Reliability Engineering History

Number of Components/System $f(t)$

Time of Application
Reliability Engineering: Why worry about reliability?

- Well managed reliability programs pay-off:
  - Discover failure modes during design and development
  - Discover mission critical failure modes
  - Simplify and improve designs
  - Provide solid base for design improvements
  - Provides LOWEST COST of ownership

![Cost of Ownership Graph](image_url)
NLC Reliability Engineering
Data Sources
NLC Reliability Engineering
Data Sources

• Common reliability tools found to be in use in most companies and governments:
  – Inductive (Bottoms Up Analysis):
    • Reliability Analysis Math Models
    • Failure Modes and Effects Analysis (FMEA)
  – Deductive (Top Down Analysis):
    • Reliability Block Diagrams (RBD)
    • Availability Allocation
    • Logistics Support Analysis Report (LSAR)
Reliability Analysis Flow Chart

Phases:
- Design
- Production
- Operation

Design Review

Reliability Block Diagram

Failure Modes and Effects Analysis

Math Models and Reliability
Allocations:
- MTF
- Failure Rates
- MTTR
- Availability

Data Sources:
- MIL-HDBKs
- Bellcore
- Manufacturer

Benchmarks based on the SLC:
- DC Magnet Power Supply Reliability Study

### Project Planning and Coordination

- We are currently in this phase.
5045 Klystron-Pulse Tank System RBD

SLC 5045 Klystron–Pulse Tank System RBD
18JUL97 WBS#: 1.5.3.2
Duane Reliability Growth (5045 Klystron)

- This model assumes that the plot of MTBF versus time is a straight line when it is plotted on log-log paper.
- It should be noted that the model assumes that a change or fix in the design is immediate.
## Example FMEA

<table>
<thead>
<tr>
<th>Part Name &amp; Number</th>
<th>Potential Failure Mode</th>
<th>Potential Effects of Failure</th>
<th>Potential Causes of Failure</th>
<th>Severity Ranking Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klystron-Pulse Tank Assembly</td>
<td>Provide rf power to amplify and accelerate the electron beam</td>
<td>Loss of RF Power</td>
<td>Loss of Function, Possible failure of sector resulting in machine downtime</td>
<td>5 Gun ceramic failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 RF window failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 Unstable rf output</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4 Vacuum leak</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4 Gassey cathode</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 Mechanical failure of water system</td>
</tr>
</tbody>
</table>

**System Name:** Stanford Linear Collider  
**Subsystem Name:** RF Power Sources  
**Component:** Klystron-Pulse Tank  
**Design Responsibility:** Klystron Department  
**Suppliers & Groups Affected:** SLC Operations  
**Other Areas Involved:**  
**WBS#:**  
**Prepared By:** Zane Wilson  
**FMEA Date (Orig):** 7/10/97  
**Engineering Release Date:** Jun-94  
**Severity Ranking Table:**  
1. None: No effect  
2. Minor: Functional & performing; loss of cosmetic functions  
3. Low: Operable but at a reduced level of performance  
4. High: Operable but at a reduced level; loss of control functions  
5. Very High: Inoperable - loss of primary function
**Example FMEA (Cont.)**

**Failure Mode and Effects Analysis**

*Design FMEA*

<table>
<thead>
<tr>
<th>Occurrence Rating Table</th>
<th>Detection Ranking Table</th>
<th>Iteration #: 003</th>
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</thead>
<tbody>
<tr>
<td>5 VERY HIGH: Must be addressed (Rate: $1 \times 10^{-5}$)</td>
<td>5 VERY HIGH UNCERTAINTY</td>
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</tr>
<tr>
<td>4 HIGH: Cause frequent downtime (Rate: $3 \times 10^{-6}$)</td>
<td>4 HIGH UNCERTAINTY</td>
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</tr>
<tr>
<td>3 MODERATE: Cause some downtime (Rate: $1 \times 10^{-6}$)</td>
<td>3 LOW UNCERTAINTY</td>
<td></td>
</tr>
<tr>
<td>2 LOW: Cause very little downtime (Rate: $3 \times 10^{-7}$)</td>
<td>2 VERY LOW UNCERTAINTY</td>
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</tr>
<tr>
<td>1 REMOTE: Failure unlikely (Rate: $1 \times 10^{-7}$)</td>
<td>1 NO UNCERTAINTY</td>
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<table>
<thead>
<tr>
<th>Design Evaluation Technique</th>
<th>DET</th>
<th>RPN</th>
<th>WHEN</th>
<th>WHY</th>
<th>Recommended Actions</th>
<th>Corrective Actions</th>
<th>Area/Individual Responsible &amp; Completion Data</th>
<th>Action Results</th>
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<td>Test, breakup of rf</td>
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<td>Vacuum readings</td>
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<td>Visual inspection, rf breakup, material assurance</td>
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**Data Choice Table: Used for pull downs**

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<td>3 LOW UNCERTAINTY</td>
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<tr>
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</table>

**Project Planning and Coordination**

Z. Wilson
Criticality Analysis

Criticality Matrix

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<tr>
<th>Occurrence</th>
<th>REMOTE</th>
<th>LOW</th>
<th>MODERATE</th>
<th>HIGH</th>
<th>VERY HIGH</th>
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</table>
When & Why Matrix

When & Why Matrix

Why

Quantity

Manufacturer Defect  Design Defect  Radiation  Temperature  Humidity  Vibration  Lack of QA/QC  Personnel  Stress

Design
Fabrication
Transit/Installation
Post-installation

Z. Wilson
Reliability, Maintainability, Availability Program

- **CDR Goals**
  - Identify RMA activities and tools.
  - Define RMA requirements, including Design Reference Mission.
  - Develop availability requirements budget.
  - Identify critical systems for RMA engineering.
  - Start development, test and evaluation programs.
  - Validate RMA budgets.
  - Develop Failure Reporting Analysis and Corrective Action System (FRACAS).