Reliability for the 21st Century: Meeting Challenges of New Technologies and New Markets

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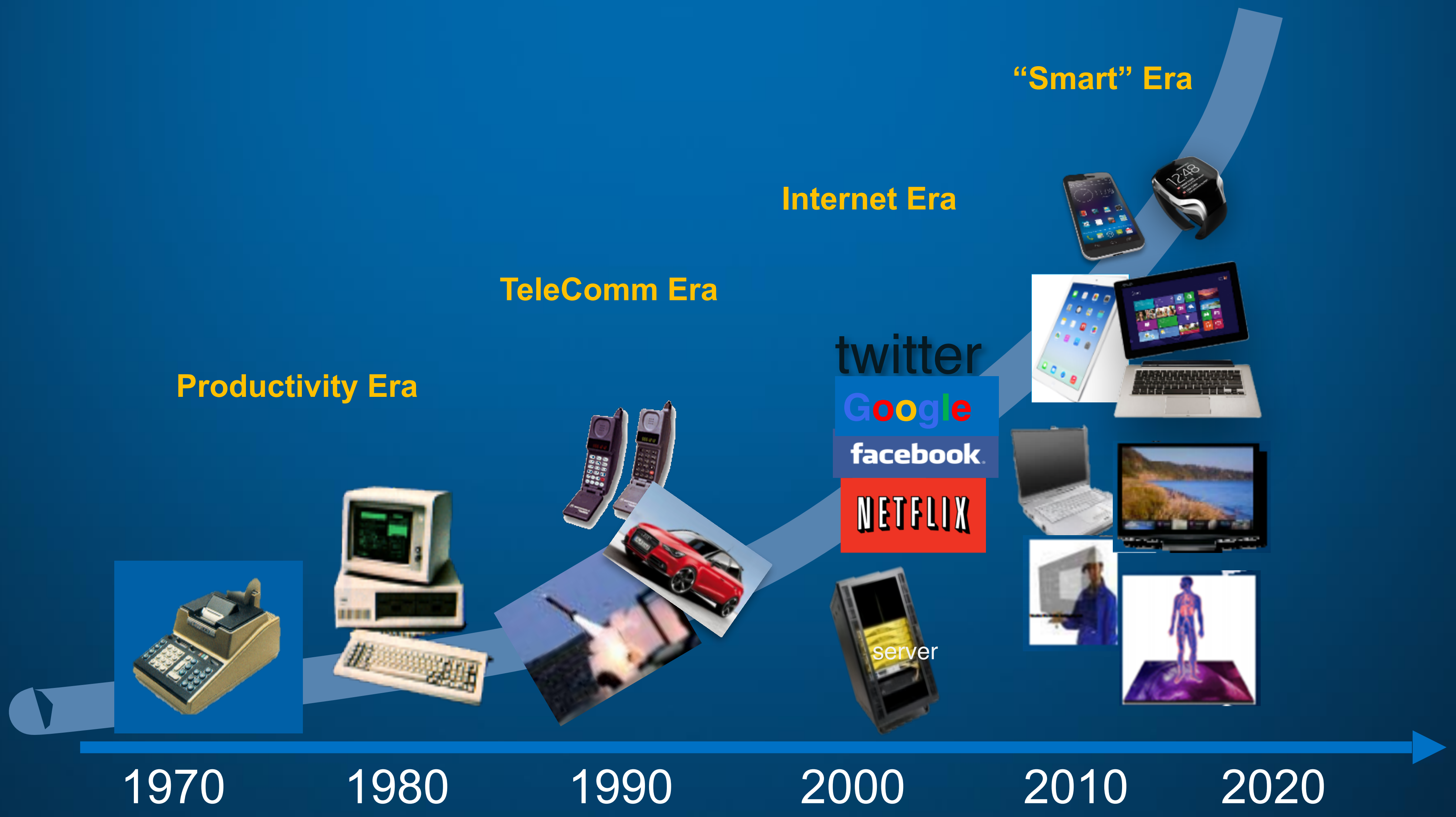
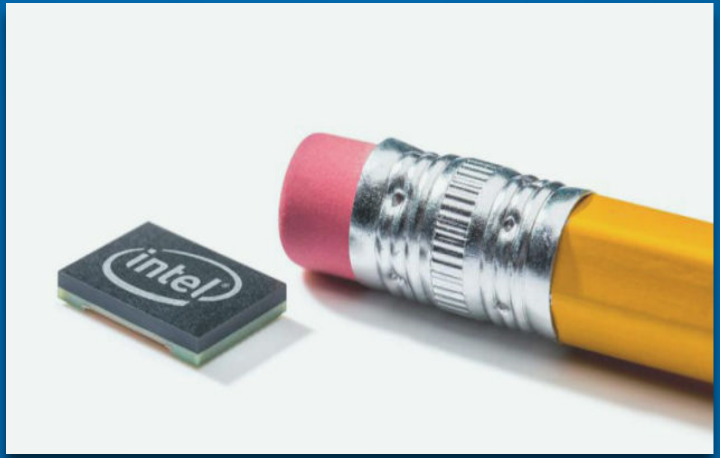
NCCAVS symposium, February 22, 2018

Singularity is Near



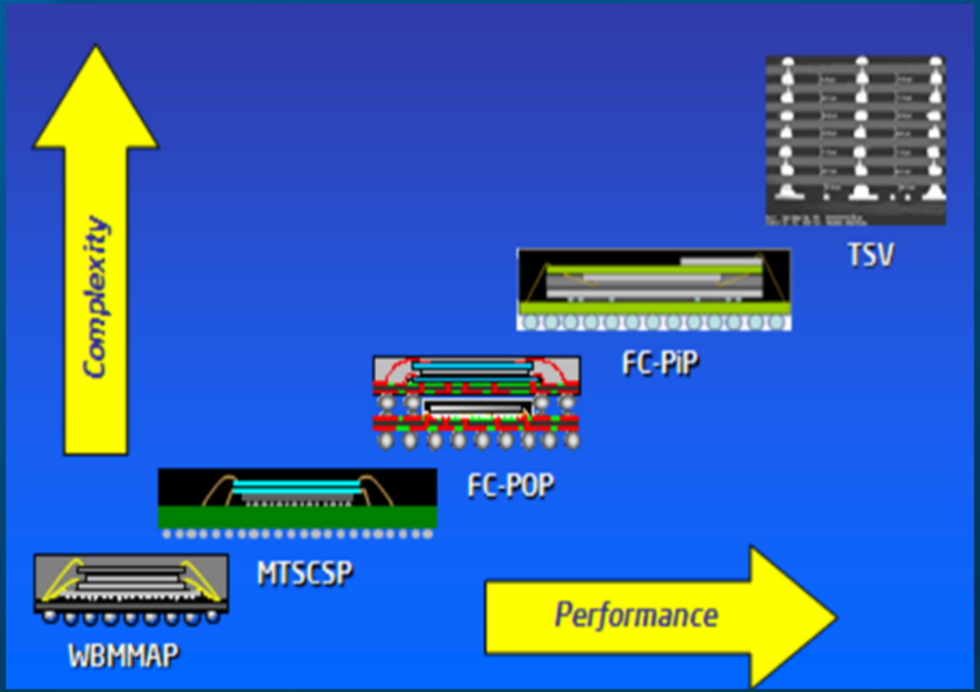
Smaller

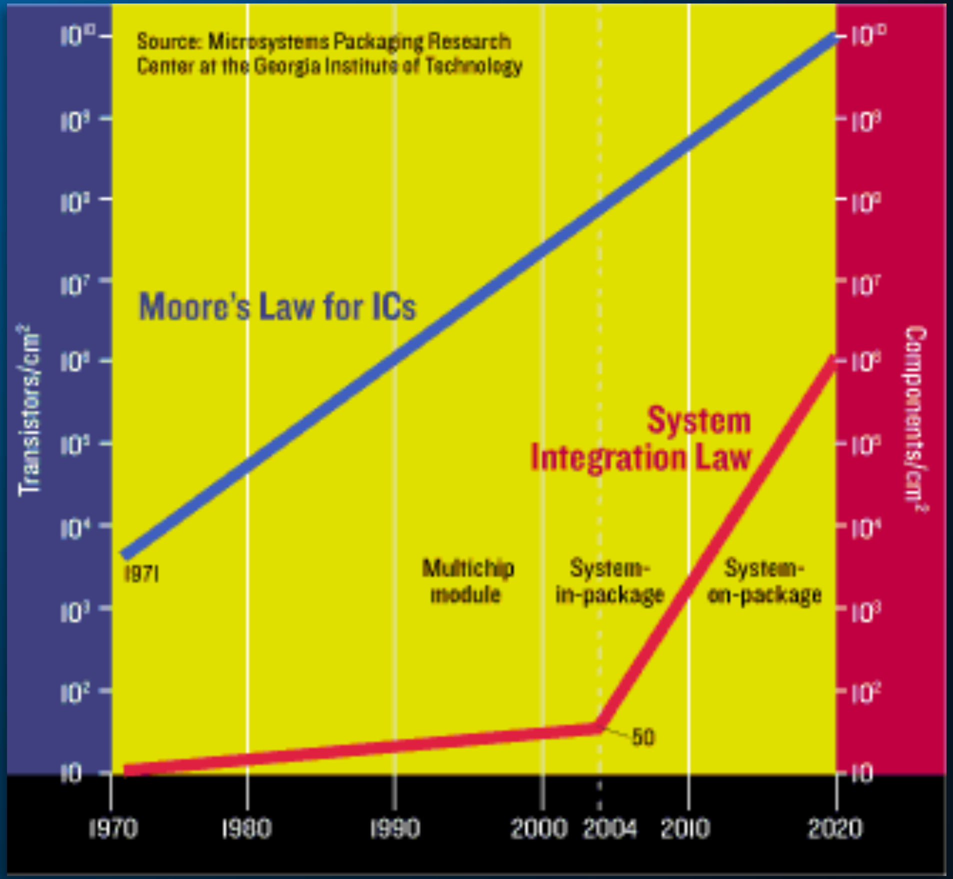
Features



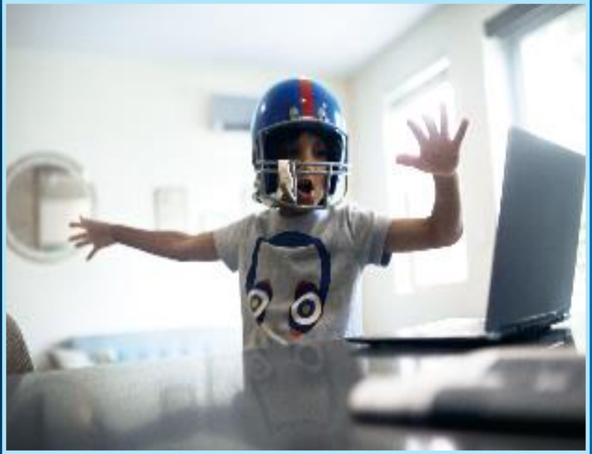
High

Complexity





Electronics everywhere



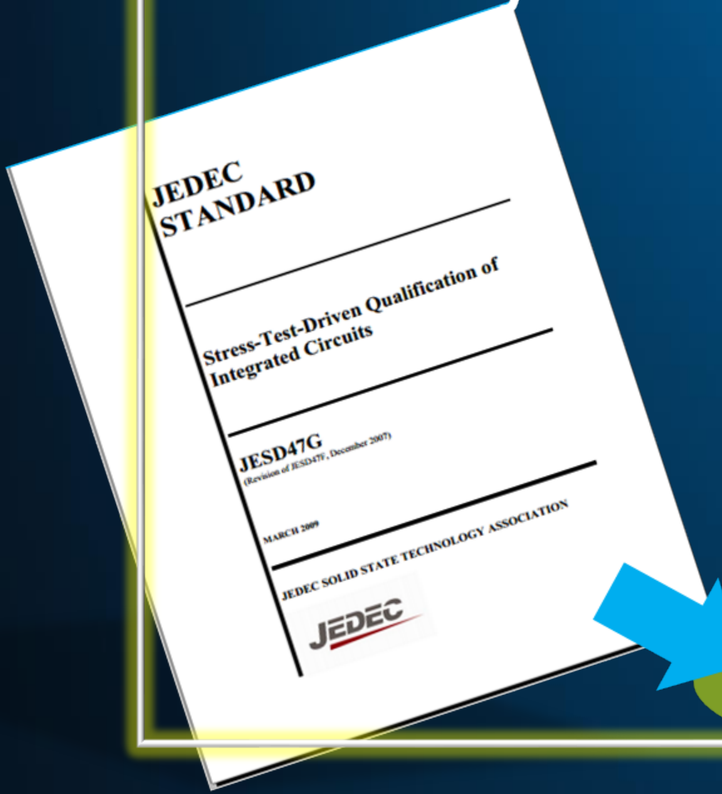
New use conditions

How to define qualification criteria to continuously meet customer’s Q&R needs when technology is rapidly changing ?

Reliability response choices

Standards (Stress) Based Qualification (SBQ)

- Product is "as good" as past products
- "We did the same as the rest of the industry"


JEDEC STANDARD

Stress-Test-Driven Qualification of Integrated Circuits

JESD47G
(Revision of JESD47F, December 2007)

MARCH 2009

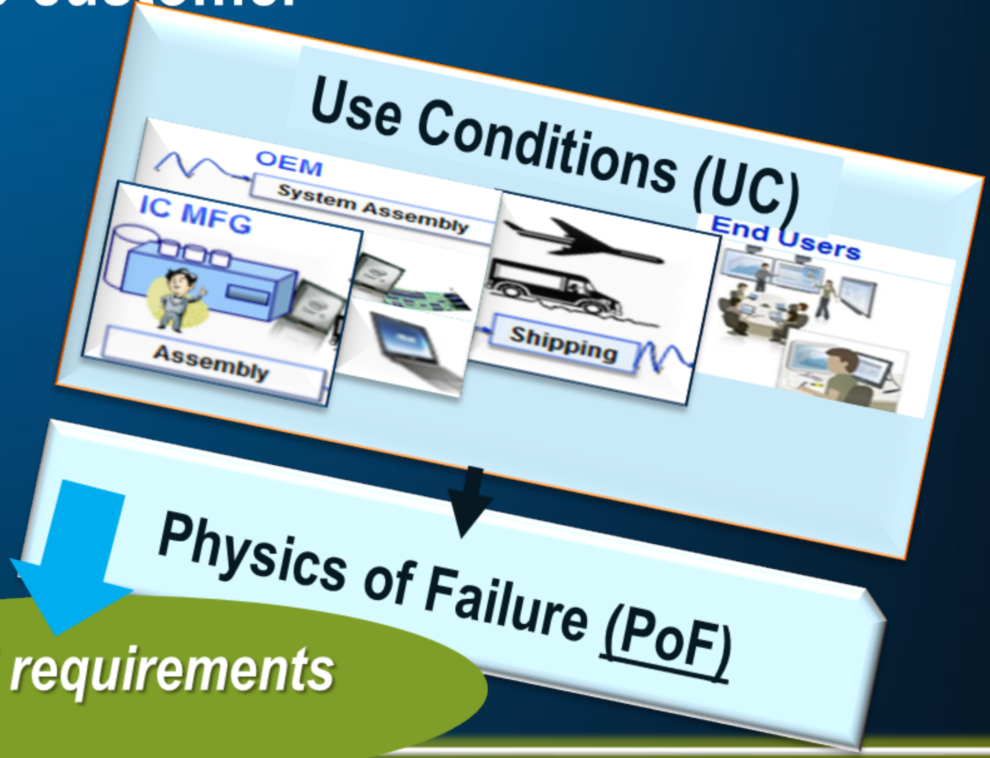
JEDEC SOLID STATE TECHNOLOGY ASSOCIATION

JEDEC

Qual requirements

Knowledge Based Qualification (KBQ)

- Product engineered for real usage
- "We did what was necessary to protect the customer"

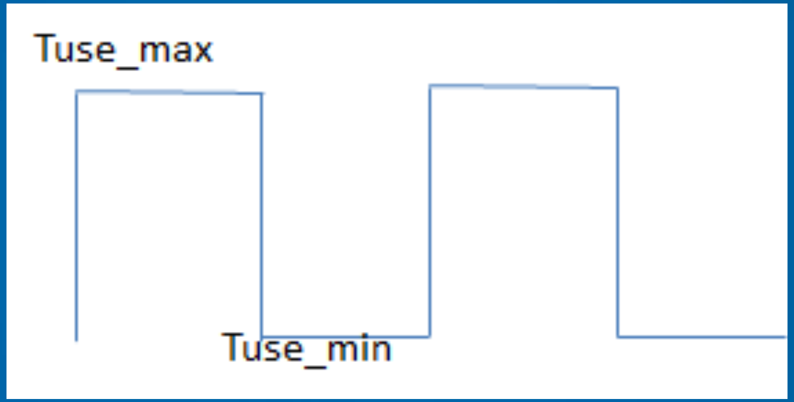


Qual requirements

Standards

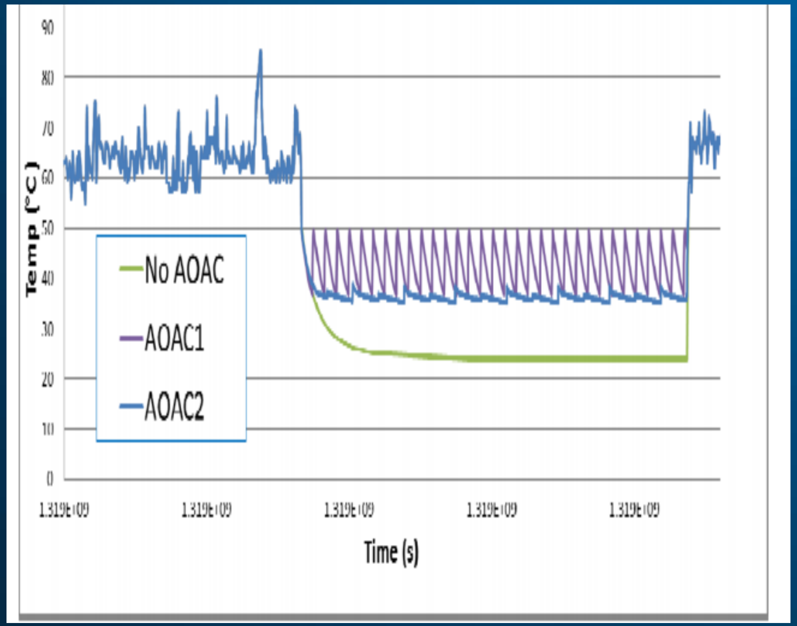
Accounting for UC

Standards

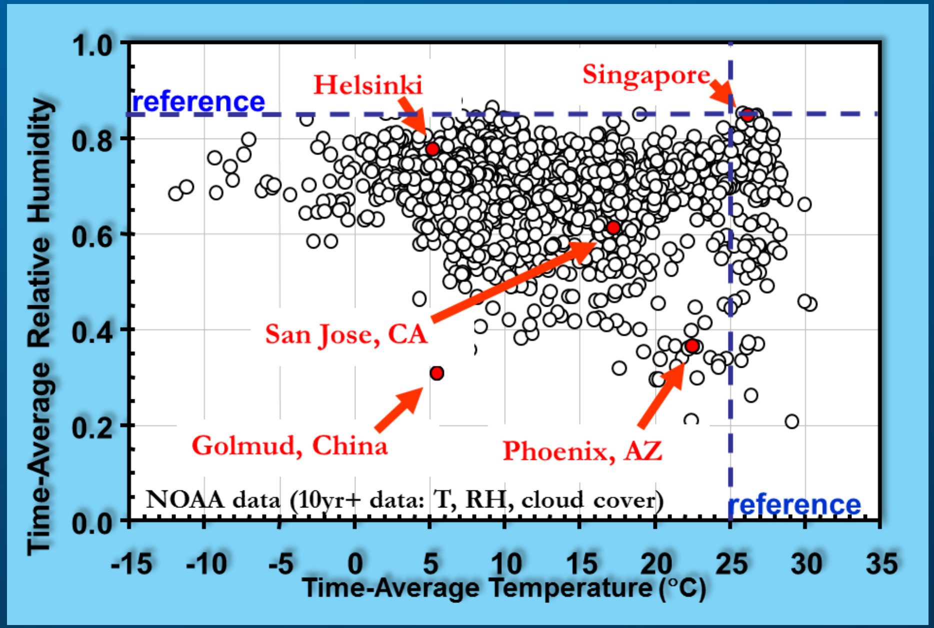


Reality

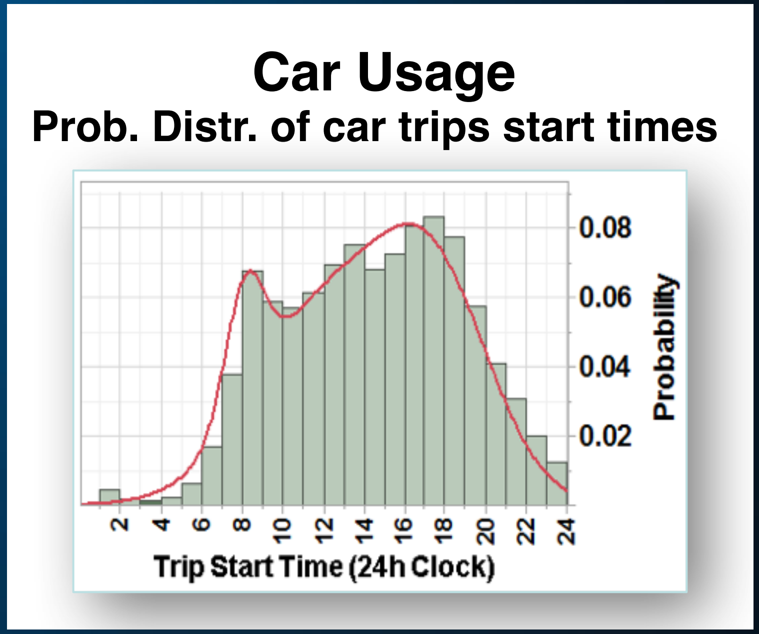
Real Workload



Real Environment



Real User Behavior



Standards not capturing real use conditions

Accounting for Physics

Name	Empirical acceleration model/equation	Primary stress
Coffin-Manson **1950s**	$\frac{N_{use}}{N_{test}} = \left(\frac{\Delta T_{use}}{\Delta T_{test}}\right)^{-n}$	ΔT
Norris-Landzberg **1968**	$\frac{N_{use}}{N_{test}} = \left(\frac{\Delta T_{use}}{\Delta T_{test}}\right)^{-n} \left(\frac{f_{use}}{f_{test}}\right)^{m} e^{\left[1414\left(\frac{1}{T_{hi,use}}-\frac{1}{T_{hi,stress}}\right)\right]}$	$\Delta T, Tmax,$
Peck **1983**	$\frac{N_{use}}{N_{test}} = \left(\frac{RH_{use}}{RH_{test}}\right)^{-n} Exp\left(\frac{E_a}{k}\right)\left[\frac{1}{T_{use}} - \frac{1}{T_{test}}\right]$	RH-relative humidity
……..	…….	…..

CHALLENGE

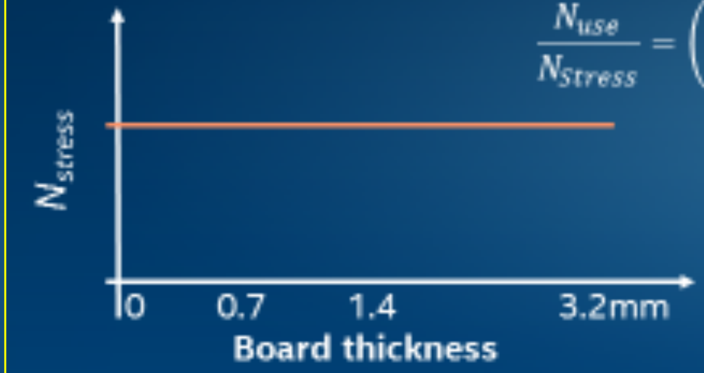
ACCOUNTING FOR SYSTEM BOUNDARY CONDITIONS

Ex: FLI qualification

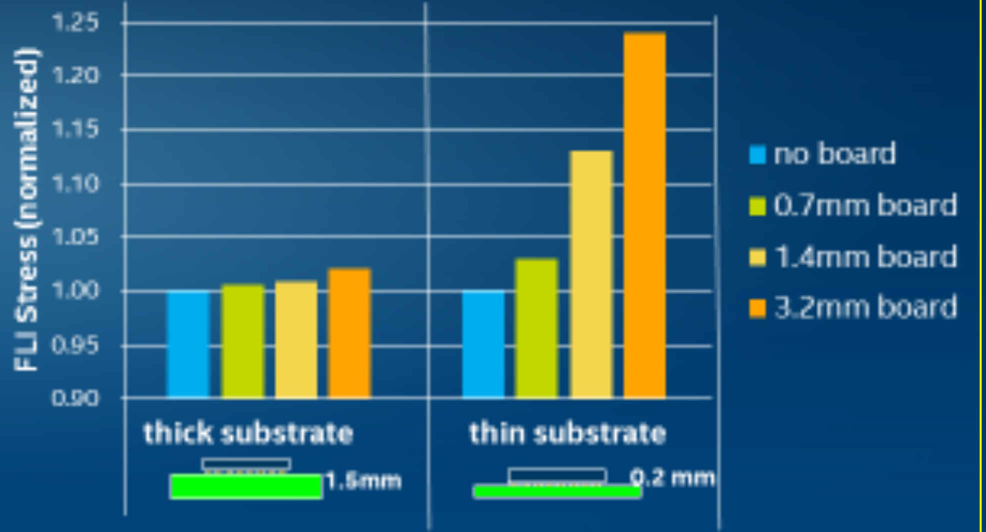
Reliability Risk Assessment vs. Field Risk

Qual Requirements

$$\frac{N_{use}}{N_{Stress}} = \left(\frac{\Delta T_{use}}{\Delta T_{stress}}\right)^{-n}$$



Use Condition Risk



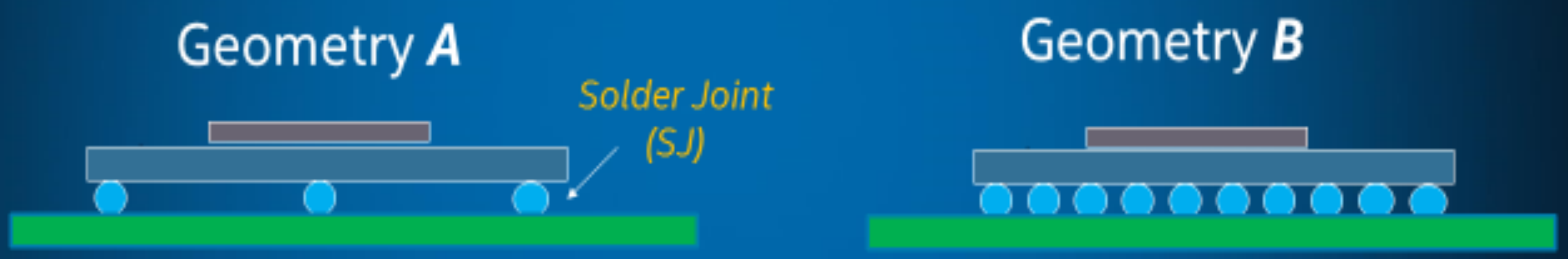
Not impacted by brd. thickness

Impacted by board thickness

CHALLENGE

ACCOUNTING FOR GEOMETRY (FF)

Example: Solder Joint T-M qualification

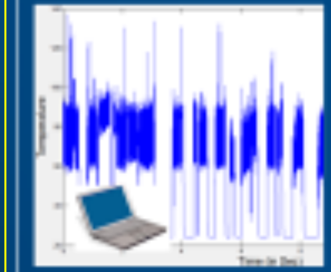
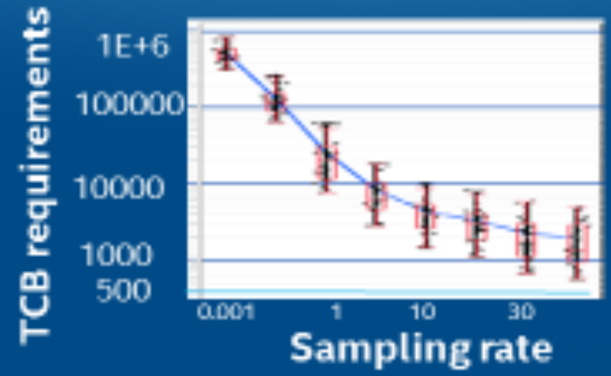


Qualification requirement	Use Condition Risk
$\frac{N_{use}}{N_{test}} = \left(\frac{\Delta T_{use}}{\Delta T_{test}}\right)^{-n} \left(\frac{f_{use}}{f_{test}}\right)^{m} e^{\left[1414\left(\frac{1}{T_{hi.use}} - \frac{1}{T_{hi.stress}}\right)\right]}$	
Requirement (*A*)=Requirement (*B*)	SJ damage (*A*) >> SJ damage (*B*)
Not a function of FF	A function of FF

CHALLENGE

ACCOUNTING FOR ACTUAL USE CONDITIONS

Ex. T-M FLI qual

Use Condition	Empirical Acc. Model	Requirements (N_{stress})
Assumed 	$$\frac{N_{use}}{N_{Stress}} = \left(\frac{\Delta T_{use}}{\Delta T_{stress}}\right)^{-n}$$	**750 TCB**
Measured UC 	$$\frac{N_{use}}{N_{Stress}} = \left(\frac{\Delta T_{use}}{\Delta T_{stress}}\right)^{-n}$$	**It depends!!**  Extreme sensitivity to sampling rate!

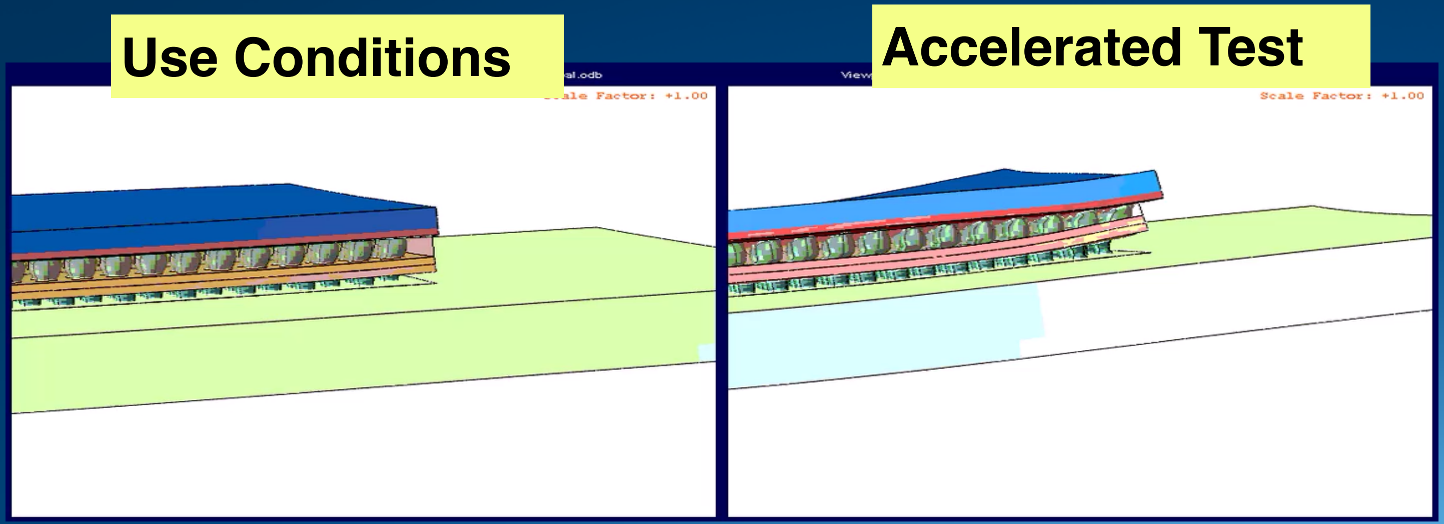
Empirical Acc. Equations	Why?
Do not account for FF (architecture, geometry, materials)	Defined in terms of applied stress, like ΔT Applied stress is often <u>a very remote</u> proxy for damage/failure ***Damage = f (applied stress, FF, system BC, materials….)***
Do not account for system boundary condition	
Have difficulties accounting for measured UC	Every ΔT (both large and small) is considered to contribute to damage; more UC cycles always results in more damage and higher requirements

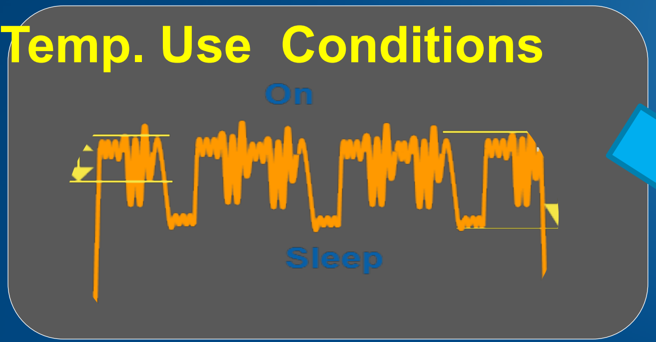
Standards not capturing real physics of failure

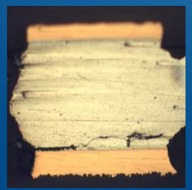
How to get closer to damage?

Getting Closer to the Physics

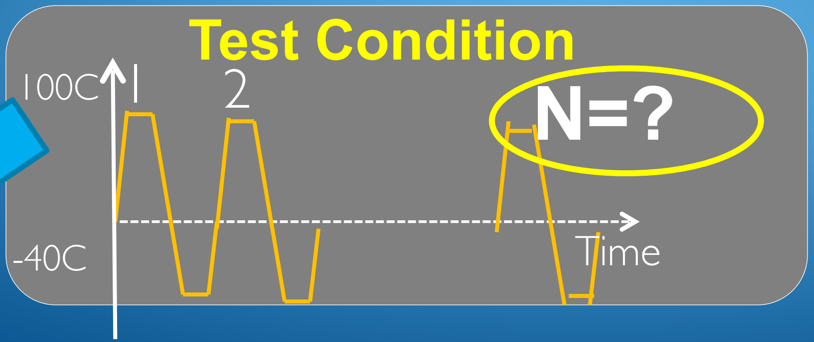
Example: Solder Joint (SJ) qual in temp.cycling (TC)



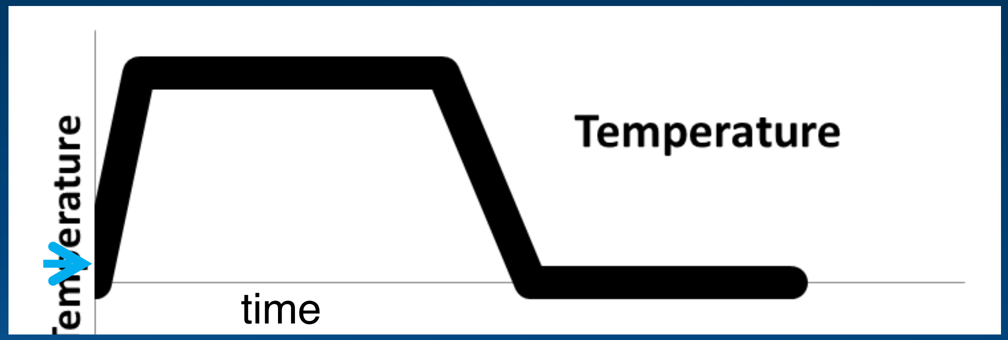




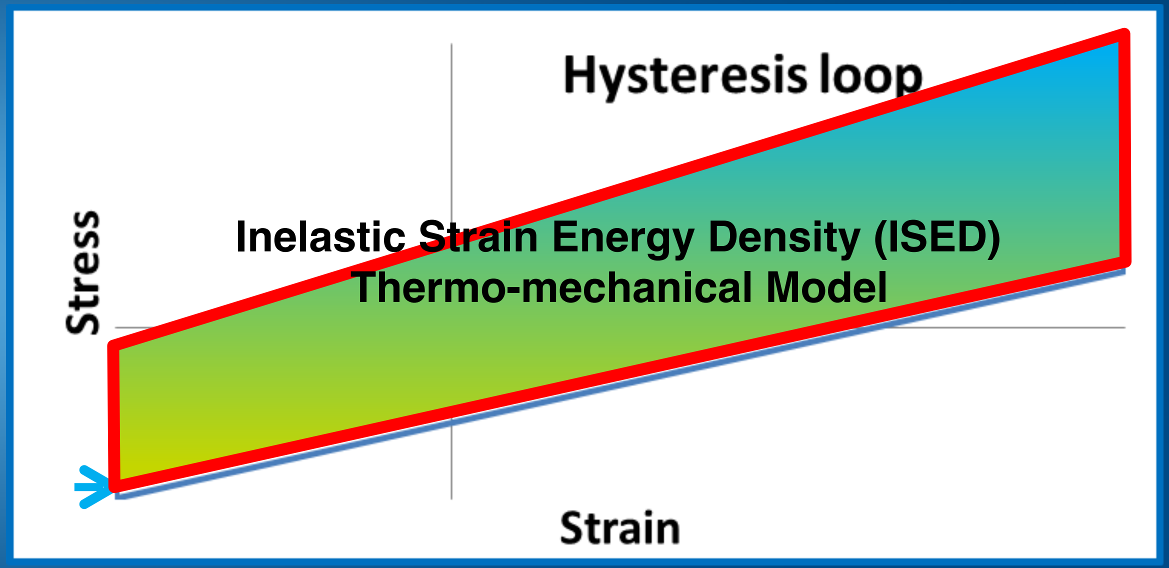
Damage (D)



SJ damage accumulation in 1 TC



SJ Stress vs. strain



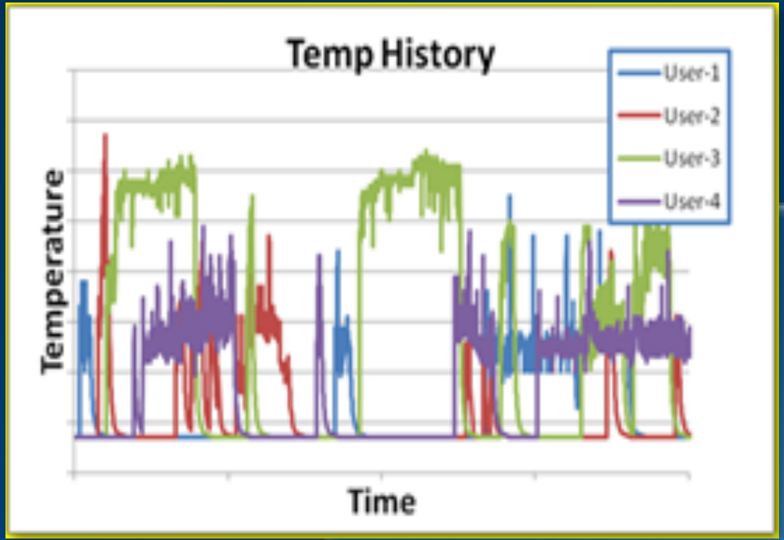
New Application of Computational Modeling :
Definition of Qualification   Requirements

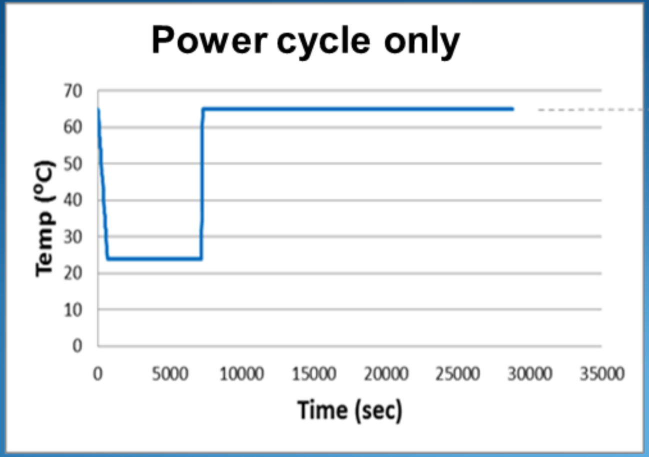
M. Pei, et. al, "Define Electrical Packing Temperature Cycling Requirement with Field Measured User Behavior Data", ECTC 2013, PP159-65
M. Vujosevic, "Predictive Modeling and New Frontier of Reliability, **IEEE EurosimE**, Dresden, Germany, April 2017, Industry Keynote

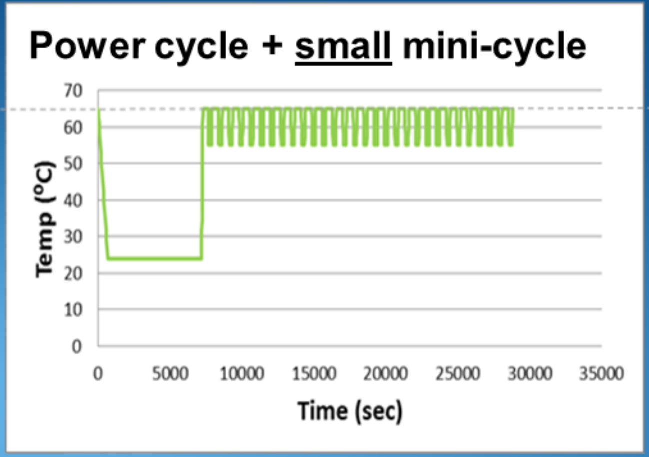
Approach	Metric	Use Conditions	Acceleration equation
SBQ Standard (stress) based Qualification	Applied stress: **(ex:ΔT)**	Representative user	**MTTF vs. ΔT**
KBQ Knowledge-based Qualification	PoF metric **(ex: ISED)**	Field measured users	**MTTF vs. ISED**

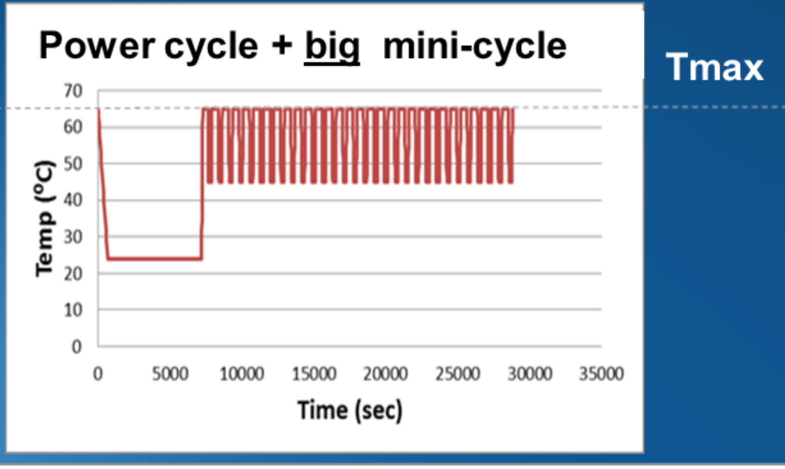
KBQ: Based on the PoF metrics and measured use conditions. Predictive modeling/simulation are necessary to overcome the limitations of empirical reliability models.

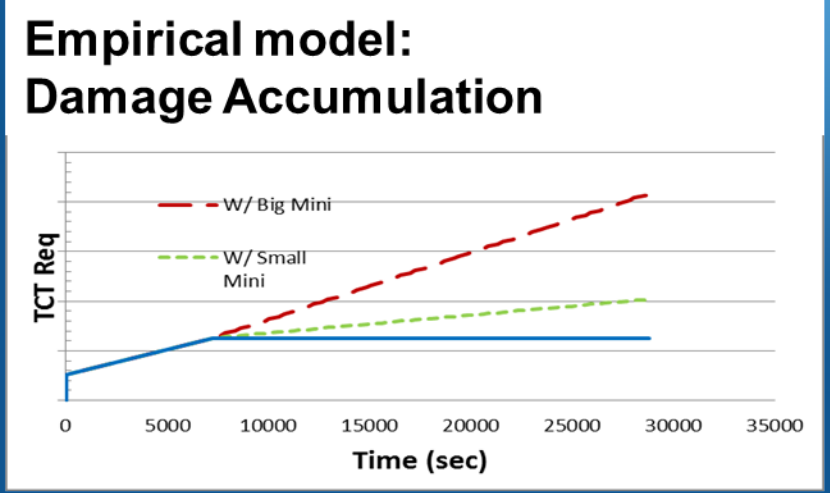
KBQ: Realistic Account of use conditions

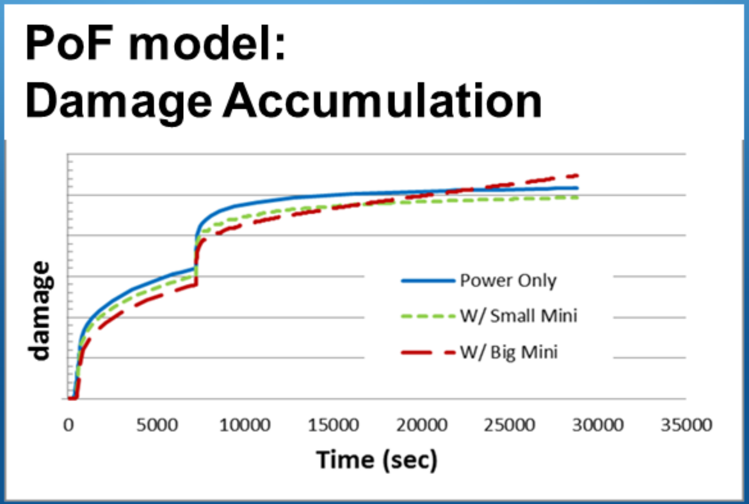


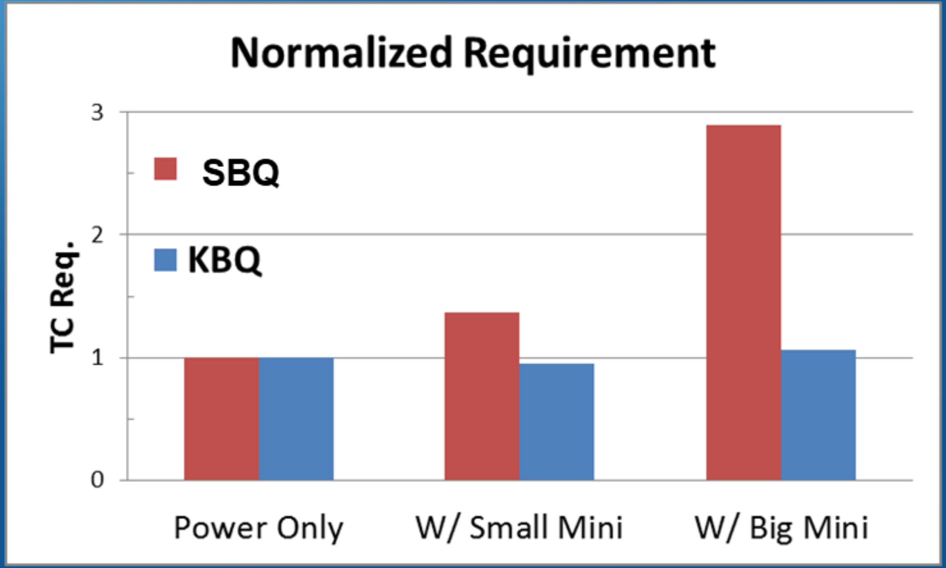






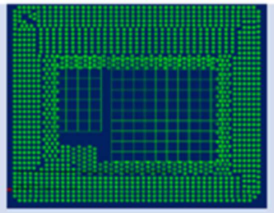
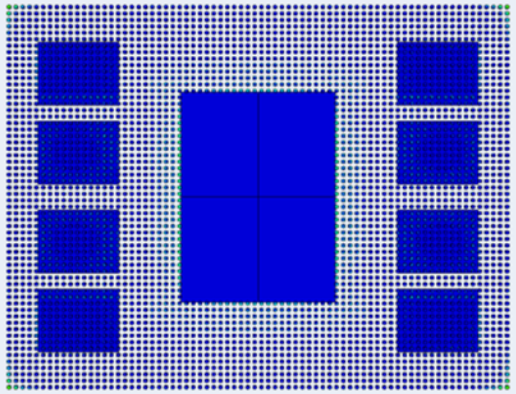
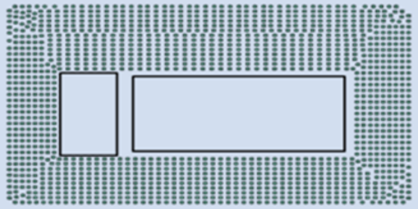






M. Pei, M. Vujosevic, S. Mukherjee, "Knowledge Based Requirement Calculation for Server BGAs Temperature Cycling (TC) Qualification", **ASME InterPACK2017**, San Francisco, CA August 29-Sept 1, 2017

KBQ: Accounting for FF

FF	SBQ UC: 5cycles/day	KBQ UC: measured
	1135 TCT	375 TCT
	1135 TCT	95 TCT
	1135 TCT	210 TCT

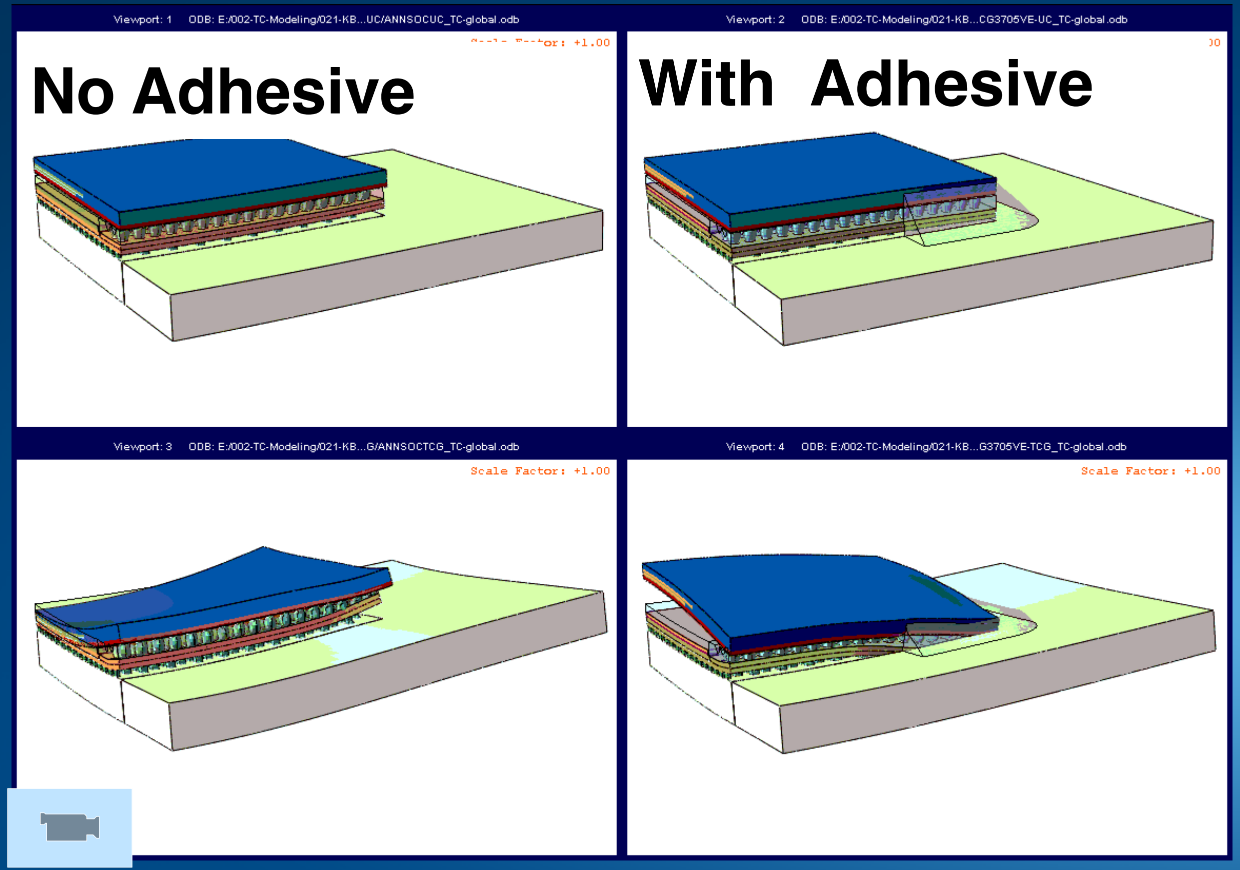
Geometry drives requirements

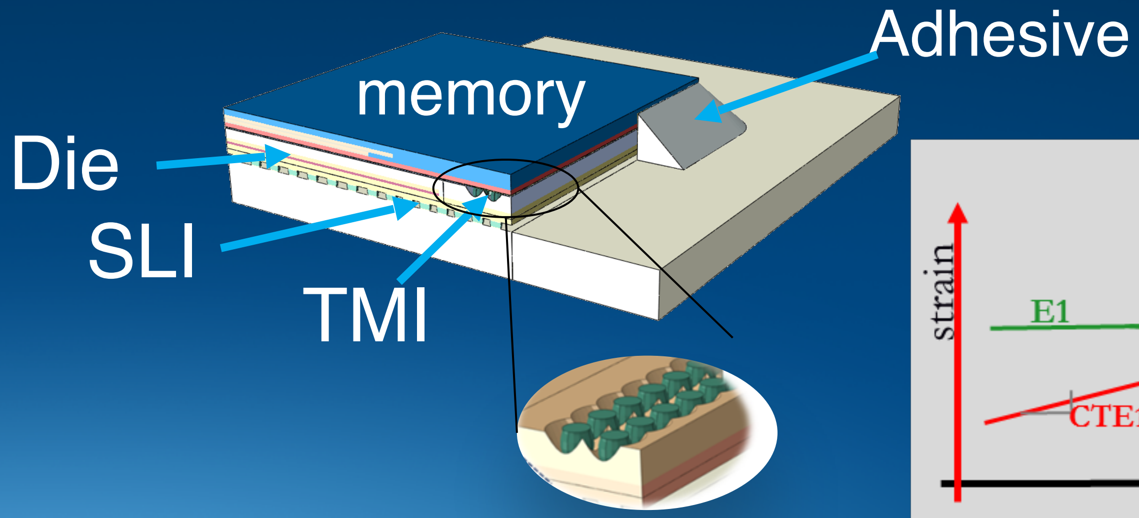
M. Pei, M. Vujosevic, S. Mukherjee, "Knowledge Based Requirement Calculation for Server BGAs Temperature Cycling (TC) Qualification", **ASME InterPACK2017**, San Francisco, CA August 29-Sept 1, 2017
M. Vujosevic, "BGA Temperature Cycling Reliability in Automotive Applications: Knowledge Based Qualification", technical talk, **ASME InterPACK2017**, San Francisco, CA August 29-Sept 1, 2017

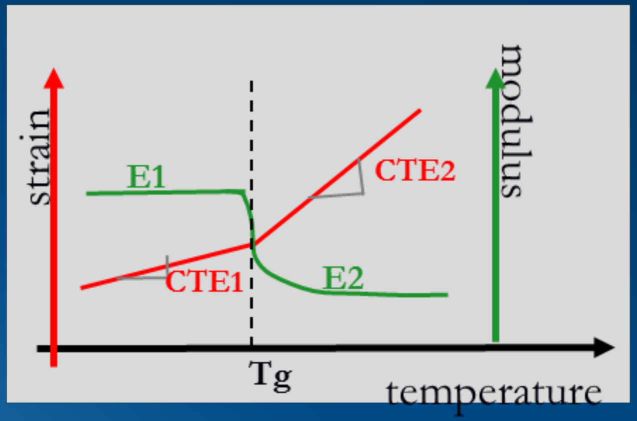
KBQ: Accounting for system BC

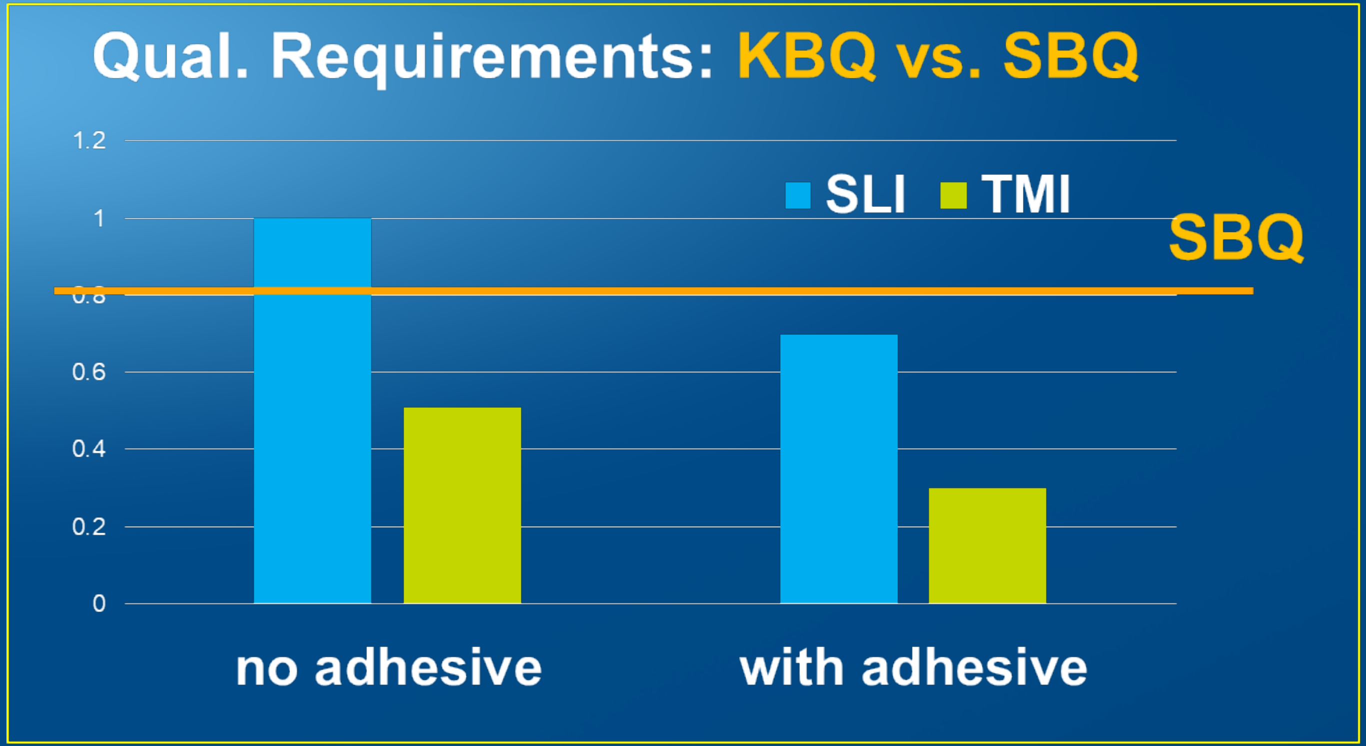
Use Condition

Accelerated









Adhesive properties drive requirements

- R. Han, M. Vujosevic, M. Pei, ‘Physics Based Requirements for Qualification of BGA Components in Temperature Cycling’, **InterPACK2015**, San Francisco, July 2015
- G. Arakere, M. Vujosevic, M. Pei, ‘Accessing Adhesive Induced Risk for BGAs in Temperature Cycling’, **ECTC2014,** Florida, May 2014.

Conclusions

The new reliability frontier is knowledge based

Standards must evolve to meet the needs of the 21st century