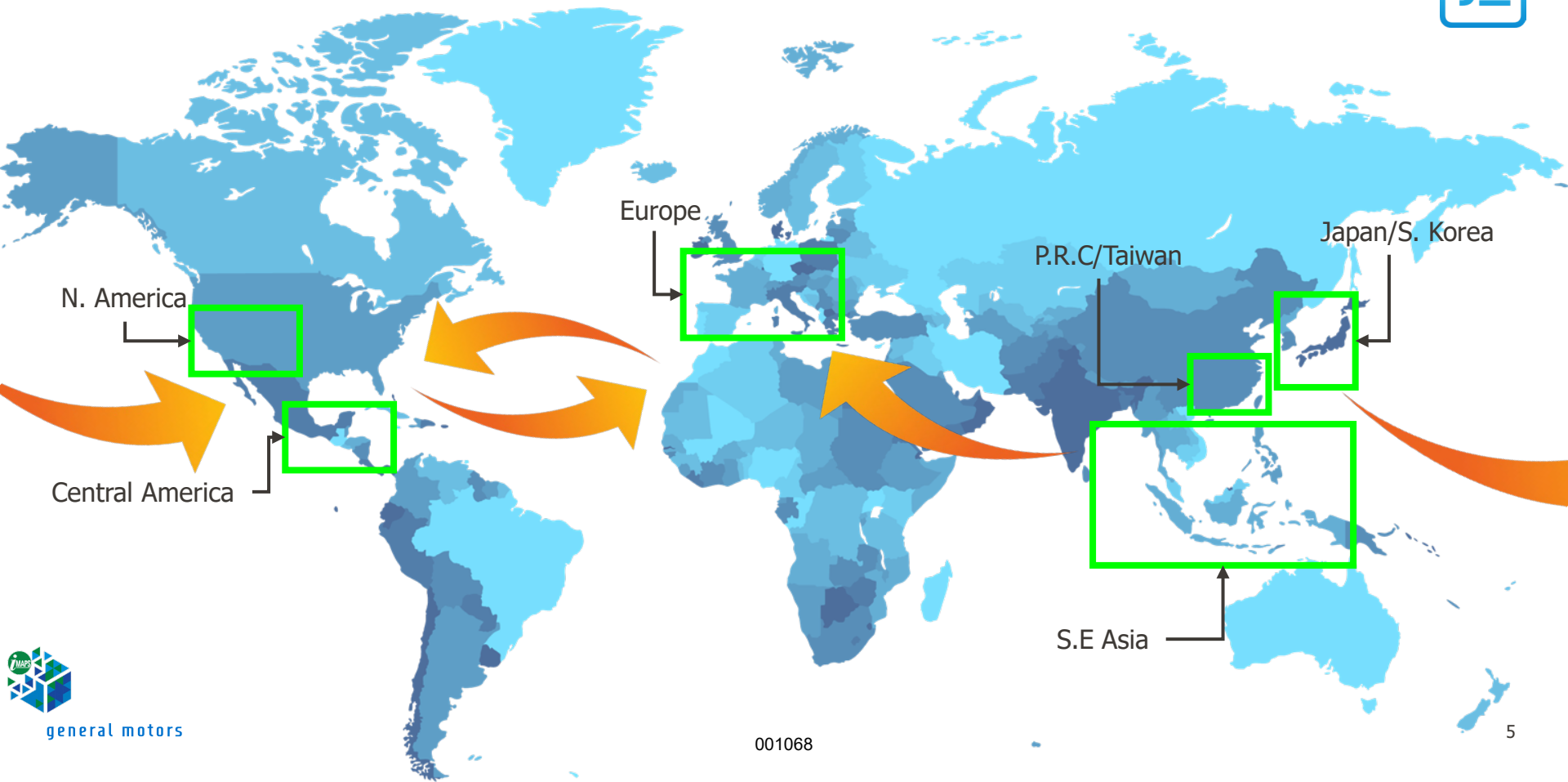
Sources: Press releases; public information (such as interviews) from OEMs, integrated device manufacturers, and foundries; BCG analysis.

Note: IC = integrated circuit; LED = light emitting diode; MCU = microcontrollers; SiC = silicon carbide; SoC = system on a chip.



Diversification of Critical Semiconductor Infrastructure

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Transition to Modern SI Nodes

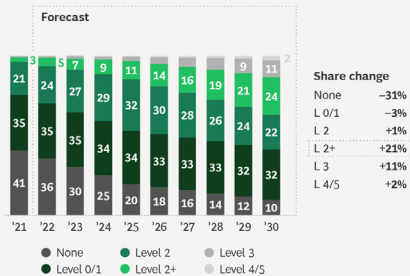
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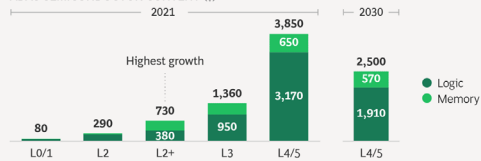
- Innovation in Automotives is driving significant uptick in adopting advanced nodes
- Drivers include advancements in ADAS, content rich IVI, and Autonomous driving features (L2+)

ADAS Level 2+ will see the highest penetration growth through 2030, increasing demand for logic and memory

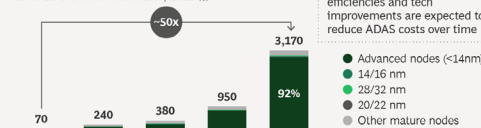
ADAS SHARE OF LIGHT VEHICLE PRODUCTION (%)



ADAS SEMICONDUCTOR CONTENT (\$)

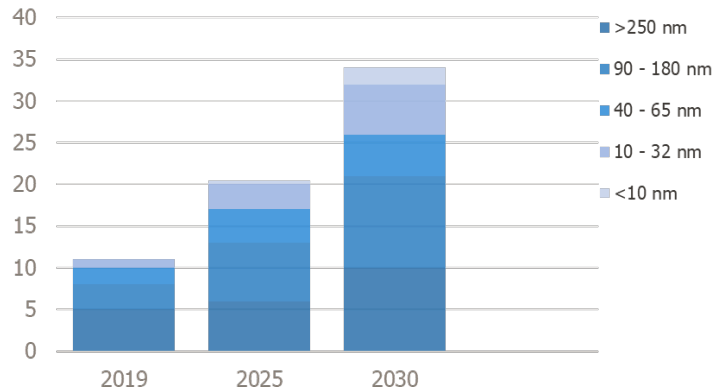


ADAS LOGIC CHIP CONTENT, 2021 (\$)



Source: Gartner; Strategy Analytics; BCG Analysis.

ANNUAL DEMAND FOR 12IN WAFERS, AUTOMOTIVE SEMICONDUCTORS, BY NODE (NM)



Source: McKinsey & Company; McKinsey Center for Future Mobility 2022

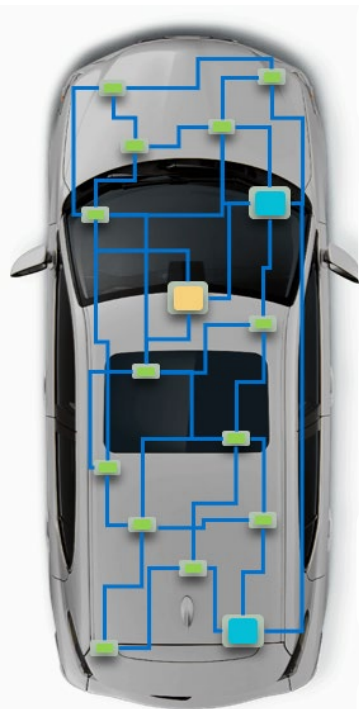
- Benefits of up-integration of heterogeneous integration drawing interest to advanced packaging
- Advanced nodes providing improved scaling, power consumption, IPs, and access to advances in MCP designs (UCIe, HBM, 2.5D+, MoP, etc)



general motors



Today's Electrical Architecture



Highly distributed, unscalable, massive integration required for compute upgrades

50+ individual ECU per program, 100's different VIP ECUs

70+ Unique MCUs - uncontrolled supply chain

Single program cost optimized

Fast time to market, but still limited by architectural constraints

Centralized SDV

Centralized, highly scalable, upgradable by customers in field

~50% reduction in ECU per program

Semiconductors with 7-year design life, secure supply control

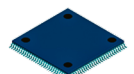
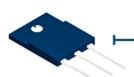
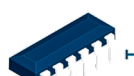
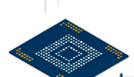
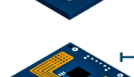
Enterprise cost optimized, new sales opportunities after SOP

Industry leading time to market for software development





Products examples

-  **Analog IC**
(e.g., amplifiers, voltage regulators)
-  **Discretes**
(e.g., rectifiers, Silicon Carbide modules)
-  **Logic IC**
(e.g., FPGA - Field Programmable Gate Arrays)
-  **Memory IC**
(e.g., Flash memory, DRAM)
-  **Microcomponent IC**
(e.g., Digital signal processor)
-  **Optical Semiconductor**
(e.g., Light emitting diodes, image sensors)
-  **Sensors and Actuators**
(e.g., radar sensors)

Body & Interaction

Keyless Entry, User Profile, Advanced Lighting, etc

Infotainment & Communications

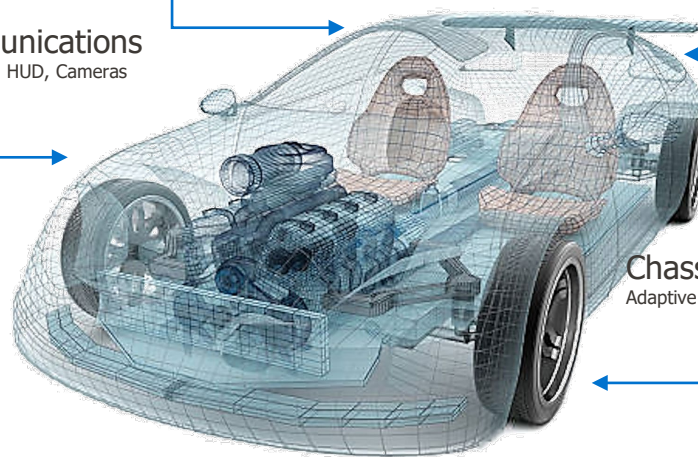
Displays, Digital Cockpit, Connectivity, HUD, Cameras

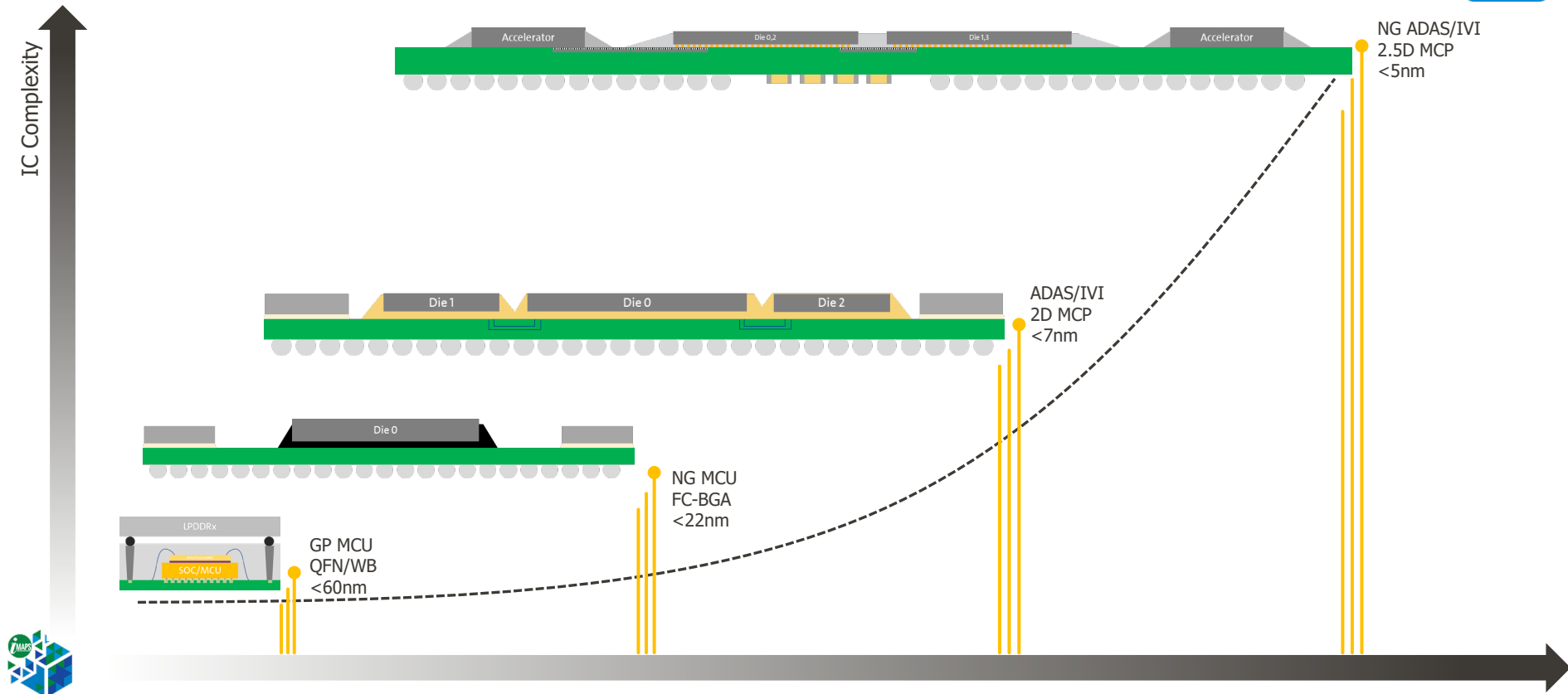
ADAS

RADAR, LiDAR, Imaging, Compute

Chassis Control & Safety

Adaptive Cruise, Auto Braking, Lane Keep Assist





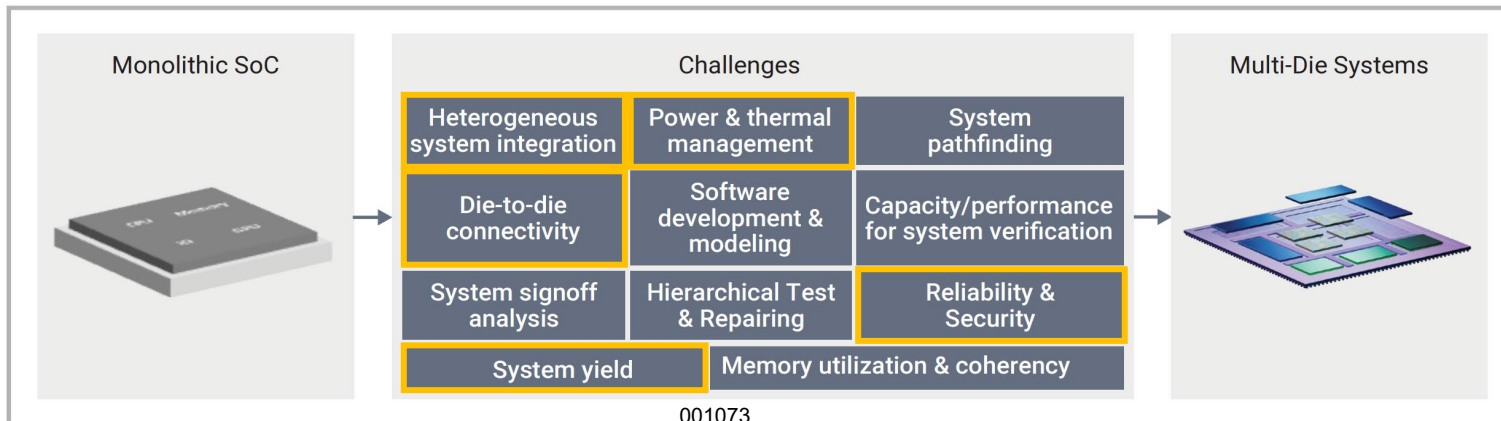


- **Benefits of Disaggregated Architectures**

- Reuse of Specialized IP
- Improved Yield
- Optimization of Node Selection
- Reduced Si Cost
- Improved Time-to-Market
- Improved Scalability across vehicle trims/stack

- **Main Challenges to Resolve**

- Power/Thermal Management
- Standardizing FF & D2D Communication
- System Design & Characterization
- Qualification and Reliability (+ Automotive)
- Chiplet Compatibility and Integration



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general motors

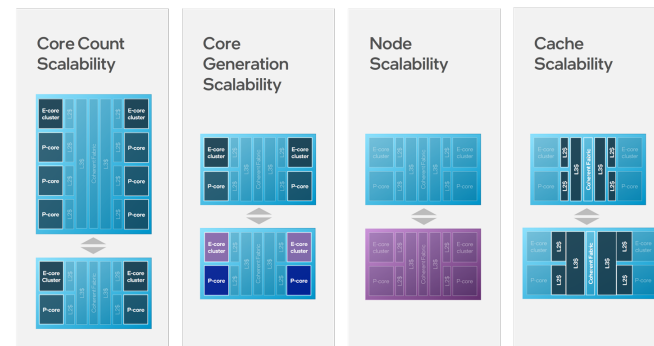
Drivers in Adopting Advanced Packaging – Chiplet Scaling

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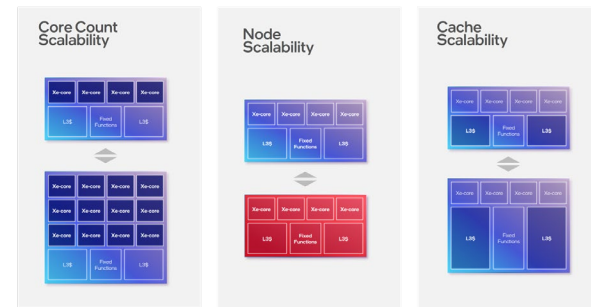


- Scalability through entire silicon/trim stack is critical to deployment
 - Reduced BOM cost
 - Predictable performance scaling
 - Optimized Node Selection
 - Improved Time to Market
- Enabling “off the shelf” IP Blocks or **Auto-Ready Chiplets**
 - Reduces qualification time by ensuring reliability
 - Standardized interconnect protocols and packaging requirements
 - Standardized form factors to enable generational refresh with minimal redesign of substrate, bridge/interposer, etc
- Integrating critical Automotive IPs at older nodes
 - SerDes, Memory, NVM/Flash, xPU, Safety Island, XCVR

Compute Tile



Graphics Tile



Source: Intel; Hot Chips 2022

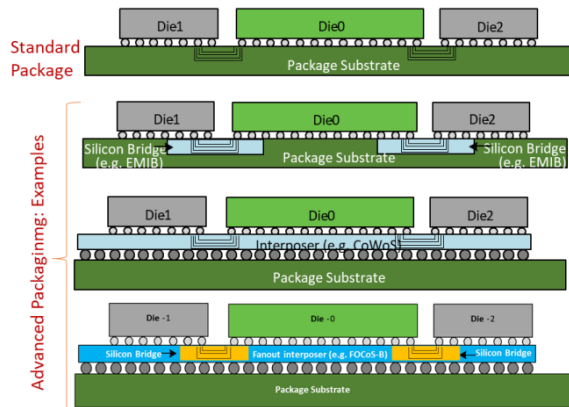




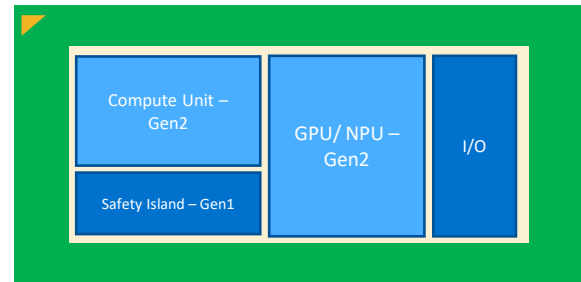
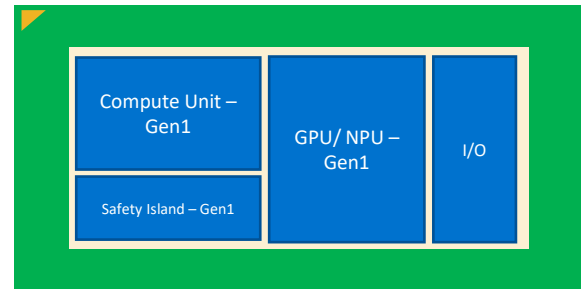
Challenges in Adopting Advanced Packaging – Chiplet Standardization

Standardized Protocols & Form Factors

- Concentrated efforts to unify communication protocols (UCIe, ODSA, etc)
- Standardized Form Factors and Bump Maps (similar to JEDEC DRAM) promote intergeneration refresh & enables IP to be provided as OTS chiplets
- Flexible implementation based on bandwidth, latency, and cost
 - EMiB, CoWoS, FOCoS, BoW, etc



(b. Packaging Options: 2D and 2.5D)



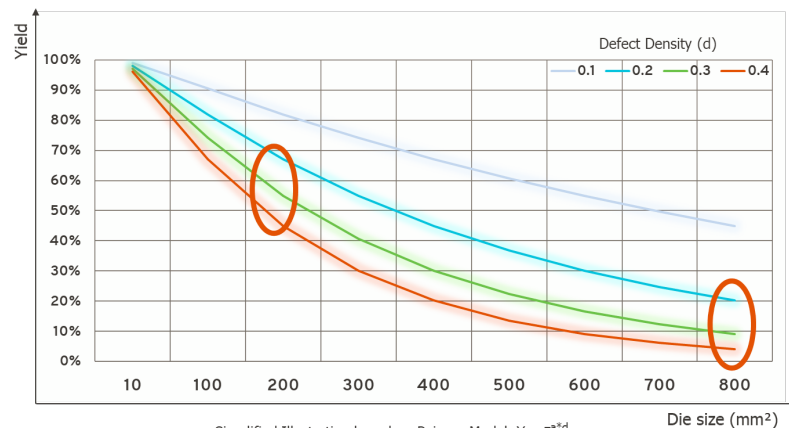


Drivers in Adopting Advanced Packaging –Yield, Cost, & Node Optimization

- Automotive ICs are moving towards advanced nodes for improved performance, advanced IPs, access to on-shored Fabs, and enabling advanced packaging
- Proliferating the use of Known Good Die through singulated die sort/test further improves packaging yield and enables march towards Zero Defect at EOL
- Node Optimization allows for further cost balancing by allowing lower scaling IP (analog) and older IP (Flash, SaIl, etc) to remain optimized on older nodes while critical IP (xPU, Memory, Cache) scale on newer nodes

	5nm Si Node			PAT Cost	Total Cost
	Area	Yield	Cost/KGD		
 Monolithic Die	800mm ²	~20%	~\$1700	~\$150	~\$1850
 A B C D E 1200mm ² (5x200mm ²) **Includes D2D I/F		~80%	~\$150x5	~\$250	~\$1000

Source: Synopsys; 2023

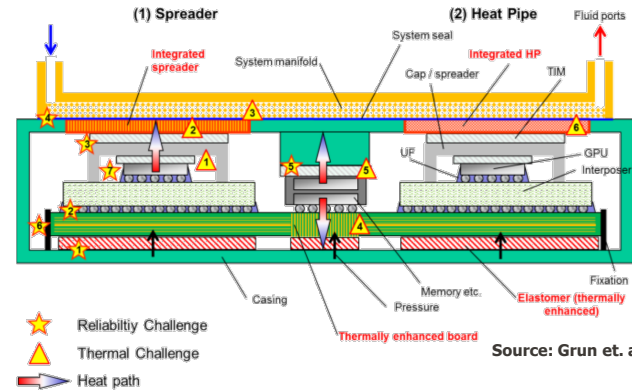
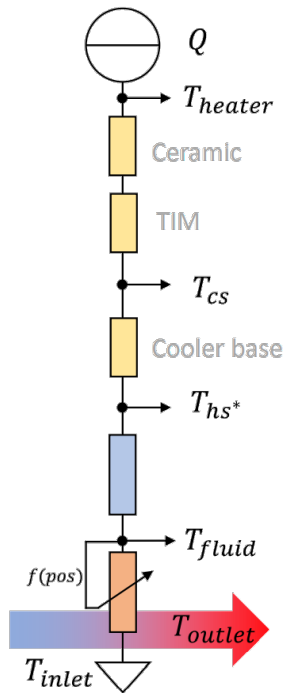
Simplified Illustration based on Poisson Model: $Y = e^{-a \cdot d}$

Thermal Solutions for Automotives – TIMs and Liquid Cooling[

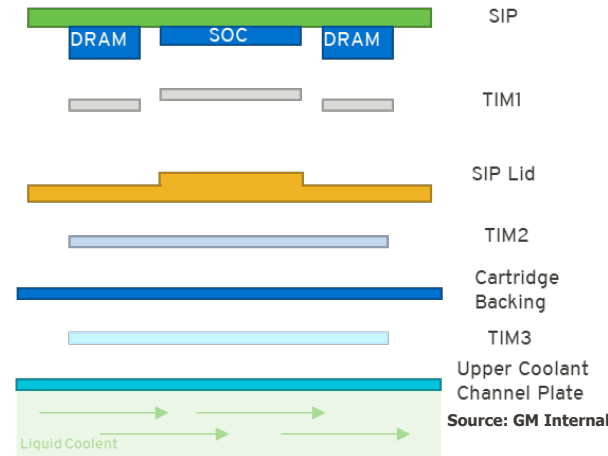
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- Automotive compute is transitioning to central ECUs and leveraging liquid cooling
- Ambient requirements transitioning to Auto Grade 1; relaxing REL requirements
- TIM development (TIM1 and TIM2) needed to ensure optimal T_{jc}
 - How do we move metal-based and carbon-based TIMs into Auto qual
- Development on liquid compositions and cold plate designs (direct liquid contact, optimized block designs, additive mfg)



Source: Grun et. al IEEE



Source: GM Internal

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Closing Remarks

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- Automotive Industry is going through a shift in sourcing, compute requirements, and engagement
- Development of advanced packaging with Automotive Deployment in Mind
 - “Data Centers on Wheels” needs Data Center development
- Emergence of Advanced Packaging and Heterogeneous Integration critical to scaling and deployment
- Standardized D2D Protocols enabling various fab nodes mission critical



A close-up, rear view of a silver Chevrolet vehicle, showing the taillight and the rear window. The text 'zero crashes' is overlaid in white and yellow.

zero crashes

A wide-angle shot of a long, straight road stretching towards a sunset over mountains. The text 'zero emissions' is overlaid in white and green.

zero emissions

An aerial view of a complex highway interchange with multiple lanes and overpasses. The text 'zero congestion' is overlaid in white and orange.

zero congestion



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Challenges in Adopting Advanced Packaging - Thermals



Warpage

- Improved monitoring of package
- Material Development
- System Interactions





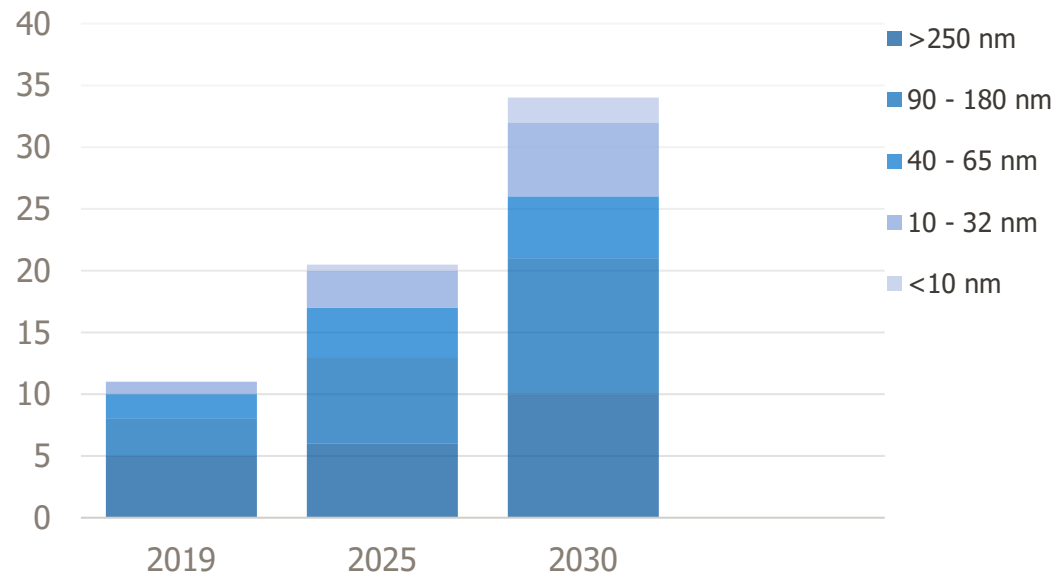
Presentation Overview

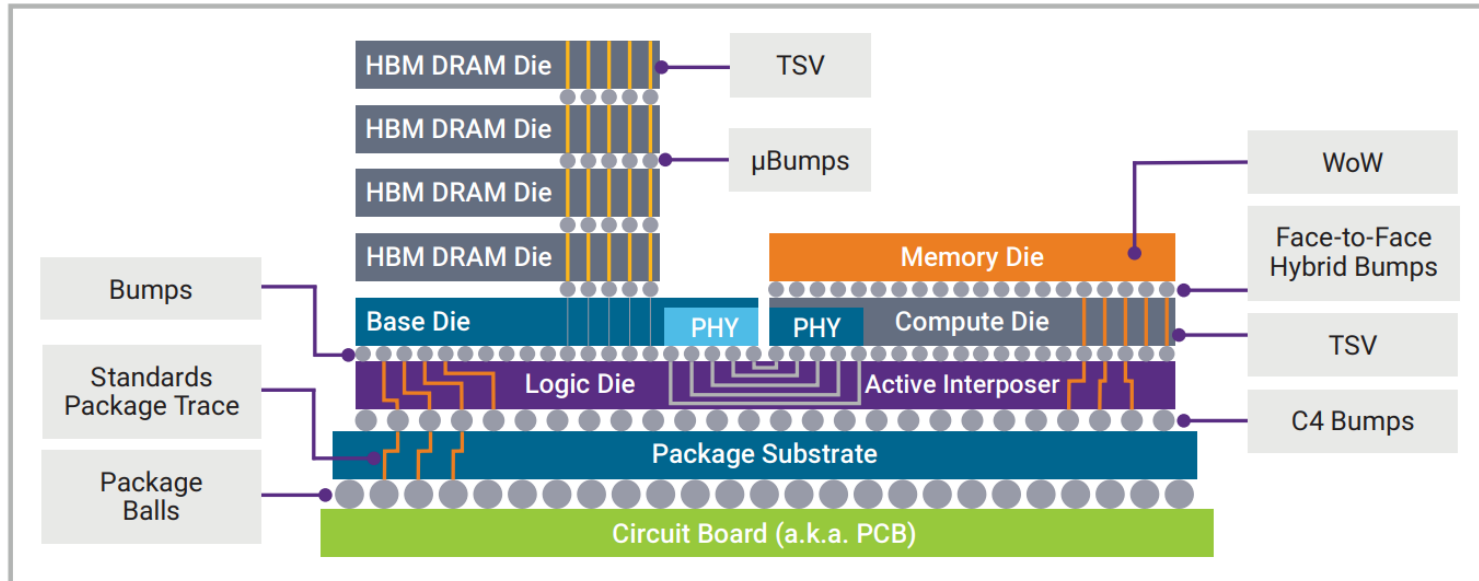
- Overview of Automotive Semiconductors
 - Types of Semiconductors and Classifications
- Changes to Automotive Supply Chains
 - Changes in strategic partnerships
 - Transition to Newer Nodes as Legacy Nodes drop Capacity
 - Onshoring of Fab and Packaging
- Transition from Zonal to Centralized Software Defined Vehicles
 - Image of Zonal vs Centralized E/E Architecture
- What's Driving the Automotive Semiconductor Renaissance
 - ADAS; IVI; Communication
 - Transition to newer nodes; adopting advanced packaging for improved performance
- Challenges to Adopting Advanced Semiconductors
 - Packaging
 - Thermals
 - Qualification
 - Scalability

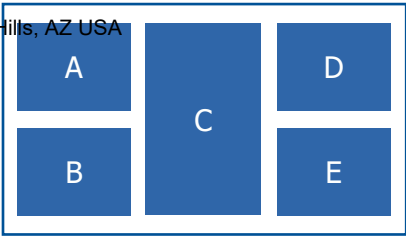
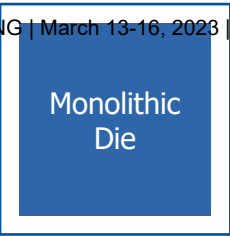


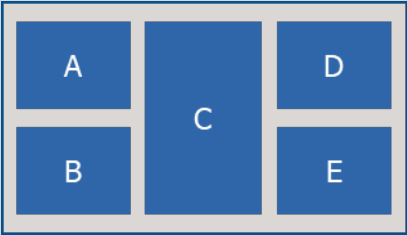


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