Part 2: Using FMEA, DFR, Test and Failure Analysis in Lean NPD
Overview

• Introduction and Definitions
• Part 1: Lean Product Development
  – Lean vs. Traditional Product Development
  – Key Elements of Lean NPD
    • Customer Defines Value
    • Front Loaded and Knowledge Based
    • Eliminate Redesign Waste
  – Reliability Requirements
• Part 2: Reliability Elements of Lean NPD
  – Lean FMEA and DRBFM
  – Critical Characteristics
  – DFR and Physics of Failure
  – Accelerated Testing to Failure
  – Failure Analysis and Knowledge Capture
Lean FMEA

- Some teams attempt to lean FMEA process by creating product family FMEAs but fail to update FMEA for new applications or changes
- Instead Lean FMEA Should Focus on New Design Features and Changes to Baseline Design to Assess Associated Risks
Tools to Focus Lean FMEA

• Diagramming Tools
  – Functional Block Diagram
  – Boundary Diagram
  – Parameter Diagram
  – Process Flow Diagram

• Highlight Changes to Product or Process on the Diagrams
Functional Block Diagram

Annotate Retained and Changed Items & Functions
Consider a Functional Block Diagram of the System With Modules and Interfaces.
Elements of the P-Diagram

- **Signal (Inputs)**
  - Controlled by Input Function
  - Static or Dynamic
  - May be Variable

- **Control Factors**
  - Functional Design Parameters
  - Fixed or Adjustable
  - Fundamental to Design of Function
  - Reduce Variation

- **Noise Factors**
  - Forces Beyond Control
  - Cause Output Variation
  - Environment Factors

- **Response (Output, Function)**
  - Performance Mean, Std Dev
  - Customer Requirement

- **Product, Process, or System**
  - Managed by Input Function
  - Static or Dynamic
  - May be Variable
Process Flow Diagram

MANUFACTURING FLOW

- Receiving
- IQC
- Stock
- Material to Production
- SMT Line Loading
- Solder Paste/Glue Printing
- Chip Mount
- Reflow
- MFG 100% Insp.
- SMT QC Sampling
- PTH Line Loading
- Moving in Process Audit
- Wave Soldering
- Wash/Dry
- Touch Up
- MFG Insp.
- ICT Testing
- PTH QC Sampling
- Final Ass'y
- Function Test
- Packing
- OQC Sampling
- Shipping

Annotate Retained and Changed Process Steps
Selecting Process Steps for Analysis

• On Process Flow Map:
  – Identify Steps Being Modified
  – Identify New Steps Required for New Product

• Drill Down to Identify Sub-Steps Within the Target Steps Identified for Analysis

• Complete Lean PFMEA on Selected Process Steps

• Integrate with Previous PFMEA on Standard / Unchanged Process Steps
Key Characteristics

• Include:
  – Product Features
  – Manufacturing Processes
  – Assembly Characteristics

• That Significantly Affect:
  – Product Performance
  – Form, Fit, Function

• Lean NPD Focuses on the Critical Few Characteristics the Customer Values
Key Characteristics

- Requirements Documents
  - Customer Specification
  - Regulatory
  - Dimensions
  - Appearance

- Requirements Document Drawings
- Field History

Robustness Tools
- Functional Block Diagram
- Boundary Diagram
- P-Diagram
- Interface Matrix

Technical Requirements, Tools Identify Special Product Characteristics

Characteristics Matrix
Identifying Key Characteristics

<table>
<thead>
<tr>
<th>Severity</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-2</td>
</tr>
<tr>
<td>2</td>
<td>3-4</td>
</tr>
<tr>
<td>3</td>
<td>5-6</td>
</tr>
<tr>
<td>4</td>
<td>7-8</td>
</tr>
<tr>
<td>5</td>
<td>9-10</td>
</tr>
</tbody>
</table>

- **Potential Critical Characteristic**
- **Potential Key Characteristic**
- **Possible Annoyance Zone**
### Special Characteristics Matrix

**Severity**
- Severity
- Process Steps

**Process Steps from Flow Chart**
- Primary Drive Manufacturing Process Steps

**Direction of Improvement**
- Potential Critic and Significant
- Characteristics from Requirements and DFMEA

**Effect of Step on Characteristics**
- Customer Assessment

**Weighted Importance**
- 0 81 81 72 8 41 0 27 54 285

**Relative Importance**
- 0 0 0 0 0 54 27 45 0 0

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**Characteristics from Requirements and DFMEA**

**Process Steps from Flow Chart**

**Effect of Step on Characteristics**
Developing the Control Plan

• Prioritize Process Risks Identified in the PFMEA and the Special Characteristics Matrix
• Process Flow Diagram
• Lessons Learned from Similar Processes
• Process Control Data from Related Processes
• Measurements Required for Process Control
• SPC Control Limits
• Complete the Items in Control Plan Template
# Control Plan Items

<table>
<thead>
<tr>
<th>Machine, Device, Jig, Tools for Mfg.</th>
<th>For each operation that is described, <strong>identify the processing equipment machine, device, jig, or other tools</strong> for manufacturing, as appropriate.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No.</strong></td>
<td>Enter a <a href="#">cross reference number</a> from all applicable documents such as, but not limited to, process flow diagram, numbered blue print, FMEAs, and sketches.</td>
</tr>
<tr>
<td><strong>Product</strong></td>
<td><strong>Features or properties of a part, component or assembly</strong> that are described on drawings or other primary engineering info. Compilation of important product characteristics.</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td>Process variables that have a cause and effect relationship with the identified product characteristic. <strong>Identify those process characteristics for which variation must be controlled to minimize product variation.</strong> There may be more than one process characteristic for each product characteristic.</td>
</tr>
<tr>
<td><strong>Product/Process Specifications/Tolerance</strong></td>
<td><strong>Specifications/tolerance</strong> may be obtained from various engineering documents, such as, but not limited to, drawings, design reviews, material standard, computer aided design data, manufacturing, and/or assembly requirements.</td>
</tr>
<tr>
<td><strong>Evaluation/Measurement/Technique</strong></td>
<td><strong>Identify the measurement system</strong> being used, including, gages, fixtures, tools, and/or test equipment required to measure the part/process/manufacturing equipment.</td>
</tr>
<tr>
<td><strong>Sample</strong></td>
<td>When sampling is required list the <strong>corresponding size and frequency</strong>.</td>
</tr>
<tr>
<td><strong>Control Method</strong></td>
<td>Brief description of <strong>how the operation will be controlled</strong>, including procedure numbers where applicable. <strong>Operations may be controlled by SPC, inspection, attribute data, mistake proofing, sampling plans</strong>, and other. If elaborate control procedures are used, reference document by ID name/number.</td>
</tr>
<tr>
<td><strong>Reaction Plan</strong></td>
<td><strong>Specify the corrective actions necessary to avoid producing nonconforming products</strong> or operating out of control. May also refer to a specific reaction plan number and identify the person responsible for the action.</td>
</tr>
</tbody>
</table>
Using the Control Plan

• For Critical Characteristics, Use Control Plan to Identify:
  – Measurements: How, When, How Often
  – Controls to Keep Characteristic in Tolerance
  – Actions if Characteristic Out of Tolerance
    • Containment
    • Corrective Actions

• Robust Design + Controlled Processes = Reliable Products
DRBFM and DRBTR
Design Review Based on Failure Modes & Test Results

Key Elements of Mizenboushi (Reliability Problem Prevention)

GD^3 (Good Design, Good Discussion, Good Dissection)

Toyota’s “Creative FMEA” Method
Problem Prevention – GD$^3$

- **Good Design = Robust Design**
  - Design for Reliability (DFR)
  - Design for Six Sigma (DFSS)

- **Good Discussion = Eliminate Risk**
  - Apply Design Review Based on Failure Modes (DRBFM) to identify problems and develop countermeasures or corrections

- **Good Dissection = Effective Validation**
  - Apply Design Review Based on Test Results (DRBTR) to Evaluate Effectiveness. Test to Failure & Analysis of Test Failures is Critical
OBJECTIVE:
Discover & Resolve All Problems Before Launch

GD³ Problem Resolution

Good Design
(Robust Design To Prevent Problems)

Good Discussion

Good Dissection
(Discover Unknown Problems)

Total Problems to be Solved

Unknown Problems

Discovered Problems

Development

Pre-Production

Validation
DRBFM Approach

• Elements from FMEA, FTA, and Design Review
  – These tools previously used for management and control of projects
  – Toyota developed “creative FMEA” approach
  – Shift focus to improve perceptiveness and problem solving

• Focus is on finding and preventing problems – not completing forms and checklists (which de-motivate participants)
DRBFM is a method which is focused on the changes within a design in the process of development. Variant and application development projects provide the highest potentials and benefit for DRBFM.
DRBFM is a Forum for Thinking
Teamwork and Participation

What has changed?
* What did you change? Why?
* What surrounding conditions have changed outside your control?

Concerns about the changes?
* Your Concerns? What other concerns?
* Draw on expertise and knowledge of past problems

When will concerns appear?
* Could concerns become causes of failures or incidents? Visualize concerns & causes

What effects will there be?
* How will causes effect the customer?
* Consider effects on the OEM and end user

What preventive measures have been & should be taken?
* What has been done to assure concerns will not actually appear?
* Consider other measures that can be implemented

How is DRBFM Done?

• Preparation for the Design Review
• Conducting the DRBFM
• Capturing the Inputs
• Assigning and Tracking Actions to Completion
Pre-Work for the DRBFM

• Design Engineer or Core Team:
  – Functional Diagram, Operating Environment
  – Changes from Previous Baseline Design
  – Drawings and Analysis
  – Failed and Sectioned Parts
  – Draft DRBFM with Components / Changes, Concerns with Causes and Factors, Effect on Customer, Design to Eliminate Concerns

• Participants (Functional Experts):
  – Perceptive mindset, interest in improving product
  – Past experience and knowledge on similar items
Capturing the Data


1. Component Name Changes
2. Concerned Functions and Requirements
3. Concerns Regarding Change (Failure Mode)
   - Potential Failure Mode due to Change
   - Any other Concerns?
4. When and How Concern Points appear?
   - Causes
   - Any other Causes?
5. Effect to Customer (System)
   - Evaluation

6. Current Design Steps to avoid Concerns
7. Items to reflect in „Design“
   - Responsibility and Deadline
8. Items to reflect in „Evaluation“
   - Responsibility and Deadline
9. Items to reflect in „Production Process“
   - Responsibility and Deadline
10. Action Results

„creative FMEA“ (Phase 1)  Design Review (Phase 2)
Typical DRBFM Session

Source: A Guide to GD3 Activities and DRBFM Technique to Prevent Trouble, Kano & Shimizu, Toyota 2001
Changes and Results Documented

Source: Carl Hanser Verlag, QZ, Munich, 4-2005
Linking DRBFM with FMEA

- DRBFM captures the information needed for FMEA except scoring
- Scoring columns can be added to fill need for FMEA if required by customer or standards
DRBFM to FMEA (1)

<table>
<thead>
<tr>
<th>Item</th>
<th>Item</th>
<th>Potential</th>
<th>Potential</th>
<th>Cause(s) / Mechanism(s)</th>
<th>Current</th>
<th>Design</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Failure</td>
<td>Effect(s) of</td>
<td>Failure</td>
<td>of Failure</td>
<td>Current</td>
<td>Design</td>
<td>Controls</td>
</tr>
<tr>
<td>Mode</td>
<td>Failure</td>
<td></td>
<td>Mode</td>
<td></td>
<td>Current</td>
<td>Design</td>
<td>Controls</td>
</tr>
</tbody>
</table>

DRBFM Form:

<table>
<thead>
<tr>
<th>Component name/ Intentionally &amp; Incidentally Changed Portions</th>
<th>Function</th>
<th>Points of Concern regarding change (Failure mode)</th>
<th>When and how do points of concern appear</th>
<th>Effect to customer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Potential failure mode due to change</td>
<td>Any other concern? (DRBFM)</td>
<td>Root cause/ dominant cause</td>
</tr>
</tbody>
</table>

FMEA Form:

<table>
<thead>
<tr>
<th>Item</th>
<th>Potential</th>
<th>Cause(s) / Mechanism(s)</th>
<th>Current</th>
<th>Design</th>
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<td>Controls</td>
</tr>
</tbody>
</table>

Add Scores
DRBFM System Integration

[Diagram showing the process of DRBFM System Integration with steps]

Applying DRBFM in Lean NPD

- Use “Missing Knowledge” Decision Flow from Lean QFD as starting point
- These unknowns and known changes from current technology or design are the greatest risks
- Focus DRBFM on these unknown and changed areas during concept and prototype team reviews & Integration Points
Integrating Product & Process Design

- DFMA – Design for Manufacturing and Assembly
- Integrated Product and Process FMEA / DRBFM
- Concurrent Engineering Team
- Visual Management – Decision Flow and Value Stream Map to Manage Tasks
Impact of Lean Focused FMEA

• **Allocation of Resources** Targeted to Reduce Highest Risks and Unknowns
• **Impact Product and Process Design**
• **Drive Test Planning and Analysis** to Resolve Issues and Understand Unknowns
• **Verify Corrective Action Effectiveness**
• **Critical Characteristics and Process Measurement / Control**
Lean FMEA Summary

• Focus FMEA on Changes in Design or Process

• Use Supporting Tools to Narrow Focus:
  – Parameter & Boundary Diagrams
  – Process Flow Charts
  – DRBFM Techniques
  – Characteristics Matrix

• Use Lean NPD Tools to Identify Unknowns, Apply Resources, Assign Tasks
Design for Reliability and Robustness
How do we Design-in Reliability?

• Stress Analysis and Test
  – Find Product Limits & Understand User Needs
  – Products fail due to variation or in limit environments where stress exceeds strength
  – Stress and strength distributions:
DFR Strategies

- Increase Design Margins
- Reduce Variation in Product Strength
- Reduce Effect of Usage/Environment
Stress-Strength vs. Age
Reducing Stress / Strength Interference

• Increase strength of the part
  – Understand operating environment stresses
  – Select more robust parts or materials
  – Increase design margin
  – Supplement deterministic design with probabilistic tools

• Reduce part strength variability
  – Understand sources of part variation and deterioration
  – Controlled production process (SPC)
  – Protect vulnerable components

• ROBUST DESIGN + CONTROLLED PROCESSES = RELIABLE PRODUCT
Robust Design Tools

DFSS and DFR Tools: Differences and Commonality
Probabilistic Design

Traditional design – Safety factors versus Probabilistic approach
Reliability Based Design Optimization

Almost 75% of the designs around $\star$ fails

- $\bullet$ Deterministic Optimum
- $\star$ Reliable Optimum

$g_1, g_2, f$
Elements of Probabilistic Design

• Understand physics of failure and stresses that precipitate failure
• Use predictive modeling and accelerated test to failure to estimate probability of failure
• Consider variability of applied stresses and variability of product strength
• Eliminate stress-strength interference
Physics of Failure Approach

• Robust Design Considerations
• FMEA or DRBFM Methods
  – Design Review Based on Failure Modes Integrates FMEA and Design Review
• Test to Failure and Understand Cause Mechanisms
• Failure Analysis Methods
Understand Physics of Failure

• What physical phenomenon in the part is caused by the stresses applied?
• If we understand the root cause, we can improve strength or reduce variability to prevent or mitigate the failure.
• Most hardware failures can be traced to four physical categories / mechanisms:
  – Wear
  – Corrosion / Contamination
  – Mechanical Failure (fatigue, vibration resonance, etc.)
  – Overstress (electrical or mechanical, transients)
Physics of Failure Tools

• Tools Used in Physics of Failure Analysis
  – Principal Physics Model
  – CAD Drawings / Solid Modeling
  – Finite Element Analysis

• Dynamic Simulation (Transients)
• Fatigue Analysis (Cumulative Damage)
• Thermal Analysis
• Accelerated Testing
• Simulation
Design of Experiments (DOE)

• Tool to Evaluate Design Alternatives
• Determine Factors and Response
• May need Two Phased DOE Approach
  – Fractional Design to Find Main Factors
  – Full Factorial Design to Evaluate Effects and Interactions on Reduced Set of Factors
  – Consider Time and Cost
• Analysis of Results and Optimization of Solution
Iterative DOE Process

Used to select most significant variables from whole set.

Determine optimal variable set-points by using multiple levels of each variable.

Determine appropriate product and process specifications. Full factorial response can be used here.

Phase 3 output: Validated Product and Processes

Use Trade-Off Curves to Capture Knowledge

- Point Data from Analysis and Experiments
- Relationship Between Key Parameters
- Apply to Support Design Decisions
Trade-Off Curves

- Understand
- Communicate and negotiate between specialties and functions
- Train new engineers
- Record knowledge
- Negotiate and communicate between customer and supplier
- Conduct design reviews
- Communicate between developers and managers
- Design quality into the product

Capture Knowledge from Point Solutions
Trade Off Curve Example

Allowable Bending Moment

Pipe Diameter (mm)

Safe Region

Failure
Key is Understanding

• Methods Build Knowledge of Alternatives
  – Physics of Failure
  – Design of Experiments
  – Design for Robustness and Reliability

• Enable Better Design Decisions

• Eliminate or Reduce Redesign Waste
Reliability Testing and Data Analysis
Phased Robustness Testing

• Prototype Phase
  – Accelerated Test to Failure (Well beyond Spec – HALT, Step Stress, Specific Stresses and Failure Modes)

• Design Verification Phase
  – Quantitative Accelerated Life Test
  – Selected Qualification Tests

• Production Validation
  – Demonstrate Corrective Action is Effective
  – Validate Final Product Made on Production Tools
Robustness Indicator Figure

Requirement or Specification

Factors (Temperature, Vibration, Humidity etc)

If Requirement Exceeds Test Result or has Small Margin, Design is Not Robust

Analysis & Test Results for Each Factor on current or new product

Margin or Robustness of Design Factor

(Can be Created in Excel using Radar Chart)
General Approach to Accelerated Life Test (ALT)

- Understand Failure mechanisms
- Understand Operating and Design Limits
- Clarify Use Level Stress Application
- Conduct Qualitative tests like HALT or step-stress tests to define product limits and failure modes
- Conduct Quantitative ALT to extrapolate life at use level conditions
  - Times to Failure at Accelerated Stress Levels
  - Use life-stress relationships and distributions
ALT Plan

• Stresses to be Considered
• Life-Stress Relationship for Each Stress
• Application Use Level for Each Stress
• Use Level Failure Criteria / Threshold
• Test Duration and Resources Available
• Consider Use of DOE to help estimate:
  – Stress Factors with Most Effect
  – Probability of Failure at Specified Use Level
  – Probability of Failure at Maximum Stress
  – Interactions to Help Define Life-Stress Relationship
Highly Accelerated Life Test (HALT) – Qualitative ALT

1. Improve Reliability by Finding Weaknesses and Correcting Them Early.

2. Establish Upper and Lower Operating and Destruct Limits of Environmental Stressors

3. Typically done in Temperature & Vibration Chamber for Electronics & Electromechanical Products

4. Concept can be Applied to Other Stressors (Voltage, Current, Mechanical Loads, etc.)
Quantitative ALT

- Test to Failure at Multiple Accelerated Stress Levels
- Use Analysis to Extrapolate Reliability or Life at Application Use Level Stress
- Can be Used to Demonstrate Ability to Meet Reliability Requirements
Cautions on Acceleration

- Understanding product limits helps prevent accelerating to unrepresentative stresses and failure modes
- **Time**
  - Consider Heat Buildup
  - Effects of Cycling
- **Temperature**
  - Material Phase transitions
  - Non-linear response
  - High temperature or thermal cycling?
- **Power**
  - Protective and limit devices
  - Transients
- **Vibration**
  - Mechanical limits or resonances
- **What failure mechanism are we accelerating?**
Data Collected

• Test Parameters Measured
  – Temperature, Power Density, Cycle Rate, Vibration, Humidity, Voltage, etc. applied
  – Product Response or Function (monitor during test)
• Time to Failure or Run Time (Suspended)
  – At least 3 Different Stress Levels
  – Fit Data Points to Appropriate Distribution
• Product Limits from Step Stress Test
• Failure Mode Observations
Data Analysis

• Analyze Data and Extrapolate Life at Use Level Stress

• Life-Stress Relationships (predictive models)
  – Arrhenius – Temperature
  – Eyring – Temperature or humidity
  – Inverse Power Law – Voltage, Power, Mechanical
  – Multiple Life-Stress Models
    • Temperature / Humidity
    • Temperature / Non-Thermal: Temp / Voltage or Power
    • General Log Linear: multiple accelerating stresses
    • Proportional Hazards: multiple covariates
    • Cumulative Damage – Time varying stress profiles
Data Analysis – Use Level

ReliaSoft ALTA 7 - www.ReliaSoft.com

Use Level Probability Weibull

Beta=3.7483; Alpha(0)=-6.0220; Alpha(1)=5776.9341; Alpha(2)=-1.4340; Alpha(3)=0.6242

Unreliability

Time

Use Level CB@90% 1-Sided TB

Data 1
General Log-Linear
Weibull
338 | 0.01
F=35 | S=55

Data Points
Use Level Line
Top CI#1
Bottom CI#1

John Paschkewitz
Watlow Electric Mfg Co
2/4/2008
3:39:07 PM
Life vs. Stress as Trade-Off

Life, Cycles

Region of Acceptable Watt Density

Region of Unacceptable Watt Density

Wire Watt Density, WSi

ALT Cycles from 250 to 400 C
ALT Cycles from 250 to 430 C
ALT Cycles from 250 to 500 C

John Paschewitz
Watlow Electric Mfg Co
10/8/2009 3:06:05 PM

0.168" diameter
0.021" diameter PC NiCr wire cycled using controlled duty cycle ramp over 78 minutes cycle

Std= 0.7937; K= 7.1350E-12; n= 3.6556

ALT Cycles from 250 to 400 C
ALT Cycles from 250 to 430 C
ALT Cycles from 250 to 500 C

Region of Unacceptable Watt Density

Wire Watt Density, WSi

ALT Cycles from 250 to 400 C
ALT Cycles from 250 to 430 C
ALT Cycles from 250 to 500 C

Region of Unacceptable Watt Density

Wire Watt Density, WSi

ALT Cycles from 250 to 400 C
ALT Cycles from 250 to 430 C
ALT Cycles from 250 to 500 C

Region of Unacceptable Watt Density

Wire Watt Density, WSi

ALT Cycles from 250 to 400 C
ALT Cycles from 250 to 430 C
ALT Cycles from 250 to 500 C

Region of Unacceptable Watt Density

Wire Watt Density, WSi

ALT Cycles from 250 to 400 C
ALT Cycles from 250 to 430 C
ALT Cycles from 250 to 500 C

Region of Unacceptable Watt Density
Production Validation Test

- Repeat selected Qualification Tests on any Changes in Product or Process
- Test Samples made on Production Processes
- On-Going Reliability Test (ORT)
  - HASS – Highly Accelerated Stress Screening
  - HASA – Highly Accelerated Stress Audit
  - Periodic HALT Re-Test on Production Units
Failure Analysis / FRACAS
Failure Analysis Tools

• Basic
  – Recovery of Failed Samples
  – Electrical Test, Microscopy, Digital Photography

• Non-Destructive Methods
  – X-Ray (Real Time Digital is Particularly Helpful)

• Disassembly / De-capsulation
  – Tools or Chemicals to remove layers

• Scanning Electron Microscopy & EDS
  – Defects, Corrosion, Material Failure

• Acoustic Microscopy / Imaging (Voids / Defects)

• Some Internal, Others at Outside Labs
NDT – Electrical Characteristics

Curve Tracer – Showing Good and Failed Part Response
Real Time Digital X-Ray
Real Time X-Ray Example

Wire separation from the solder joint

Solder joint
Digital X-Ray Examples
SEM / EDS
Example of SEM / EDS Analysis

Pt: Rh: Al
87:10 : 3

Pt : Rh : Si
82.7:10.3:6.7
PCB Failure Analysis Methods

FIGURE 1. A burned PCA shows shearing near the J2 label. Note the damage to the component area. The high temperature in this area melted solder and let several components fall off the PCB.

FIGURE 2. This infrared image shows two hot areas (red and pink) and cooler areas (purple) on a PCA. Analysts use such images to locate abnormally hot areas that may indicate or cause failures.

FIGURE 3. The red area in this acoustic-microscopy image shows delamination (separator) of the die and the packaging material. The large black dot indicates carbonized plastic caused by excessive heat.

FIGURE 4. An x-ray view taken at an angle through a BGA shows individual solder balls and wire bonds but reveals little about micro-cracks and corrosion on PCB solder pads.

FIGURE 5. Liquid dye placed between this BGA and the PCB it was soldered to penetrated a space that existed between the center solder ball and its solder pad. The other balls were soldered properly to their respective pads, so no dye penetrated these junctions.

FIGURE 6. This cross-section image of a PCB via shows a crack that caused an open circuit. Stress, contamination, or insufficient plating might have caused the crack.

Failure Analysis Summary

• Progressive Use of Tools from NDT to Dissection and Cross-Section Exam
• Objective is to Find Physical Evidence of Failure Mechanism
• Document with Photos and Analysis to Capture Knowledge Gained
• Update FMEA or DRBFM with FA Findings
FRACAS
Failure Reporting, Analysis & Corrective Action System

- Build Knowledge Base
- Process and Tool
  - Reliability & Quality of Product, Service, Process or Software is Tracked, Measured, and Improved
  - Applies to Entire Product Life Cycle
  - Consistently Ranked Among the Most Important Reliability Tasks
  - Closed Loop: Ability to Feed Root Cause & Corrective Action Information Back Into Design Process for Further Improvement
Hierarchy of Failure Causes

- Design Related Failures
- Manufacturing & Quality Related Failures
- Repair Induced
- Customer Induced

Capture Failures from Verification Test to Field Operation
Capturing FA Knowledge

• Capture Failure Analysis Results in Searchable Tool
  – Commercial Data Base Tool
  – A3 Format Documents with Keywords
  – SharePoint (Microsoft)

• Key is Ability to Retrieve Knowledge with Minimal Search Effort

• Lean NPD is Knowledge Based – Key is Continually Adding to Accessible Knowledge
Summary

• Features of Lean NPD for Reliability
  – Front End Focus to Gain Knowledge
    • Basis for Better Design Decisions
  – Design for Robustness, Reliability
  – Understand Physics of Failure
• Testing to Learn and Verify
  – Test to Failure and Understand Causes
• Knowledge Capture for Future Re-use
• Develop & Control Critical Characteristics
References


• *Robustness Validation Manual*, ZVEI, January 2010; [www.zvei.org/RobustnessValidation](http://www.zvei.org/RobustnessValidation)

• Jusko, Jill; *New Models for Product Development*, Industry Week, April 21, 2010.

References

• Sarakakis, Georgios; *Fundamentals of Life Data Analysis: Concepts and Applications*, Tutorial, 2010


References


• Lean FMEA Training, Quality Associates International, at www.quality-one.com

Feedback / Follow-up

• Please provide your feedback on this web based short course: e-mail to jjpengr@gmail.com or to ASQ RD

• One day seminar on this topic available through:
  http://www.hobbsengr.com/Accelerated_Reiability_Seminar_Schedule.htm
  – Apr 13, 2011 in Chicago, IL
  – May 2, 2011 in Minneapolis, MN