Design for Reliability

- *Theory and Examples on Telecommunication Systems and Optical Components*

可靠性設計

- 運用於電訊系統及光電產品之理論與實例

Handout

Industry
September 23 , 2009

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Design for Reliability Seminar

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Design for Reliability Seminar

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專案研討– 高可用性系統

創造可靠產品的最佳方法是在產品量產之前，
就進行可靠性設計，並以低成本、短設計周期方式
，達成顧客期待的可靠水準。

Why Design For Reliability ?

爲何需要可靠性設計

Resolution

- Apply "Design for Reliability" techniques:
  - Evaluate **system architecture capability** to meet reliability requirements.
  - **Predict reliability level** in early design phase.
  - Identify **design weakness** and **over-design** issues.
  - Improve design on the **hidden failures** and **interface design** between software and hardware.
  - Provide **new product reliability information to customer** and build their confidence on new product.

What is "Design for Reliability" ?

"Design for Reliability" (DFR) is an integrated process of **reliability**, **design** and **operations** departments by applying techniques to review and improve product design, test and monitor reliability in manufacturing and field so as to assure we have **capable system architecture**, **reliable components** and adequate **fault avoidance and fault tolerance schemes**.

The Challenge To Company

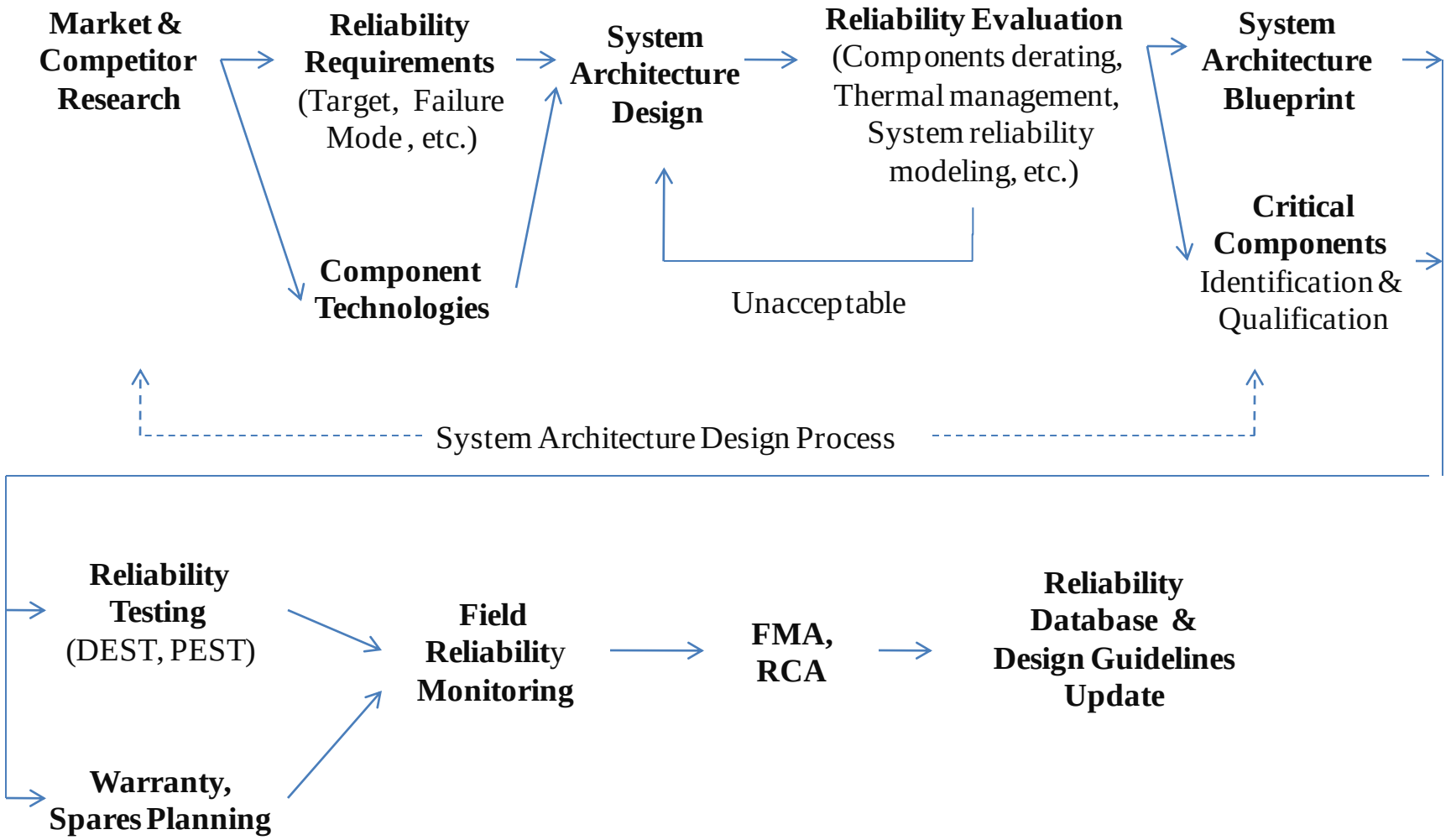
To establish a customer return rate and/or downtime goals that are at least 2X better than the leading competitor's level.

How do we implement DFR?

- **Leadership team** support and involvement.
- **Benchmark** with leading industrial companies.
- **Share best-current-practices** among project teams inside company.

DFR Process
可靠性設計的流程

DFR & System Architecture Design Process



Key Elements in DFR Plan

1. Reliability target and allocation of the target.
2. New component technologies and critical components identification.
3. Supplier qualification and management program.
4. System reliability model establishment.
5. Electrical stresses derating & thermal management.
6. EST evaluation and key failure mechanisms identification.
7. Field reliability monitor and FMA

Properties Of DFR
可靠性設計的特質

- **Scalable**
  - from small to large systems,
    from component to complicated systems
- **Universal**
  - applicable to most of industries
- **Quantitative**
  - measurable and comparable
- **Predictable**
  - look into future using past experience,
    proactive vs. reactive
- **Accurate**
  - in relative way,
    improve through sharpen inputs and use
    better models

Concept and Theory of Reliable Product Design

設計可靠產品的觀念與理論

Reliability Fundamentals

Non-maintained & Maintained System

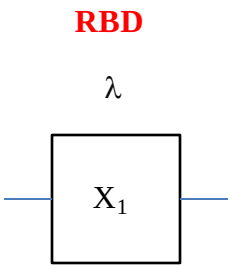
- **Non-maintained system**
  - Customer focused measure are “Reliability” or “Dependability”.

- **Maintained system**
  - Customer focused measure are “Availability”, or “Down Time”.

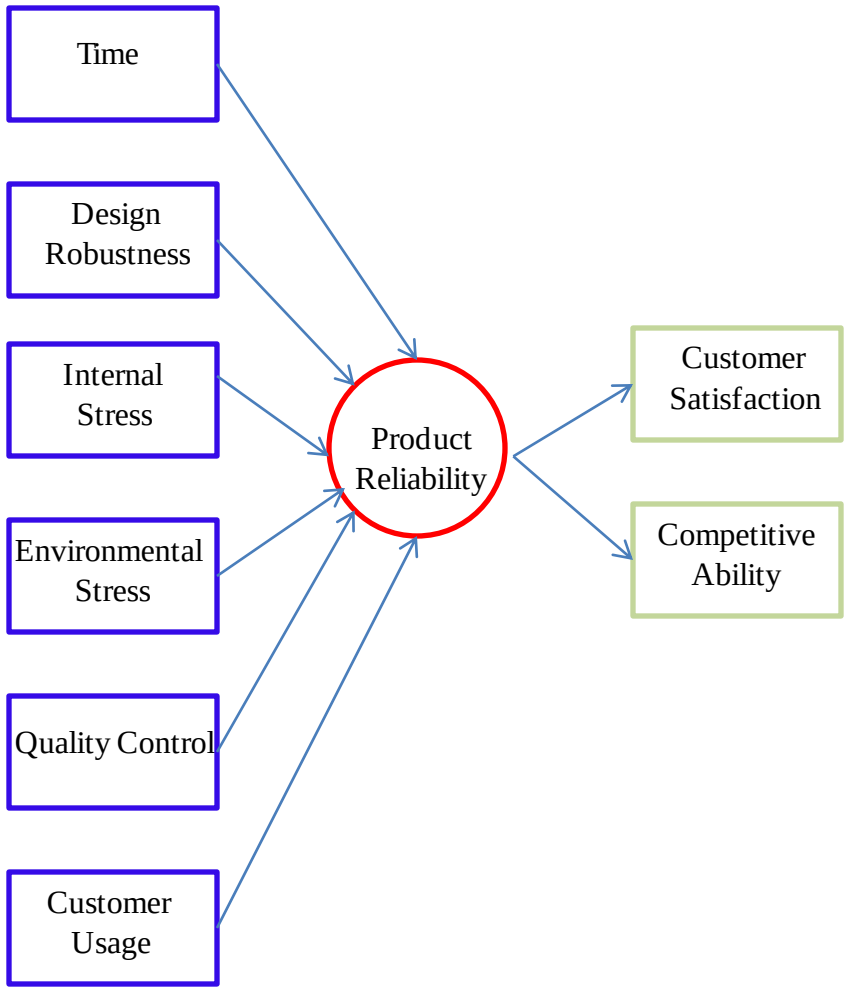
Definition of Reliability

- A persistence of quality over lifetime of product.
- Reliability of a system, *R(t)*, is the probability that, when operating under stated environmental conditions, the system will perform its intended function adequately for a specified interval of time.
- For constant failure rate λ,

$$R(t) = e^{-\lambda t} \qquad t \geq 0$$



Influence Factors on Reliability



Grades of Product Reliability

- Annual return rate (%) = (1- Reliability(t = 1 year)) * 100

  Example: λ = 1000 FITs, R(1 year) = $e^{-\lambda t}$ = 99.13%

  Annual return rate = 0.87%

- There is no commonly used definition of High Reliability.
  We may apply similar definition from HA (High Availability) as reference.
  - **3-nines** reliability

    0.999 for the mission time t
  - **4-nines** reliability

    High Reliability ⇨ 0.9999 for the mission time t
  - **5-nines** reliability

    Ultra-high Reliability ⇨ 0.99999 for the mission time

Principles of Reliable Product Design

Principles for Reliable Product Design

1. **System architecture design assessment**
   - Making sure the framework for product reliability.
2. **Proper usage of components and simplicity of design**
   - Prevent components misapplication, avoiding using non necessary parts, integrating components into single chip or module. etc.
3. **Ensure component reliability**
   - Selection of right components and suppliers
4. **Component stress derating**
   - Emphasis on derating of electrical, thermal and mechanical stresses

Principles for Reliable Product Design (cont.)

5. **Robust design**
   - Tolerance design on component parameter variation and drift failure.
   - Input/output protection on EOS/ESD resistance ability.
6. **Redundancy design**
   - Classification of non-redundancy and redundancy design
7. **Ensure software reliability**
   - Software process maturity index assessment, software fault number, software reliability growth test.

System Reliability Modeling
系統可靠性模式分析

Reliability Prediction and Modeling

- Reliability predictions are based on statistics and therefore contain **inherent variability or uncertainly.**

- **Better reliability model** means capable on providing **more useful information** for reliability improvement.

Advantages of using Markov Modeling – A Strategic Choice

- **Competitive Advantage in the Marketplace**

  - Markov modeling is a method recognized by industry and has better accuracy in general.
    - Use of Markov modeling method to demonstrate system reliability prediction base on system architecture is a competitive advantage in the market place, as compared with use of unapproved prediction method.

- **Uncovers buried assumptions (Silent Failures)**
  - Markov provides insight into how the system is functioning and where the silent failures occur. Buried assumptions are uncovered.

Advantages of using Markov Modeling – A Strategic Choice (cond.)

- Uncovers buried assumptions (cond.)
  - Cover important product failure modes, known and estimated, which in terms transform to system downtime and reliability.
  - Include key engineering controllable factors that have influence on system reliability.
  - Provide R&D useful information on best approach to improve architecture/design from reliability, functional and economic views.

Component Stress Derating and Application on Reliability Prediction

零件應力降額設計及其在可靠性預測的應用

Electrical Stress by Component Category

- **Selected electrical stress by part categories:**

Capacitor:	Sum of applied DC voltage plus AC peak voltage / Rated voltage
Resistor, fixed	Applied power / Rated power
Switch / Relay	Contact current / Rated current
Diode, general	Average forward current / Rated forward current
Transistor	Power dissipated / Rated power

Component Derating Guidelines - Sample

Derating level determination:

Weighted based on factors of

- Reliability challenge,
- System repair,
- Safety,
- Size and weight,
- Life cycle.

Components Derating Guidelines Reference Sources

- Derating levels by electronic and optoelectronic components:
  Reliability Engineer's Tool Kit, The Rome Laboratory, 1993

- Derating factor vs. Failure rate adjustment factor (temperature factor, electrical stress factor) , failure rate information.

  - **Telcordia SR-332,** "Reliability Prediction Procedure for Electronic Equipment", Issue 2, 2006

  - **MIL-HDBK-217F**, "Reliability Prediction of Electronic Equipment"

  Comment: MIL-217 prediction on component FIT rate is a relatively conservative estimate.

Field Reliability Monitor and Failure Rate Stage Analysis

場域的可靠性追蹤與故障率型態分析

Missions of Field Reliability Monitor

- Projection of field disaster problems for prevention
- Root cause diagnosis
  - reliability physics and component failure rate stage analysis
- Supplier failure responsibility verification
- Reliability prediction database update using field data

Reliability Software Tools
可靠性應用軟體

Reliability Software Tools

- **Relex**
  - http://www.relex.com/

  - A reliability tool for solving Markov models
    Capable to handle large scale models

    Input:
    - failure rate, repair rate and other model parameters,
    - state transition matrix,
    - identify state as up or down states

    Outputs:
    - reliability results,
    - availability results in transient and steady-state phase,
    - downtime

    Limitation:
    - unable to handle time dependent failure rates and repair rates for sensitivity analysis.

  - Capable in other statistical analysis and reliability and cost evaluations.

Reliability Software Tools

- **Minitab**
  - http://www.minitab.com/en-US/default.aspx
  - Statistical software tool
- **MS Excel**
  - Manual input data and equations for steady-state Markov availability model solution.
  - Convenient for steady-state availability analysis
  - Difficult on transient period early availability study
  - Low cost option

Explore Your Passion on Reliability