

Your Partner Throughout the Product Life Cycle

DfR lends a guiding hand on quality, reliability and durability (QRD) issues through our expertise in the emerging science of Reliability Physics, providing crucial insights and solutions early in product design, development and test throughout manufacturing, and even into the field.

Your Needs...

- ...faster time to market
- ...find, incorporate new technologies
- ...extend warranty period
- ...reduce warranty costs
- ...technically manage suppliers
- ...improve employee skills
- ...out perform your competition

...Our Capabilities

- DfR uses Physics-of-Failure (PoF) and Best Practices expertise to provide knowledge-based strategic quality and reliability solutions to the electronics industry
 - Technology Insertion
 - Design
 - Manufacturing and Supplier Selection
 - Product Validation and Accelerated Testing
 - Root-Cause Failure Analysis & Forensics Engineering
- Unique combination of expert consultants and state-of-the-art laboratory facilities
 - Capabilities at package, board, product, and system-level

How Do Companies Use DfR?

- Work overflow
 - Maximize the efficiency of your current staff
- Independent party on critical design reviews
- Supplier benchmarking (commodity / custom)
- Test plan development and execution
- Reliability predictions
- Root-Cause Analysis
- Continuing education

Military / Avionics / Space

Lockheed Martin
 Northrop Grumman
 Boeing
 General Dynamics
 BAE Systems
 Honeywell
 Hamilton Sundstrand
 Rockwell Collins

Enterprise / Telecom / ATE

Cisco Systems
 Huawei
 Sun Microsystems
 Motorola
 Alcatel-Lucent
 Juniper Networks
 KLA-Tencor

Consumer / Appliance

Dell Computers
 Hewlett Packard
 Apple
 Fujitsu
 Samsung
 LG Electronics
 Microsoft
 Carrier

Industrial / Power

General Electric
 Siemens
 Emerson Electric
 Schlumberger
 Ingersoll Rand
 Danaher Motion
 Olympus
 Tyco Electronics

Auto / Transportation

General Motors
 Caterpillar
 Panasonic Automotive
 TRW
 Magna
 Takata

Government

NAVAIR
 NASA
 Air Force

Portables

LG Electronics
 Kyocera

Medical

Philips Medical
 Medtronic
 Boston Scientific
 Cardinal Health
 Beckman Coulter

Contract Manufacturers

Flextronics
 Benchmark Electronics
 Jabil
 Gold Circuit Electronics
 Viasystems

Components

Samsung
 Fairchild Semiconductor
 International Rectifier
 Nvidia
 Amphenol
 AMD

Materials

Graftech
 Nihon Superior

DfR Solutions – Senior Experts

- **Dr. Craig Hillman, CEO and Managing Partner**

- Expertise: Design for Reliability (DfR), Pb-free Transition, Supplier Benchmarking, Passive Components, Printed Circuit Board
- PhD, Material Science (UCSB)

- **Dr. Nathan Blattau, Vice President**

- Expertise: Power Devices, DfR, Nonlinear Finite Element Analysis (FEA), Solder Joint Reliability, Fracture, Fatigue Mechanics.
- PhD, Mechanical Eng. (University of Maryland)

- **Walt Tomczykowski, Vice President**

- Expertise: Life cycle management (including obsolescence), counterfeit mitigation,
- B.S., Electrical Engineering (Rutgers)

- **Cheryl Tulkoff, CRE**

- Expertise: Pb-Free Transition, PCB and PCBA Fabrication, IC Fabrication, RCA (8D and Red X)
- B.S., Mechanical Engineering (Georgia Tech)

- **Dr. Ron Wunderlich**

- Expertise: Design for EMI/EMC, Power Supply Design, Analog Circuit Design, Spice Model Development, Monte Carlo Circuit Simulation
- PhD, Electrical Engineering (SUNY – Binghamton)

- **Greg Caswell**

- Expertise: Nanotechnology CMOS, CMOS/SOS, Input Protection Networks / ESD, SMT, Pb-free
- B.S., Electrical Engineering (Rutgers)

- **Dr. Randy Schueller**

- Expertise: IC Fabrication, IC Packaging, Pb-Free Transition Activities, Supplier Benchmarking, Corrosion Mechanisms
- PhD, Material Science (University of Virginia)

- **Dr. Gregg Kittlesen**

- Expertise: LEDs, LCDs, Microprocessors, Memory Components, Photonic and RF Technologies, Supply Chain Management
- PhD, Analytical Chemistry (MIT)

- **James McLeish, CRE**

- Expertise: FMEA, Root-Cause Analysis, Warranty Analysis, Automotive Electronics, Physics of Failure, Battery Technology
- M.S., Electrical Eng. (Wayne State University)

- **Norm Anderson**

- Expertise: Avionics, Product Qualification, Safety Criticality Assessment, FTA, FMEA, Component Upgrading, Obsolescence
- B.S., Electrical Engineering (Iowa State University)

- **Anne Marie Neufelder**

- Expertise: Software Reliability Prediction, Best Practices in Software Risk Management
- B.S., Systems Engineering (Georgia Tech)

DfR Locations (North America)



DfR Resources and Equipment

Electrical

- Oscilloscopes (Digital and Analog)
- Curve Tracers (Digital and Analog)
- Capacitance Meters
- Low/High Resistance Meters
- High Voltage Power Supplies (Hi-Pot)
- Network Analyzer (up to 3 GHz)

Testing

- HALT / HASS
- Temperature Cycling
- Thermal Shock
- Temperature/Humidity
- Vibration
- Mechanical Shock / Drop Tower
- Mixed Flowing Gas
- Salt Spray
- Capacitor Testing (Ripple Current, Step Stress, Partial Discharge)
- Fan Testing
- Bend Testing (Cyclic and Overstress)
- Mechanical Testing

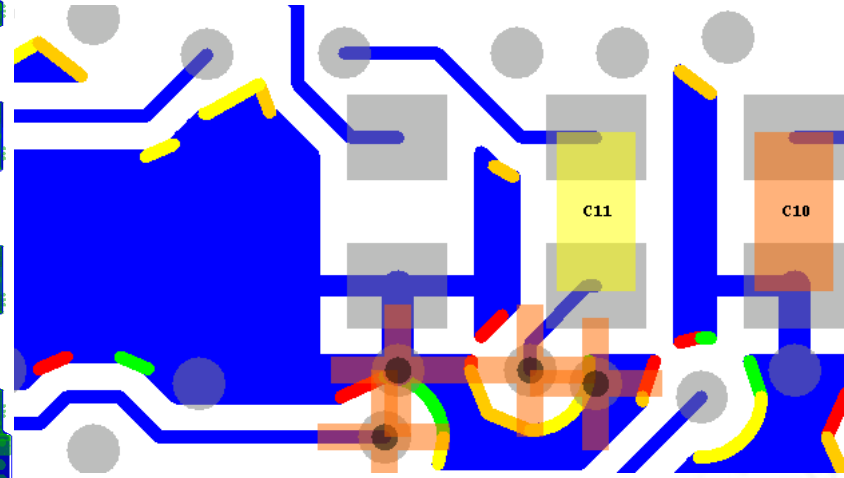
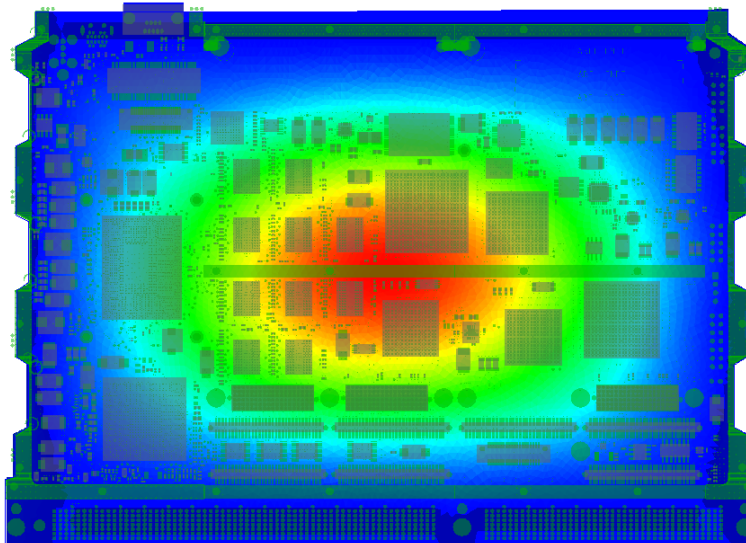
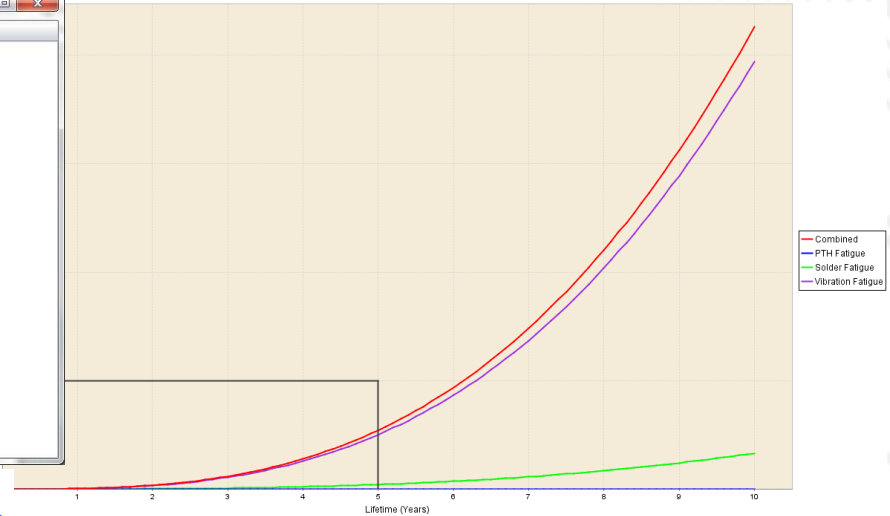
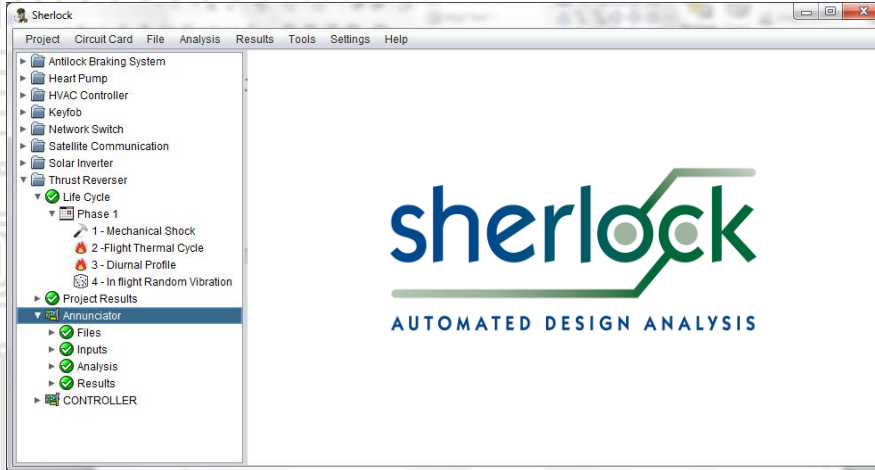
Material Analysis

- X-ray
- Acoustic Microscopy
- Infrared Camera
- Metallographic Preparation
- Stereoscope / Optical Microscope
- Scanning Electron Microscope
- Energy Dispersive Spectroscopy
- Ion Chromatography
- FTIR (Solid / Film / Liquid)
- Thermomechanical Analyzer
- Mechanical Testing (Tension, Compression, Shear, etc.)
- SQUID Microscopy

Other

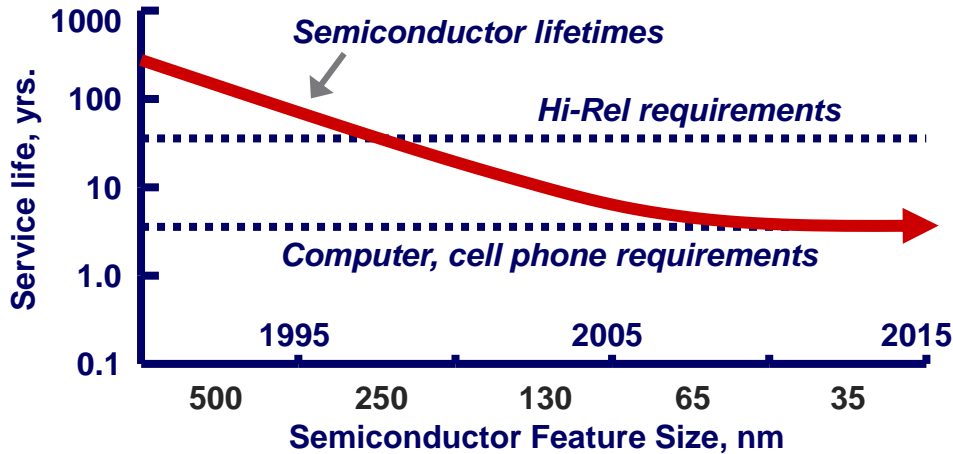
- Circuit Simulation
- Finite Element Analysis (FEA)
- Computational Fluid Dynamics
- **Reliability Prediction (Physics of Failure)**

- DfR has developed a revolutionary tool that allows for an early-stage assessment of hardware design
 - Easy-to-use + Comprehensive
 - Identification of high risk design elements
 - Tradeoff analysis
 - Faster time-to-market through guarantee of test success
 - Physics-based reliability prediction
 - Warranty reduction



- **Meets current market needs, including**
 - Accelerates time-to-market through earlier and more robust analysis
 - Mitigates risk in move to environmentally friendly materials
 - Effectively manages the original design manufacturer (ODM) supply chain
 - Meets new requirements from end-users and regulators for knowledge based assessment

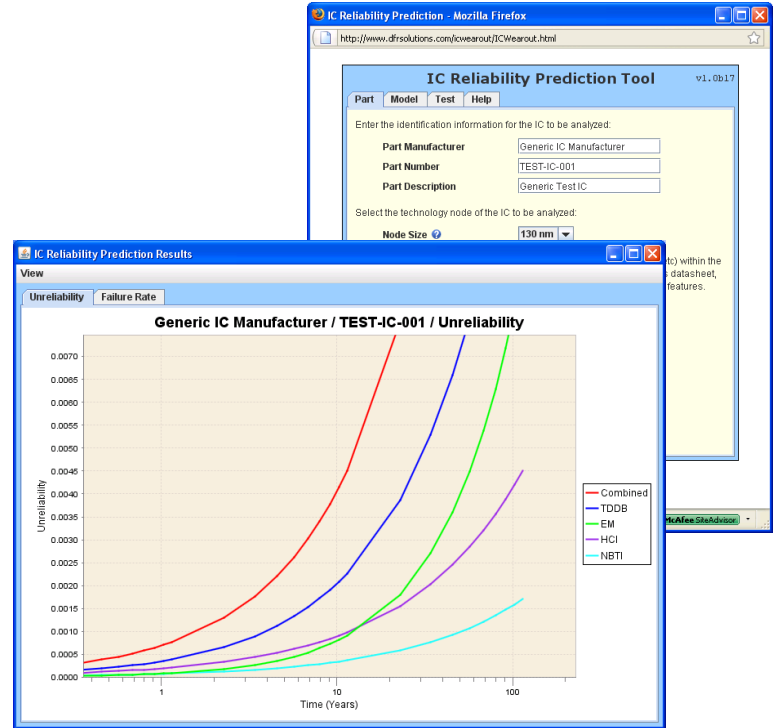
Tech Insertion: Integrated Circuit Wearout



The notion that a transistor ages is a new concept for circuit designers ... <sic> engineers traditionally guarantee the transistor will operate for 10 years or so... But as transistors are scaled down further and operated with thinner voltage margins, it's becoming harder to make those guarantees...
 IEEE Spectrum, June 2009

- Developed multi-mechanism solution
 - Designed for the end-user (OEM)

- Value Proposition
 - Tradeoff studies, reliability predictions, system prognostics / self-healing, supplier engagement




Tech Insertion: Second Generation Pb-Free Solder

- Major solder manufacturer needed to demonstrate reliability of 2nd generation Pb-free alloy
- DfR provided a turn-key solution
 - Test plan development
 - Test coupon design
 - Test execution
 - Failure analysis
 - Solder reliability model
- Results
 - Developed new test technology to meet schedule and cost constraints
 - Online calculators now available for customers world-wide



Solder Joint Fatigue

SOLDER JOINT FATIGUE INPUTS

 Fatigue of solder joints under Leadless Chip Components (LCC), such as chip resistors and capacitors, can influence long-term reliability of electronic products operating in environments with temperature cycling. This model allows the user to predict the lifetime of leadless chip components accounting for solder alloy (Sn63Pb37 or SAC305), Printed Circuit Board (PCB) material, and use environment. The calculations are performed using a strain energy based model developed by DfR Solutions.

Solder Material: Use default solder parameters

Component Type:
Component Case Size:
Note: Case sizes below 0805 do not tend to experience solder joint failures

PCB Material:

PCB Thickness: mm
Note: These calculations tend to be valid only for boards with a thickness of 1.5 mm (62 mil) or greater

PCB CTE XY: ppm/°C

PCB Tensile Modulus: MPa

Minimum Temperature: °C min
Maximum Temperature: °C min

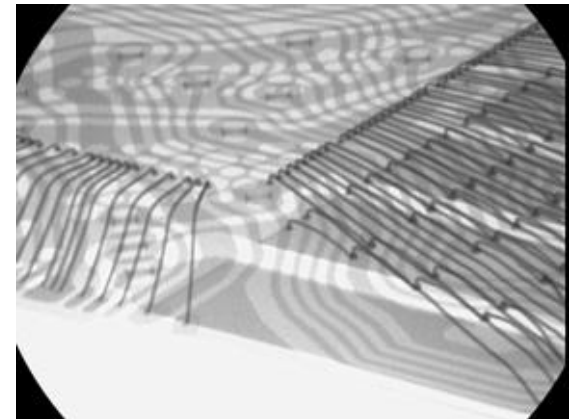
SOLDER JOINT FATIGUE RESULTS

Delta Temperature: N/A
Average Temperature: N/A
Cycles To Failure: N/A



Tech Insertion: Tech / Market Benchmarking and Surveys

- DfR uses its unique expertise to benchmark critical technologies and capture risk / current market acceptance
 - Degree of maturity, major suppliers and capabilities, expected costs, quality/reliability concerns
- Technologies recently assessed
 - 0201/01005, System-in-Package (SiP), GaN FETs, Optoelectronics, PCB Platings



Property	6H-SiC	4H-SiC	GaN
Bandgap (eV)	3.03	3.26	3.45
Breakdown Field (KV/cm)	2500	2200	2000
Electron Mobility (cm ² /V-s)	500	1000	1250
Hole Mobility (cm ² /V-s)	101	115	850
Saturated E-Drift Velocity (10E7/cm)	2	2	2.2
Thermal Conductivity (W/cm-K)	4.9	4.9	1.3
Thermal Expansion (x10E-6/K)	3.8	4.2	5.6

DfR Solutions

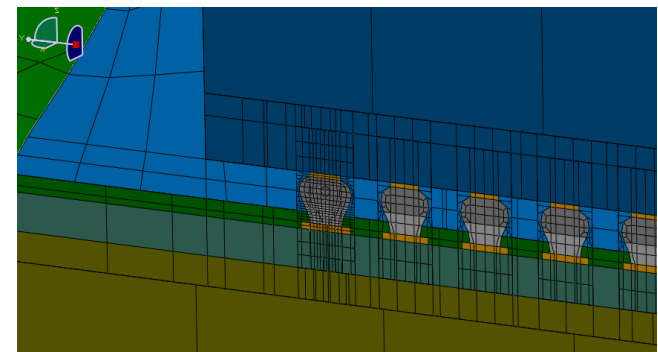
Design Review: Network Switch

- Manufacturer of network switches wanted to understand potential costs of switch from 3-yr warranty to lifetime warranty
- Identified components that could experience wearout
 - Fans, electrolytic capacitors, integrated circuits, solder joints, plated through holes, ceramic capacitors, connectors, LEDs, overstressed components
- Performed circuit/thermal analysis to identify overstressed components
 - Especially based on usage model (validated through internal DfR testing)
- Predicted reliability for each component based on validated algorithms
 - Primarily conducted through Sherlock™
 - Conducted component testing when necessary



Design Review: Power Amplifier

- Component manufacturer pushing the limits to increase market share
 - Driving RF CMOS transistors beyond foundry's specification
 - New packaging technologies (copper pillar, copper wirebond, low Tg underfill)
- Comprehensive assessment
 - Initial transistor life prediction
 - Finite modeling for prediction of 1st and 2nd level lifetime
 - Guidance on qualification plan

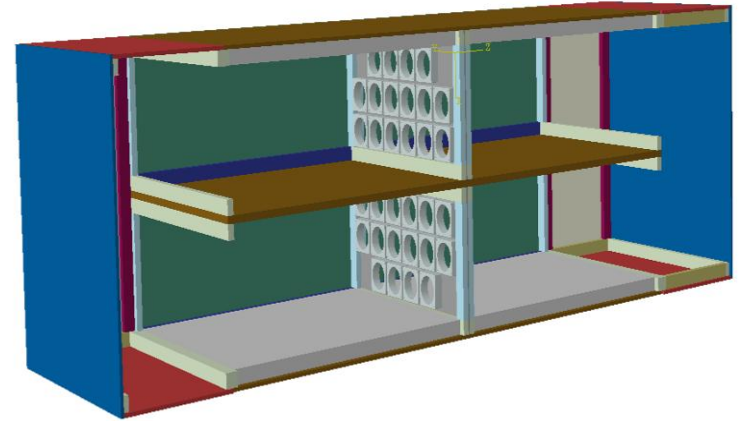


Supplier Assessment: Expertise

- Senior staff at DfR has audited over 200 suppliers
 - Printed Circuit Board
 - Contract Assembly
 - Optoelectronics
 - Integrated Circuits
 - Passive Components (Tantalum, Aluminum, etc.)
 - Connectors
- Range of guidance on supplier assessment
 - Development of audit documents and guidelines
 - Onsite reviews (technical audit)
 - Testing and qualification

Supplier Assessment: Fans

- Developed internal capability based on strong market need
- Unique environmental chamber
 - Elevated temperature w/ power cycling
 - Fan loading through pressure differentials
 - Multiple failure detection techniques (sound, current draw, rotational velocity)
 - Up to 200 fans
- Develop accelerated technique based on knowledge of fan failure mechanism and degradation algorithms

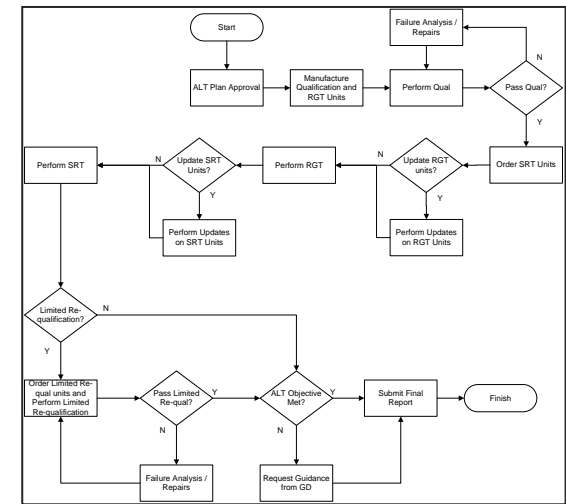


Testing: Next Generation Microprocessor

- Selected as the preferred vendor for package qualification testing
 - Reviewed coupon designed, identified deficiencies
- Tests performed
 - Nine point cyclic bend
 - Static bend
 - Drop
 - Mechanical shock
 - Harmonic vibration
 - Random vibration
 - Thermal cycling
 - Temperature / humidity

Testing: Intelligent Gas Meter

- Customer transitioning into new product space, concerned about long-term performance
- DfR reviewed potential use environment
 - Identified potential drivers for failure (temperature, humidity, salt spray, sulfur gas, etc.)
- Started with industry standards and best practices
 - Modified based on understanding of Physics of Failure
 - Developed optimized test plan acceptable to management and customers
- Other examples of test plan development
 - Consumer appliances
 - Telecom
 - Avionics (engine controls)
 - Tracked vehicle
 - Automotive
 - Down-hole oil-drilling



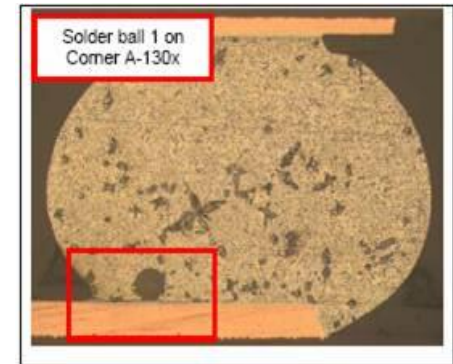
Month	Cycles/Year	Ramp	Dwell	Max Temp (°C)	Min Temp (°C)	ΔT	Cycles per Day	AF
Jan+Feb+Dec	90	6 hrs	6 hrs	30	5	25	1	12.654
Mar+Nov	60	6 hrs	6 hrs	35	10	25	1	11.799
Apr+Oct	60	6 hrs	6 hrs	40	15	25	1	10.944
May+Sep	60	6 hrs	6 hrs	45	20	25	1	10.26
Jun+Jul+Aug	90	6 hrs	6 hrs	50	25	25	1	9.576
Operational	16.6	5 min	3 hrs	25	-40	65	1	2.223

Root Cause Analysis (RCA) -- Personnel

- The number one requirement in failure analysis
- DfR has all the necessary elements
 - Electrical engineers, mechanical engineers, materials scientists, inorganic chemists, etc.
- Extensive in-house expertise
 - PhD, MS, BS + industry experience
- The right background
 - Over 1000 failure analyses combined

Root Cause Analysis: Desktop Computer

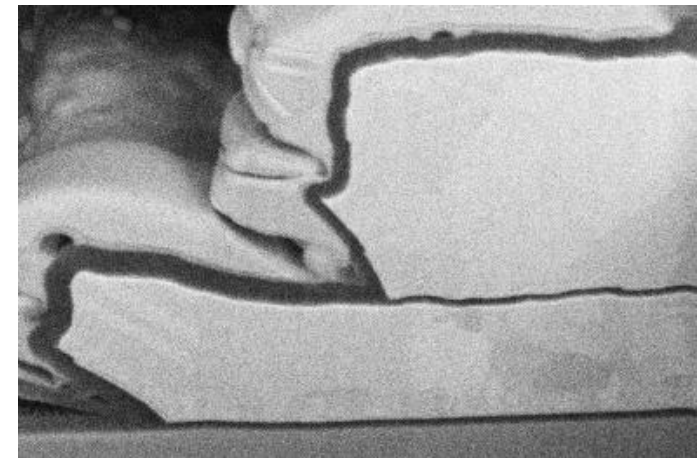
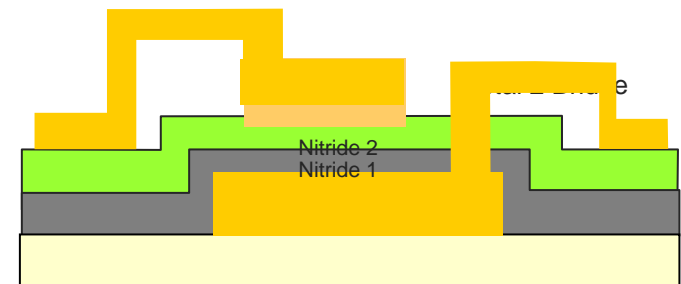
- Failures during HALT
 - Exposure to vibration
- Electrical testing indicated electrical open
 - Under BGA socket
- Validity of failure mechanism?
 - Shearing of electrolytic capacitor leads
- Dependent upon orientation of capacitors
 - Only those along the board length
- Vibration test may not have applied random loads
 - Potential issues with vibration table or fixturing



Root Cause Analysis: Die Fabrication

- **Component manufacturer**
 - Issues with new silicon nitride technology in MIMCAP structure
 - Halted multi-million dollar product launch
- **Identified potential root causes based on**
 - Knowledge of semiconductor process technology
 - Fundamental behavior of the material
- **Recommended experimental design and analytical techniques to confirm failure mechanism**
 - Guided modification in process parameters for fundamentally more robust technology

Standard dual nitride layer MIMCAP



Knowledge and Education (Website)

- Let your staff learn all day / every day

E-LEARNING

- Scholarly articles
- Technical white papers
- Case studies
- Reliability calculators
- Online presentations

DfR Solutions
reliability designed, reliability delivered

Our newsletter contains valuable information on a wide spectrum of electronic engineering subjects; from Pb-free and RoHS, design for reliability, and more!
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EDUCATION

Featured Articles

- An Experimental Investigation into the Creep Behavior of Pressure Sensitive Adhesive Tapes for Air-cooled Component-Heat Sink Assemblies
- Determining the Lifetime of Silver-filled Isotropic Conductive Adhesive (ICA)/Solder-plated Interconnections
- Has the Electronics Industry Missed the Boat on Pb-free? Failures in Ceramic Capacitors with Pb-free Solder Interconnects
- Improved Methodologies for Identifying Root Cause of Printed Board Failures
- The Kinetics of Formation of Ternary Intermetallic Alloys in Pb-Sn and Cu-Ag-Sn Pb-free Electronic Joints

• [\[more...\]](#)

Featured White Papers

- Derating of Schottky Diodes
- Qualifying for Moisture Containing Environments
- Temperature Dependence of Electrical Overstress

• [\[more...\]](#)

Featured Case Study

- Identification of BGA Failure

• [\[more...\]](#)

UPCOMING EVENTS

- **DfR Solutions on Orange County, CA August 05**
[\[Click for details...\]](#)
- **DfR Solutions in Los Angeles, CA August 11-12**
[\[Click for details...\]](#)
- **DfR Solutions in Southern Wisconsin & Illinois August 25-27**
[\[Click for details...\]](#)
- **DfR Solutions in Huntsville, AL and Atlanta, GA September 15-16**
[\[Click for details...\]](#)
- **Symposium on Defense and Aerospace Electronics**
Huntsville, AL - September 16

Our Clients

eywell Applied Data Systems

Read our May/June Newsletter
DfR Solutions, in collaboration with bestTest and IPC, will hold the first ever Design for Excellence (DFE) Course in October 2009. This collaborative effort will provide tools on how to meet time-to-market deadlines and reduce warranty issues. For more information, please click here.

Dr. Craig Hillman's Webinar presentation "Root-Cause Analysis in the HALT Process" part of the series *Ask the Experts* hosted by the Qualmark Corporation, is now available on our website! To access the presentation, please click here.

DfR Solutions welcomes Cheryl Tulkoff, CRE, as New Senior Member of Technical Staff. To read more, please click here.

WHAT WE DO

Field/Customer Returns
Technology Insertion
Design
Testing Product Qualification
Supply Chain

Field/Customer Returns
How can you keep your products from being returned? Any return from the customer, regardless of cause, should be considered a failure. DfR has the resources to perform extensive failure analyses and to make recommendations regarding the products that remain in the field. Our expertise with lifetime prediction and statistical analysis all add to the finished report, providing a complete picture to our clients about their product.
[\[more...\]](#)

Technology Insertion
How disruptive does technology have to be? DfR assists companies with their transition into using new technologies and materials. DfR's expert consulting and testing services allow companies to efficiently shift their structure with minimal risk.
[\[more...\]](#)

Design
Will your product meet expectations? DfR has the resources to answer questions that arise during the



Interested?

- Could your next product benefit from DfR's extensive expertise and PoF knowledge base?
 - Bring us in as an independent party during critical design reviews
- Are you concerned with new technologies?
 - DfR's scientists and engineers can provide comprehensive analysis to ensure risk-minimization during these difficult transitions
- Take advantage of our unique Open-Door policy!
 - See how much we already know about your current issues
 - Chances are we have already solved your problem at least once before
 - We work around the clock and around the world
 - Contact us by phone (301-474-0607) or email (askdfr@dfrsolutions.com)