Solder Attachment Reliability - A Physics of Failure Approach

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West Penn SMTA, July 19, 2013

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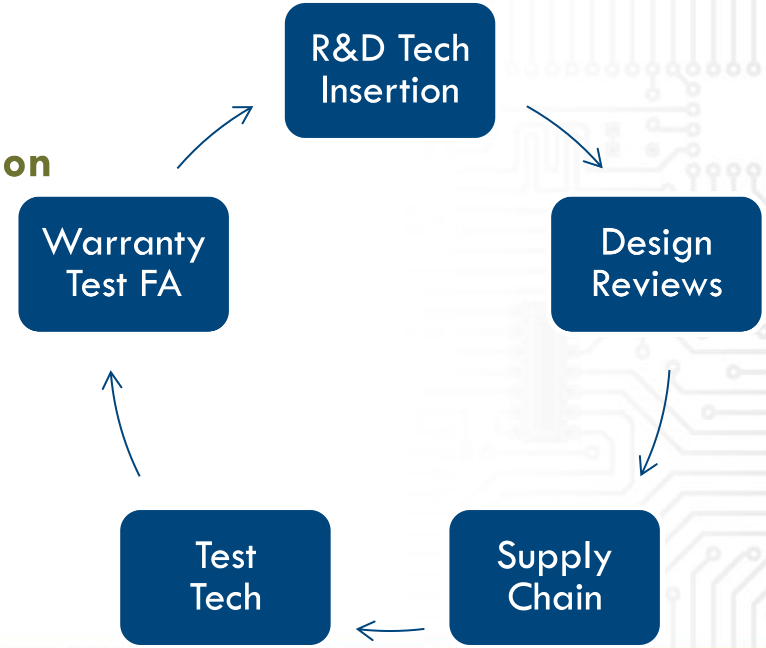
Introduction

- Jim McLeish >35 Yrs of Vehicular, Military & Industrial E/E Enrg. & QRD Experience
  - ESA/EFC Digital Task Force (1st Microprocessor Based Engine Controller) - Chrysler Corp.
  - 3 Patents Automotive Electronic Control Systems - GM Adv. Product Engineer
  - System Engineering and Architecture Planning - GM Saturn Project
  - E/E EGM - GM Military Vehicle
  - EE Reliability Manager – GM CPC & Mid Lux.
  - Manager Reliability Physics (Advance Reliability Method Development) – GM NAO
    - 3 GM EE Test Standards GM9123, GMW3172 GMW8288
    - 2006 GM People Make Quality Happen award
  - EE QRD Tech Expert/EE QRD Strategists – GM VEC
  - SAE EE Reliability & ISO 26262 Functional Safety Workgroups
  - Michigan Office Manager & Partner – DfR Solutions

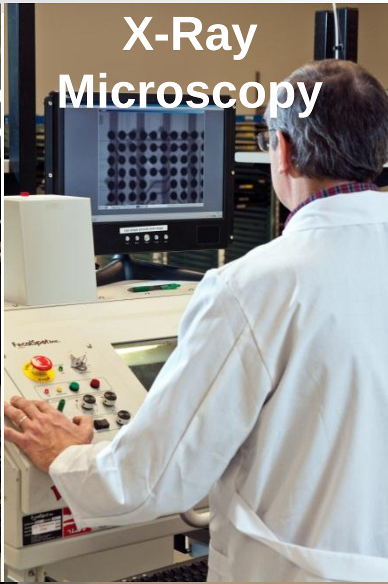
DfR Solutions

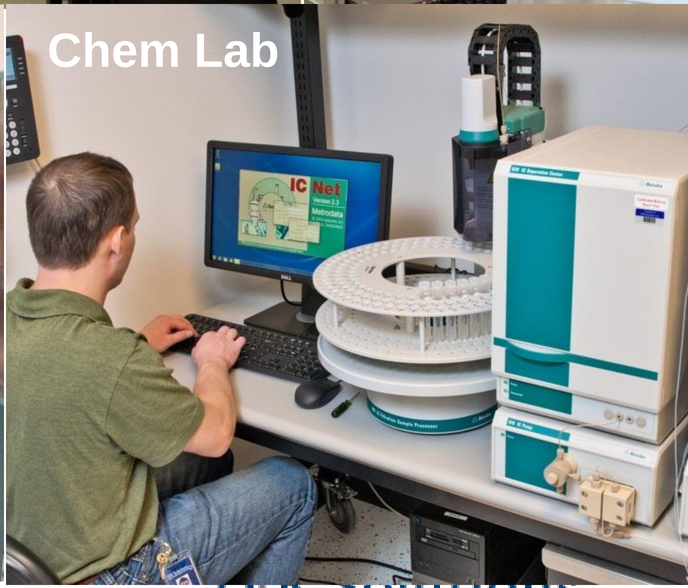
Introduction DfR Solutions

- DfR Solutions is an Failure Analysis, Engineering Consulting & CAE Software firm.
  - Evolved out of a DoD/NSF consortium that developed the Physics-of-Failure approach developing Ultra Reliable Electronics for defense application & industrial competitiveness
- DfR's Physics of Failure research experience & our multi-disciplined team from "Hi-Rel" & related industries provides knowledge & science based QRD solutions
  - (Specializing in the Physics of Failure (PoF) /Reliability Physics (RP) tools & methods.
  - Forensic engineering knowledge and science based solutions for:
    - Maximizing product integrity
    - While accelerating product development
  - Electrical/Electronic Robustness, Failure Prevention & Total Product Integrity >400 projects/year
    - Quality, Reliability and Durability (QRD),
    - Advanced accelerated testing methods
    - Selection & Validation of Robust EE parts appropriate for High Reliability and Harsh Environment Applications



DfR Solutions HQ - Beltsville, Maryland





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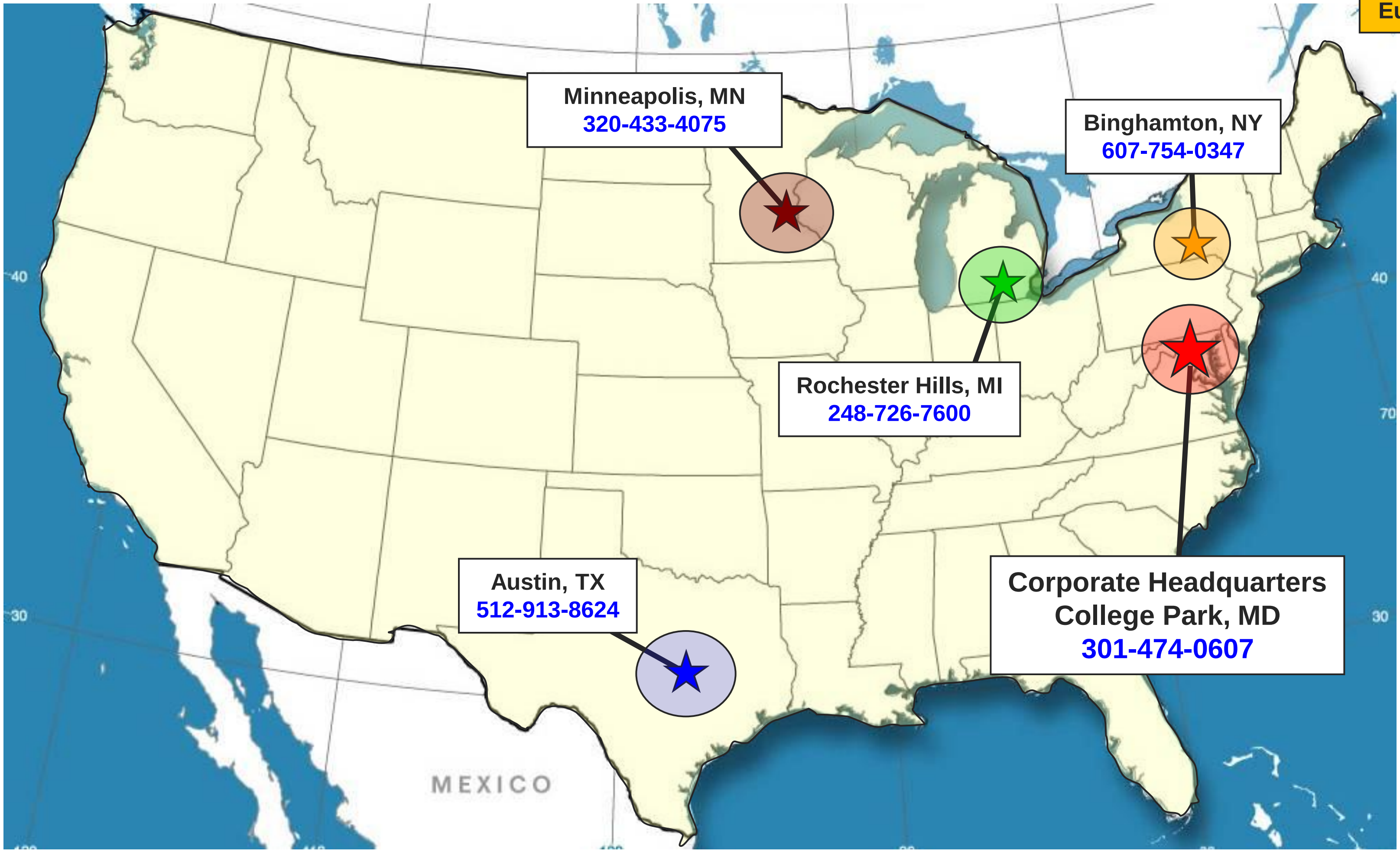

Physics of Failure / Reliability Physics Definitions

- **Physics of Failure** - A Formalized and Structured approach to Root Cause Failure Analysis that focuses on total learning and not only fixing a current problem.
  - To achieve an understanding of "CAUSE & EFFECT" Failure Mechanisms AND the variable factors that makes them "APPEAR" to be Irregular Events.
  - Combines Material Science, Physics & Chemistry with Statistics, Variation Theory & Probabilistic Mechanics.
    - A Marriage of Deterministic Science with Probabilistic Variation Theory for achieving comprehensive Product Integrity and Reliability by Design Capabilities.
  - Failure of a physical device or structure (i.e. hardware) can be attributed to the gradual or rapid degradation of the material(s) in the device in response to the stress or combination of stresses the device is exposed to, such as:
    - Thermal, Electrical, Chemical, Moisture, Vibration, Shock, Mechanical Loads . . .
  - Failures May Occur:
    - Prematurely because device is weaken by a variable fabrication or assemble defect.
    - Gradually due to a wear out issue.
    - Erratically based on a chance encounter with an Excessive stress that exceeds the capabilities/strength of a device,

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Physics of Failure / Reliability Physics Definitions

- **Reliability Physics** *(a.k.a. the PoF Engineering Approach)*
  - A Proactive, Science Based Engineering Philosophy for applying PoF knowledge for the Development and Applied Science of ***Product Assurance Technology*** based on:

- Knowing how & why things fail is equally important to understand how & why things work.
- Knowledge of how thing fail and the root causes of failures enables engineers to identify and avoid unknowingly creating inherent potential failure mechanisms in new product designs and solve problems faster.
- Provides scientific basis for evaluating usage life and hazard risks of new materials, structures, and technologies, under actual operating conditions.
- Provides Tools for achieving Reliability by Design
- Applicable to the entire product life cycle
  - Design, Development, Validation, Manufacturing, Usage, Service.

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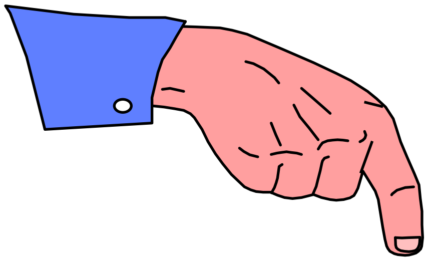
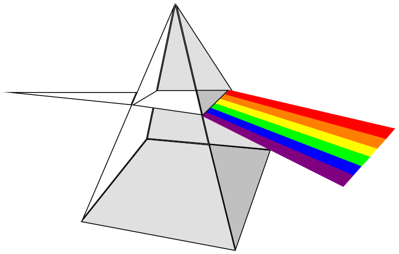
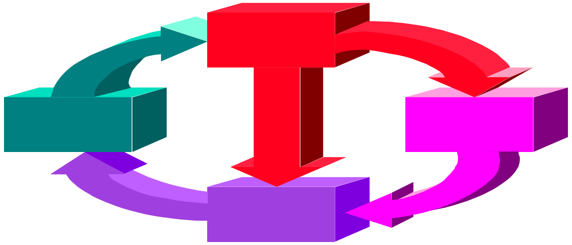
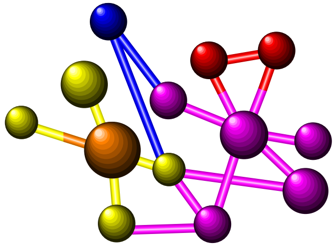
Key PoF Terms and Definitions

- **Failure Mode:**
  - The EFFECT by which a failure is OBSERVED, PERCEIVED or SENSED.


- **Failure Mechanism :**
  - The PROCESS (elect., mech., phy., chem. ... etc.) that causes failures.

- FAILURE MODE & MECHANISM are NOT Interchangeable Terms in PoF.

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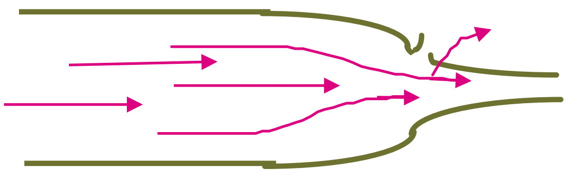
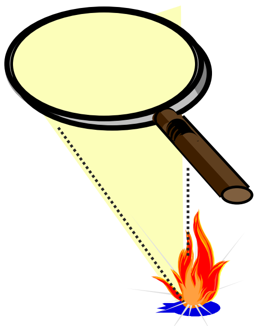
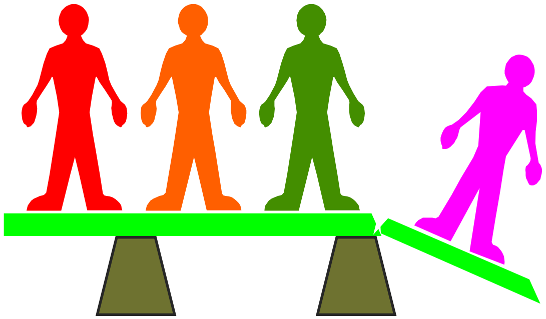
Key PoF Terms and Definitions

- **Failure Site :**
  - **The location of potential failures, typically the site of a designed in:**

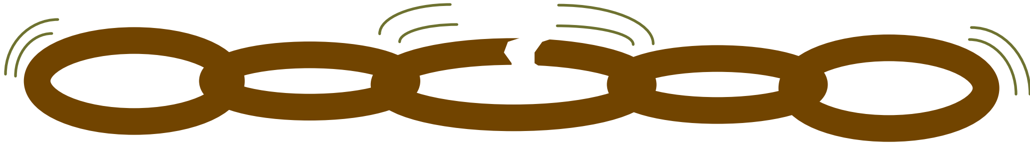




    - *stress concentrator* ,



    - *design weakness* or
    - *material variation or defect*.
  - **Knowledge Used to Identify and Prioritized Potential Failure Sites and Risks in New Designs During PoF Design Reviews.**



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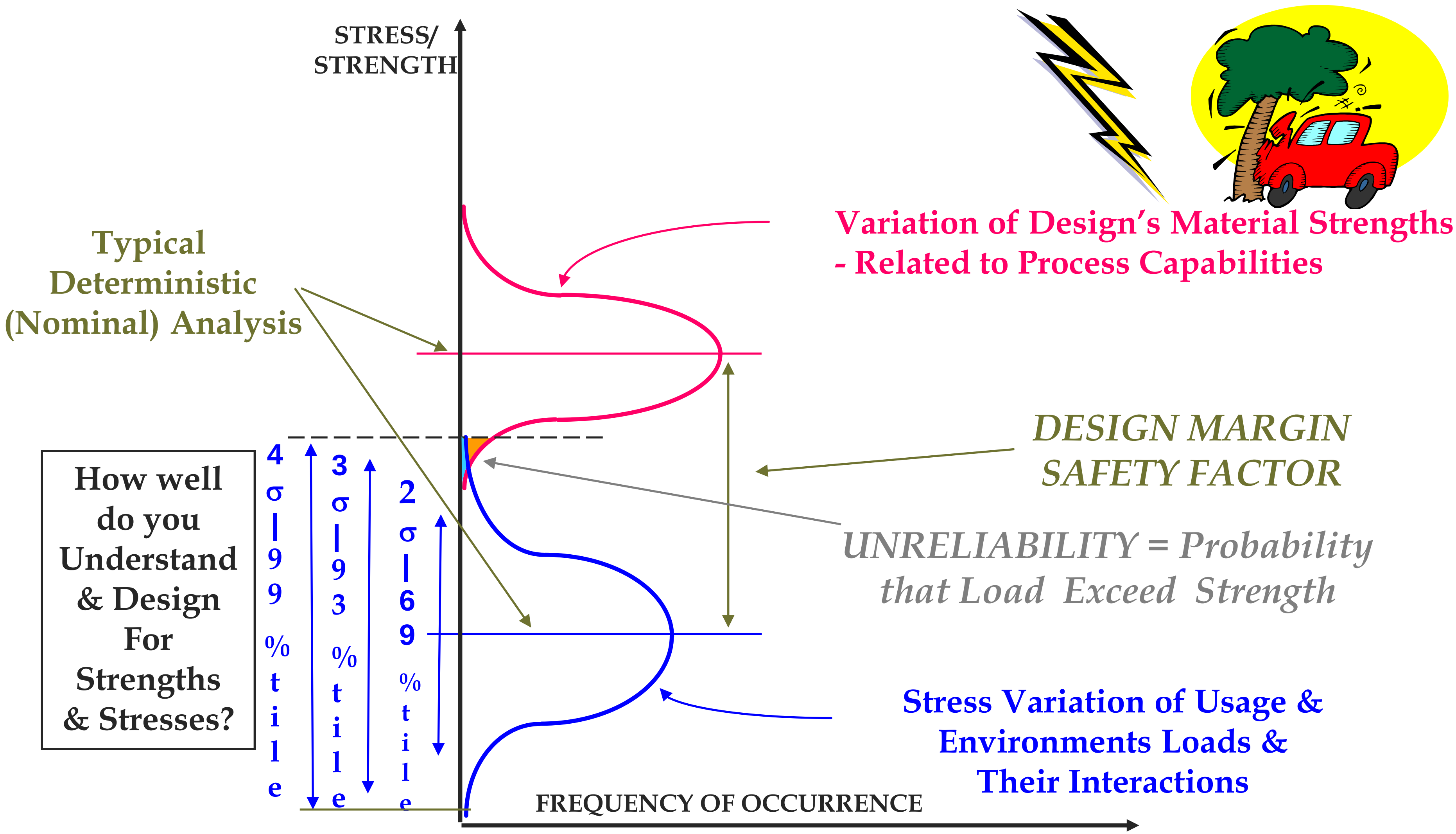
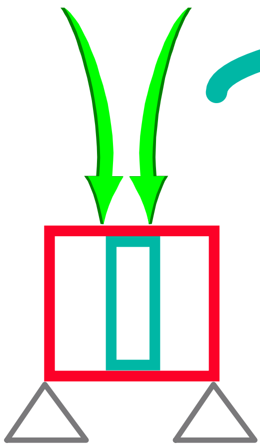
Generic Failure Categories

Overstress - When Loading Stress Exceed Material Strength

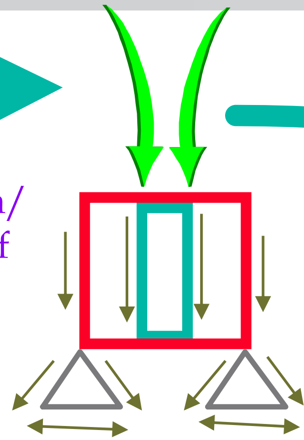


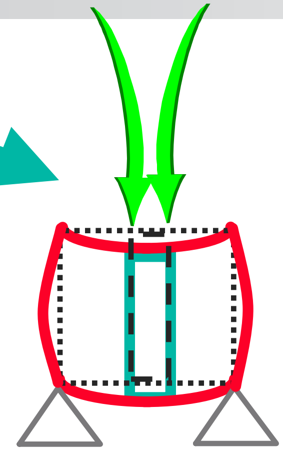
Overview of How Things Age & Wear Out
- Stress Driven Damage Accumulation in Materials



1. Loads
Elect. Chem. Thermal, Mech… Individual or combined, from environment & usage act on materials & structure.

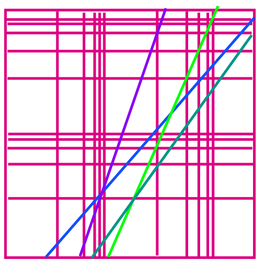
2. Stress
The distribution/ transmission of loading forces throughout the device.





3. Strain :
Instantaneous changes (materials\structural) due to loading, different loads interact to contribute to a single type of strain.

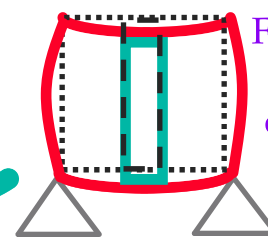
Knowledge of how/ which "Key Loads" act & interact is essential for ***"efficiently"*** developing good products, processes & evaluations.



6. Time to Mean Failure:
(Damage Accumulation verses Yield Strength A Function of: Σ [Stress Intensity, Material Properties, & Stress Exposure Cycles/Duration].

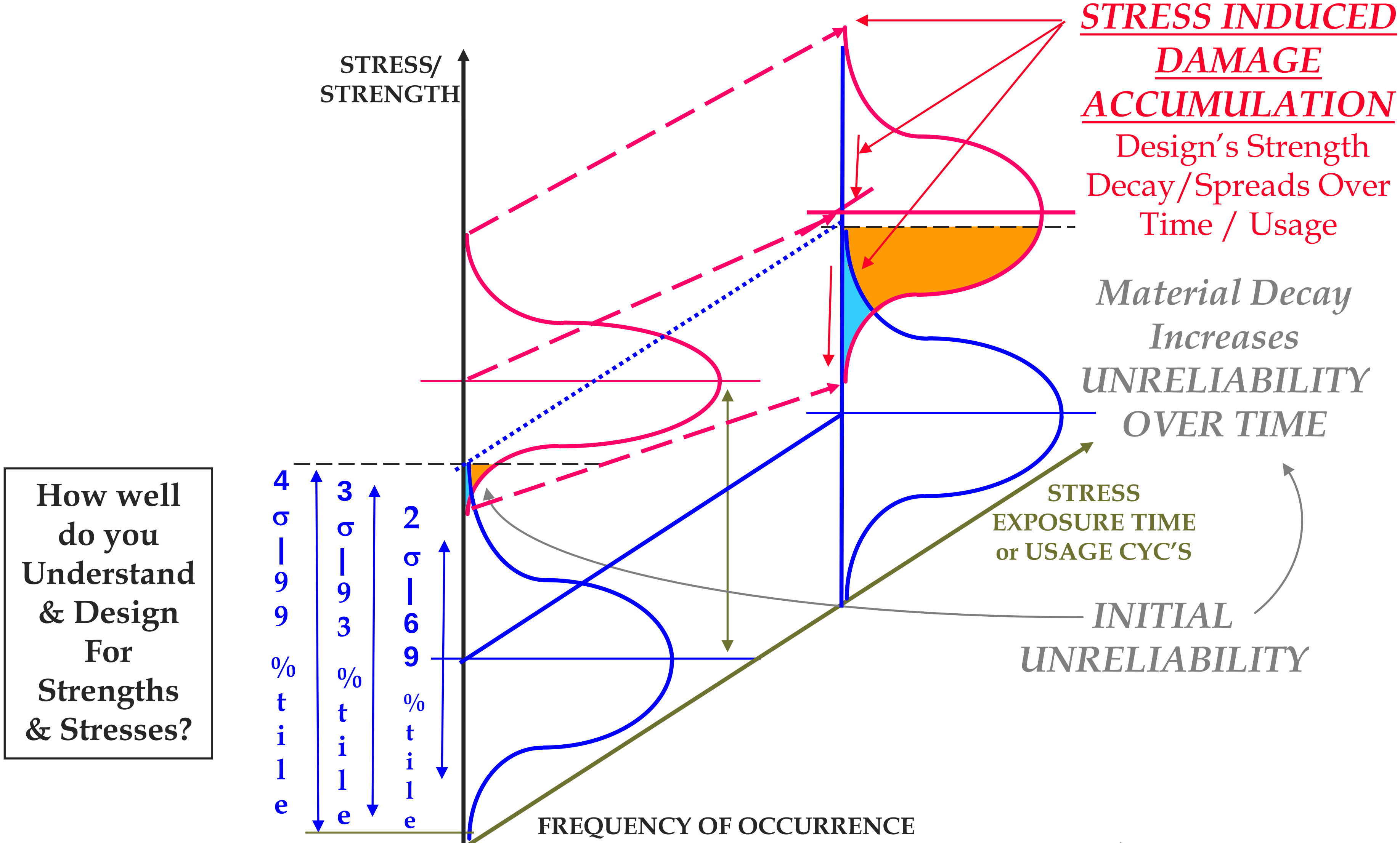
7. Project the Distribution About the Mean i.e. Rate of Failure (Fall out)
A function of variation in; Usage, Device Strength & Process Quality Control (i.e. latent defects).

4. Damage Accumulation (or Stress Aging):
Permanent change degradation retained after loads are removed. From small incremental damage, accumulated during periods/cycles of stress exposure.



5. Failure Site & Type:
Typically due to a designed in: *stress concentrator* , *design weakness*, *material/process variation* or *defect*.

Generic Failure Categories - Wearout (Damage Accumulation) - Over Time of Stress Exposure



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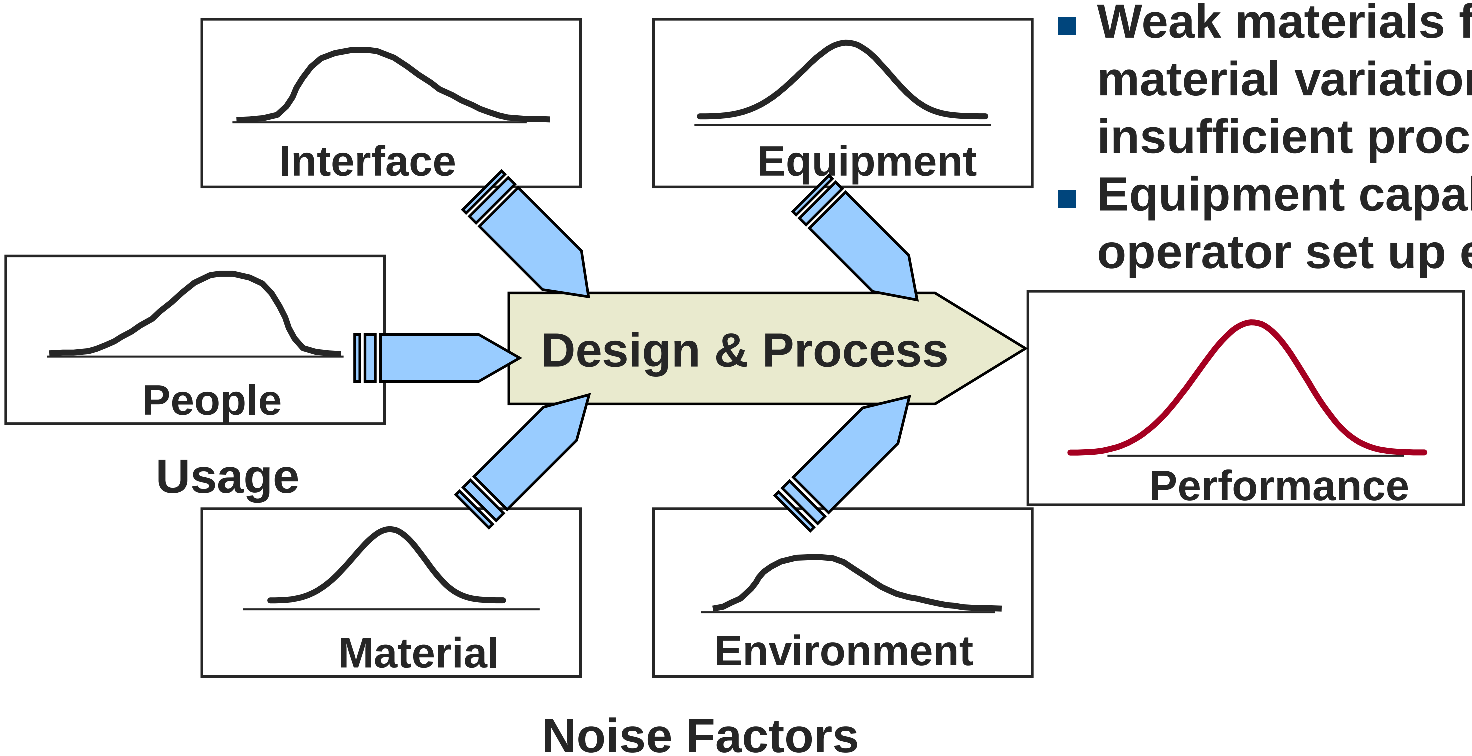
Errors and Excessive Variation

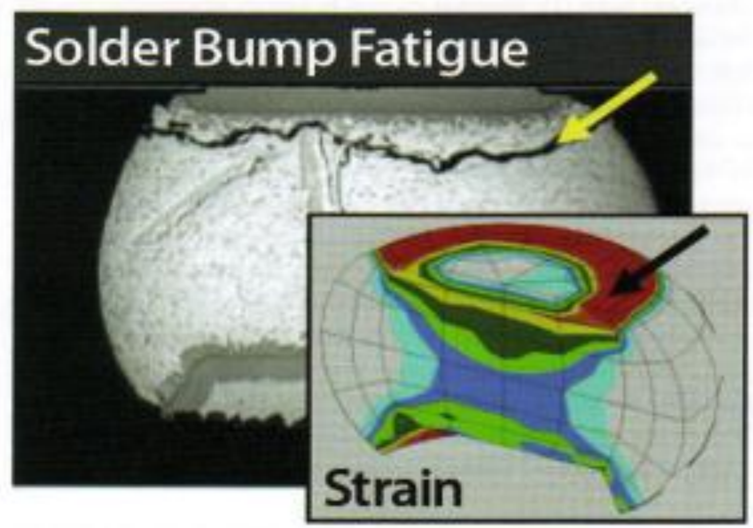
- Errors Broadest Category
  - Errors in Design, Manufacturing, Usage & Service.
  - Missing knowledge
  - Human factor Issues
- Variation
  - Fine line between excessive variation & out right errors.
  - Both related to quality issues.
    - Equipment wear out & failure from maintenance errors.
    - Weak materials from raw material variation or insufficient processing.
    - Equipment capabilities limits or operator set up error.



Thermal Cycling Fatigue

- The majority of electronic failures are thermo-mechanically related*
  - By thermally induced stresses and strains
  - Root cause: excessive differences in coefficient of thermal expansion

*Wunderle, B. and B. Michel, “Progress in Reliability Research in Micro and Nano Region”, Microelectronics and Reliability, V46, Issue 9-11, 2006.



A. MacDiarmid, “Thermal Cycling Failures”, RIAC Journal, Jan., 2011.

Temperature Cycles in the Field

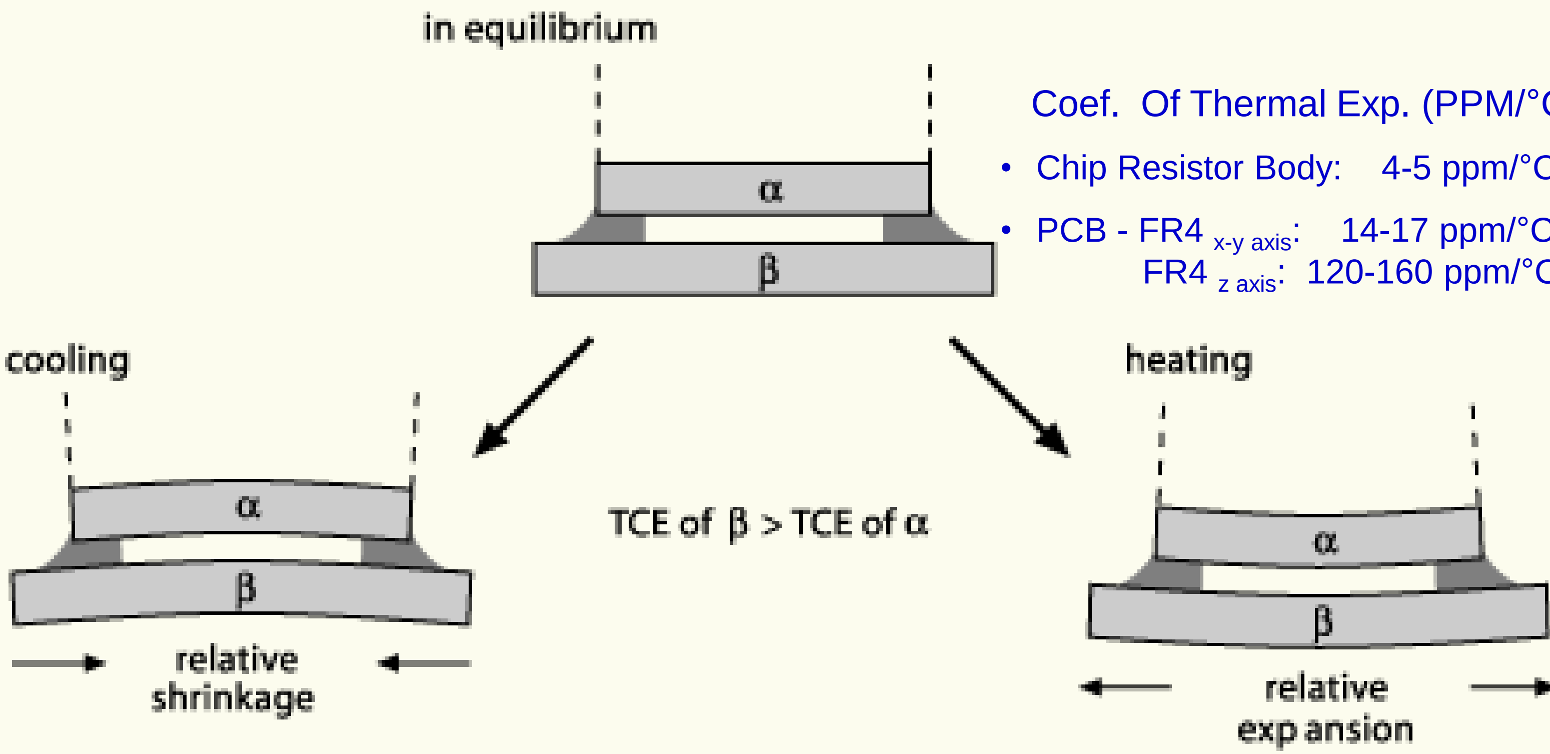
- Field conditions are based on usage and application
- The same electronics assembly can have several field conditions depending on the industry

	Temp range	Cycles/year	Service time	Failure rate
Consumer	0 to 60 °C	365	1 year	1 %
Computer	15 to 60 °C	1460	5 years	0.1 %
Telecom	-40 to 85 °C	365	7 to 20 years	0.01 %
Aircraft	-55 to 95 °C	365	20 years	0.001 %
Automotive	-55 to 95 °C	100	10 years	0.1 %

- Examples: LCD touchpanels, voltage regulators, networking modules and many more.
- Special field conditions may exist
  - Long period of storage followed by short period of usage (Munitions, launch platforms, AED, airbags)

PoF Example Solder Thermo-Mechanical Fatigue Driven by:
hermal Expansion/Contraction (CTE) Mismatch During Thermal Cycling

- As a circuit board and its components expand and contract at different rates the differential strain between them is absorbed by the attachment system leads and solder joints which drives metal fatigue.



Coef. Of Thermal Exp. (PPM/°C)

- Chip Resistor Body: 4-5 ppm/°C
- PCB - FR4 $_{\text{x-y axis}}$: 14-17 ppm/°C
  FR4 $_{\text{z axis}}$: 120-160 ppm/°C

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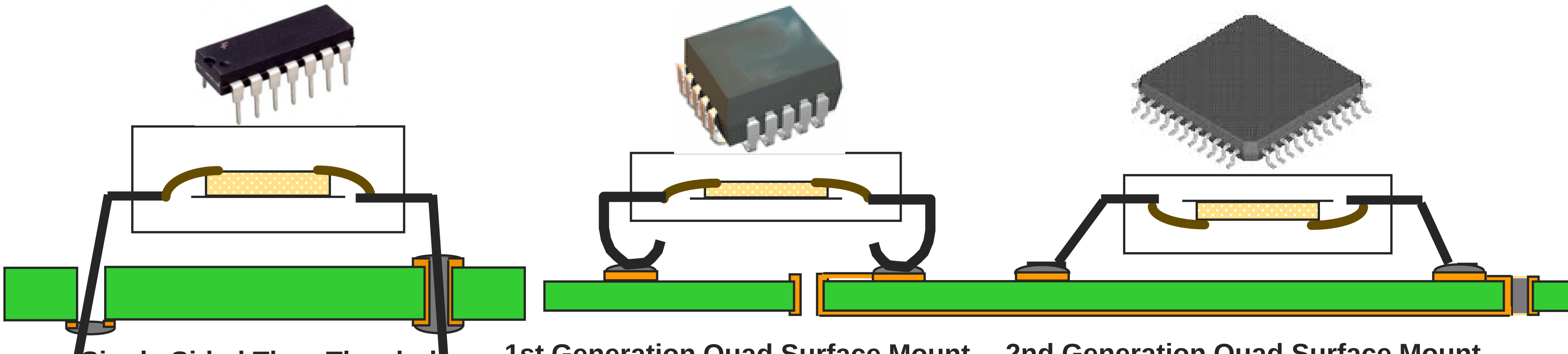
The Component Package Now Influences QRD more than the IC Die

EE Component Solder Fatigue Life is Directly Related to Component Packaging & Solder Attachment Scheme



Single Sided Then Thru-hole
DIP Integrated Circuits
1970 's- Today
~4 up to 68 I/O, 1" x 3.5"
Up to 10 Meg Hz Speeds.

1st Generation Quad Surface Mount
J Lead PLCC, 1982 - Today
~6 Up to 160 I/O, 1.5 in sq.,
Up to 100 Meg Hz Speeds
Source of Many Reliability Problems.

2nd Generation Quad Surface Mount
Fine Pitch Gull Wing I.C, 1993 - Today
~54 Up to 450 I/O, 1.75 in sq
Up to 250 Meg Hz Speeds
>10 Time the Life of J Lead in Auto ECMs.

Bump & Ball Grid Arrays ;Leadless Attachments
1996 - Today
~24 - 1000 I/O 1.2 in. sq
500+ 1000 Meg Hz Speeds.
Life Varies w/Size & Conf.

No Lead Chip Scale Packaging (NLCSP)
(LCCC, QFN, DFN, SON, LGA)
2002 - Today
~8 - 480 I/O, .75 in SQ, Gigi Hz Speeds
Can have significantly reduces life

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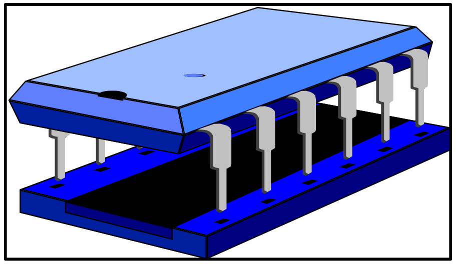
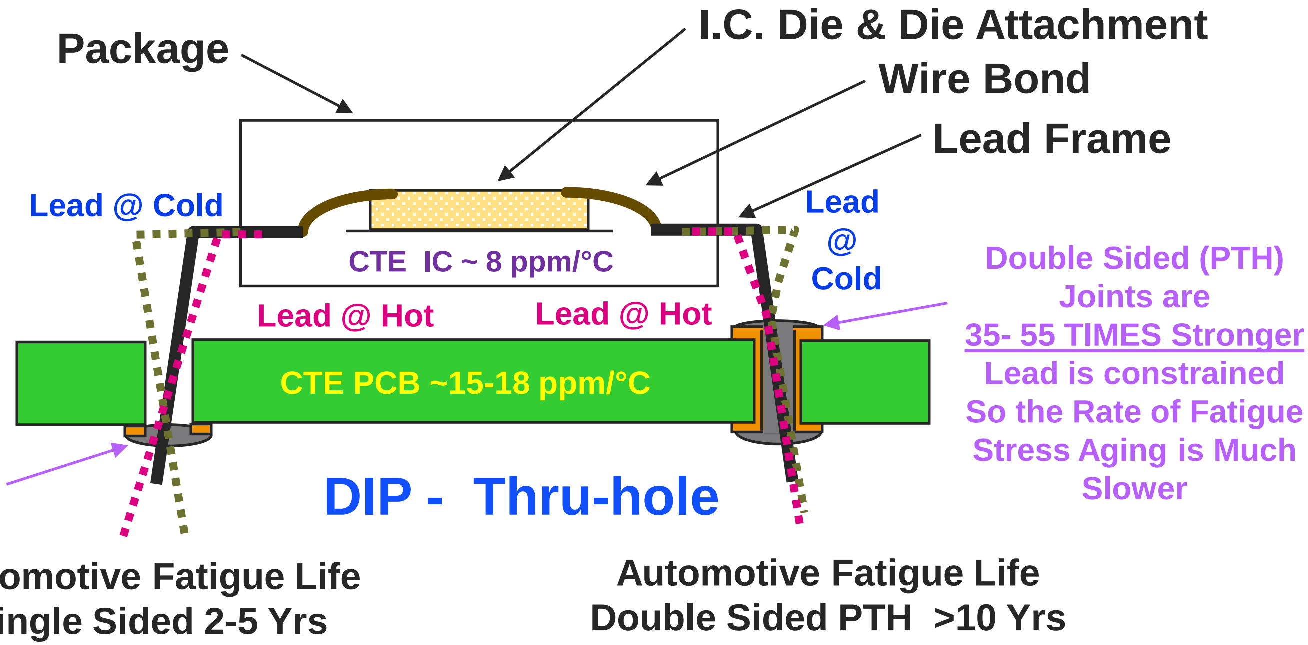
Impact of E/E Component Packaging & Attachment Configuration - Through Hole Dip Chip ICs





- Since Electrical Engineers Design Most Printed Circuit Boards (PCB)
  - Their only motivation to accepted the added costs of Plated Through Hole (PTHs) was when increasing component density required placing component and traces on both sides of the circuits board.
  - <u>THE RELIABILITY OF MORE COMPLEX EE MODULES SKY ROCKETED with the use of Double Sides PCB.</u>
  - Thus More Complexity DOES NOT ALWAYS HAVE TO RESULT IN LESS RELIABILITY.
    A More Capable or Smarter Design Approach
    Can Overcome the Inherent QRD Risks of Increased Complexity

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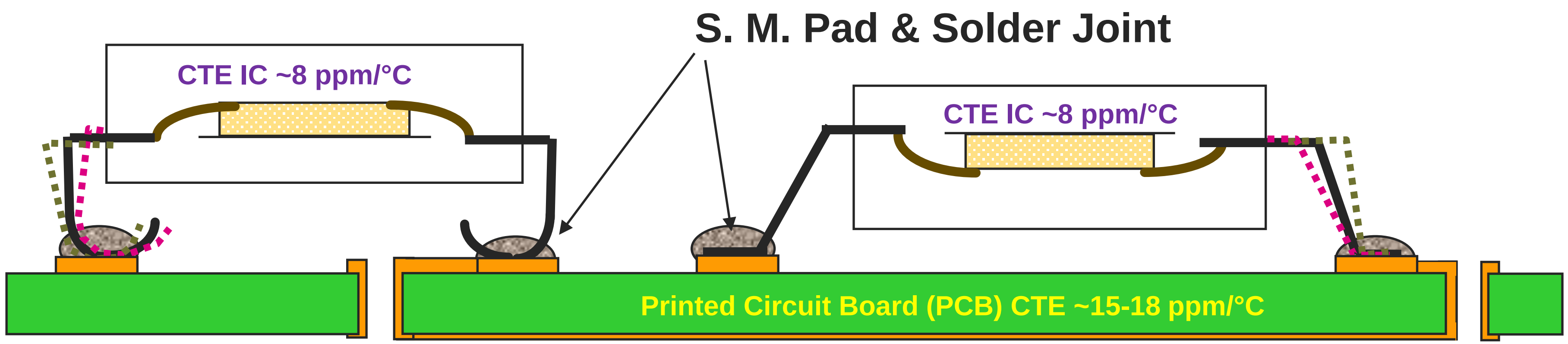
Impact of E/E Component Packaging & Attachment Configuration - Leaded Surface Mount ICs



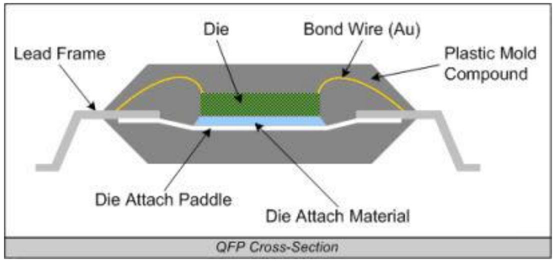
1st Generation
Surface Mount Devices
J lead - Thermal
Expansion/Contraction
Cause Rapid Fatigue Due To
Lead Rocking

2 Generation Surface Mount Devices
Have Gull Wing Fine Pitch Leads
Are Designed as an Articulated Spring,
Their Leads Flex at Two Bend Points
Instead of Transmitting Stress to the Weaker Solder
Similar Sized GWFP Devices
Avg. 10x the Durability Life of Similar Sized J Leaded Parts
under the Same Thermal Cycling Conditions.

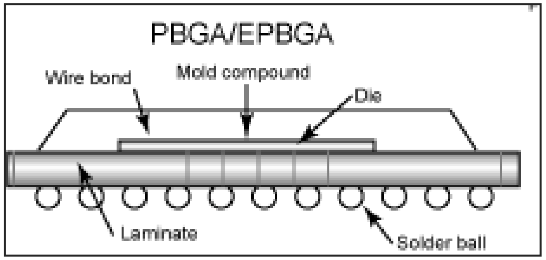
GW FP Devices Take Up More Board Areas
So a Larger Boards May Be Require to
Hold the Same Number of Components

4) Comparing Thermal Cycling Durability of Flat No Lead (FNL) IC Package Reliability: Thermal Cycling

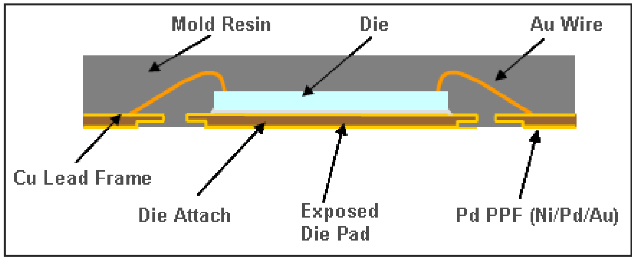
- Without a flexible terminal lead to absorb thermal Expansion/Contract motions, a high amount of thermal expansion stress is applied to the low profile under body solder joints, which accelerate solder fatigue failure.
- Solder Attachment Cycles to Failure
  - Order of magnitude (10X) reduction from QFPs
  - 3X reduction from BGAs



Gull Wing Leaded QFPs
TTCL: >10,000



Laminated BGAs:
TTCL: 3,000 to 8,000



FNL CSP:
TTCL: 1,000 to 3,000

**TTCL = Typical Thermal Cycle Life During -40° to +125°C Testing*

Package Type	Typical Thermal Cycles to Failure (-40C to 125C)
QFP	>10,000
BGA	3,000 – 8,000
QFN	1,000-3,000

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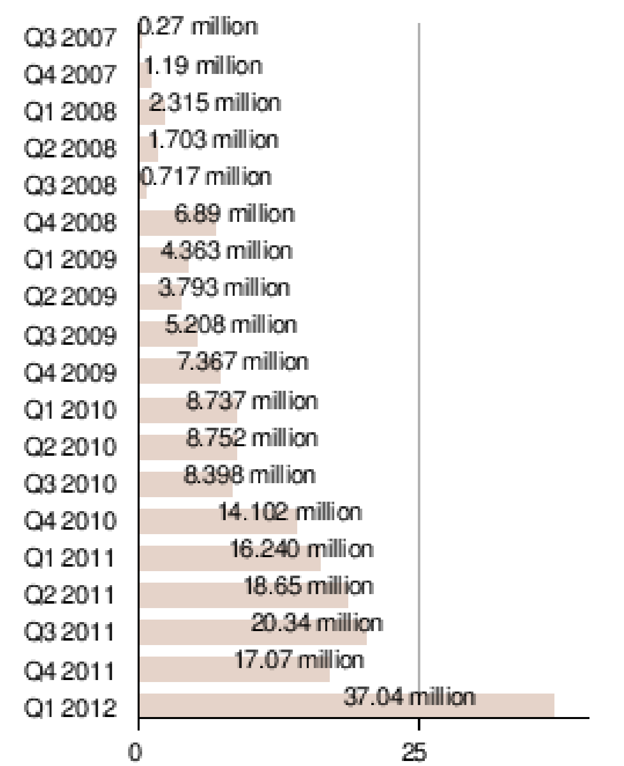
Flat No Lead (FNL) Chip Scale IC Packages?

- FNL ICs help make ultra thin and light portable consumer electronic products possible.
  - Products with a short service life (2-5 years)
  - In a relative benign environment
- The vastly large size of the consumer electronics market provides significance power to influence IC suppliers to develop IC packages & products that meet their needs and priorities.
- With significantly less market influence the high reliability, harsh environment, long life market like the auto and defense industries must increasing learn to use and adapt to the components produced by the predominate market trends.



Worldwide iPhone sales by Apple's fiscal quarters (Q1 2012 = Oct–Dec 2011).

The Reliability Challenge of Keeping Up With Constantly Evolving E/E Technology

- Every time electronic component packages, attachment schemes & materials change or application usage and environmental conditions change, QRD performance also change and design rules updates are needed.

- This is why PoF CAE based microstructural stress analysis and failure mechanism modeling is becoming essential for accurate reliability assessments of new products.

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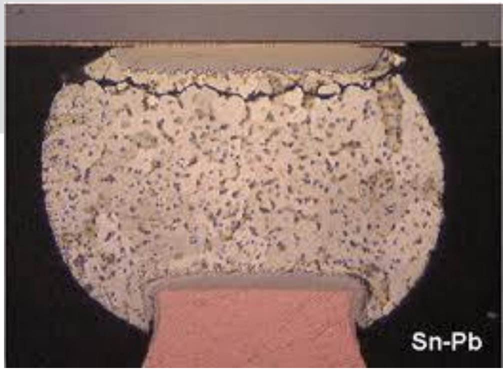
Thermal Cycling Solder Fatigue Model

(Modified Engelmaier – Leadless Device)



- Modified Engelmaier
  - Semi-empirical analytical approach
  - Energy based fatigue

$$\Delta\gamma = C\frac{L_D}{h_s}\Delta\alpha\Delta T$$

- Determine the strain range ($\Delta\gamma$)
- Where: C is a function of activation energy, temperature and dwell time, L_D is diagonal distance, α is CTE, ΔT of temperature cycle & h is solder joint height
- Determine the shear force applied at the solder joint

$$(\alpha_2-\alpha_1)\cdot\Delta T\cdot L_D = F\cdot\left(\frac{L_D}{E_1A_1}+\frac{L_D}{E_2A_2}+\frac{h_s}{A_sG_s}+\frac{h_c}{A_cG_c}+\left(\frac{2-\nu}{9\cdot G_b a}\right)\right)$$

  - Where: F is shear force, LD is length, E is elastic modulus, A is the area, h is thickness, G is shear modulus, and a is edge length of bond pad.
  - Subscripts: 1 is component, 2 is board, s is solder joint, c is bond pad, and b is board
  - Takes into consideration foundation stiffness and both shear and axial loads *(Models of Leaded Components factor in lead stiffness / compliancy)*
- Determine the strain energy dissipated in the solder joint

$$\Delta W = 0.5\cdot\Delta\gamma\cdot\frac{F}{A_s}$$

- Calculate N50 cycles-to-failure using:
  - An Energy Based model for SnPb
  - The Syed-Amkor model for SAC

$$N_f = (0.0019\cdot\Delta W)^{-1}$$

$$N_f = (0.0006061\cdot\Delta W)^{-1}$$

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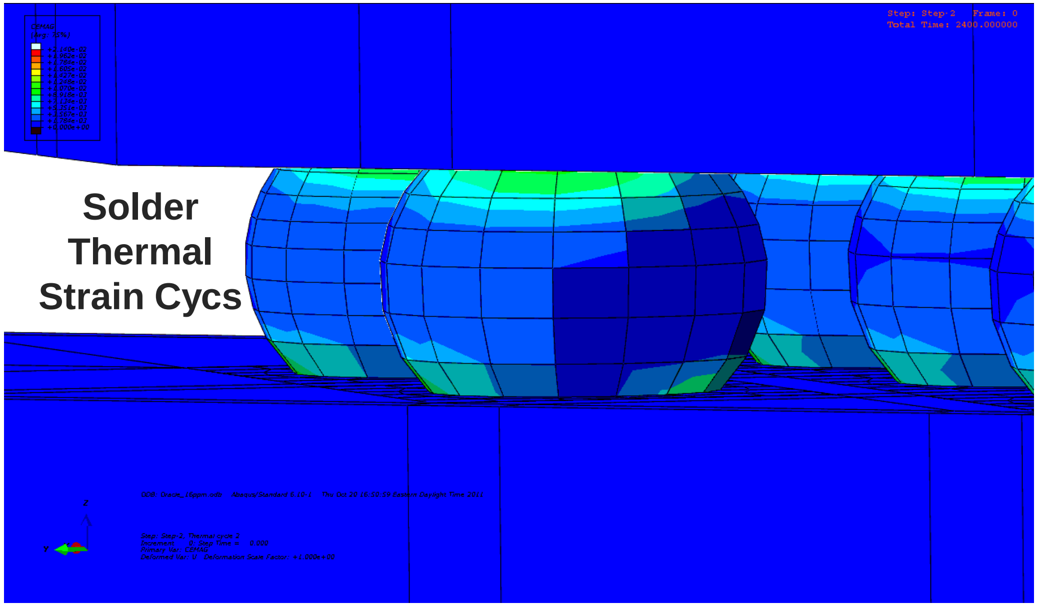
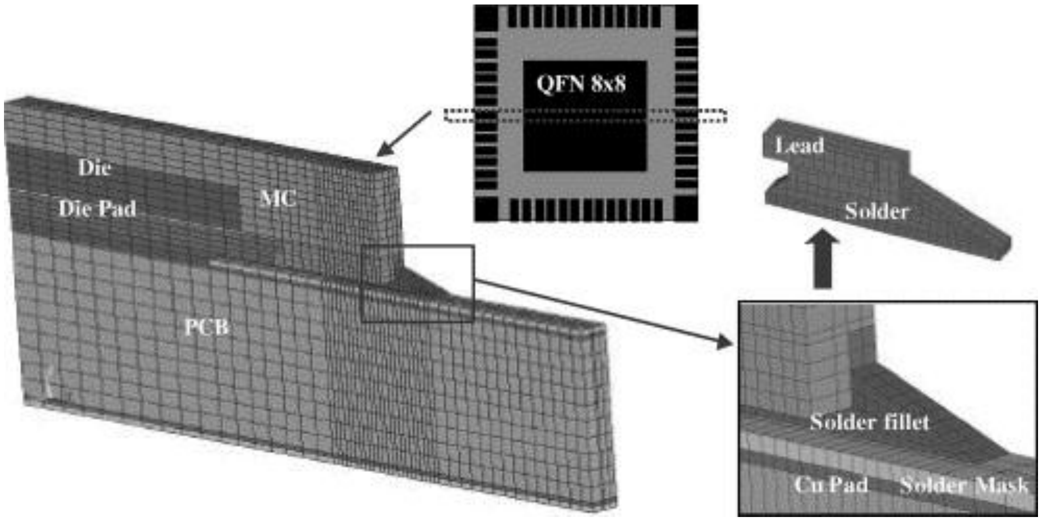
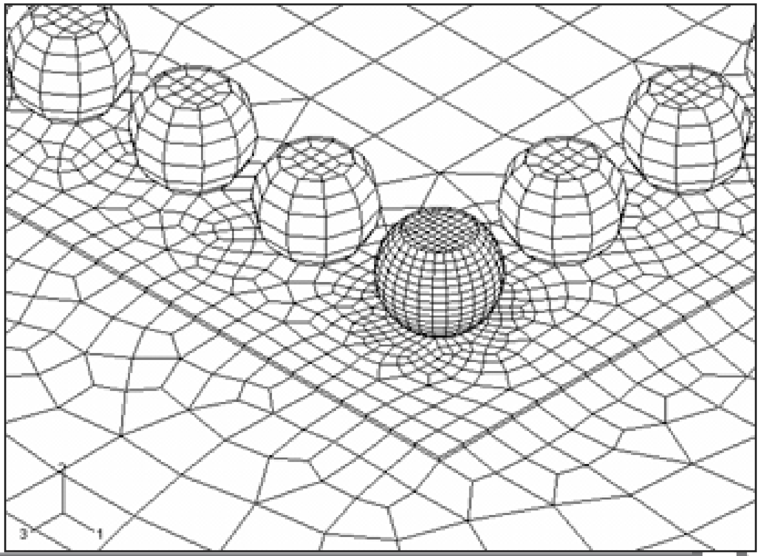
Electronic Reliability: Risk Mitigation
- Physics of Failure – CAE Durability Simulations



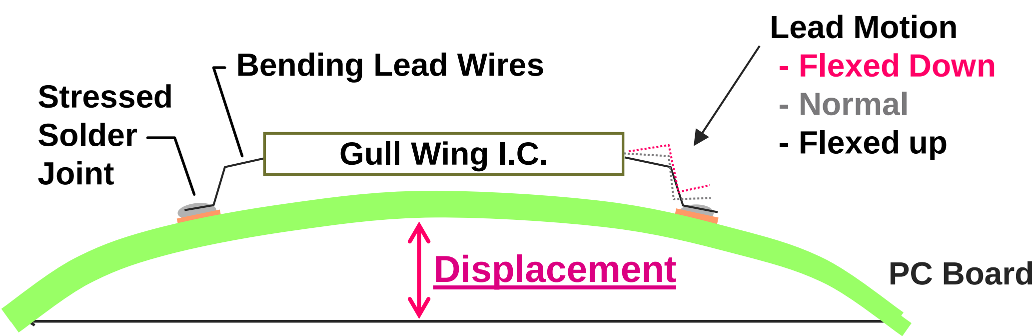
- PoF Models for Stress-Stain Structural Analysis of Electronics are well proved.
- But creating custom FEA models of EE modules is not easy:
  - Time Consuming & Expensive
  - Shortage of PoF CAE modelers.
  - Structural analysis CAE resources are not deployed to EE Enrg. Depts.





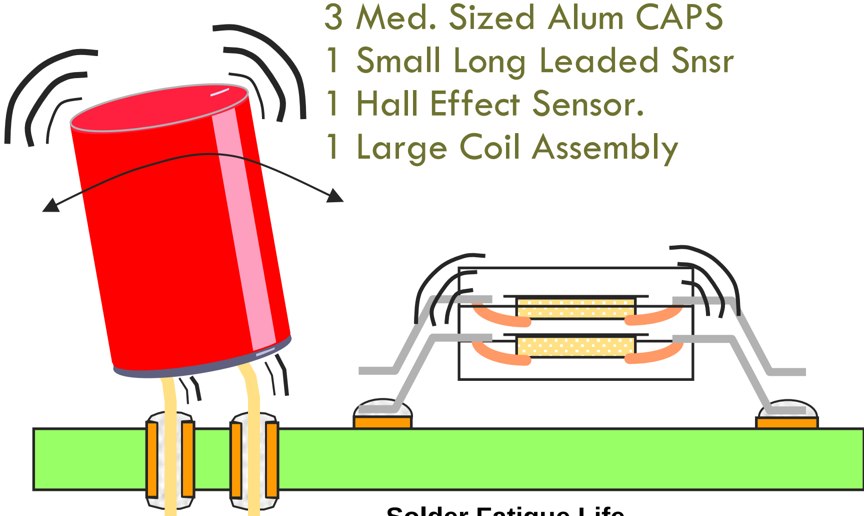
Also Two Types of Circuit Board Related Vibration Durability Issues

- Board in Resonance
  - Components. Shaken Off/Fatigued by Board Motion.
    - By Flexing Attachment Features



- Components In Resonance.
  - Components Shake/Fatigue themselves apart or off the Board.
  - Especially Large, Tall Cantilever Devices

3 Med. Sized Alum CAPS
1 Small Long Leaded Snsr
1 Hall Effect Sensor.
1 Large Coil Assembly



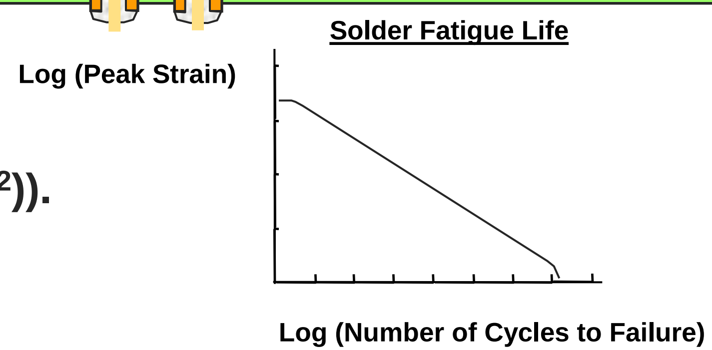
- Time to Failure Determine by Intensity/Frequency of Stress Verses

  Strength of Material

Steinberg's Criterion:

For a 10 million cycle life, $Z < 0.0008995 \cdot B/(C \cdot h \cdot r\ (L^{1/2}))$.

Ref: Vibration Analysis for Electronic Equipment, by David S. Steinberg



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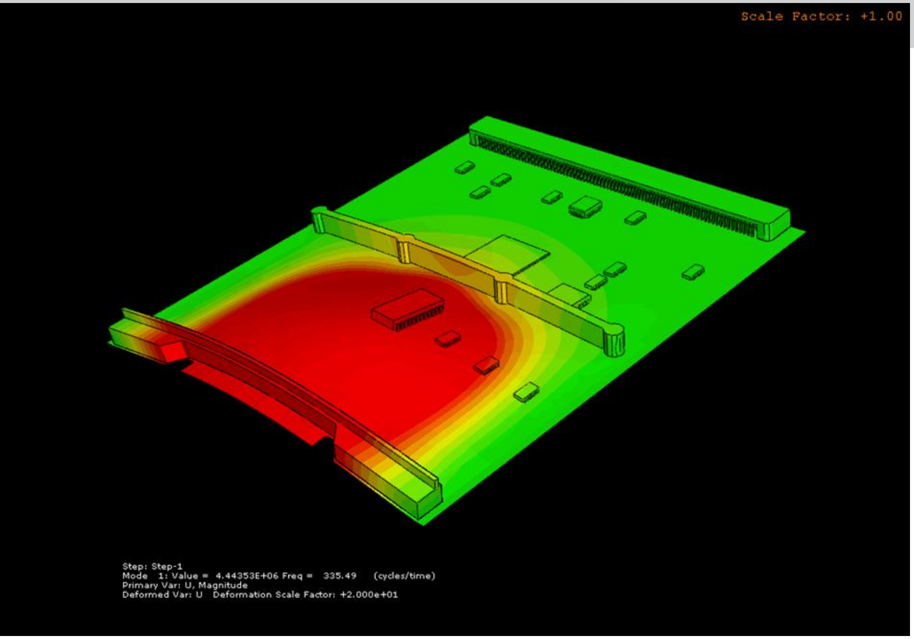
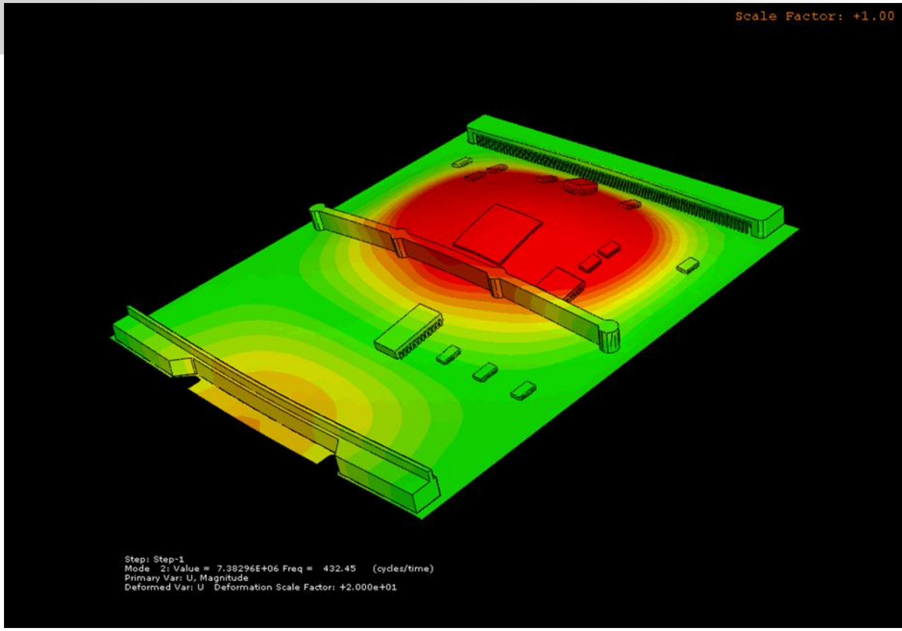
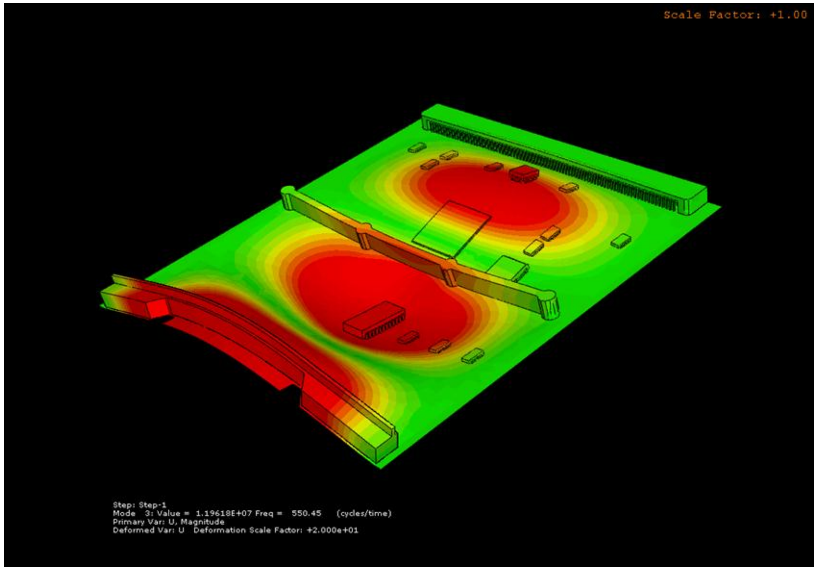
PCB Vibration - 1st, 2nd & 3rd Harmonic Modals



1st Harmonic



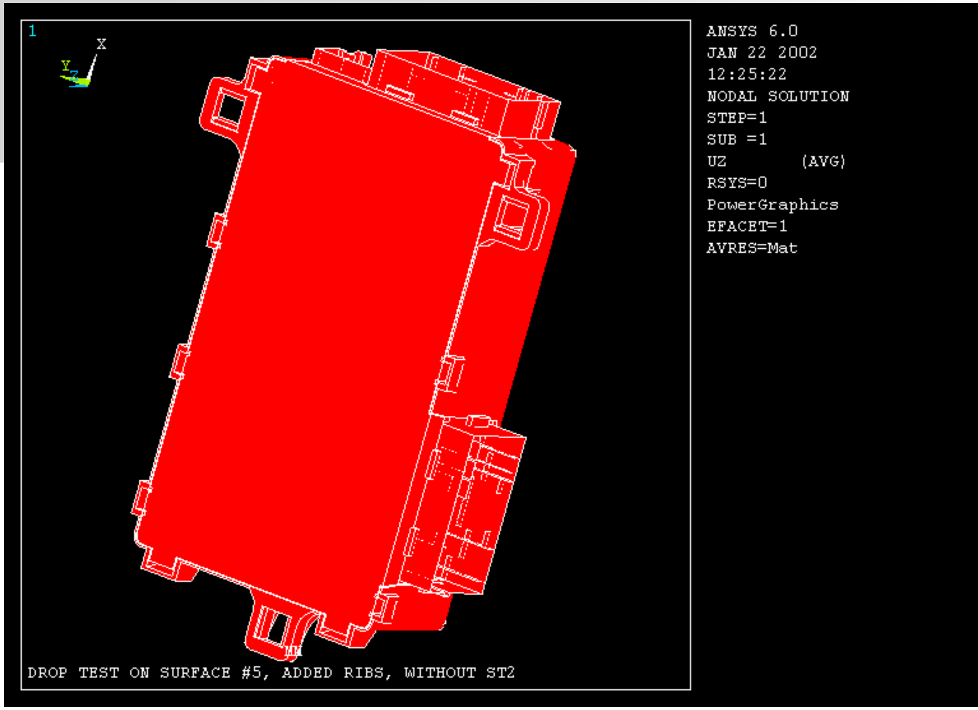
2nd Harmonic

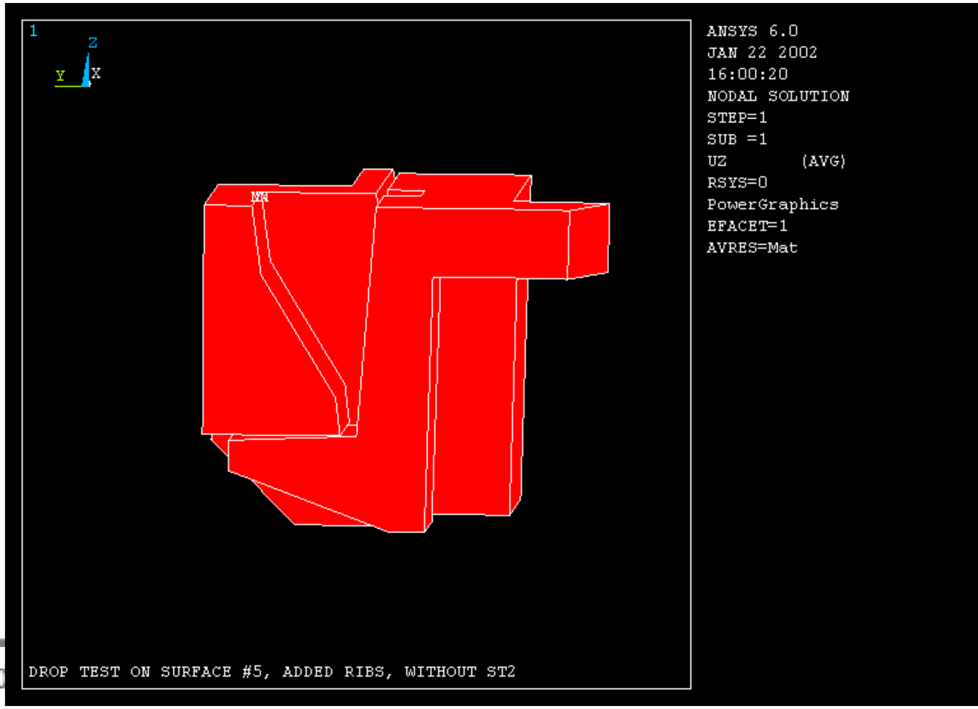


3rd Harmonic

Physics of Failure Example - Shock

- Animated Simulation Visualizes Transition of the Shock Wave Through the Structure of the Module.
- Peak Stresses, Material Strain, Motions & Displacements Can be Identified.
- Potential Failure Sites Where Local Stresses Exceed Material Strength Can Be Identified & Prioritized.
- Zoom In On Surface Such as Potential for Snap Lock Fastener Release
- Wire Frame View Allows Xray Vision of Internal Features.





Drop/Shock Simulation CAE Programs Developed By Telecom in the Mid 1990's

Fourth International *LS-DYNA3D* Users Conference

September, 1996
Minneapolis, Minnesota, U.S.A.

Commercial Drop/Shock CAE SW Available Since 1996

Drop/Impact Simulation of Electronic Products

Jason Wu
Chao-pin Yeh
Karl Wyatt

Applied Simulation and Modeling Research
Motorola Inc.
1303 E. Algonquin Road (IL01), Room AN2
Schaumburg, IL, 60196-1079, USA

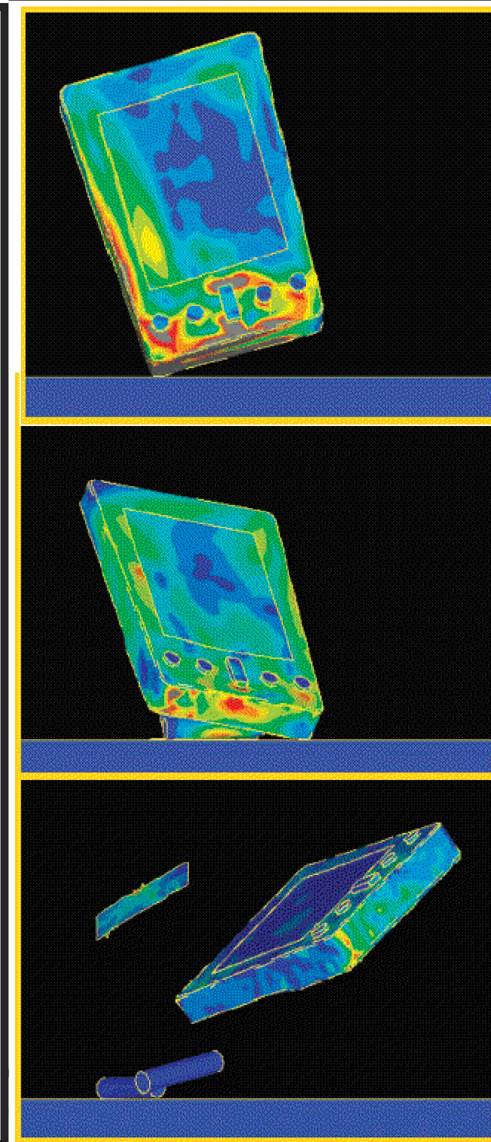
Motorola

Many Product Engineers are Unaware of Physical CAE Capabilities and How to Use Them to Design QRD in as part of a Product Development Program.

- Many E/E Devices Have Drop/Shock Requirement s.
- Most Use Test & Fix "Free Fall Drop Validation Test" of Physical Parts.
- A "Design for Reliability" Approach Would Integrate CAE Virtual Validation Evaluations into the Design Creation Process.

structural design. To obtain the detailed understanding of impact behavior and damage mechanism of electronic products, there are two approaches - test and computer simulation. One can detect failure mechanisms by collecting the impact acceleration, contact force and strain/stress data in both package and component level tests. The disadvantages of this test-based analysis are high cost and after-design determination, and it is quite difficult to mount the sensors on small components.

Drop Module From ANSYS LS-DYNA



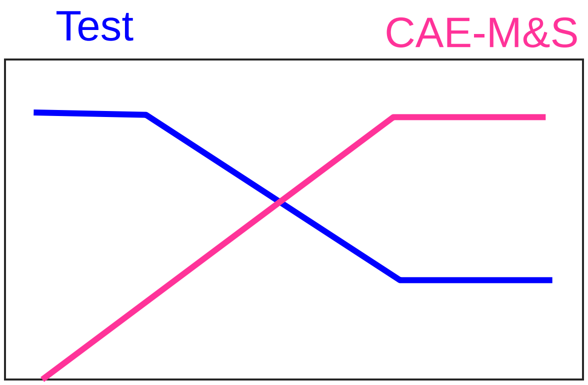
The Auto Industry Has Reaped Significant Product development Efficiencies & QRD Benefits Through Math Based, Virtual CAE Tools and Methods

A Result of Initiatives to:
Migrate Evaluations

from Road
to Lab
to Computer,

at the Vehicle, Subsystem & Component Level

Reduced Dependence on Costly D-B-T-F (Design – Build – Test – Fix)



As the use of CAE based modeling & simulation methods increase, dependence on physical testing can be reduced and refocused.

By 2004 GM was able to reduce vehicle road testing to the point that the southern portion of their Mesa Az. Proving Grounds was sold. In 2006 the remaining northern 5 square miles, that formerly operated with 1,200 people, was sold for Real Estate Development.
GM now operates with a much smaller DPG in Yuma Az.
and realized a significant reduction in structural costs.

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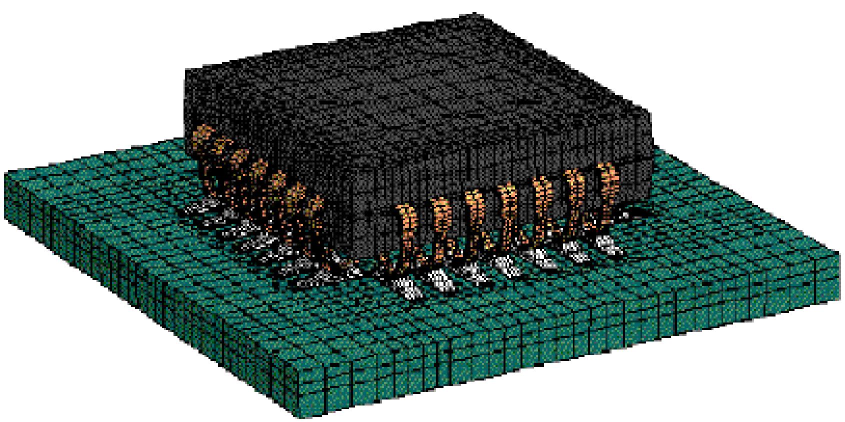
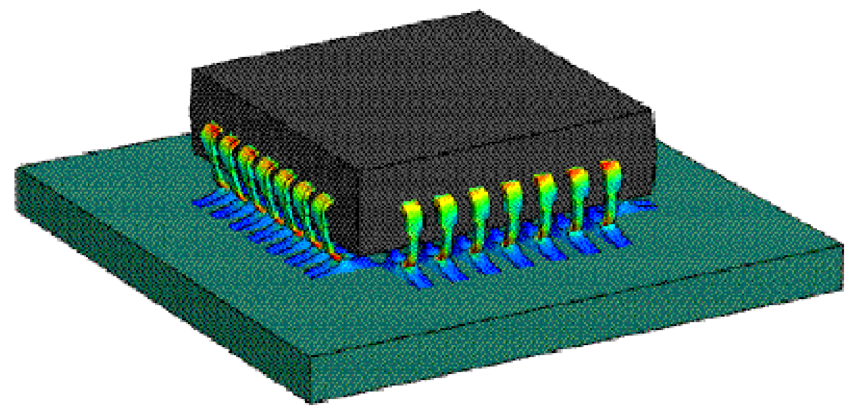
PoF Durability/Reliability Simulations for Virtual Reliability Growth of Electronics

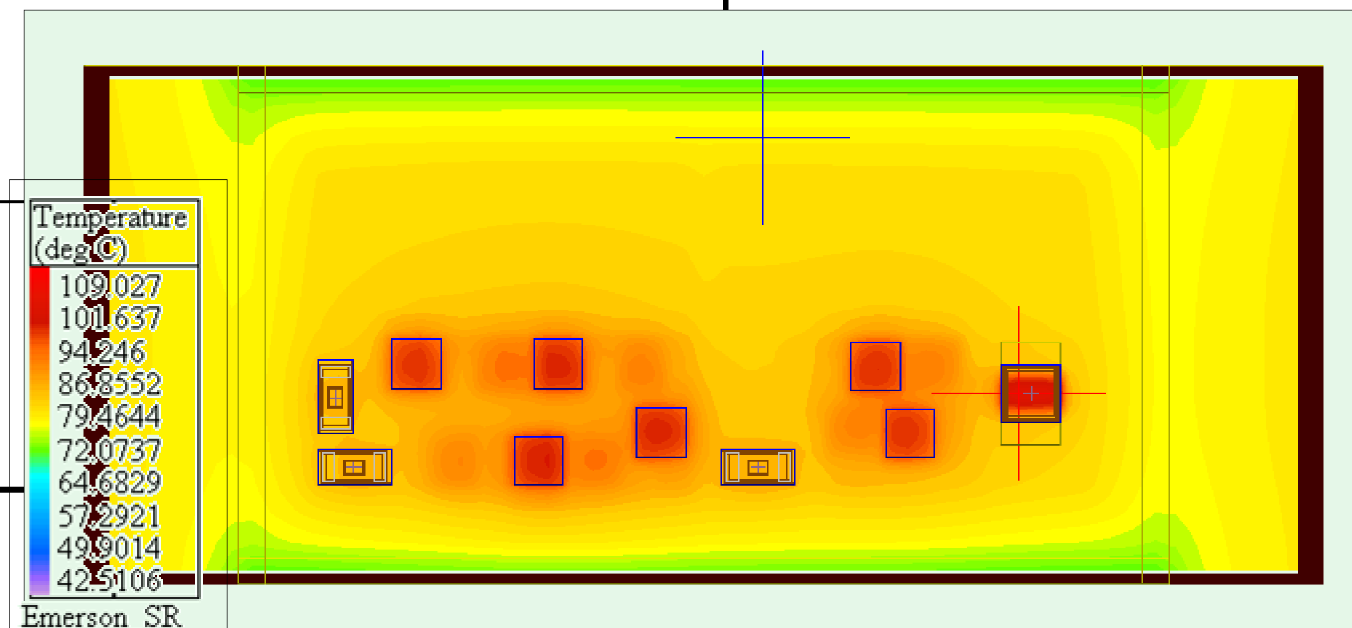
Start with PoF/PoS Mechanism Knowledge → **Build & Validate PoF / PoS Math Models** → **Program Model(s) into Standalone Simple Math Data Tools** → **Integrated In a Sophisticated CAE Tool.** → **Add in Statistical Tools for Variation** → **Account for Operational Loading Drift**





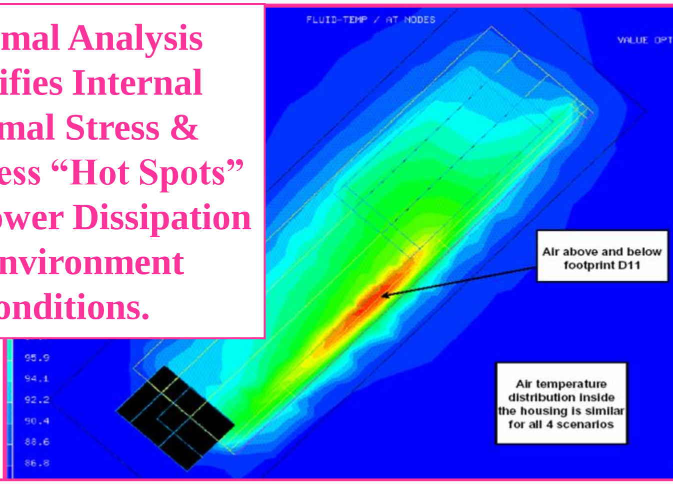
Thermal Modeling Identifies the Thermal Stress Conditions

SR (HSink@85°C)	T_J (°C)	T_{Case} (°C)	T_{HSink} (°C)	P (W)	$Rth_{J\text{-}C}$ (°C/W)	$Rth_{J\text{-}HS}$ (°C/W)
$Q6_{IGBT}$	96.29	89.23	**85.0**	6.50	1.09	**1.74**
$D6_{Diode}$	103.40	89.52	**85.0**	13.80	1.01	**1.33**
$Q3_{IGBT}$	98.35	90.20	**85.0**	6.50	1.25	**2.05**
$D9_{Diode}$	104.98	90.99	**85.0**	13.80	1.01	**1.45**
$Q5_{IGBT}$	97.95	90.56	**75.0**	6.50	1.14	**3.53**
$D4_{Diode}$	104.07	90.74	**85.0**	13.80	0.97	**1.38**
$Q2_{IGBT}$	96.89	89.59				
$D8_{Diode}$	104.08	90.42				
Shunt R8	103.98	87.14				
Shunt R9	103.68	87.17				
$Q4_{IGBT}$	96.61	89.40				
$D2_{Diode}$	103.40	89.89				
$Q1_{IGBT}$	96.98	89.13				
$D7_{Diode}$	103.29	89.94				
Shunt R6	108.75	86.50				
Shunt R7	104.64	87.95				



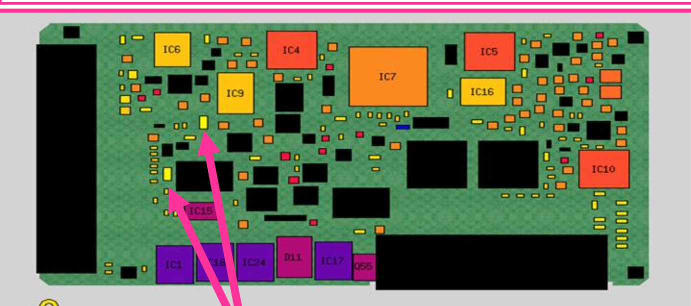
Predicting & Confirming Thermal Stress & Thermal-Mech. Reliability
- Detection of the Module's Durability Weak Link,
- Two Large 1020 Resistors, Located in the High Temperature Zone

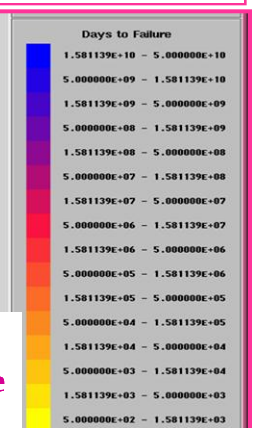
Thermal Analysis Identifies Internal Thermal Stress & Overstress "Hot Spots" From Power Dissipation & Environment Conditions.



Infrared Thermal Imaging Of Thermal Stress & Overstress "Hot Spots"

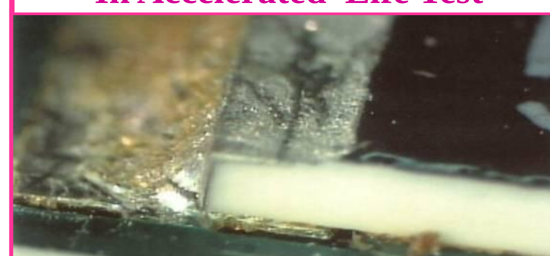
Thermal-Mechanic Durability Modeling to Identify Potential Intermittent Circuits Due to Themo-Mechanical Fatigue





Durability Simulations Identifies Most Likely Parts to Fail Due To Thermo-Mechanical Fatigue Identified (Large Body 1020-S.M. Resistors)

1020 Resistor Fatigue Confirmed In Accelerated Life Test



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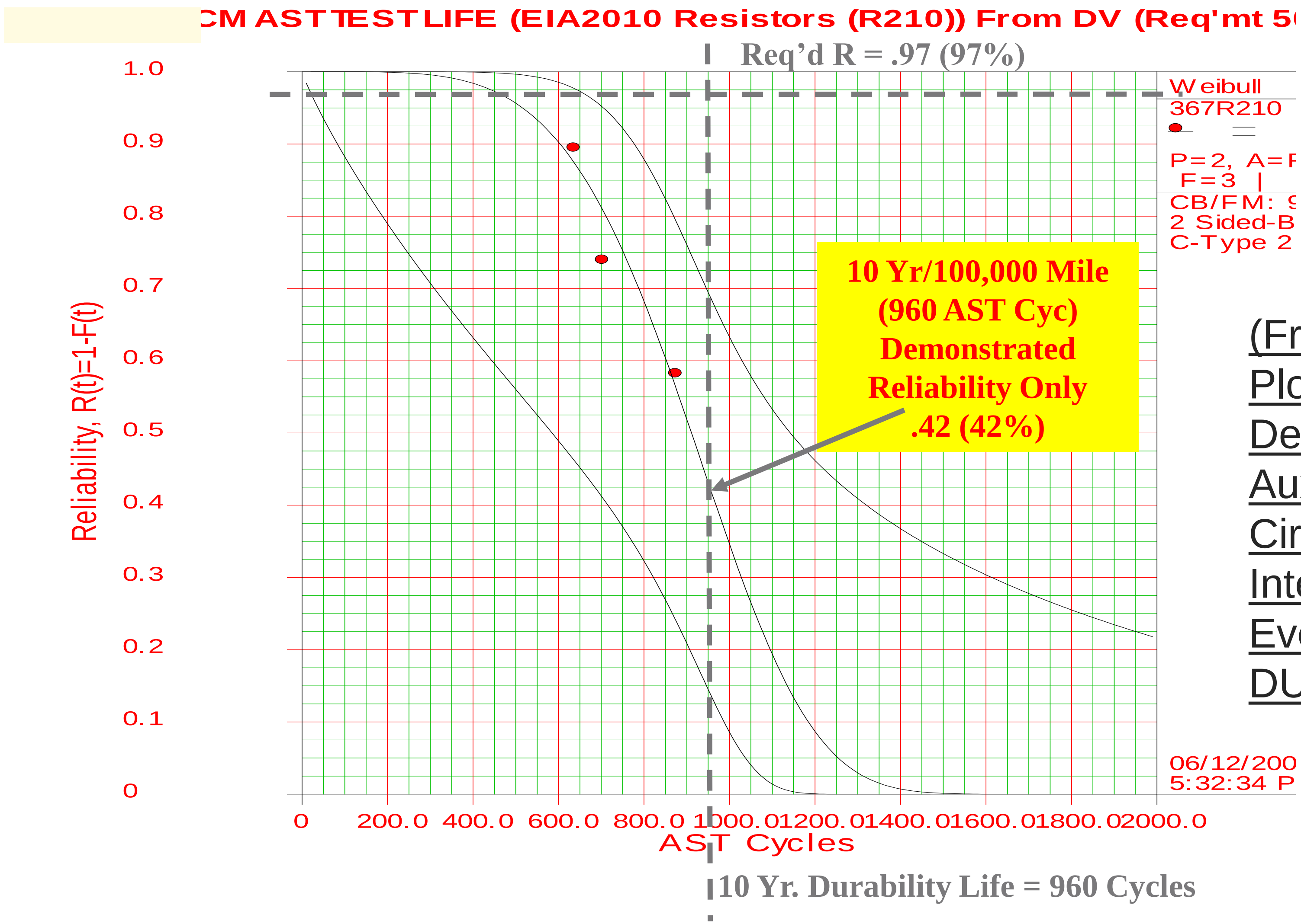
1020 Resistor Reliability vs AST Cycles as Demonstrated During DV Testing



(From Weibull Plot of 1st Detection of 3 Aux. Sw. Circuit Intermittent Events out of 6 DUTs)

DfR Solutions

INTELLIGENCE ACCELERATED

sherlock

AUTOMATED DESIGN ANALYSIS

Predicting the Future

A Award Winning CAE App for Physics of Failure Durability Simulations & Reliability Assessments

DfR Solutions

reliability designed, reliability delivered

SAE Aerospace Engineering – Cover Story April 2012 - Putting CAE to Work for Non-Experts

- Application Specific Customized CAE Solutions.
- An emerging trend where auto guided, specific function, CAE Apps or analysis templates are created
  - Provides a common, reusable semi-automated interface
    - Perform regularly needed product optimization modeling
    - Solving frequently encountered problems.
    - Allows product teams to perform expert level CAE analysis without a rare, high cost PoF CAE expert
    - To see full article: http://www.sae.org/mags/SVE/10767

DfR Solutions

CAE Apps

- The shortage of time and modeling experts has limited the expansion of CAE tools in many industries.
  - More upfront CAE analysis work would be performed if engineering organizations could find and afford enough high priced CAE experts.
  - A growing trend to resolve this bottleneck is the development of CAE Apps and Templates.
  - This new generation of CAE solutions provide common, application specific, reusable, semi-automated interface for solving frequently encountered problems and performing regularly needed product optimization tasks that allow non-CAE experts to rapidly perform expert level evaluations.
  - Knowledge based, application specific, CAE Apps are now available for PoF analysis of electronic products that allow non-CAE experts to perform expert level PoF evaluations. This course will introduce and provide examples of PoF CAEs Apps for electronic equipment.

Yes - There's a App For THAT!!!!

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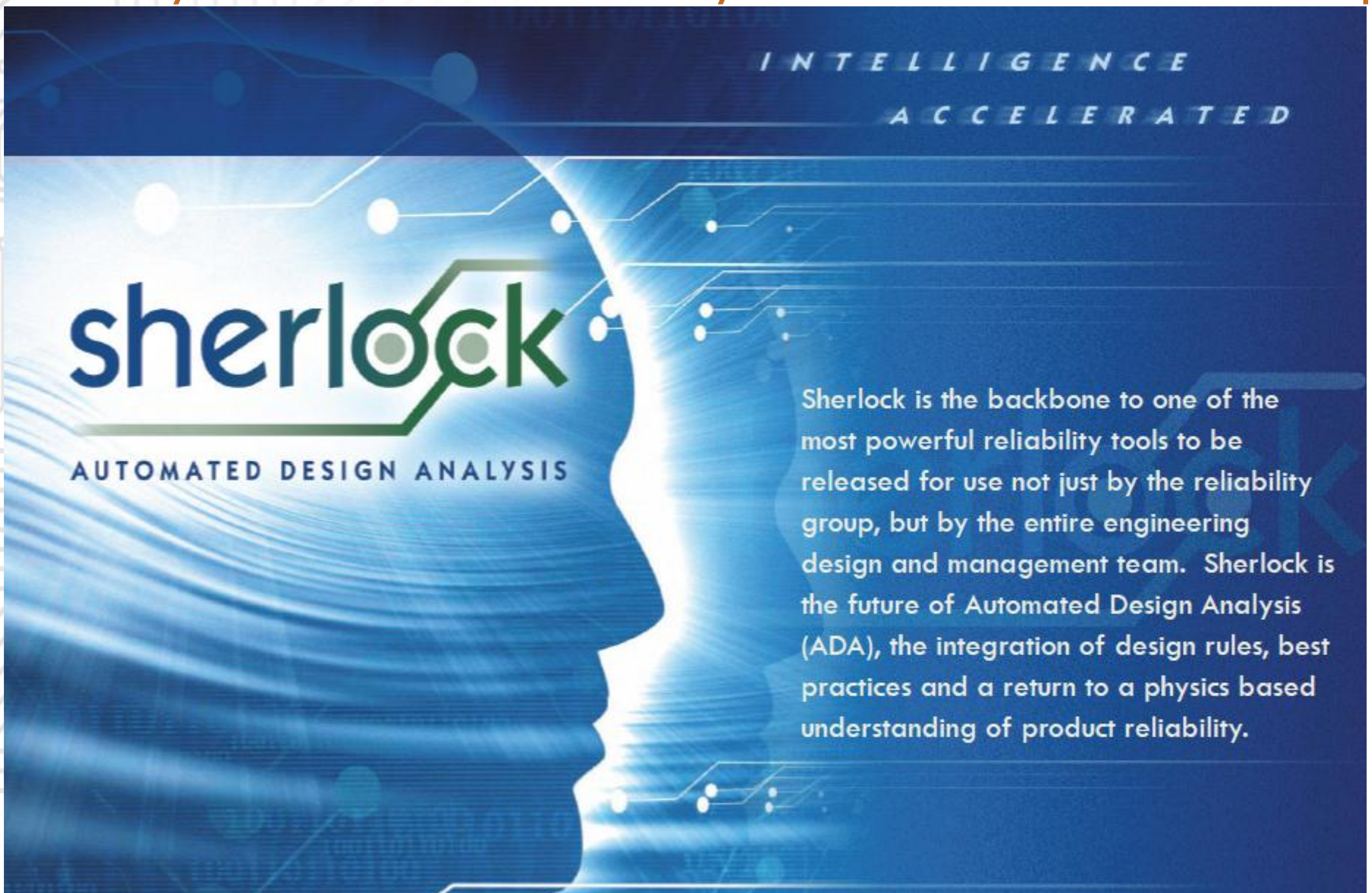
Sherlock ADA – A Durability Simulation Reliability Assurance CAE Tool Suite - the Physics of Failure App.

Sherlock is a Semi-Automated CAE App program for Physics of Failure durability simulations & reliability assessment of electronic equipment



It is not at the Iphone or Droid App store. But yes there is now a Physics of Failure Durability Simulation App

A New Revolutionary CAE Tool Suite for Electronic Design Analysis

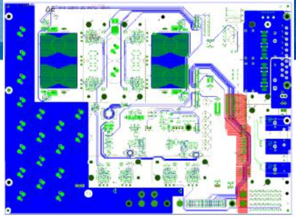
DfR Solutions

Sherlock Key Characteristics

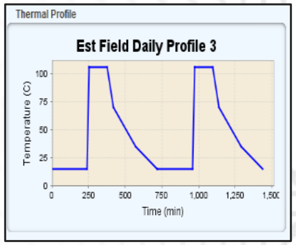
- **A Semi-Automated CAE knowledge based tool suite for:**
  - Performing Physics of Failure durability simulation and reliability assessments on electronic equipment.
  - Semi-Automated features simplifies model creation and analysis
  - Eliminates the long, complicated, model creation process and the need for a PhD level expert in PoF, FEA and CFD numerical modeling.
- **Designed to be used by non-CAE experts to quickly create and perform PoF durability & reliability analysis.**
  - The "Knowledge Based" features customized for E/E component and materials includes customizable, preloaded libraries of:
    - Component models
    - Material properties
    - Design templates
    - Analysis wizards
    - Environmental profiles for various applications.

The 4 Parts of a Sherlock Analysis

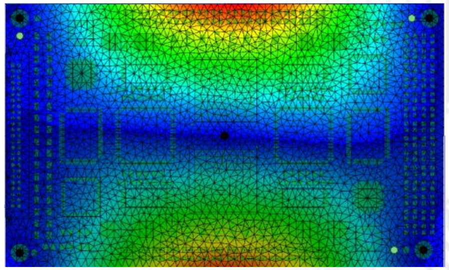
1) **Design Capture -** provides the detailed inputs to the modeling software and calculation tools



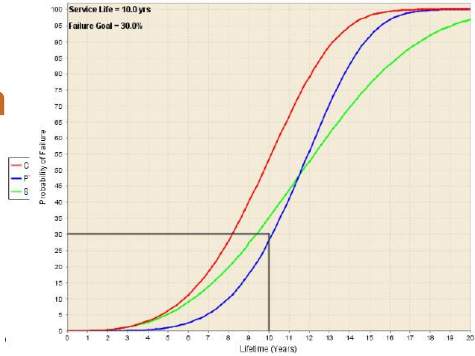
2) **Life-Cycle Characterization -** define the reliability/durability objectives and expected environmental & usage conditions (Field or Test) under which the device is required to operate



3) **Load Transformation –** automated calculations that translates and distributes the environmental and operational loads across a circuit board to the individual parts

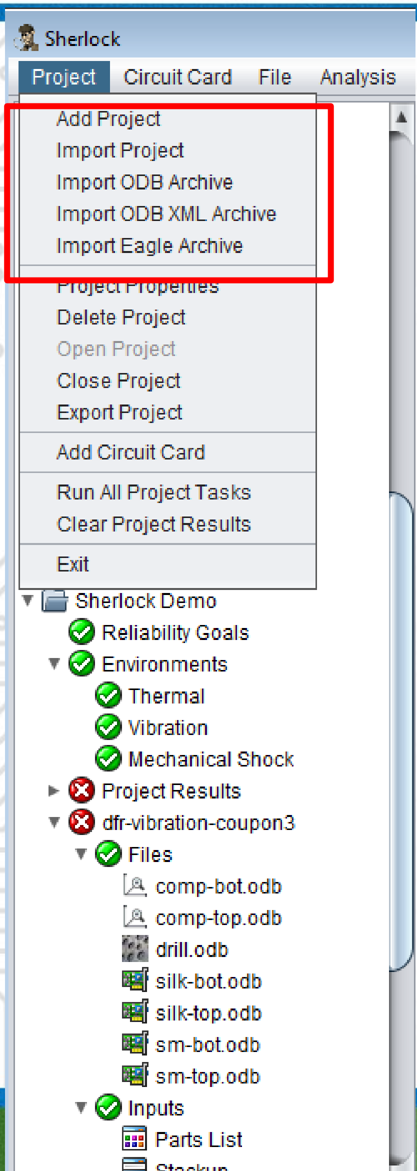


4) **PoF Durability Simulation/Reliability Analysis & Risk Assessment –** Performs a design and application specific durability simulation to calculates life expectations, reliability distributions & prioritizes risks by applying PoF algorithms to the virtual PCBA model created in steps 1, 2 & 3



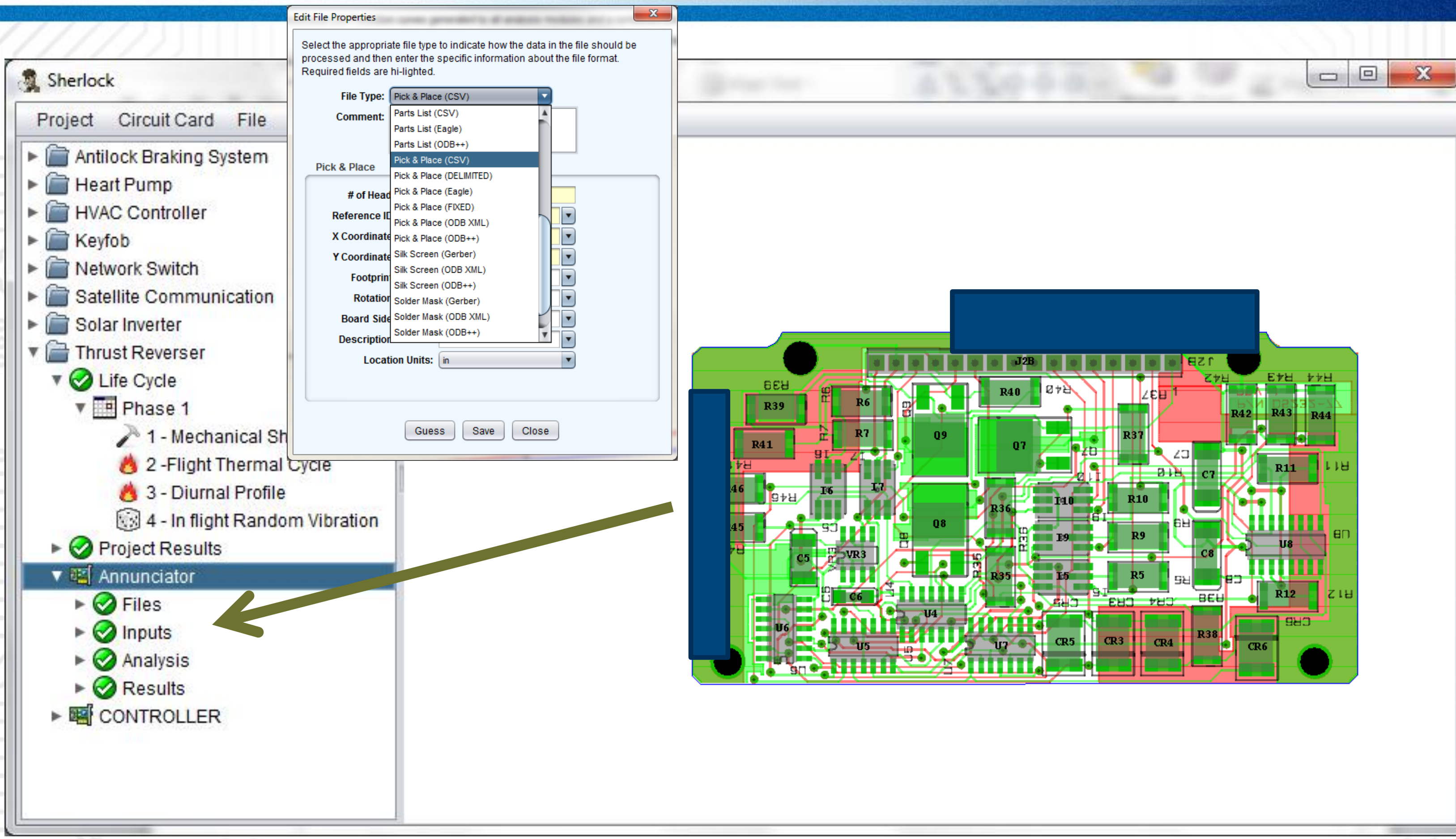
sherlock
AUTOMATED DESIGN ANALYSIS

1) Files Imported/Exported Via Intuitive Drop Down & Side Menus



- Import PCBA Layout,
  - Gerber, ODB++, Eagle & Valor CAD formats.
- Import BOM Parts List
  - Correlated supplier component part # and industry/JEDEC package styles to auto link component to Sherlock's libraries of component geometry and material property to the individual parts locations mounted on the PCB to create the computer models for the life assessment.
- Define PCB Laminate & Layers to Calculate Substrate Performance
- Automated FEA Mesh generation.

1) Design Capture



- Creates CAE virtual model from standard circuit board CAD/CAM design files (Gerber / ODB Format)

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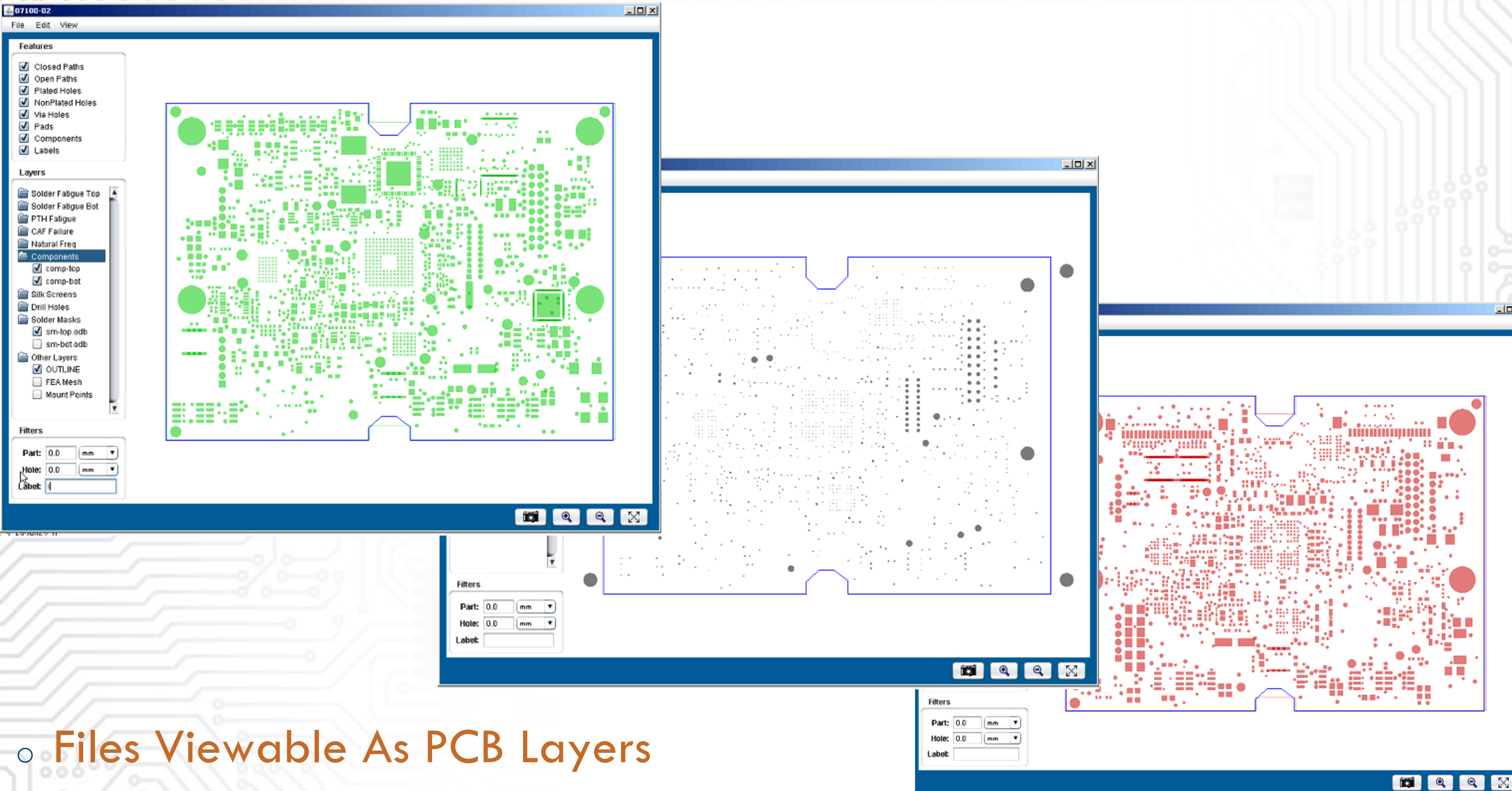
AUTOMATED DESIGN ANALYSIS

Step 1 – Design Capture – Graphic Verification



- Files Viewable As PCB Layers
- Provides Feedback To The User

1) Design Capture - Define PCB Laminate & Layers to Calculate

sherlock AUTOMATED DESIGN ANALYSIS

Calculates
- Thickness
- Density
- CTE x-y
- CTE z
- Modulus x-y
- Modulus z
- From the material properties of each layer
- Using the Built in Laminate Data Library

Stackup Properties

The following board properties are based on the currently defined board outline and the individual layer properties shown below:

Board Size: 193 x 115 mm [7.6 x 4.5 in]
Board Thickness: 1.8 mm [69.0 mil]
Board Density: 2.6833 g/cc
Copper Layers: 4

CTExy: 13.576 ppm/C
CTEz: 57.310 ppm/C
Exy: 37,972 MPa
Ez: 4,094 MPa

Stackup Layers

Double click any row to edit the properties for that layer **or** select one or more rows and press the **Edit Selected** button below to edit properties for a batch of layers. Press the **Generate Stackup Layers** button to replace all layers using a given PCB thickness and default layer properties.

Layer	Type	Material	Thickness	Density (g...	CTExy (pp...	CTEz (pp...	Exy (MPa)	Ez (MPa)
1	SIGNAL	COPPER (50%)	2.0 oz	5.2800	17.600	17.600	113,000	113,000
2	Laminate	FR408	19.3 mil	1.9000	13.000	65.000	23,442	3,450
3	POWER	COPPER (90%)	2.0 oz	8.1760	17.600	17.600	113,000	113,000
4	Laminate	F...						...450
5	POWER							...000
6	Laminate							...450
7	SIGNAL	C...						...000

Select All

Edit Selected Layers

Enter values for each layer property.

Laminate Layer Properties

Laminate Material: Isola | FR-4 | FR408
Laminate Thickness: 19.3 mil

250 HR
254
370 TURBO
370HR
370HR-CORE
DE104/104ML
DE104TS
DE104i

Save | Reset | Cancel

.6 x 4.5 in]

1) Design Capture PCB Material Property Database

1	ID	Company	Material	Product Name	CAF Resist	Dicy / Phenc	Halogen Fr	Filled?	IPC Slash Sheet (4101)	Tg	Tg tech	Td	T260 (m	T288 (mi	Density (g/	CTE, Z (p	CTE, Z (pd	CTE, XY (p	CTE, XY	CTE, XY	CTE, XY z
109	4	ITEQ	FR-4	IT180	No	Dicy	No	N/A	24	175	DSC	350	60	20	~1.9	50	250	~16	~16	~16	~16
110	4	ITEQ	FR-4	IT180CAF	Yes	Dicy	No	N/A	~126	175	DSC	350	60	20	~1.9	50	250	~16	~16	~16	~16
111	4	ITEQ	FR-4	IT588																	
112	4	ITEQ	FR-4	IT600																	
113	5	Elite Materials (EMC)	FR-4	EM-220(5), EM-22B (5)																	
114	5	Elite Materials (EMC)	FR-4	EM-280																	
115	5	Elite Materials (EMC)	FR-4	EM-285																	
116	5	Elite Materials (EMC)	FR-4	EM-320																	
117	5	Elite Materials (EMC)	FR-4	EM-825																	
118	5	Elite Materials (EMC)	FR-4	EM-827																	
119	6	Kingboard	CEM-1	KB-5150																	
120	6	Kingboard	CEM-3	KB-7150																	
121	6	Kingboard	FR-4	KB-6150/6150C																	
122	6	Kingboard	FR-4	KB-6150/6160																	
123	6	Kingboard	FR-4	KB-6160/6160C																	
124	6	Kingboard	FR-4	KB-6162																	
125	6	Kingboard	FR-4	KB-6164																	
126	6	Kingboard	FR-4	KB-6165																	
127	6	Kingboard	FR-4	KB-6167																	
128	7	Ventec	FR-4	VT-42																	
129	7	Ventec	FR-4	VT-42 (Anti-CAF)																	
130	7	Ventec	FR-4	VT-44																	
131	7	Ventec	FR-4	VT-45																	
132	7	Ventec	FR-4	VT-46																	
133	7	Ventec	FR-4	VT-47																	
134	7	Ventec	FR-4	VT-481																	
135	7	Ventec	GI (Polyimide)	VT-90																	
136	8	Grace	FR-4	FR4-97																	
137	8	Grace	FR-4	GA-150																	
138	8	Grace	FR-4	GA-150-LDP																	
139	8	Grace	FR-4	GA-170																	
140	8	Grace	FR-4	GA-170-D7																	
141	8	Grace	FR-4	GA-170-LDP																	
142	8	Grace	FR-4	GA-180																	
143	8	Grace	FR-4	GA-180-LDP																	
144	8	Grace	FR-4	GA-HF																	
145	8	Grace	FR-4	GA-HF-14																	
146	8	Grace	FR-4	GA-HF-14-LDP																	
147	8	Grace	FR-4	GA-HF-LDP																	
148	8	Grace	FR-4	GA-LD																	
149	8	Grace	FR-4	GA-LD-18																	
150	8	Grace	FR-4	UV Block FR4-97																	
151	8	Grace	FR-4	UV Block FR4-97 (CF)																	
152	8	Grace	FR-4	UV Block FR4-97 (CW)																	
153	8	Grace	GI (Polyimide)	2BIS																	
154	8	Grace	GI (Polyimide)	2BIS-LDP																	
155	9	Doosan	CEM-1	DS-7106																	
156	9	Doosan	CEM-1	DS-7106 (HC)																	
157	9	Doosan	CEM-1	DS-7106A																	
158	9	Doosan	CEM-3	DS-7209	No	N/A	No	N/A	~12, 81	135	DSC	~310	~5	0	~1.5	55	~350	24	28	~18	~18
159	9	Doosan	CEM-3	DS-7209 (HC)	No	N/A	No	N/A	~12, 81	130	TMA	~310	~5	0	~1.5	55	~350	24	28	~18	~18

laminate

Show desktop

- Laminate Library
  - Defines 48 Categories Of PCB Material Properties and Characteristics
  - Currently 319 Circuit Board Laminates Materials
  - From 20 Global Producers.
  - New Entries Can Added as New Laminate Materials are Introduced to the Market.

electronic components package and material databases

All IPC 4101 Laminates are not equal

ISOLA 410, ISOLA IS415 Nelco N4000-29 ISOLA 370HR

Stackup Properties (ISOLA 410)

Based on the currently defined board outline and the stacku

Board Size: 139 x 117 mm [5.5 x 4.6 in]
Board Thickness: 62.8 mil
CTExy: 12.227 ppm/C
CTEz: 52.320 ppm/C
Exy: 48,410 MPa
Ez: 4,658 MPa

Stackup Layers

Double click any row to edit the properties for that layer or s
button to replace all layers using a given PCB thickness an

Layer #	Type	Thickness	Material
1	SIGNAL	2.0 oz	COPPER (50%)
2	Laminate	10.0 mil	IS410
3	SIGNAL	2.0 oz	COPPER (50%)
4	Laminate	8.0 mil	IS410
5	SIGNAL	2.0 oz	COPPER (50%)
6	Laminate	10.0 mil	IS410
7	SIGNAL	2.0 oz	COPPER (50%)
8	Laminate	8.0 mil	IS410
9	SIGNAL	2.0 oz	COPPER (50%)
10	Laminate	10.0 mil	IS410
11	SIGNAL	2.0 oz	COPPER (50%)

Stackup Properties (ISOLA IS415)

Based on the currently defined board outline and the stack

Board Size: 139 x 117 mm [5.5 x 4.6 in]
Board Thickness: 62.8 mil
CTExy: 13.977 ppm/C
CTEz: 52.320 ppm/C
Exy: 50,417 MPa
Ez: 4,658 MPa

Stackup Layers

Double click any row to edit the properties for that layer or s
button to replace all layers using a given PCB thickness ar

Layer #	Type	Thickness	Material
1	SIGNAL	2.0 oz	COPPER (50%)
2	Laminate	10.0 mil	IS415
3	SIGNAL	2.0 oz	COPPER (50%)
4	Laminate	8.0 mil	IS415
5	SIGNAL	2.0 oz	COPPER (50%)
6	Laminate	10.0 mil	IS415
7	SIGNAL	2.0 oz	COPPER (50%)
8	Laminate	8.0 mil	IS415
9	SIGNAL	2.0 oz	COPPER (50%)
10	Laminate	10.0 mil	IS415
11	SIGNAL	2.0 oz	COPPER (50%)

Stackup Properties (Nelco N4000-29)

Based on the currently defined board outline and the stackup lay

Board Size: 139 x 117 mm [5.5 x 4.6 in]
Board Thickness: 62.8 mil
CTExy: 17.156 ppm/C
CTEz: 44.995 ppm/C
Exy: 48,410 MPa
Ez: 4,658 MPa

Stackup Layers

Double click any row to edit the properties for that layer or select
button to replace all layers using a given PCB thickness and defa

Layer #	Type	Thickness	Material
1	SIGNAL	2.0 oz	COPPER (50%)
2	Laminate	10.0 mil	N4000-29
3	SIGNAL	2.0 oz	COPPER (50%)
4	Laminate	8.0 mil	N4000-29
5	SIGNAL	2.0 oz	COPPER (50%)
6	Laminate	10.0 mil	N4000-29
7	SIGNAL	2.0 oz	COPPER (50%)
8	Laminate	8.0 mil	N4000-29
9	SIGNAL	2.0 oz	COPPER (50%)
10	Laminate	10.0 mil	N4000-29
11	SIGNAL	2.0 oz	COPPER (50%)

Stackup Properties (ISOLA 370HR)

Based on the currently defined board outline and the stacku

Board Size: 139 x 117 mm [5.5 x 4.6 in]
Board Thickness: 62.8 mil
CTExy: 13.977 ppm/C
CTEz: 37.670 ppm/C
Exy: 49,407 MPa
Ez: 4,658 MPa

Stackup Layers

Double click any row to edit the properties for that layer or s
button to replace all layers using a given PCB thickness an

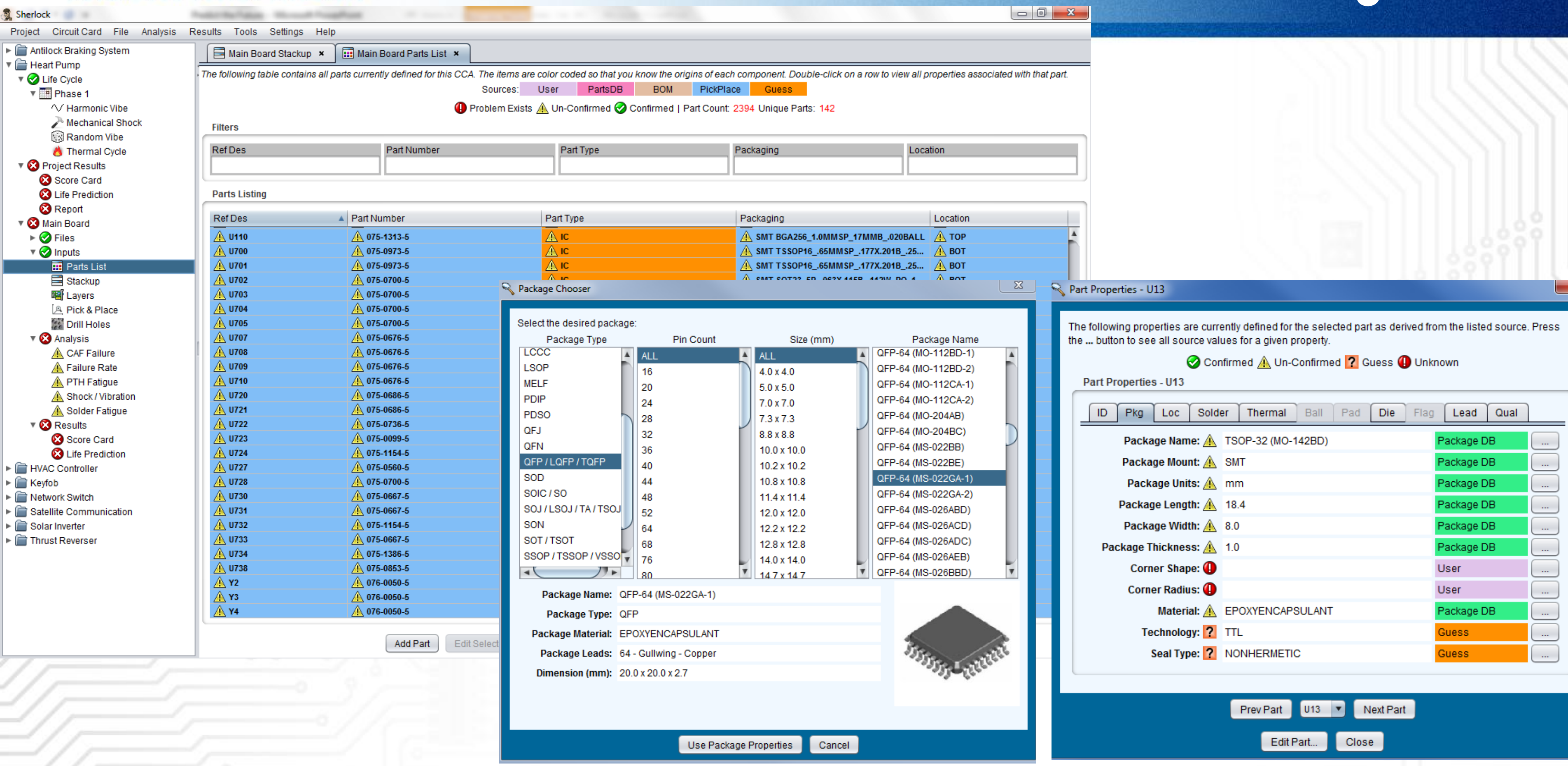
Layer #	Type	Thickness	Material
1	SIGNAL	2.0 oz	COPPER (50%)
2	Laminate	10.0 mil	370HR
3	SIGNAL	2.0 oz	COPPER (50%)
4	Laminate	8.0 mil	370HR
5	SIGNAL	2.0 oz	COPPER (50%)
6	Laminate	10.0 mil	370HR
7	SIGNAL	2.0 oz	COPPER (50%)
8	Laminate	8.0 mil	370HR
9	SIGNAL	2.0 oz	COPPER (50%)
10	Laminate	10.0 mil	370HR
11	SIGNAL	2.0 oz	COPPER (50%)

Plated Through Hole Fatigue Life Projections

CTEz Laminate	Delta T	Laminate	CTEz PCB Stack	Calculated Results - Cycle to Failure at Life Point: 0.10%	1%	10%	50%	63%	Test to Field Correlation
	Field								
45	25 - 75	ISOLA 370HR:	37.67	305,339,412	543,592,804	978,133,260	1,566,516,307	1,714,362,676	144,021
55	25 - 75	NELCO N4000-29:	44.995	522,431	930,079	1,673,571	2,680,286	2,933,249	910
65	25 - 75	ISOLA 410:	52.32	27,707	49,327	88,759	142,150	155,566	104
65	25 - 75	ISOLA 415:	52.32	27,707	49,327	88,759	142,150	155,566	104
	Test								
45	-45 - +85	ISOLA 370HR:	37.67	2,120	3,774	6,792	10,877	11,904	
55	-45 - +85	NELCO N4000-29:	44.995	574	1,022	1,839	2,945	3,223	
65	-45 - +85	ISOLA 410:	52.35	266	473	852	1,364	1,493	
65	-45 - +85	ISOLA 415:	52.35	266	473	852	1,364	1,493	

sherlock
AUTOMATED DESIGN ANALYSIS

1) Parts ID & Management



- Minimizes data entry through intelligent parsing and embedded electronic components package and material databases

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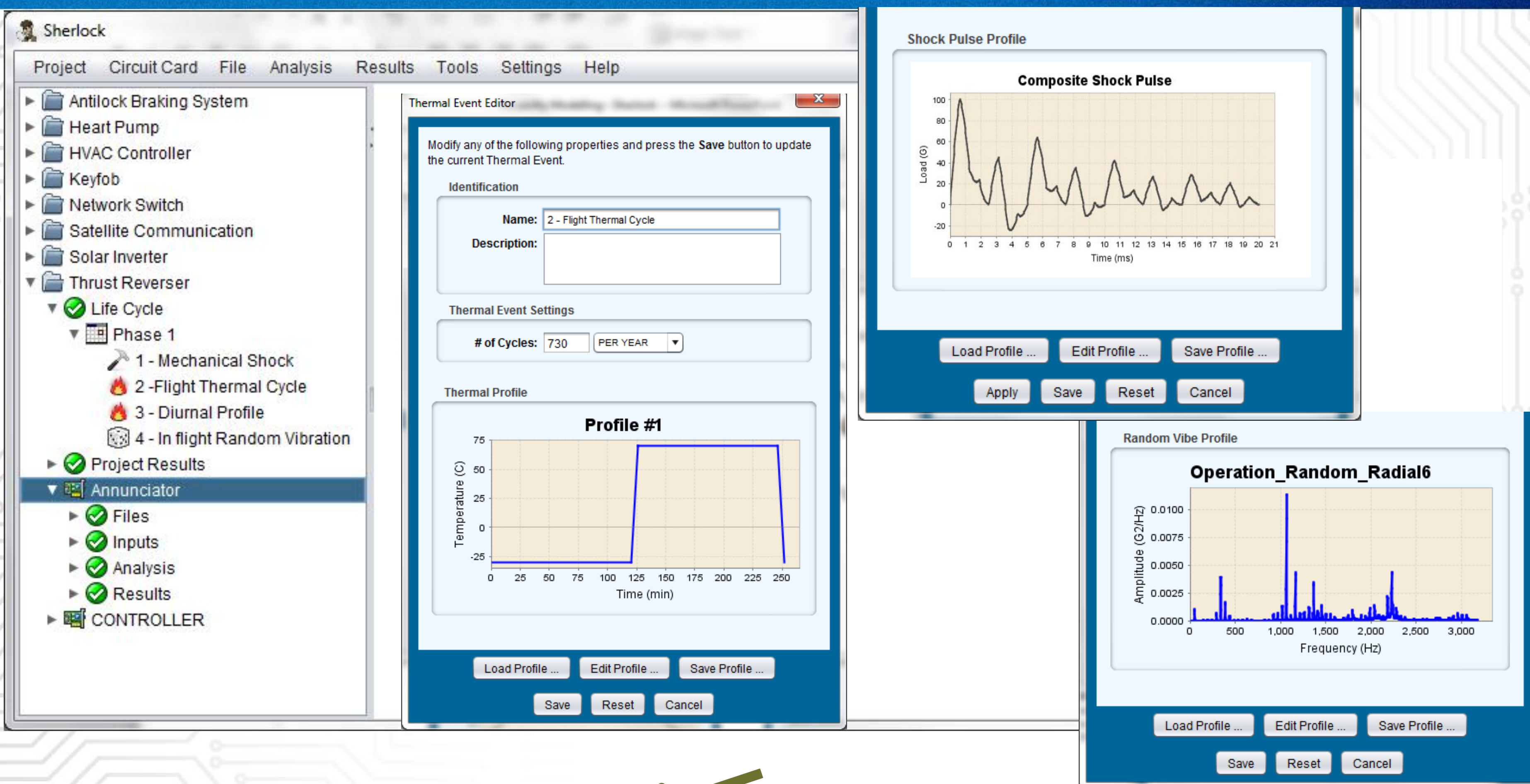
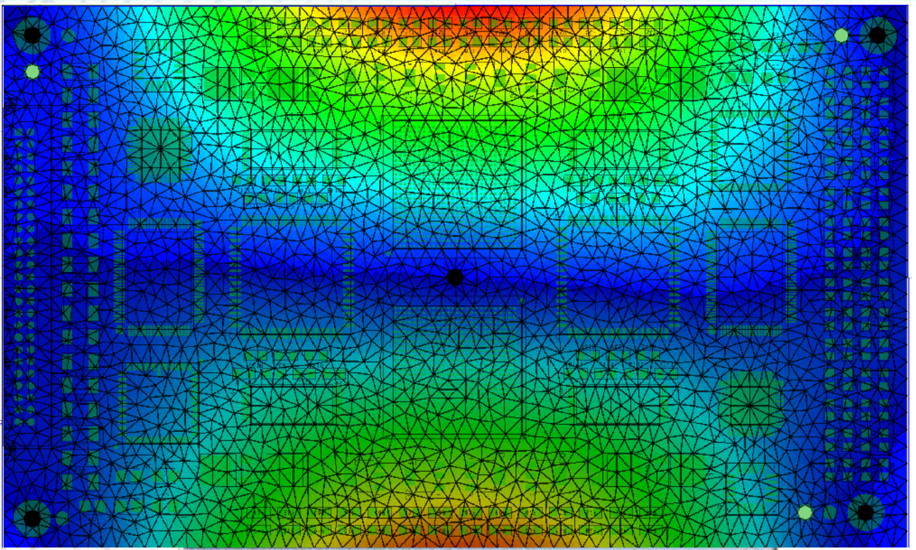
2) Define Environments



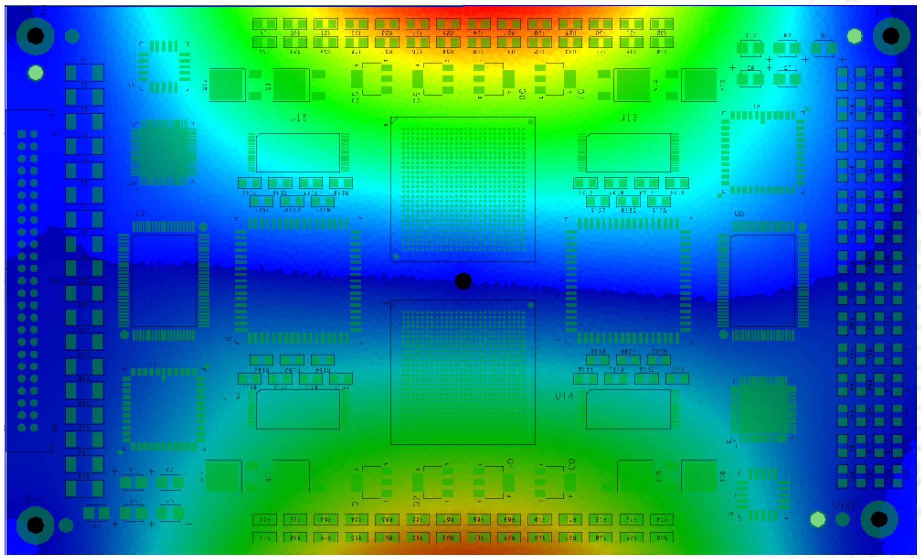
- Handles very complex environmental or test stress profiles

3) Load Transformation

Automated FEA Mesh Creation for Calculating Stress Distribution Across the PCBA & to Each Component

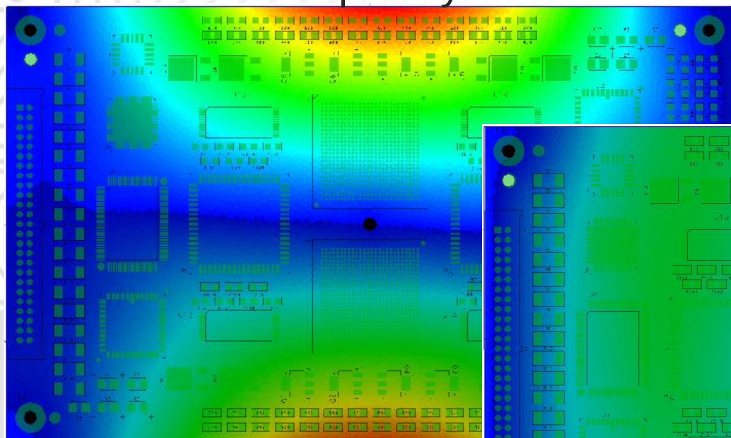


- Automatic Mesh Heneration
  - Days of FEA modeling and calculations, executed in minutes
  - Without a FEA modeling expert.

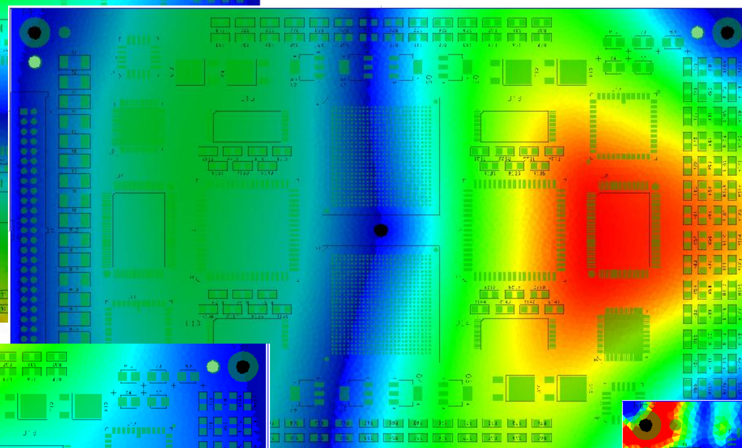


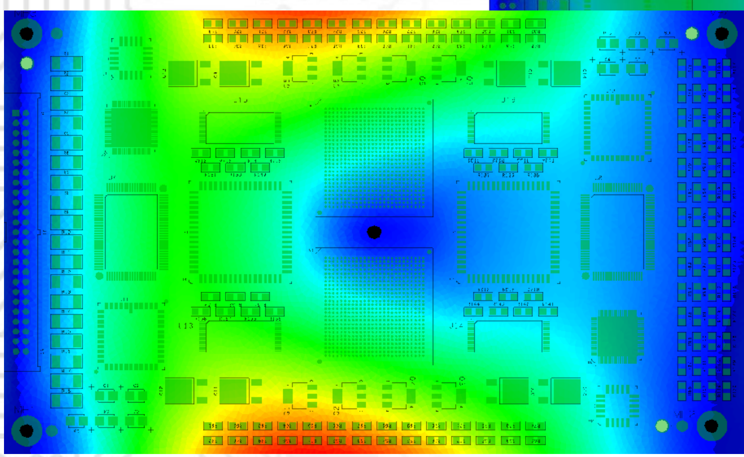
3) Load Transformation
- Automated FEA for Dynamic Vibration/Shock Modal Analysis

1st Natural Frequency



2nd Natural Frequency

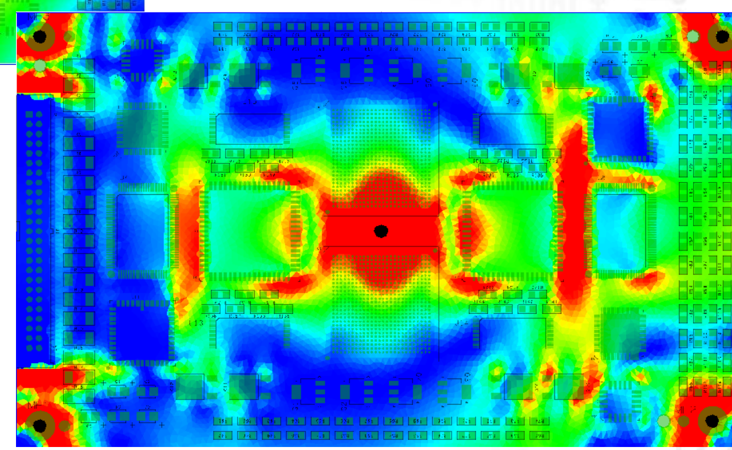




3rd Natural Frequency

- Harmonic Vibe
  - Multiple Harmonics
- Random Vibe
- Shock

Calculates PCB Stress Distribution for use in Fatigue / Fracture Analysis

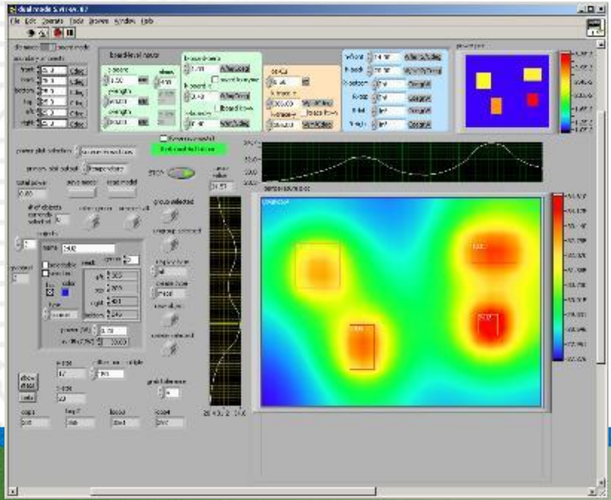


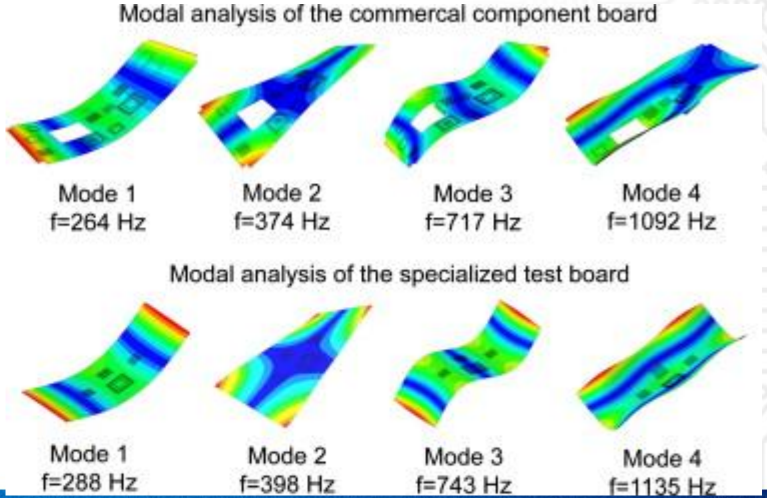
- Embedded Abacus compatible FEA engine
- Can export files and results to either Abacus or Calculix

PoF Durability Simulations & Reliability Assessments

- Finite Element Analysis (FEA) and Computational Fluid Dynamic (CFD) CAE program are regularly used to identify the stress conditions that products and systems will experience under various usage conditions.
  - A standard practice in mechanical and structural products.

- Combining CAE Stress Analysis Tools with Failure Mechanism Models enables the creation of:
  "Virtual Durability Simulations" that can Calculate Stress Driven Reliability Perfromance Over Time .
  - PoF Research has enable the migration of this technology to the materials and micro structures of E/E components and circuit board assemblies.

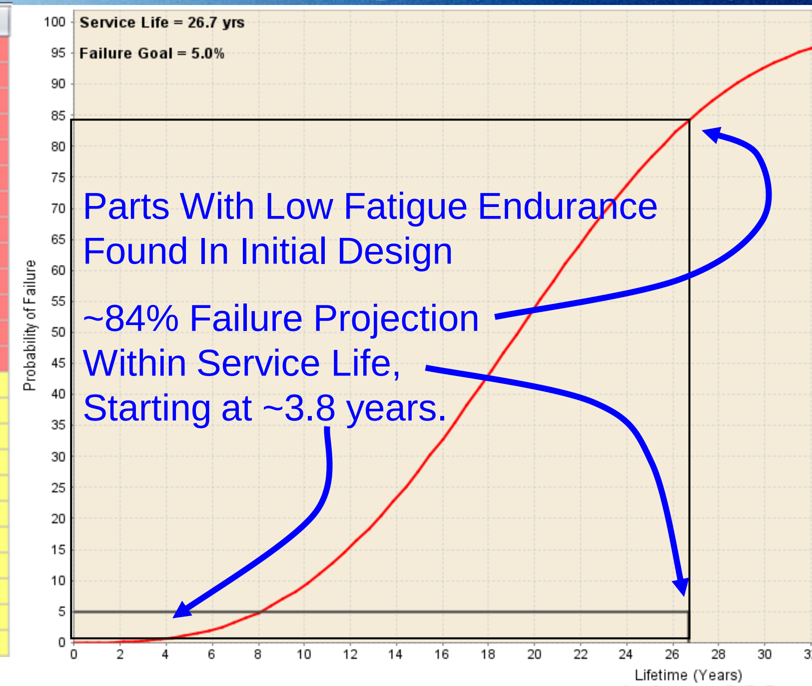




sherlock
AUTOMATED DESIGN ANALYSIS

4) PoF Durability/Reliability
Risk Assessment
Thermal Cycling Solder Fatigue

RefDes	Package	Part Type	Part Number	Solder	Temp Rise	Cycles to Fail ▲	TTF (yrs)	Score
R355	2512	RESISTOR	SCD	63Sn37Pb	0.0	90,605	93.89	1.9
R339	2512	RESISTOR	SCD	63Sn37Pb	0.0	90,605	93.89	1.9
R347	2512	RESISTOR	SCD	63Sn37Pb	0.0	90,605	93.89	1.9
R435	2512	RESISTOR	SCD	63Sn37Pb	0.0	90,605	93.89	1.9
R363	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6
R364	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6
R6	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6
R126	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6
R123	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6
R337	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6
R338	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6
R464	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6
R461	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6
R19	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9
R15	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9
R304	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9
R305	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9
R421	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9
R422	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9
R424	1210	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9
R413	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9
R419	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9
R262	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9
R265	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9



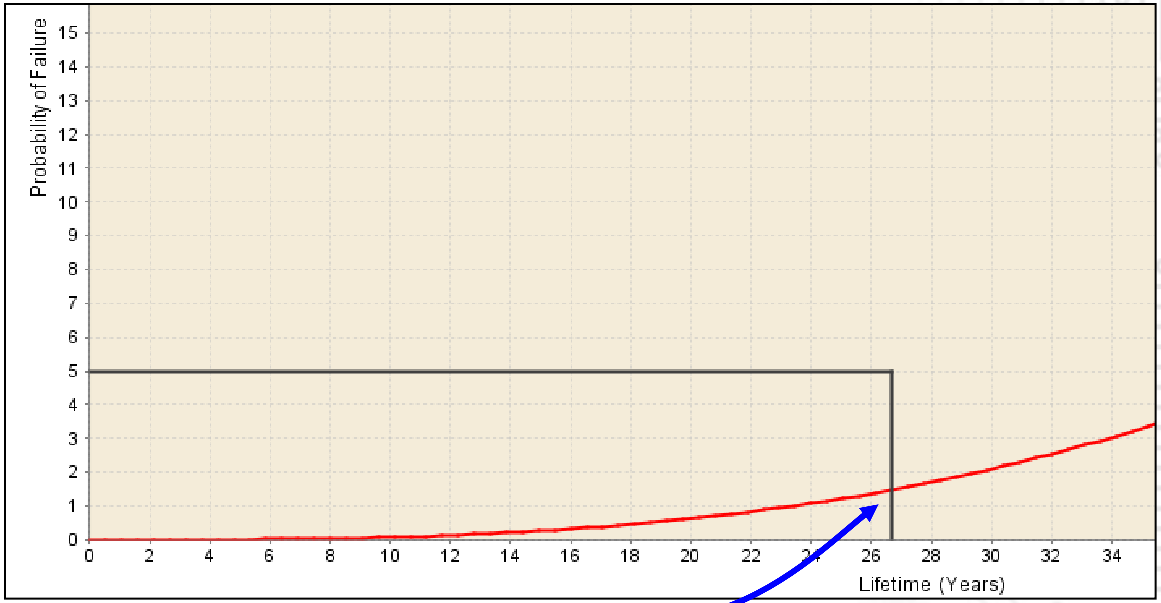
- N50 fatigue life calculated for each of 705 components (68 unique part types), with risk color coding, prioritized risk listing and life distribution plots based on known part type failure distributions (analysis performed in <30 seconds) after model created.
  - Red - Significant portion of failure distribution within service life or test duration.
  - Yellow - lesser portion of failure distribution within service life or test duration.
  - Green - Failure distribution well beyond service life or test duration.

(Note: N50 life - # of thermal cycles where fatigue of 50% of the parts are expected to fail)

4) PoF Durability/Reliability
Risk Assessment Enables Virtual Reliability Growth

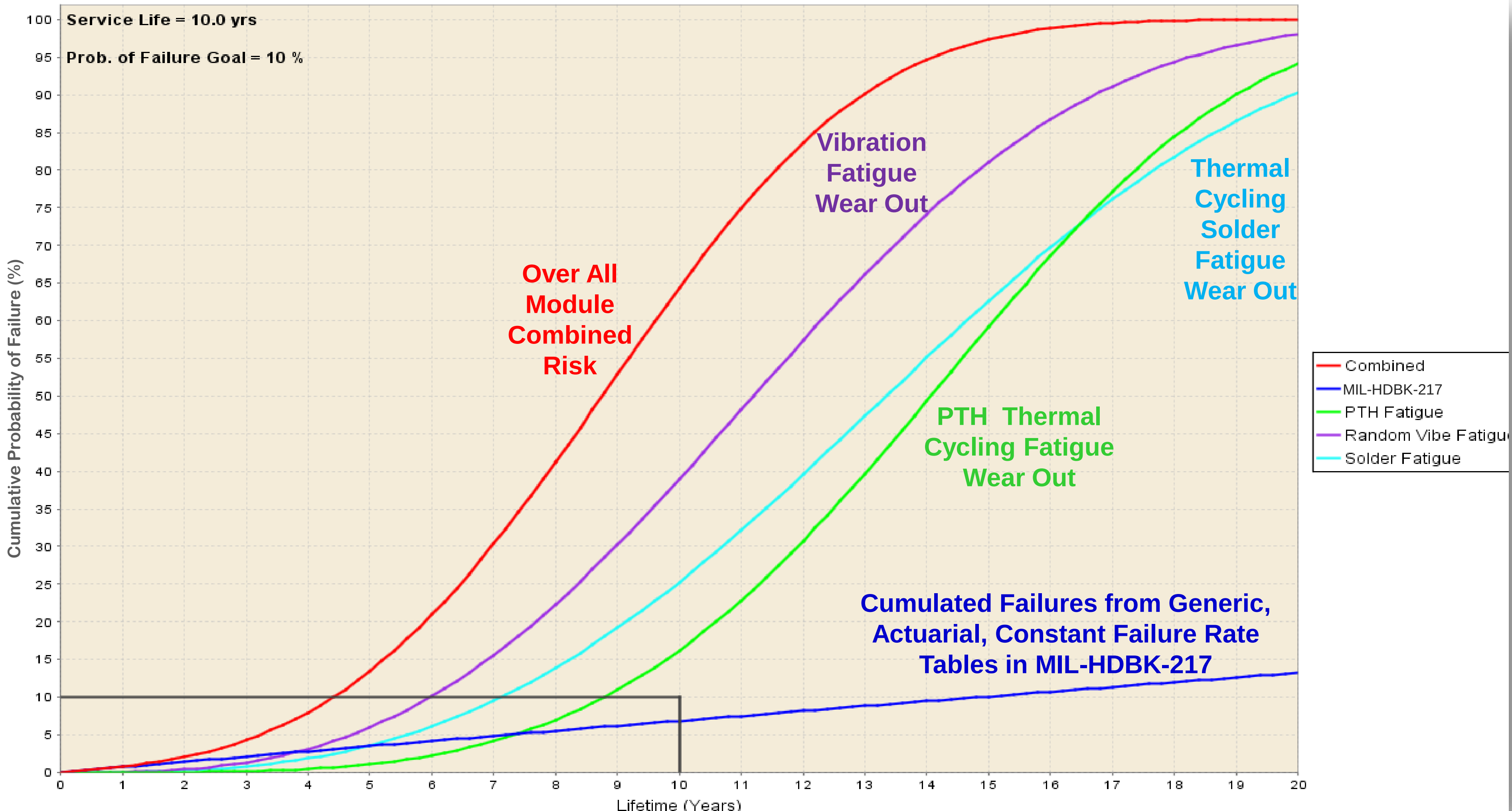
- Identification of specific reliability/durability limits or deficiencies, of specific parts in, specific applications, enables the design to be revised with more suitable/robust parts that will meet reliability/durability objectives.

- Reliability plot of the same project after fatigue susceptible parts replaced with electrically equivalent parts in component package suitable for the application.



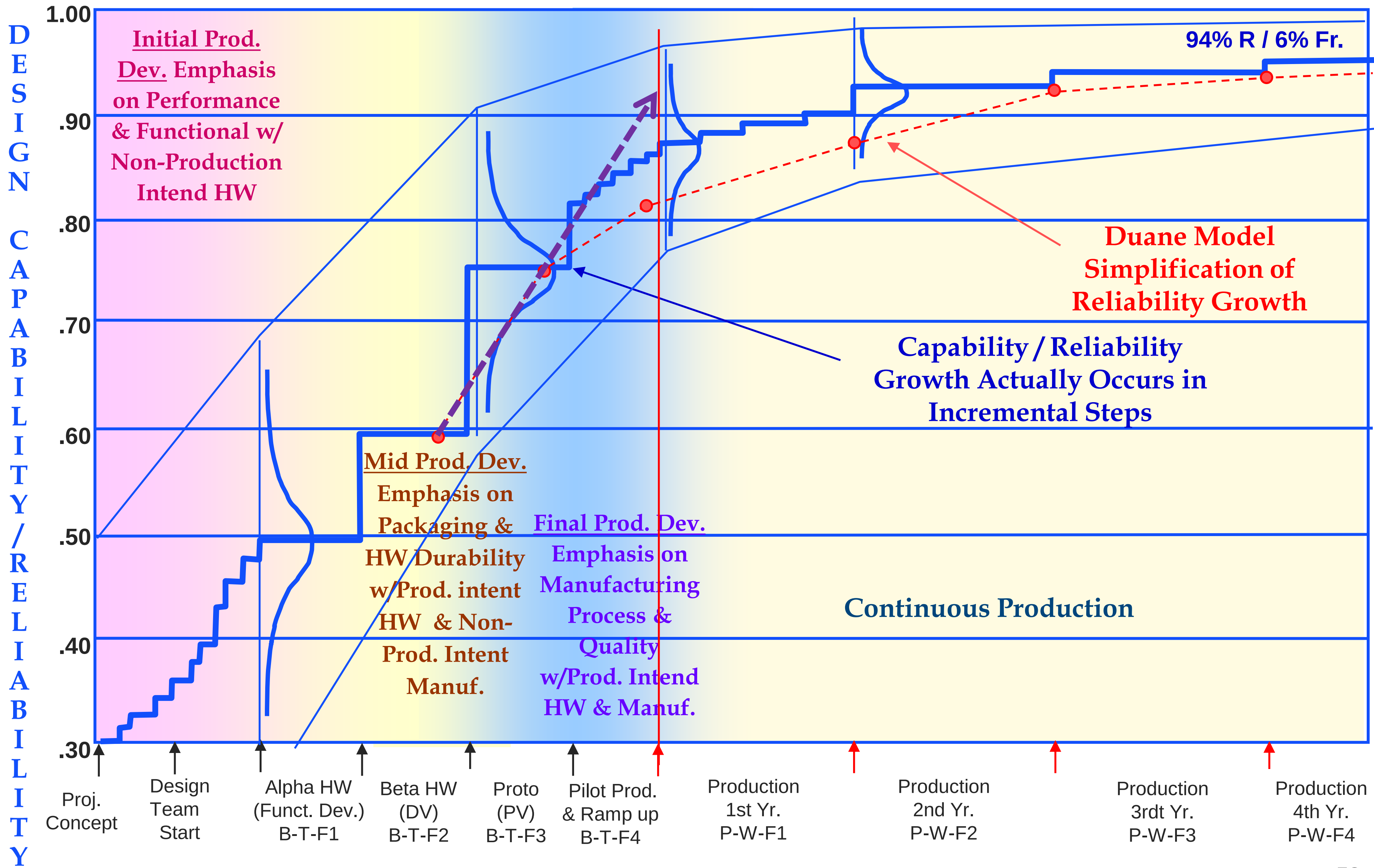
- Life time failure risks reduced from ~84% to ~1.5%

PoF Durability/Reliability of Various Failure Mechanism

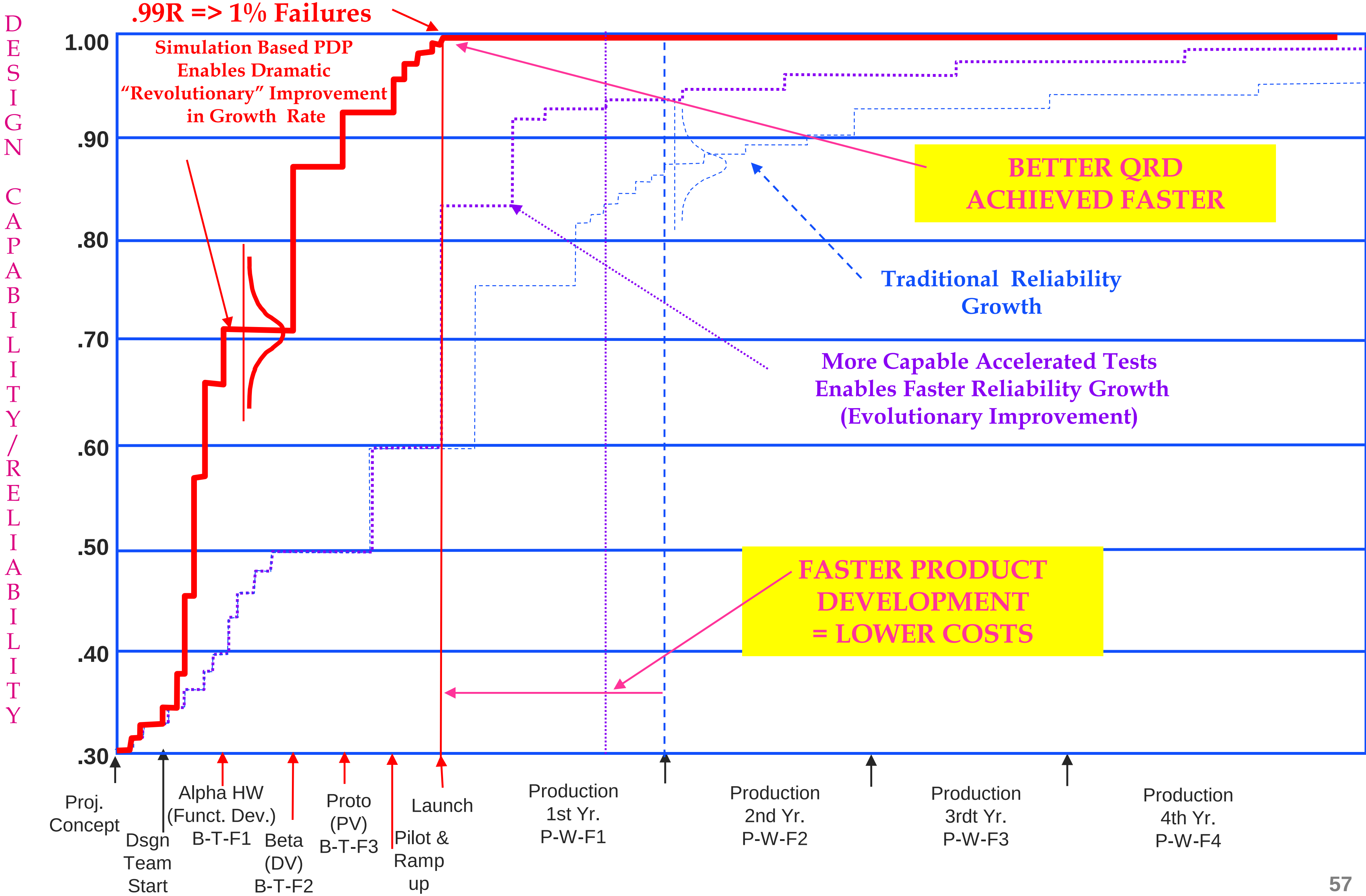


- Detailed Design and Application Specific PoF Life Curves are Far More Useful that a simple single point MTBF (Mean Time Between Failure) estimate.

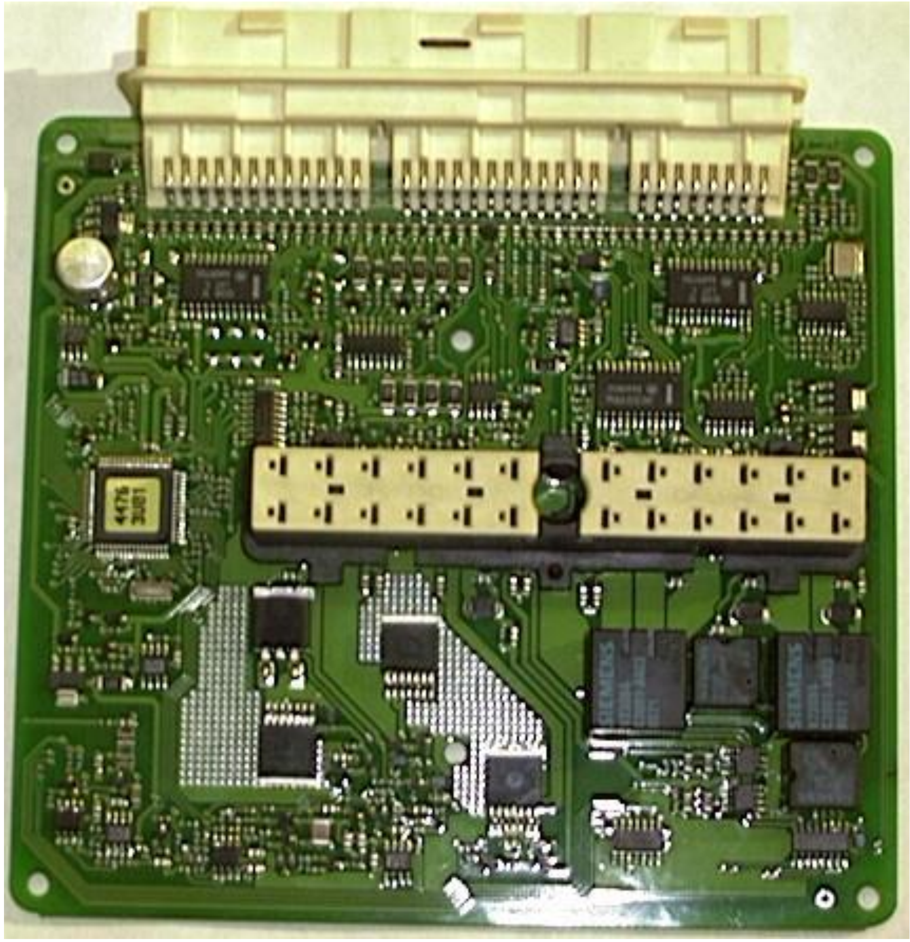
Reliability/Capability Growth with Traditional D-B-T-F Product Development Processes Takes Years to Achieve Maturity



The Efficiency Improvements of a PoF Knowledge & Analysis Based Product Development Process



Accelerating Testing Challenges E/E Modules are Complex Assemblies of Hundred of Parts and Scores of Components Types



- Combined T&V Overstress Test Profiles that Accelerate Time to Failure Testing For ***Actual Failure Mechanism*** Have Been Demonstrated on Test Coupons for Various Component Types.
  - Accelerated Test Profiles that **Produce *"Foolish Failures" Have Also Been Experienced***.
- **Developing Practical Application of Accelerated Testing for "VALIDATION" is a Challenge.**
  - ***Hard to Develop an "Optimized" Overstress Profile for REAL LIFE COMPLEX E/E Modules with MANY DIFFERENT COMPONENT TYPES***
  - ***An Overstress profile appropriated for one component on a circuit board may be excessive for the next part.***
- ***The "Weakest Links" in EACH NEW DESIGN needs to be identified and used as the pace setter in an accelerated test.***

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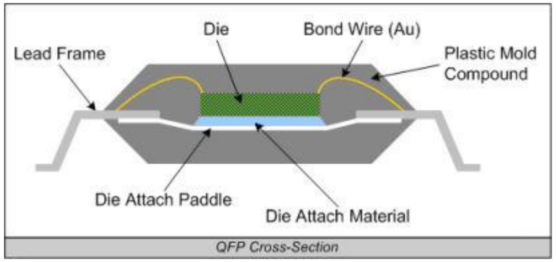
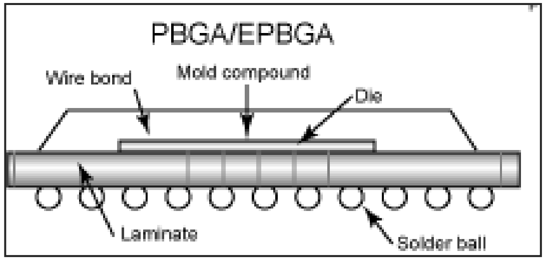
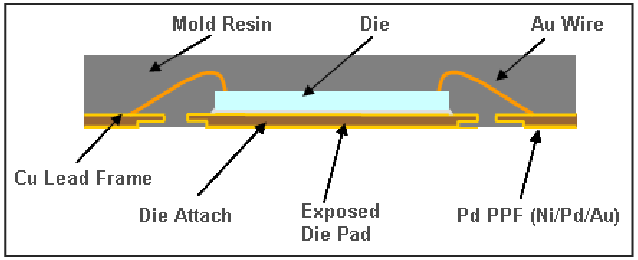
Comparing Thermal Cycling Durability - IC Packages







Gull Wing Leaded QFPs
TTCL: >10,000

Laminated BGAs:
TTCL: 3,000 to 8,000

FNL CSP:
TTCL: 1,000 to 3,000

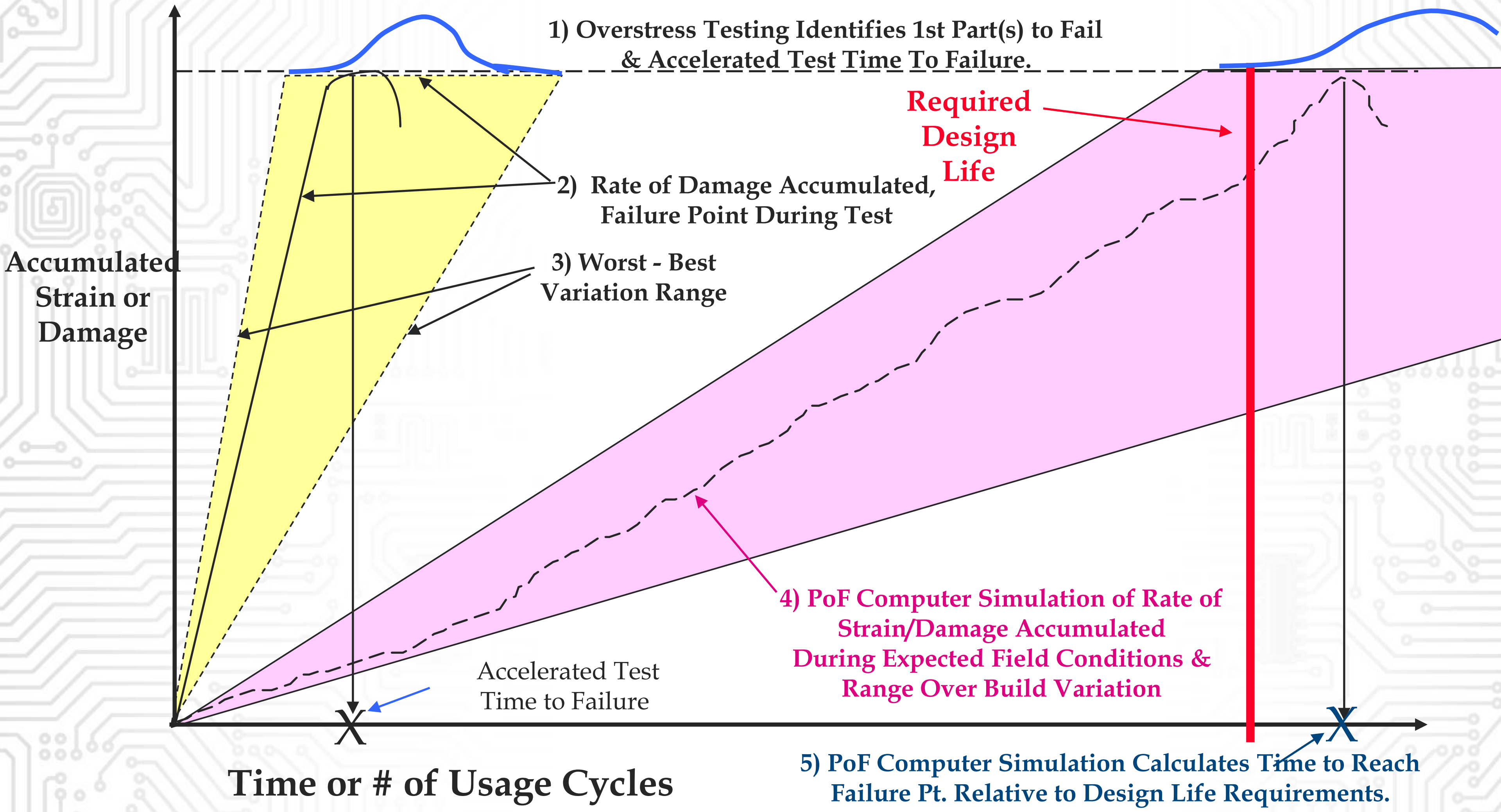
Package Type	Typical Thermal Cycles to Failure (-40C to 125C)
QFP	>10,000
BGA	3,000 – 8,000
QFN	1,000-3,000

**TTCL = Typical Thermal Cycle Life During -40° to +125°C Testing*

- Without a flexible terminal lead to absorb thermal Expansion/Contract Stresses, Flat No Lead - Chip Scale IC Packages (FNL-CSP) experience a high amount of thermal expansion stress in their low profile under body solder joints, which accelerate solder fatigue failure.
- Solder Attachment Cycles to Failure
  - Order of magnitude (10X) reduction from QFPs
  - 3X reduction from BGAs

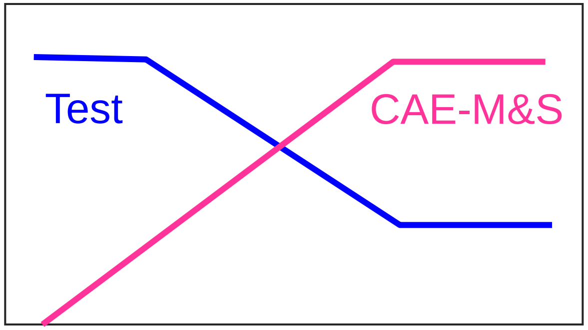
DfR Solutions

PoF SAT - Simulation Aided Testing – Accelerated Life Test to Field Correlation



Motivation for Conversion to an Upfront Analysis Based Product Development Process.

- Use Computer Simulations of "the" Design,
  - Early During the CAD Stage,
  - To Identify and Resolve Application Specific Design & Packaging Circuit, EMC, Thermal & Structural Integrity . . . etc.

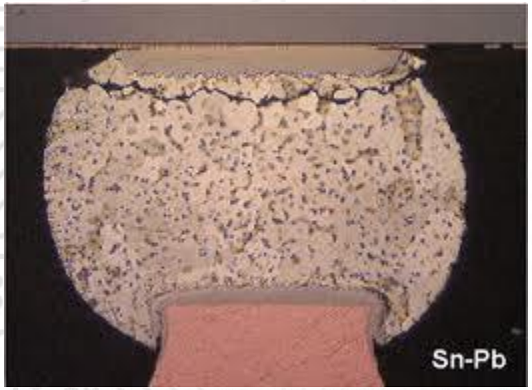


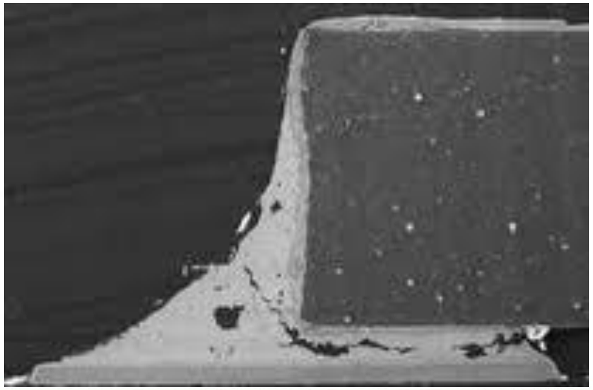
- Real, value added activities to create capable designs, faster, at lower costs via:
  - Reducing prototype part build time & costs.
  - Reducing physical testing time & costs (up to 50% reduction).
  - Reducing potential for schedule & costs over runs due to late problem discovery.
  - Reducing effort & costs of test incident investigation, reporting & resolution.

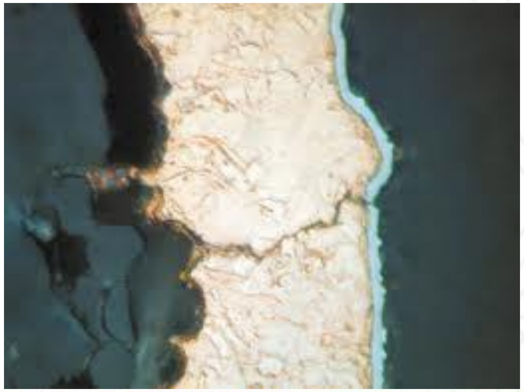
DfR Solutions

PoF Durability/Reliability Capabilities

- Thermal Cycling Solder Attachment Fatigue Life
- Thermal Cycling PCB PTH Via Barrel Cracking Fatigue Life
- Vibration Solder Fatigue Life
- Shock Solder Fracture Life
- Conductive Anodic Filament Risk Assessment
- Stress load in Fracture Risk Assessments
  - ICT Test Stress Analysis
  - Compliant Pin Connector Insertion
- ISO-26262 Functional Safety FMEA and Metric Generation







PCB Plated Through Hole Via Barrel Cracking Fatigue Life Based On IPC TR-579

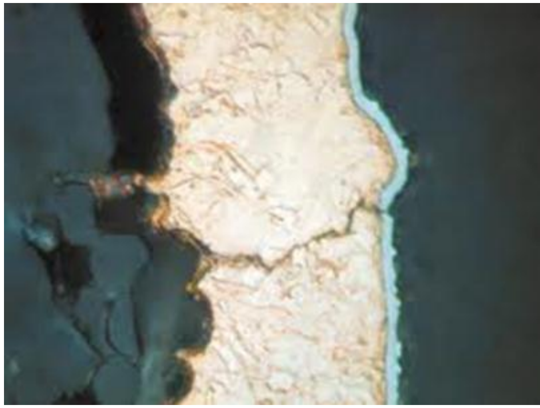
- Determine applied stress applied (σ)

$$\sigma = \frac{(\alpha_E - \alpha_{Cu})\Delta T A_E E_E E_{Cu}}{A_E E_E + A_{Cu} E_{Cu}}, \text{for } \sigma \le S_y$$

$$\sigma = \frac{\left[(\alpha_E - \alpha_{Cu})\Delta T + S_y \frac{E_{Cu} - E'_{Cu}}{E_{Cu} E'_{Cu}}\right] A_E E_E E'_{Cu}}{A_E E_E + A_{Cu} E'_{Cu}}, \text{for } \sigma > S_y$$

$$A_E = \frac{\pi}{4}\left[(h + d)^2 - d^2\right]$$

$$A_{Cu} = \frac{\pi}{4}\left[d^2 - (d - 2t)^2\right]$$



- Determine strain range (Δε)

$$\Delta\varepsilon = \frac{\sigma}{E_{Cu}}, \text{ for } \sigma < S_y$$

$$\Delta\varepsilon = \frac{S_y}{E_{Cu}} + \frac{\sigma - S_y}{E'_{Cu}}, \text{ for } \sigma > S_y$$

- Apply calibration constants
  - Strain distribution factor, K_d(2.5 –5.0)
  - PTH & Cu quality factor K_Q(0 –10)

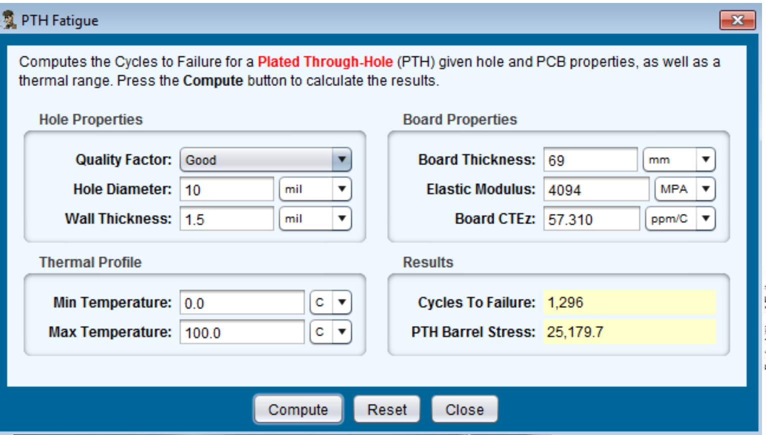
$$\Delta\varepsilon_{eff} = \Delta\varepsilon\left(K_d \frac{10}{K_Q}\right)$$

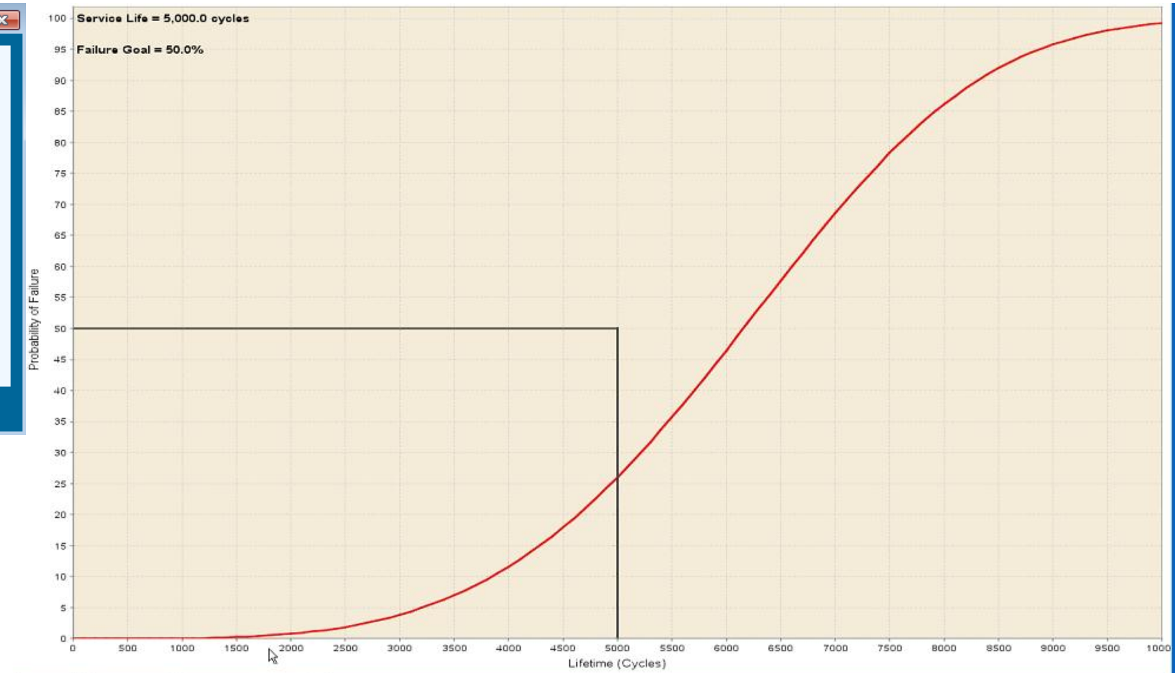
- Iteratively calculate cycles-to-failure (N_{f50})

$$N_f^{-0.6} D_f^{0.75} + 0.9\frac{S_u}{E}\left[\frac{\exp(D_f)}{0.36}\right]^{0.1785\log\frac{10^5}{N_f}} - \Delta\varepsilon = 0$$

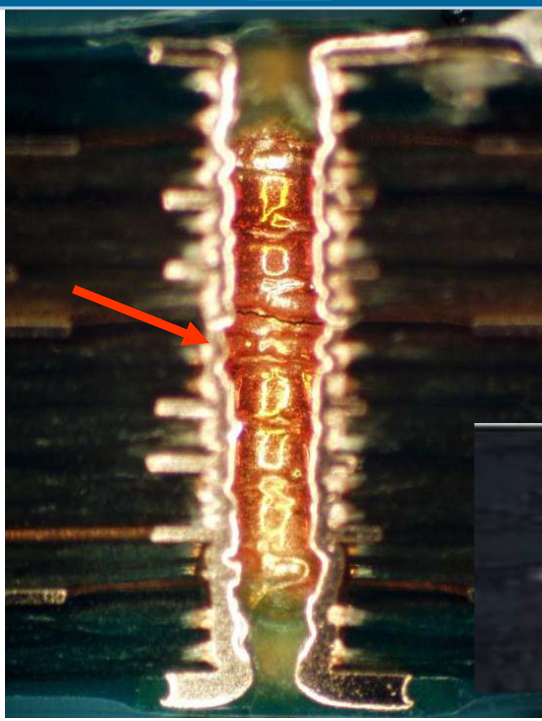
DfR Solutions

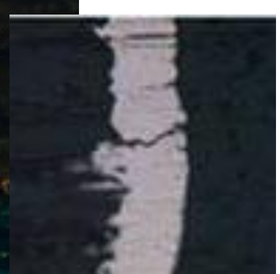
PoF Durability/Reliability Risk Assessments
PCB Plated Through Hole Via Fatigue Analysis





When a PCB experiences thermal cycling the expansion/contraction in the z-direction is much higher than that in the x-y plane. The glass fibers constrain the board in the x-y plane but not through the thickness. As a result, a great deal of stress can be built up in the copper via barrels resulting in eventual cracking near the center of the barrel as shown in the cross section photos below.





DfR Solutions

New Sherlock DFMEA Module
ISO-26262 Function Safety

Design Failure Mode and Effects Analysis (DFMEA)
Circuit Card Details

Project:	**DFMEA Example**	**Description:**	This project was created to show how Sherlock can be used to maintain and generate DFMEA spreadsheets.
Circuit Card:	**Mother Board**		
Prepared By:		**Revision:**	

SubCircuit:	**1.5V Regulator and Filters**	**Min SEV:**	1	**Min RPN:**	4
		Max SEV:	8	**Max RPN:**	32

Component: C1,C3,C5-C6 (Filters)

Failure Mode	Potential Effect	SEV	Potential Cause	OCC	Prevention	Detection	DET	RPN	Actions Taken
DC Leakage, EPR < 50K	Minimal effect	1	Cracked dielectric layers	2	Note 1	Note 2	2	4	
Open	Minimal effect	2	Open trace or solder joint	2	Note 1	Note 2	2	8	
Short to circuit ground	Controller INOP	8	Crack propagation through part	2	Note 1	Note 2	2	32	
	Min Value:	**1**		**2**			**2**	**4**	
	Max Value:	**8**		**2**			**2**	**32**	

Sheet1 / Sheet2 / Sheet3

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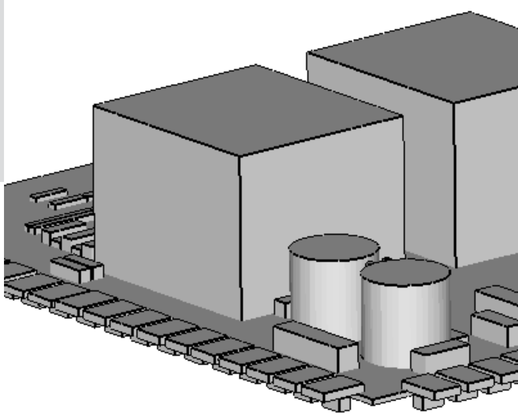
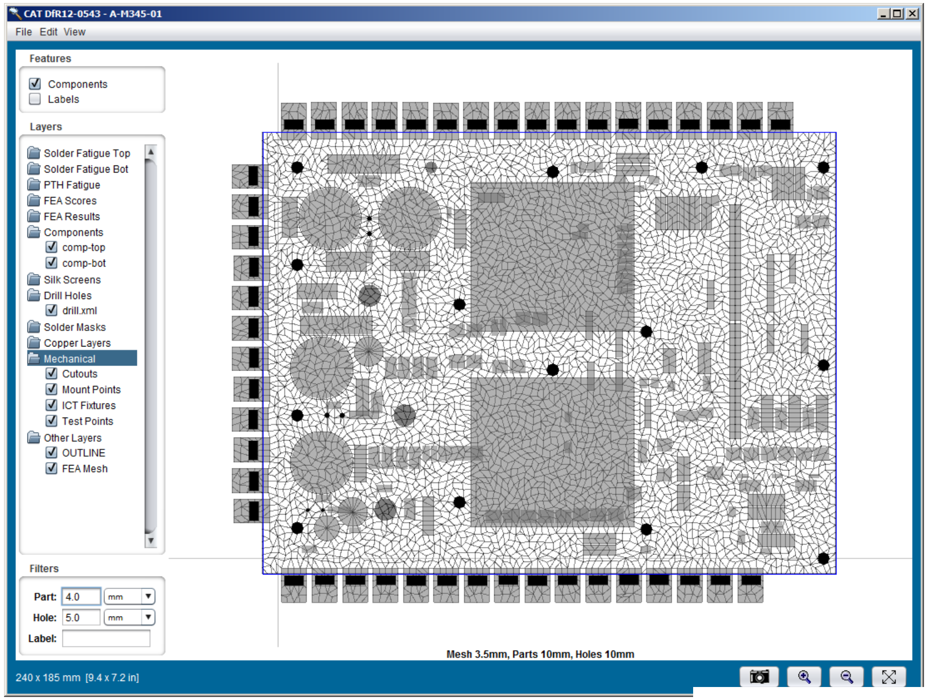
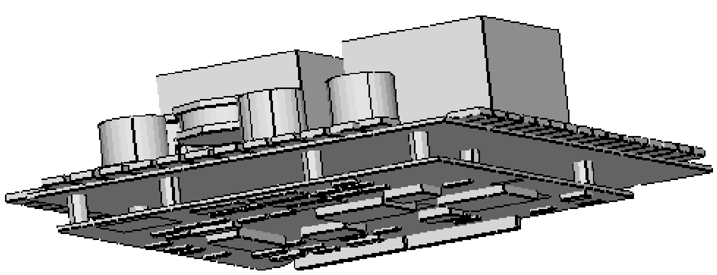
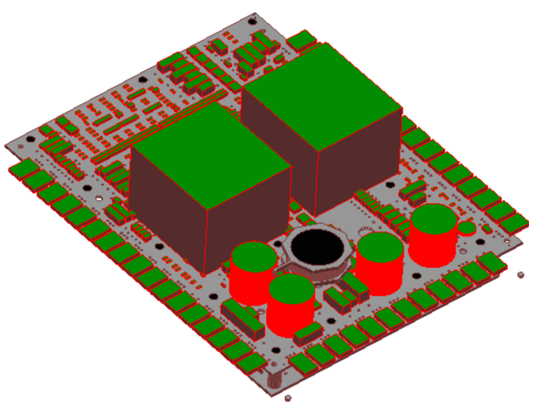
3D FEA Model in Sherlock (Version 2.8.3RC1) - Targeted Release April 2013

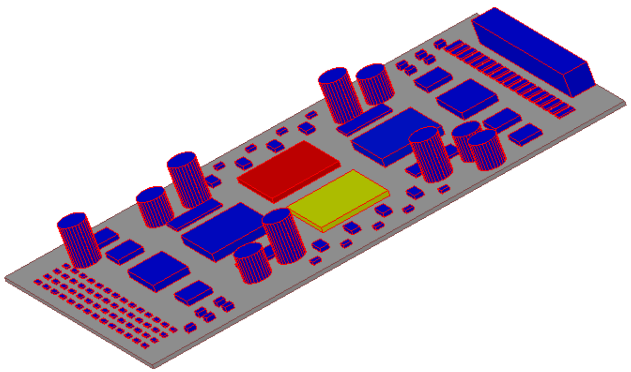




New Sherlock version will handle:
- Subassemblies (stacked boards)
- Standoffs
- Heatsinks
- Daughter cards
- Tall Parts
  (Relay, Alum Caps, Inductors . . .)







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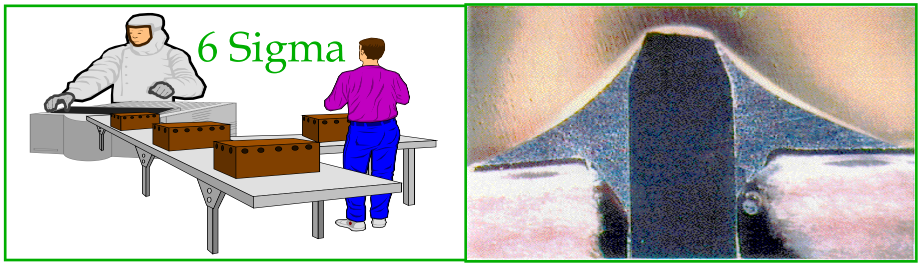
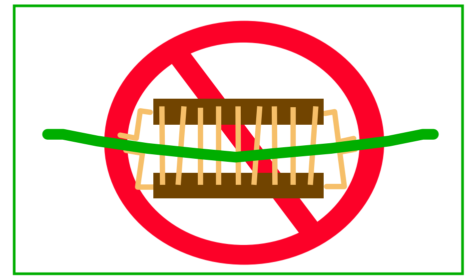
Limits of PoF Modeling - Errors & Excessive Variation

Can Not Model Probability of Manufacturing Defects, But Can Model the Outcome

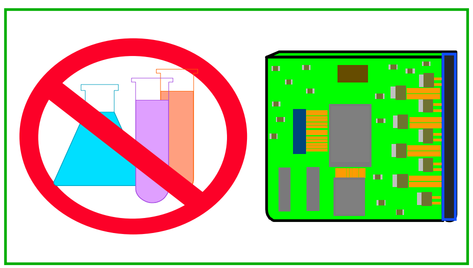
- PoF/RP can Provide Knowledge for Optimizing or Error Proofing Manufacturing Processes or Determining if Parts are built right.
- 5 Most Common E/E Device Manufacturing Issues:



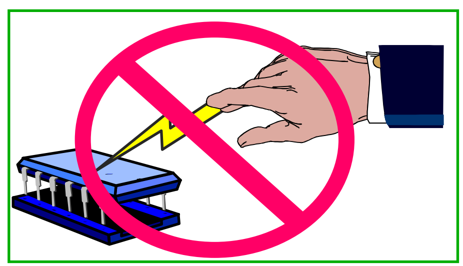
ASSEMBLY & SOLDERING PROCESS
(Related to up to 60% of E/E Assembly Issues)



In Process Board Flexure
Cracked & Missing Components.
(Related to up to 15% Of E/E Assembly Issues).



Ionic Contaminate
(Circuit Board Cleanliness to Prevent Humidity Related Short Circuit Growths)
(Up to 20% Of E/E Assembly Issues).



Electro Static Discharge (ESD)
(Component Damage)
(% Varies Often Related To Spills)

Rework & Repair
Latent Rework & Handling Damage *(% Varies)*

DfR Solutions

Summary - Physics of Failure/Reliability Physics is Reliability Science for the Next Generation

- PoF Science based Virtual Validation Durability Simulation/ Reliability Assessments Tools Enable Virtual Reliability Growth that is:
  - Faster and Cheaper than Traditional Physical Design, Build, Test and Fix Testing.
- Determines if a Specific Design is Theoretically Capable of Enduring Intended Environmental and Usage Conditions.
  - "Stress Analysis" Followed by "Material Degradation/Damage Modeling"
- Compatible with the way modern products are designed and engineered (i.e CAD/CAE/CAM).
- Sherlock the PoF CAE Apps Tools Enables Rapid, Low Cost Analysis Without a Highly Trained CAE/PoF expert.
- Produces Significant Improvement In Accelerated Fielding of High QRD Products

Want to Know More – Suggested Reading

Questions & Discussion

DfR Solutions
reliability designed, reliability delivered

Thank you for your attention.

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