Root Cause Analysis

Where Does It Fit In The Reliability – Liability Context?

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Product Reliability

- Root cause analysis allows:
  - Constant product & systems improvement
  - Reduction in product defects
  - Improved reputation and customer satisfaction
  - Ultimately, increased market share and profits
Product Liability

- Root cause analysis provides:
  - Facts and evidence to handle customer warranty claims [statutory, contractual, other]
  - Facts and evidence to assert claims “up stream” against vendors, suppliers and sub-contractors
  - Facts and evidence to avoid costly litigation
What Is Root Cause?

• Not Everyone Uses The Same Definition:
  – Root Cause
  – Failure Symptom
  – Failure Accelerator
  – Accelerating Factor
  – Characteristic of Failure
The ‘Root Cause’ is the most basic causal factor or factors that, if corrected or removed, will prevent the recurrence of the situation.*

The Purpose of Root Cause Analysis

Root cause analysis is best defined by its purpose -

The purpose of determining the root cause is to fix the problem at its most basic source so that it does not occur again, even in other products.
Root Cause Analysis Is Not

• Troubleshooting, or
• Repair of failure symptom

Troubleshooting simply eliminates a particular symptom or problem in a specific unit.
Why Are Root Cause Terms Important?

- Contractual duties may be tied to them
- Financial risks may be triggered by them
- If Buyer and Seller understand terms in different ways,
  - Cannot manage risk
  - Cannot price risk into product
Agreements among suppliers, manufacturers, distributors and retailers often contain warranties of product reliability and performance.

These warranties are devices the parties employ to shift the risk of liability for product defects.

Warranty liability for product defects is extremely difficult to project and contain.
Root Cause Analysis
A Liability Context

• Uncertain or unintended warranty obligations can be used to assert invalid claims, or deny valid claims.

• Unclear product performance and reliability requirements and expectations can be exploited.

• Root cause analysis helps contain both known and “unknown” warranty exposure.
Warranty Types

• U.N. Convention on Contracts for the International Sale of Goods ("CISG")
• Contractual Warranties – Express
  – Customized
• Statutory Warranties – Implied
  – Uniform Commercial Code ("UCC" – U.S.)
    • Article 2 – Sale of Goods
Warranty Characteristics

• Usually intensely negotiated because they shift the risk (and cost) of product defects
• Statutory warranties often eliminated or modified by Buyer and Seller in their contract
• May provide unstated reliability and performance expectations which are inconsistent with product specifications
  – The “Ticking Time Bomb” Warranty
Warranty Negotiation Factors

- **Duration** – How long are you exposed to risk?
- **Trigger Event** – What defects covered? All problems?
- **Cost to Remedy** – Repair? Replacement? Full Cost? Shipment?
- **Rate of Participation** – Costly product = higher participation by consumer.
Warranty Negotiations
Buyer’s Considerations / Motives

- Market niche (expensive/inexpensive product)
- Marketing appeal of warranty
- Competition’s warranty
- Company’s / product’s reputation
  - Value
  - Reliability
Warranty Negotiations
Seller’s Considerations / Motives

- Cost constraints – Buyer wants a Ford with the reliability / performance of a Mercedes
- Engineering issues associated with cost:
  - Manufacturing process (limited testing)
  - Components (inexpensive)
  - Inherent durability (meant to be replaced)
• Buyer wants to be able to advertise and sell its product to consumers as the very best product available, but still shift the risk of financial loss to the manufacturer, if the product’s performance and reliability does not match the buyer’s advertising.

• Seller wants to be able to manufacture the product as inexpensively as possible, but still satisfy the buyer’s ability to advertise and sell the product at highest possible cost.

• The engineer / scientist is put in the middle of these warranty negotiations, which are often conducted by non-engineers.
Warranty Negotiations
What Must The Manufacturer Know?

• What does the Buyer expect regarding:
  – Product performance?
  – Product reliability?

• How are Buyer’s expectations expressed?
  – Specifications?
  – MTTF?
  – MTBF?
  – Seller provides samples for engineering and validation testing?
Danger Signs

• Is the product warranty consistent with the Buyer’s expressed expectations?
  – If not, should you build product to expressed expectation or warranty exposure?
  – How do you engineer product to meet warranty exposure within agreed cost?
  – What should the warranty cost?
Warranty Negotiations
The Engineer

- Assist business people in understanding inherent product limitations
- Assist business people in drafting contracts that make engineering sense
- Assist the company in understanding any unstated “specifications” around which the product may have to be engineered
- Assist the company in understanding how product failures / defects ought properly to be analyzed
The Transactional Lawyer

- The transactional lawyer helps to create the contractual relationship between buyer and seller
  - Mediator among business people, engineers and other attorneys
  - Crafts precise language to protect against exposure to unwanted liability
  - Tries to define narrowly the obligations of buyer or seller to avoid later uncertainty
The litigation lawyer helps either the buyer assert claims against the seller, or the seller resist claims by the buyer—
- Exploits ambiguities created by imprecise contractual language
-Attempts to expand or contract liability for product defects
Case Study

- American computer company (Buyer) enters into contract with manufacturer (Seller) of video display units
- Hundreds of thousands of units manufactured, shipped and sold in U.S.
- Units begin to fail [color loss]
- American company asserts claim against manufacturer
- Costly litigation follows which continues for years
“Provided that Buyer notified Seller promptly in writing of any defect or nonconformity, then Seller shall, at Seller’s expense and at Buyer’s option, promptly repair, replace or accept the return of (and credit Buyer for) such defective Products . . . within ten (10) days of Buyer’s notice or a mutually agreed to turnaround time.”
“Seller shall, at Buyer’s option, promptly repair or replace Products . . . which exhibit Epidemic Failure within three (3) years of the date of manufacture.”
"Epidemic Failure means product failures at or above the rates set forth herein resulting from defects in material, workmanship, manufacturing process and/or design deficiencies attributable to Seller, including but not limited to use of components with inherent or latent defects, or consistent maladjustment’s during manufacture. Epidemic Failure is limited to product failures attributable to the same root cause."
The Epidemic Failure rate shall not exceed 1.8%.

The rate is defined as the calculation of the following data points: $A = \frac{B}{C} \times 100\%$ Where: $A$ is the epidemic failure rate, $B$ is the cumulative returned failures, and $C$ is the affected monthly production quantity of Product (data to be collected over a minimum 4 months).
“Buyer or its authorized repair facilities may repair defective Products . . . if it is deemed by Buyer and Seller to be the most time and cost effective approach. If the Products . . . are covered by warranty . . ., in such event, Buyer will promptly submit to Seller in writing, to the extent available, the serial numbers and date code of the defective Products . . ., the date of repair of the defective units by Buyer or its authorized repair facility . . . .”
“Seller shall have no liability or obligation to Buyer under this Warranty with respect to Products . . . which have been subjected to abuse, misuse, improper use, negligence, accident, alteration, tampering or faulty repair; provided, however, that Seller can demonstrate that such has occurred.”
Buyer’s Response To Product Failures / Returns

- Did not notify Seller
- Did not perform root cause analysis
- Monitors repaired by outside vendor
- Repair vendor only troubleshot
- Repair vendor personnel poorly trained
- Repair vendor failed to collect adequate and accurate data regarding failures and repairs
Buyer’s Response To Product Failures / Returns

• Repair vendor’s compensation tied to number of repairs
• Repair vendor failed to forward data timely to Buyer
• Buyer failed to analyze vendor’s repair data when received
• No information shared with Seller
• Repairs/replacements offered to consumers even after consumer warranty expired
Buyer’s Response To Product Failures / Returns

- Buyer’s financial losses increased
- Buyer’s market share decreased
- Buyer began to analyze data in effort to shift cost of returns
- Buyer claimed most failures were the result of “poor solder connections”
- Buyer claimed “poor solder connections” were the root cause of all failures
Buyer’s Response To Product Failures / Returns

- Buyer asserted Epidemic Failure claim
- Buyer provided no repair vendor details to Seller
- Seller questioned data from repair vendor
- Seller was denied access to repair vendor
- Seller refused Epidemic Failure claim
- Buyer sued Seller
- Years of costly litigation followed
Contract Language

Ambiguities

“Defects / Nonconformities”

• No standards for determining defect
• Subjective standard?
• Industry standard?
• If industry standard, which category or class?
IPC-A-610 Acceptability Classifications

- **Class-1-General Electronic Products**
  - Includes consumer products, some computer and computer peripherals, cosmetic imperfections are not important, major requirement is function

- **Class-2-Dedicated Service Electronic Products**
  - Includes communications equipment, sophisticated business machines, where high performance and extended life is required, uninterrupted service is desired but not critical

- **Class-3-High Performance Electronic Products**
  - Includes the equipment and products where continued performance or performance-on-demand is critical. Such as life support items or flight control systems. High levels of assurance are required, service is essential, or the end-use environment may be uncommonly harsh
Acceptable solder coverage: Circumferential fillet and wetting of lead and barrel should be min. 270° for Class 1 and 2.
For single sided boards, lead or wire protrusion (L), is at least 0.5 mm (0.020 in) for Class 1 and 2. There is no maximum length for class 1, so long as there is no danger of shorts.
Exposed Basis Metal (IPC-A-610, 6.5.2)

Acceptable-Class 1, 2, 3

- Exposed copper on vertical conductor edges, exposed basis metal at ends of component leads
Pin Holes/Blowholes (IPC-A-610, 6.5.4)

Acceptable - Class 1
“Within 3 years of manufacture”

- If Epidemic Failure is confirmed, are all products that exhibit the “same root cause” included, no matter when the failure is exhibited?
- How long is too long? 4 years, 5, 8 . . ?
Contract Language

Ambiguities

“Same Root Cause”

• Permits Buyer to use very broad definition which will include many, many returned products
• Permits Buyer to expand scope or trigger of traditional warranty
• Permits Buyer to extend duration of traditional warranty
Buyer’s Definition of Root Cause

“The term ‘root cause’ in this case means the characteristic of the failure that allows a remedy to be implemented.”

“The video boards ceased to function as intended as a result of defective solder connections. The defective solder connections were the root cause of the problems found in the monitors.”
Contract Language

Ambiguities

“To the extent available”

• Buyer or its repair vendor required to share data only “to the extent it is available”
  – Promotes concealment
  – Promotes delay in performing proper root cause analysis
  – No punishment for Buyer manipulating data to create epidemic failure
Contract Language

Ambiguities

“Provided that Seller can demonstrate that such [abuse] has occurred”

• If Seller excluded from repair process, Buyer can conceal facts and data

• Buyer or its repair vendor can avoid collecting data with which Seller might challenge cause of failure
The Conflict

- Buyer identified “root cause” of product failures as defective solder connections
- Repair vendor did not collect enough data to thoroughly analyze other potential root causes
- Buyer concealed data and impaired Seller’s ability to perform true root cause analysis
Potential Causes Of Product Failure

- Thermal and moisture expansion mismatch stress conditions
- Vibration (shock) stress conditions
- Components
- Poor quality solder connections
- Other [unknown due to repair vendor’s poor data collection]
Thermal & Moisture Expansion Mismatch Stress Conditions
Soldered Side of Video Board
Thermal Imaging of Video Board

Infrared image of monitor board after 60 minutes of operation showing board temperature, adjusted for a 40°C ambient air temperature.
Silicone Gel
Silicone Gel
Vibration (Shock) Stress Conditions
Vibration (Shock) Stress Conditions

- Vibration (Shock) stress conditions can be caused by
  - improper packing
  - shipping,
  - handling and
  - use
Example of Typical Cracks in Monitor Cases
Components
Component lead oxidation can arise if the leads are poorly plated by the electronics component manufacturer. Copper oxides are brittle and weak.
Group : 11-August-2000  ID# : 13
Sample : 48 Lead X-sec exterior
Comment : Full Scale : 10KeV(10eV/ch,1Kch)
Live Time : 56.520 sec  Aperture # : 2
Acc. Volt : 20.0 KV  Probe Current : 2.262E-08 A
Stage Point : X=21.446 Y=56.835 Z=11.000
Acq. Date : Mon Aug 14 15:32:45 2000

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Chi_square = 1.9899

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Total 100.000 100.0000
Normalization factor = 8.7450
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Sample : 11-August-2000  ID# : 12  
Comment : 48 Lead X-sec interior  
Condition : Full Scale : 10KeV (10eV/ch, 1Kch)  
Live Time : 57.960 sec  
Aperture # : 2  
Acc. Volt : 20.0 KV  
Probe Current : 2.248E-08 A  
Stage Point : X=21.291 Y=56.745 Z=11.000  
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Total  100.000  100.0000  
Normalization factor = 49.7733
Poor Solder Connections
Cracked solder connection in component of looper
Cracked solder connection in component of looper
Cracked Solder Connections that had been Reflowed in Loopers Looked the Same as Cracks in First Time Returns

First time return

Looper
Delaminations in solder connections that had been resoldered in loopers looked the same as delaminations in first time returns.
Was There An Epidemic Failure?

- Insufficient data to determine
- Evidence of multiple causes of failure
The Buyer’s Reliability Performance Specification Was Satisfied

Buyer’s Specification for the monitor stated that “the MTBF of this product shall meet or exceed 50,000 hours @40°C excluding CRT at a 90% lower confidence limit under all operating conditions as specified in section 2.4.”

Given the MTBF, the percentage monitors returned is calculated by

\[ Q(t) \equiv 1 - e^{-t/MTBF} \]
Buyer's Reliability Performance Specifications vs. Percentage of Monitors Returned to Repair Vendor

Therefore the return rate is within the expectations of the performance specifications

Assumes 24 hours of daily use

Assumes 6 hours of daily use

MTBF: 200,000 hrs (22 years and 10 months) λ: 5.0e-6
% of allowable monitor failures according to Buyer's Specification
% of total monitors returned to Repair Vendor
% of 1996 monitors returned to Repair Vendor
% of 1995 monitors returned to Repair Vendor
% of 1994 monitors returned to Repair Vendor
What Was The Outcome?

- Million dollars (or more) spent on lawyers and experts
- Hundreds of hours of business and engineering time spent
- Damaged relationships
- Damaged reputations
- Ultimately, both sides lost
How To Defuse Ticking Time Bomb “Warranties”

• Involve engineers in contract negotiations so business people understand design requirements imposed by hidden specs.
• Eliminate contractual ambiguities that trial lawyers might take advantage of.
• Conduct root cause analysis early, often and openly using a methodology agreed upon by the Buyer and all others involved in manufacturing the product.
Lessons Learned
The Essentials of Root Cause Analysis

• Parties must agree on the type of failure data to collect
• Collected data must be promptly distributed and analyzed
• Parties must collaborate and jointly review and analyze collected data
• Parties must agree upon a methodology for product testing
THANK YOU