

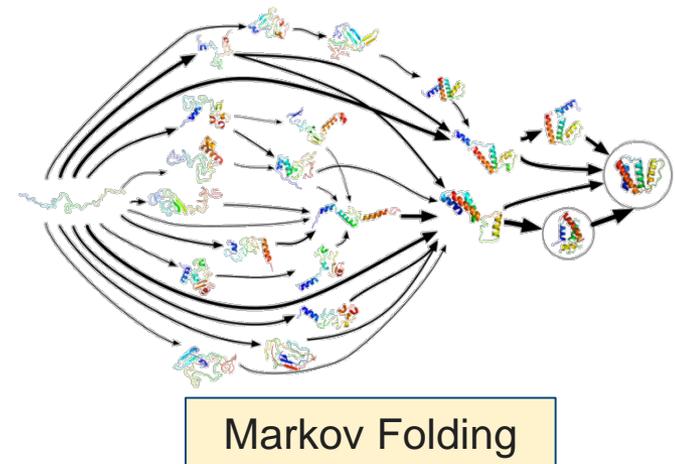
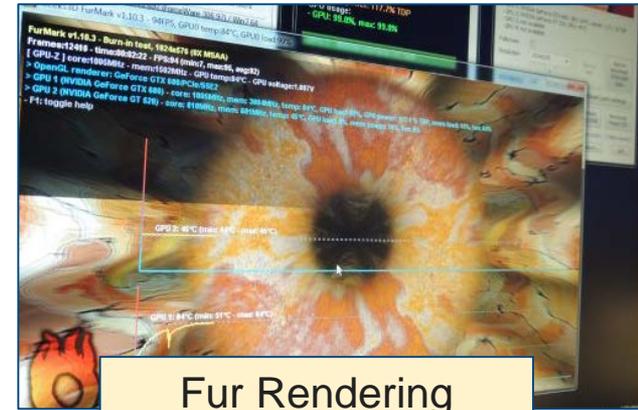
Reliability of GPUs in Autonomous Vehicle Operations

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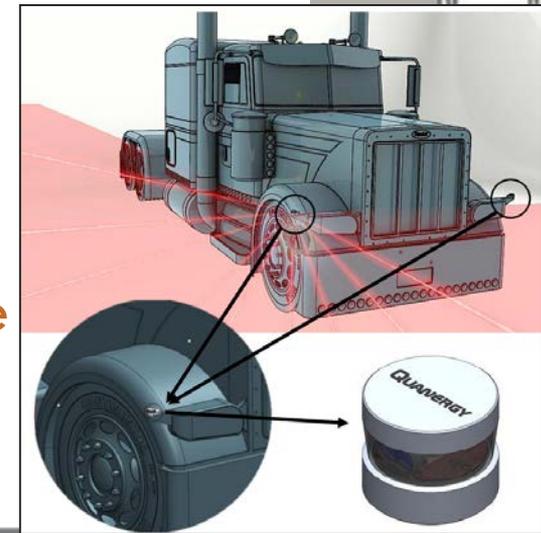
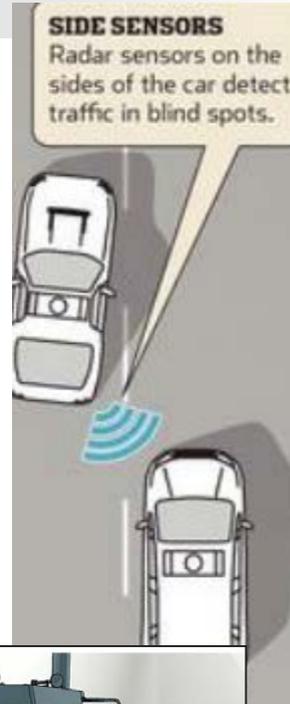
What's the News on GPUs

- Major difference in processing capabilities
 - Mainstream CPUs have up to 24 cores
 - A GPU can contain 1000s of cores
- GPU or Graphics Processing Unit
 - Traditionally used in personal computers for video graphics
 - They're now used for geophysical models, Bit Coin mining, encryption



A “Big Data” Conundrum

- A modern car can have 100 microprocessors which monitor the various states of the vehicle’s health
 - This is truly “BIG DATA” – something we associate with datacenters rather than automobiles
 - Data guzzling example:
 - 8-Beam LIDAR sensor
 - 864,000 3D points/sec
 - 144 bytes of data per point
 - 125 Mbps (requires 1 Gb/s bus link)
- All distributed or centralized processing on board the vehicle has to be real-time capable
 - CPUs would take far too long to process this data
 - Means a much wider bus is necessary (higher I/O)



Transition is Two Pronged



- The typical computer environment ...
 - Immobile (limited vibration)
 - Controlled temperature (office environment)
 - Predictable duty cycle (8x5 schedule)
 - Lifetime expectancy of 3-5 years



- A whole new ball game ...
 - Harsh mobile environment
 - Temperature extremes and diurnal cycling
 - Even when not in operation
 - Vehicle system lifetimes of 7-14 years
 - **Safety critical** vehicle systems

Leading Edge Lithography

- Very limited empirical data for technology nodes below 50nm
 - NVidia's GPU products are 16nm FinFET*
- Performance is now a dominant failure criteria
 - Performance degradation does happen, and it's worse at smaller feature sizes
- DfR has worked with component manufacturers and OEMs to develop reliability models for RF and VLSI devices, including GPUs
 - Same semiconductor degradation mechanisms: BTI, TDDB, HCI
 - Same changes in threshold voltage, clock frequency, timing delays, memory integrity



* <http://wccftch.com/nvidia-pascal-geforce-gtx-1080-gp104-gpu-may/>

Semiconductor Industry

- Typical life durations are between 7 and 14 years, while operating between -45°C and 150°C ambient temperatures.
- Test requirements vary from “under the hood” application, to passenger compartment, and other vehicle locations.
- Semiconductor suppliers may not always be aware that a particular IC will end up being used in an automotive application
 - Especially if its used in a Grade 2 or 3 application consistent with commercial-grade components

AEC-Q100	Ambient Operating Temperature Range
Grade 0	-40°C to $+150^{\circ}\text{C}$
Grade 1	-40°C to $+125^{\circ}\text{C}$
Grade 2	-40°C to $+105^{\circ}\text{C}$
Grade 3	-40°C to $+85^{\circ}\text{C}$

Table 1: AEC-Q100 grades vary based on the operating environment temperature range.

Component Packages

- Copper interconnects through a typical BGA substrate don't work
 - Copper scaling from 45nm to the 7nm node (planar) causes resistance increases of almost 50%
- Through silicon vias (TSVs) make cutting edge performance possible
 - Improved performance from ultra-short interconnections using 2.5D and 3D integration – upwards of 1 TB/s bandwidth
 - If multiple chips are to be utilized, then keeping them as close as possible will save on performance

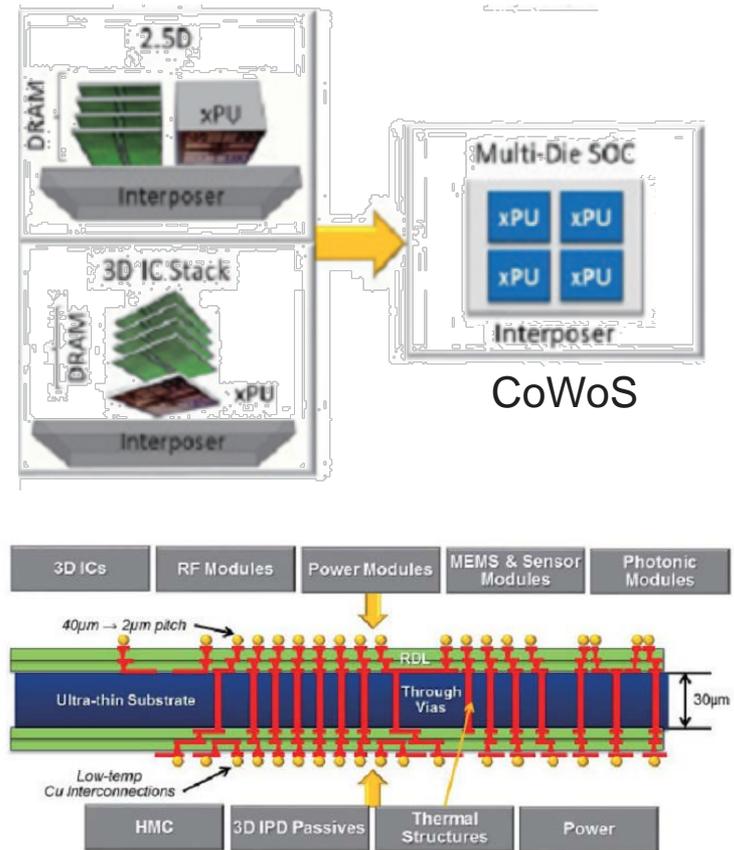
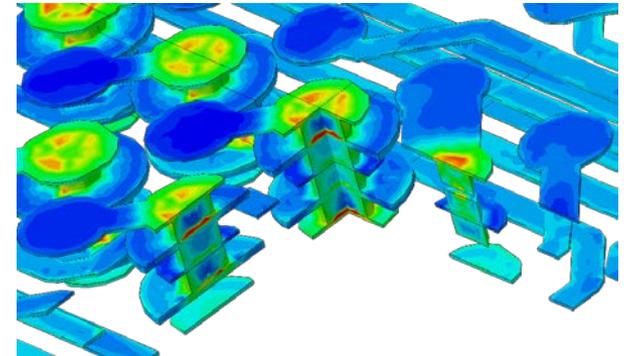


Figure 2: System Moore concept using 3D system package TPV (through-package vias).

Board Level Reliability

- High speed integrated circuits creates the need for advances in circuit boards
 - Higher I/O adds more copper to the PCB making it more rigid
 - High speed impedance matched traces
 - Controlled capacitance becomes an issue
 - ESD protection
- GPU case temperatures tend to be 70°C -85°C in a 30°C environment
 - Heat dissipation using vias
 - Heat spreading using planes and heatsinks

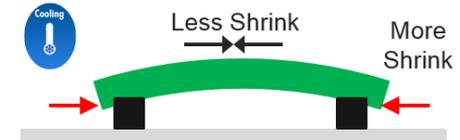
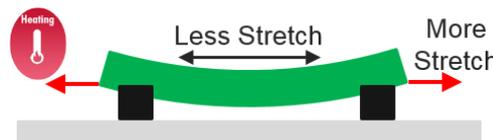
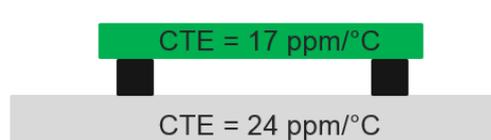
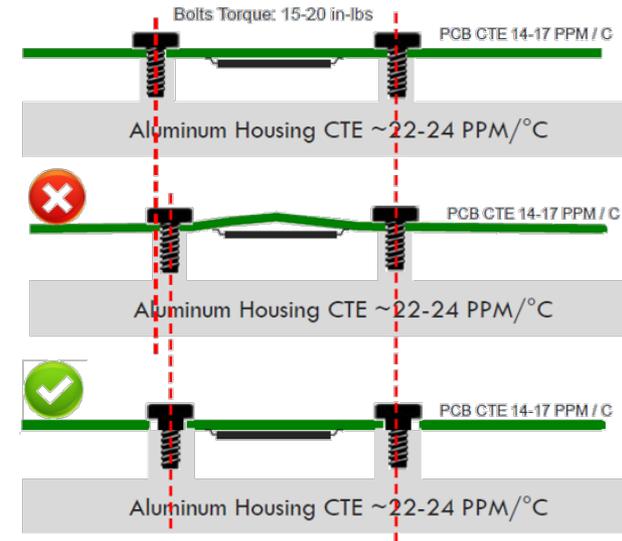


Elapsed Time (minutes)	Outside Air Temperature (°C)					
	21	24	27	29	32	35
0	21	24	27	29	32	35
10	32	34	37	40	43	46
20	37	40	43	46	51	54
30	40	43	46	48	51	54
40	42	45	48	51	53	56
50	44	47	49	52	55	58
60	45	48	51	53	56	59

<https://www.avma.org/public/PetCare/Pages/Estimated-Vehicle-Interior-Air-Temperature-v.-Elapsed-Time.aspx>

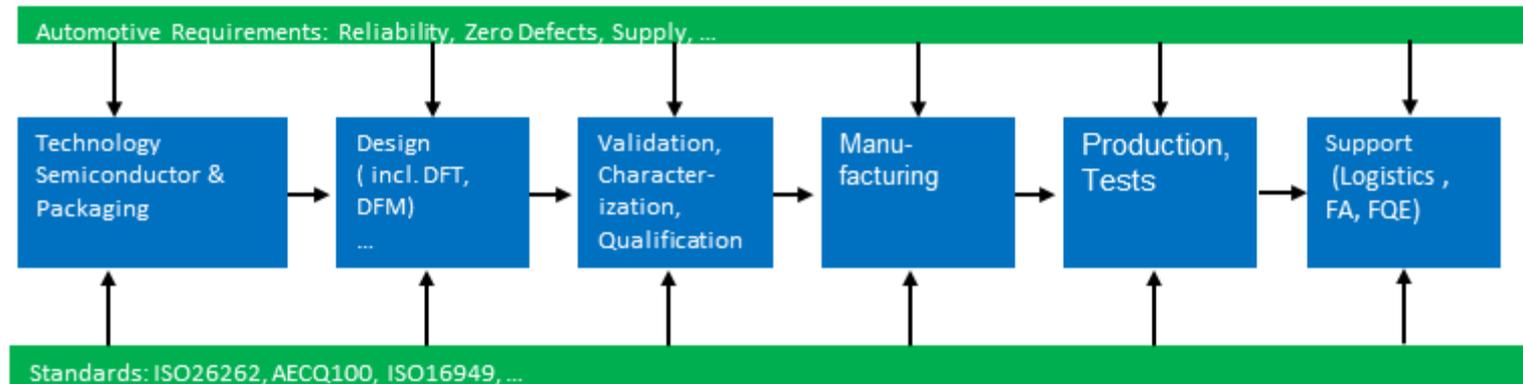
Circuit Card Housing

- Why do overly-constrained boards fail?
 - We usually consider the CTE mismatch between the board and the components
 - The board CTE value is no longer valid if it is being affected by an external source
- The board CTE and the Aluminum CTE mismatch
 - Aluminum drives all movement
 - Thermal cycling will exacerbate the effects
 - Operating between -45°C and 150°C ambient temperatures



Differences in Requirements

- Tip of the iceberg...
 - Compliance to ISO-16949, ISO-26262 and AECQ100
 - Finished assemblies may have to undergo accelerated life tests of up to 3000 hours with temperature ranges from -50°C to 150°C
 - Qualification can take > 5 years



In Conclusion

- There are many challenges ahead
 - Commercial technologies will dominate new product features in the automotive sector
 - Semiconductor and package scaling has increased reliability/durability risks
 - New thermal challenges are arising from higher density packages and circuit card modules
 - Vigorous automotive qualification tests may become the crucible for leading edge commercial technologies
- These challenges are manageable by applying best practices in design for reliability early in the lifecycle

Thanks

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