C Europe: Berlin, Germany

Sandia National Labs
PV Systems Integrators Workshop
31 March 2010

Application of a Reliability Program Plan

Putting your Reliability Competency to Work

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Manager Reliability and ICIM for Engineering
Global Reliability and ICIM Competency Owner
Delphi Thermal Systems

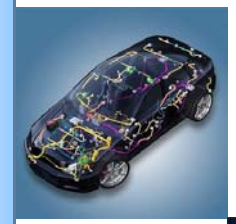
Our Time Together

- Agenda
  - ✓ Introduction 2 min
    - Style: Interactive and Sharing
  - Engaging a Reliability Engineering Network 10 min
    - Vision
    - Developing and Maintaining Competency
  - Strategy for Reliability Engineering 60 min
    - Typical Reliability Program Plan: Standard Work, Tools and Examples
      - Define, Identify, Analyze and Assess, Quantify and Improve, Validate, Monitor and Control
  - Summary 3 min
  - Questions 15 min

A Little Bit About

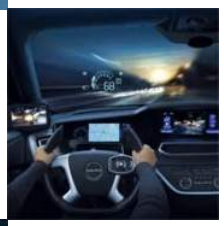
DELPHI

Innovation for the Real World



Electrical/Electronic Architecture

- Electrical/Electronic Distribution Systems
- Connection Systems



Electronics & Safety

- Electronic Controls
- Infotainment & Driver Interface

Powertrain Systems

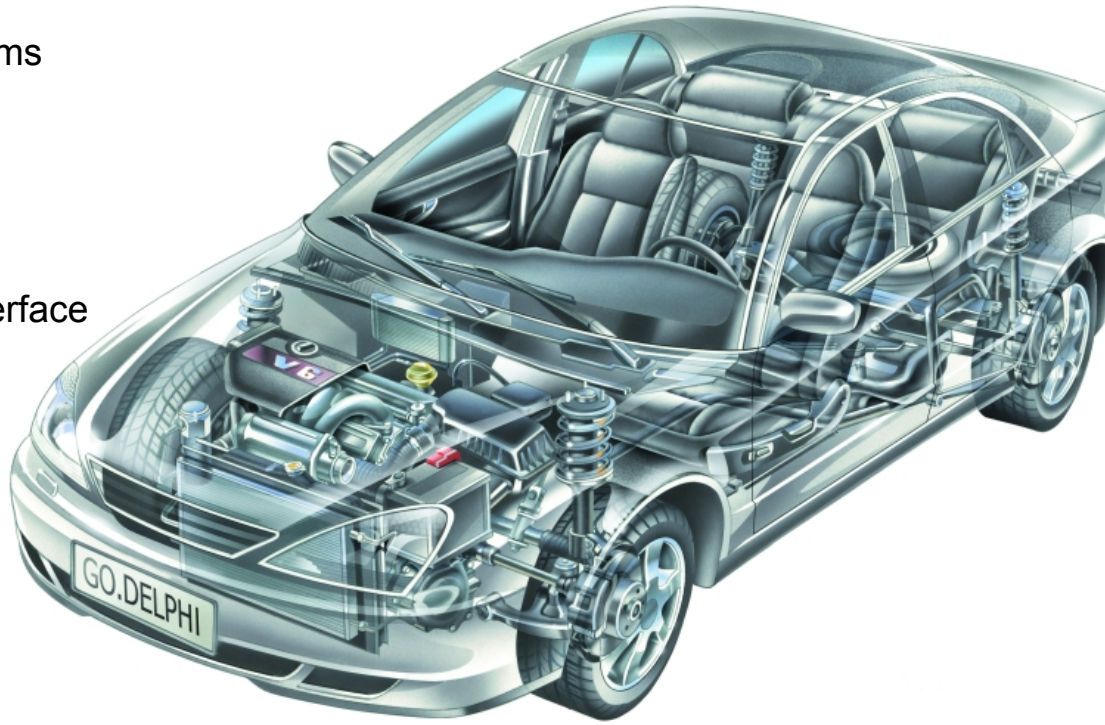
- Gas Engine Managements Systems
- Diesel Engine Management Systems

Thermal Systems

- Thermal Automotive
- Thermal Residential and Commercial Heat Exchangers

Product & Service Solution

- OE Service & Independent Aftermarket
- Diesel Aftermarket



Employment:	**107,520 globally**
# of Countries:	**32**
# of Locations:	**270**
# of Customers:	**12,400, including aftermarket**

We're a Systems Integrator too!

Vocabulary and Acronyms

- Reliability Competency
  - Knowledge – understanding gained by actual experience
  - Ability – the quality of being able, sufficient power or resource
  - Skills – developed or acquired ability to use knowledge
  - Tools – something used in doing a job
- Reliability Standard Work – known, common, expected actions
- ADP – Advance Development Process
- ADVPR – Analysis, Development, Validation, Plan and Report
- ALT – Accelerated Life Test
- CP – Change Point
- DFMEA – Design Failure Mode (Mechanisms) Effect Analysis
- DfR – Design for Reliability
- DfSS – Design for Six Sigma
- DOE – Design of Experiments
- DRBFM – Design Review Based on Failure Mode
- DRT – Design Reliability Test
- DV – Design Validation
- Fmap – Functional Process Mapping
- FMEA – Failure Mode and Effect Analysis
- HALT – Highly Accelerated Life Test
- OEM – Other Equipment Manufacturer
- PDP – Product Development Process
- Pmap – Process Map
- PRAT – Production Reliability Acceptance Test
- PV – Production Validation
- RBD – Reliability Block Diagram
- RFQ – Request for Quote
- RPP – Reliability Program Plan
- RRA – Requirements Risk Assessment
- SAE – Society of Automotive Engineers
- SOR – Statement of Requirements
- SSI – Stress, Strength and Interference

Global Reliability Engineering

- Issues that Must be Addressed
  - Global Engineering Footprint
    - Different cultures
    - Different work practices
    - Different skill levels
  - Different customers
  - Resource Constraints
  - Economic Pressures
- Delphi Thermal Systems Approach
  - Common high level Methods – DfR
  - Standard work – RPP
  - Common certification – CRP
  - Core tools with global access
  - Strategic Competency Partner
  - Monthly Global Reliability Engineering Networking (Reality Checks)

Vision

- The Design for Reliability and Reliability Program Plan Guideline were developed primarily by selecting methods from two highly recognize industry sources that outline best practices for reliability;
  - Society of Automotive Engineers' – "Reliability Program Standard Implementation Guide" (SAE JA1000-1)
  - Reliability Analysis Center's – Blueprints for Product Reliability series (RBPR 1-6)

- The goals in developing DfR and establishing the RPP process were to create a guide that would be:
  - Practical in use
  - Credible to engineering and our customers
  - Have a positive influence on product reliability
  - Enable strategic leveraging of resources to meet business needs

Reliability Competency Roles and Responsibilities

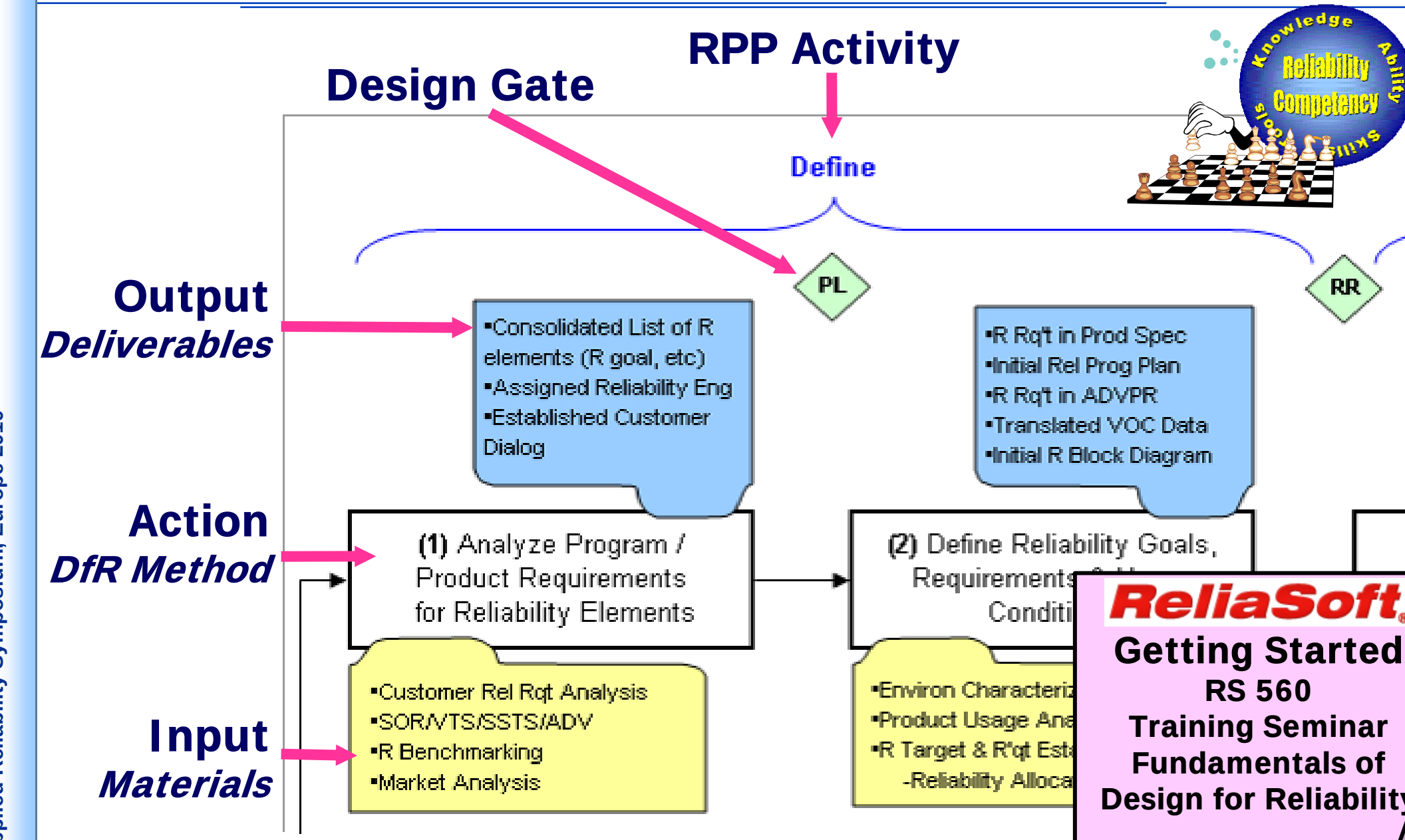
- Participate in the planning stages
  - Ensure Reliability resources are identified and aligned to project timing
- Prepare a reliability program plan
  - List the needed reliability tasks
- Budget the allowable system failures down to the component level
- Evaluate the reliability potential of alternative designs
- Ensure that all components actually behave as the designer anticipates
  - Insure products have suitably long lives
- Develop reliability tests for components, subsystems, and systems
- Provide guidance on how to improve system life and maintenance
- Investigate user complaints and field failures
  - Set up programs to ensure information about field failures is timely, accurate, organized, and used

Reliability Engineering Competency Development and Certification

- To help ensure consistent application of reliability engineering techniques a set of competency and certification requirements were established.
  - Thermal's certification process follows a learn and apply format
    - Formal Training (Combination of Internal and External)
      - Delphi Thermal committed to use the Certified Reliability Professional program for the development of reliability engineers.
        - program details can be found at http://www.reliabilityprofessional.org/
    - Do Something for the Company: Project Work (Sponsor Approval)
    - Demonstrate Technical Competency: Method and Tool Application (Master Approval)

DfR / RPP Process Map (Reliability Strategy)

(Know where you are going and how to get there)



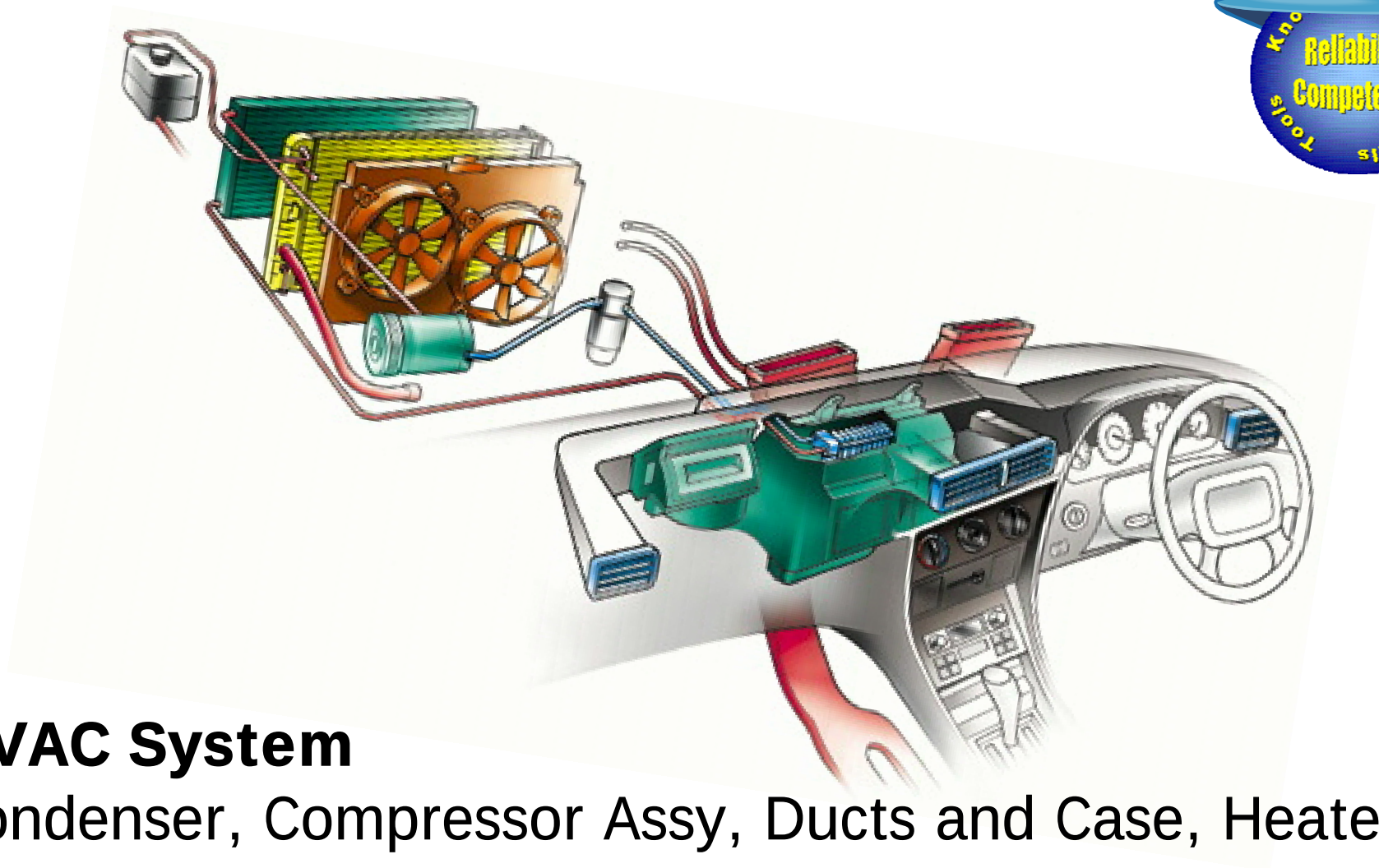
ReliaSoft

Getting Started
RS 560
Training Seminar
Fundamentals of Design for Reliability

Common Tools

- Delphi Reliability Engineering Basic Tool Box
  - Basic Data Handling and Analysis **– Excel**
    - RPP Workbook
  - Life Data Analysis and more **– Weibull ++**
  - Reliability Block Diagrams **– BlockSim**
  - Accelerated Test Analysis **– ALTA Pro**
  - Reliability Growth Analysis **– RGA Pro**
  - Statistical Analysis and DOE **– DOE++ and MiniTab**

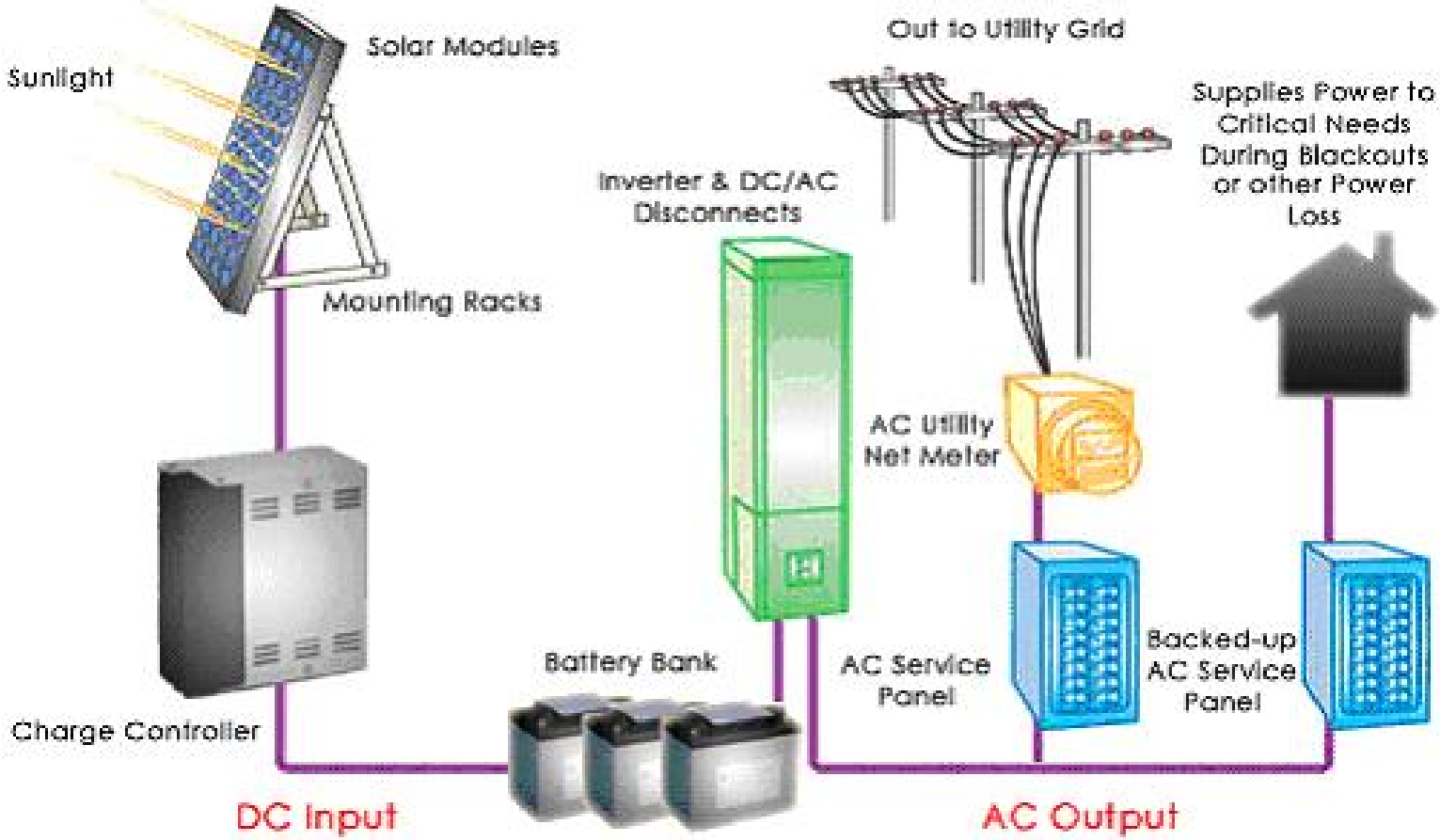
Let's Get to Work



HVAC System

Condenser, Compressor Assy, Ducts and Case, Heater and Evaporator, Blower Assy, Actuators, Controls

Relate HVAC System to PV System



PV System

PV Array, Marshaling Box, DC Disconnect, Fuse, PV Inverter, Transformer, Power Meter, AC Disconnect, Service Panels, Cables and Fittings

Define

- Defining Reliability Programs: Identify appropriate activities to be used to develop and ensure reliable products and systems.
  - The reliability engineer, working with the product team, will tailor reliability activities such that they become cost effective and timely parts of the overall product program.

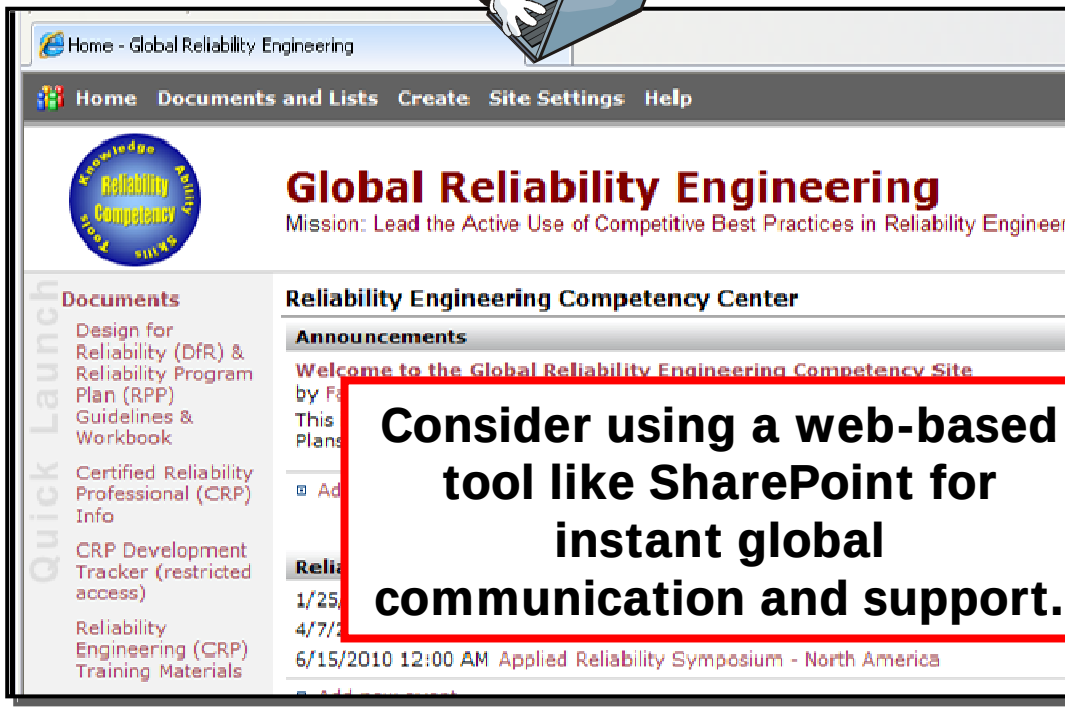
RPP Workbook

Templates to Support Reliability Engineering Activities

Effective Date: 16-Jul-09

Index

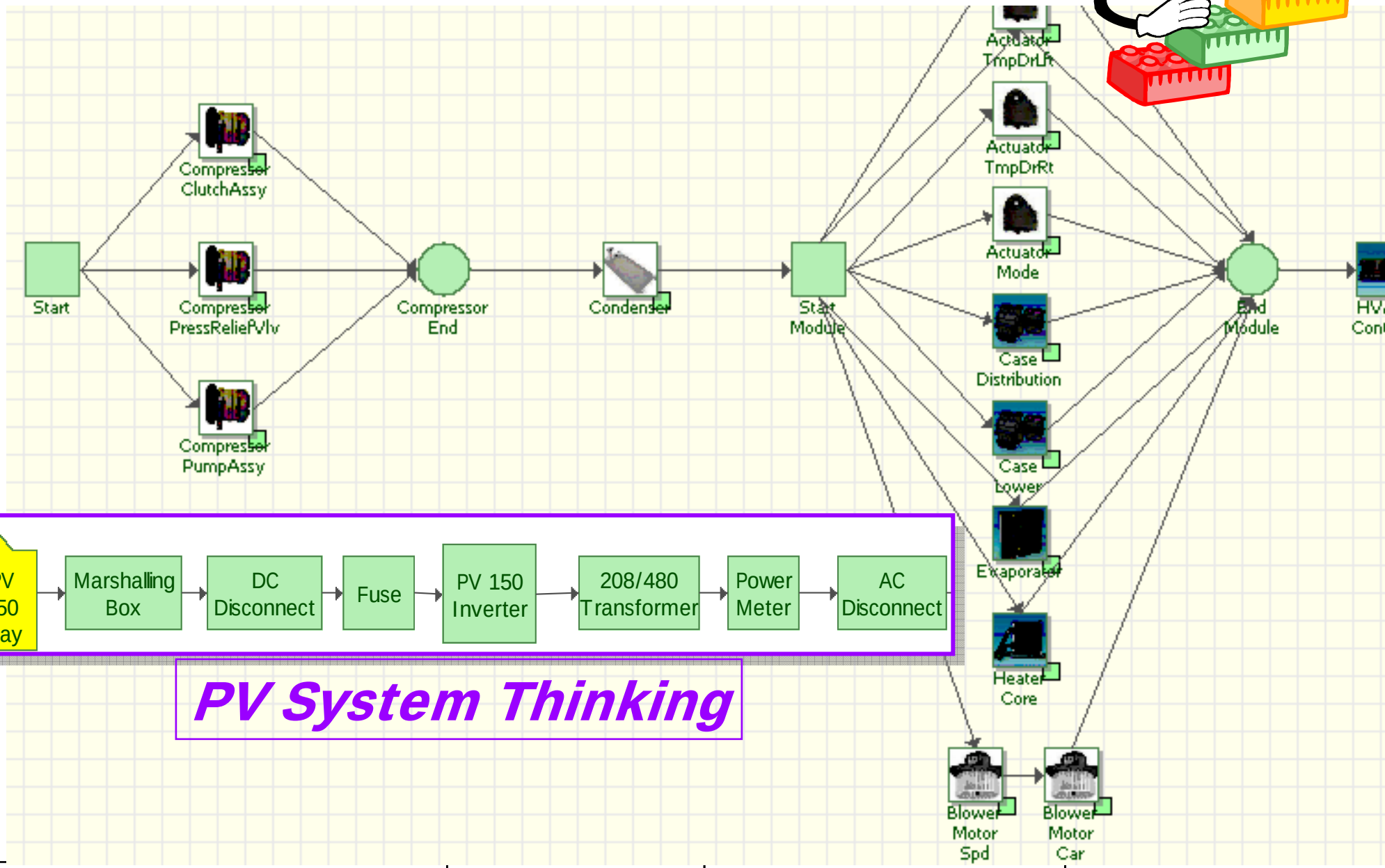
Item	Worksheet
1	DfR Strategy Thought Map
2	Design Review Prep Questions
3	Environment Check List
4	Stress Identification Template
5	Change Point Discover Sheet
6	Change Point Summary Sheet
7	3 Point Estimate Calculator
8	Design Margin Analysis
9	Usage to Test Matrix
10	RPP DV Plan
11	RPP PV Plan
12	RPP Test Summary Report Template
13	RPP Test Summary Report example
14	Robust Engineering P-diagram Test Report example
15	Basic P-map Template
16	Functional P-map Template (with life cycle)
17	DRBFM Template
18	DRBTR Aid / Template
19	Reliability DOE Planning Sheet



RPP Thought Map
Keeping Track of the Journey

Questions / Problems	Initiate Date	Actions	Tools / Resources	Results / Findings
Define				
What are customer expectations and how have they been translated into engineering metrics?				
To what conditions will the item be exposed over its life?				
What is the required level of performance expected over the products life? (i.e.: What constitutes success and failure?)				
Does the technical specification capture the requirements and operating environment in a customer relevant manner that can be validated?				
What reliability activities are the most effective for the product or system, such that the reliability				

Baseline (RBD)



Environment Check List

	Environment/Event	Probability of Exposure	Expected range/level of exposure (High, Low, Avg)	Comments (Spec Reference,
Natural Environment	High Temperature			
	Low Temperature			
	Thermal Cycling			
	Thermal Shock			
	Humidity/Moisture			
	Rain/Moisture			
	Immersion			
	Hail/Sleet/Freezing Rain			
	Frost/Ice/Icing			
	Snow/Sleet			
	Wind			
	Fog			
	Salt Atmosphere/Air/Fog			
	Salt Road/Spray			
	Sand/Dust/Mud			
	Solar Load (Sunlight)			
	Ultraviolet Rays			
	Electromagnetic Radiation			
	Lightening			
	Altitude/Air Density/Vacuum (low/high pressure)			
	Ozone			
	Chemical Attack			

Product Life Cycle

- **A** Acquire/Transport Raw Materials
- **B** Create Primary Part
- **C** Create Saleable Unit
- **D** Distribute to OEM
- **E** Installation into System
- **F** Distribute to End-User
- **G** Use of Product (QRDP)
- **E** Serviceability of Product
- **F** End of Life

Identify

- Identify Design Issues: The reliability engineer must support the product development team by clearly identifying areas of the product or system that need reliability improvement or require reliability assessment through test and analysis.
  - Core tasks typically performed in the Identify phase include: Identifying Key Reliability Risks through Change Point and Criticality Analysis.
  - Risk items are then managed either by using DFMEA for new products or using Design Review Based on Failure Modes (DRBFM) for existing products.
  - Finally, the Reliability engineer needs to establish a Reliability Program Plan for improvement and tracking of key reliability activities.

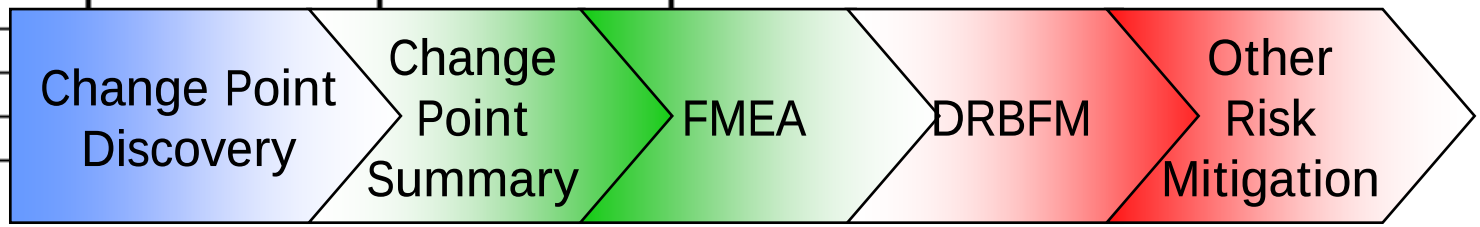
Change Point Analysis: Discove

Key words (view points)			Intentional change	Unintentional	Notes
1	Specification				
2	Function				
3	Performance				
4	Usage Environment	Load			
		High temp.			
		Low temp.			
		Humidity			
		Vibration			
		Power supply			
		Noise			
		Radio Wave			
		Light			
		Sound			
		Water			
5	System (mating parts)				
6	Structure				
7	Shape				
8	Circuit				
9	Software				
10	Component				
11	Material				
12	Processing				
13	Assembly				
14	Equipment				
15	Supplier				

If you have "good" stable products then your problems / risks will be hiding in the changes!

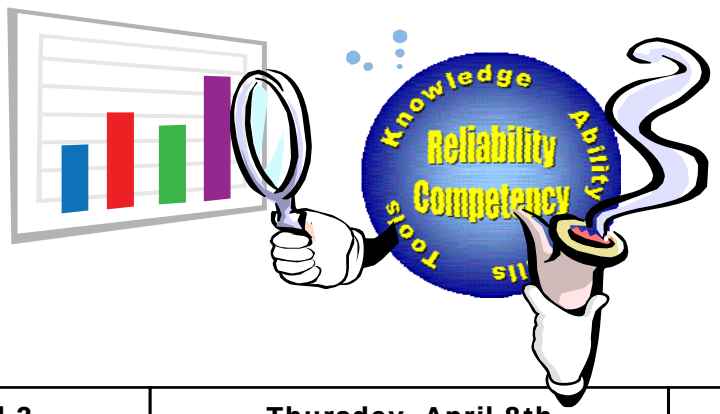
Change Point Analysis

1. List All Changes: Use CP Discovery sheet to drive thought process. (Compare: use prints, parts, specs, BOM, block diagram, etc.)
2. Pick Baseline: Current product or features
3. Copy identified changes to CP Summary Sheet
4. Compare new to baseline
5. Review with Discovery Check List
6. Categorize and List Changes
7. Review Changes and Document Concerns/ Impacts (Must be group of SME)
8. Assign Risk level and Prioritize (Document reasons, esp. why low?)
9. Mgmt Review and Approval



Analyze and Assess

- Assessment is a broad term that includes all techniques used to determine product design reliability.
  - Assessment can include analysis, modeling, simulation and testing.
  - The most significant elements are analysis and modeling, as either can be accomplished early in the design process at a much lower expense than simulation and testing.
  - Reliability assessments are performed to assess design progress towards meeting customer needs and requirements.
  - The assessment process should be considered an iterative one to review reliability progress throughout the product design and development phases.

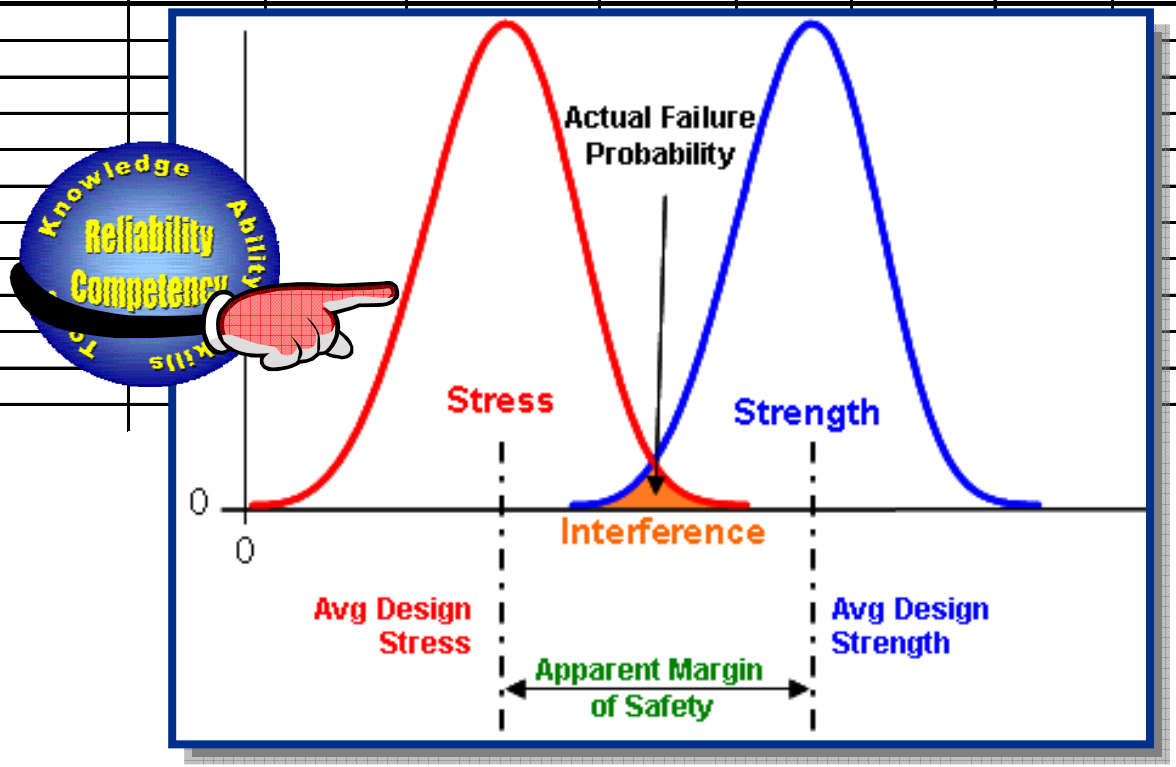


Stress Identification Template

Item _____

	Mission Time	Usage Level	Reliability	Confidence
Over-all Life Requirement	10 yrs	99.8%tile	98	50

Stress Failure Mechanism	Stress Acceleration Factor: Temp	Temp Cycle	Exposure UV	Moisture Humidity Rain Condensate	Electric Potential include corrosion	Current Density Power	Static Dynamic Vibration Pressure	Friction	Shock Pressure	Reactions Chemical Biological Corrosive	Contaminate Clogging Abrasion	Usage Mechanis
Fatigue												
Fracture												
Deformation												
Wear												
Erosion												
Corrosion												
Oxidation												
Absorption												
Creep												
Electro migration												
Electrostatic Discharge												
Dielectric Breakdown												



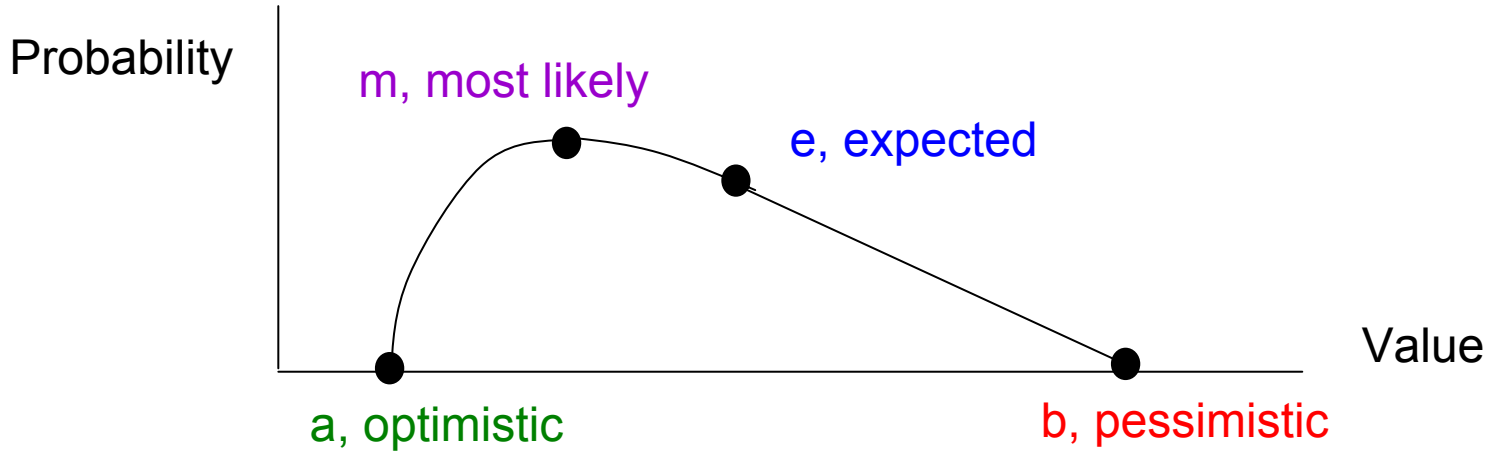
When You Don't Have Stress Data Use a 3 Point Estimate

- Generate three estimates:
  - a, most optimistic (1:1000 chance of minimal difficulties)
  - b, most pessimistic (1:1000 chance of maximum difficulties)
  - m, most likely (What would happen most of the time)
- e, expected value
  (assumes a Beta distribution)

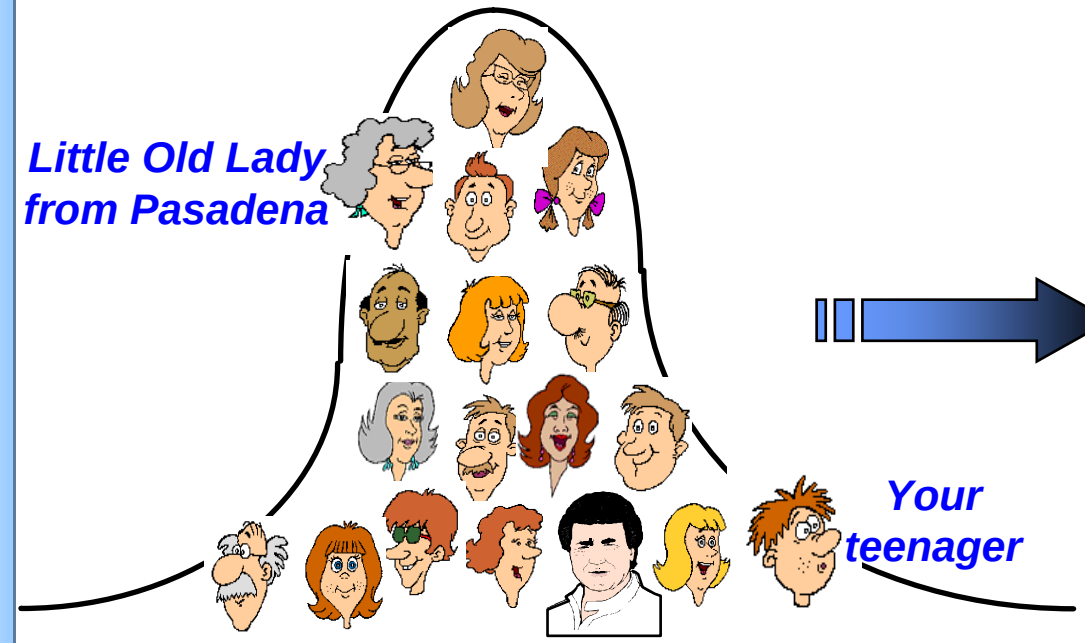
$$e = \frac{a + 4m + b}{6}$$

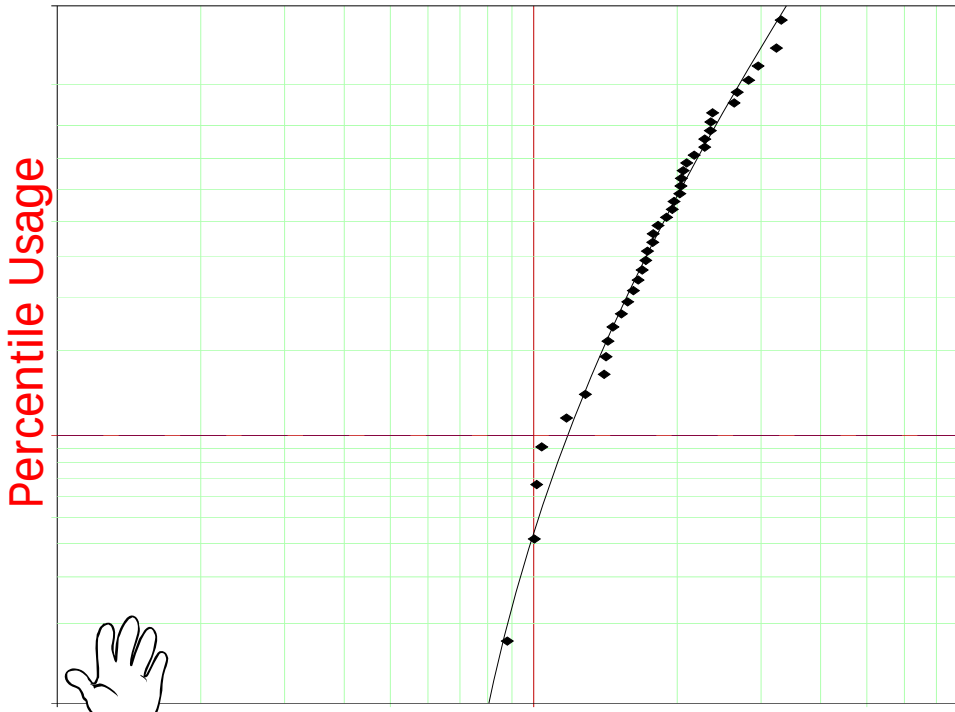
- Calculate the standard deviation
  (based on 98% between points a and b)

$$\sigma = \frac{b - a}{6}$$



Usage Data
Knowing Your Stress





Quantify and Improve

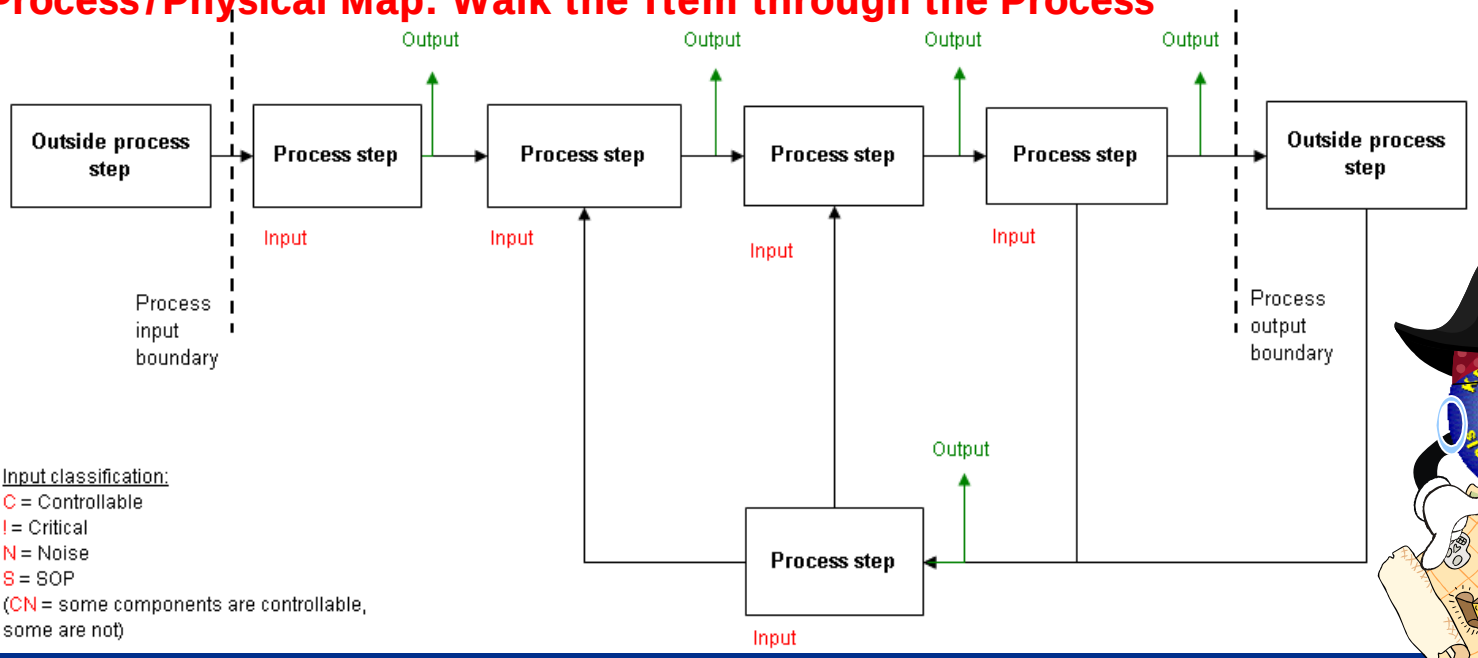
- Quantifying and making reliability improvements to a product begins with the ability to measure reliability performance.
  - Measurements are an integral part of any program.
  - Reliability like all other product characteristics needs to be measured at various times and in various ways, depending on the program.

Process and Function Maps

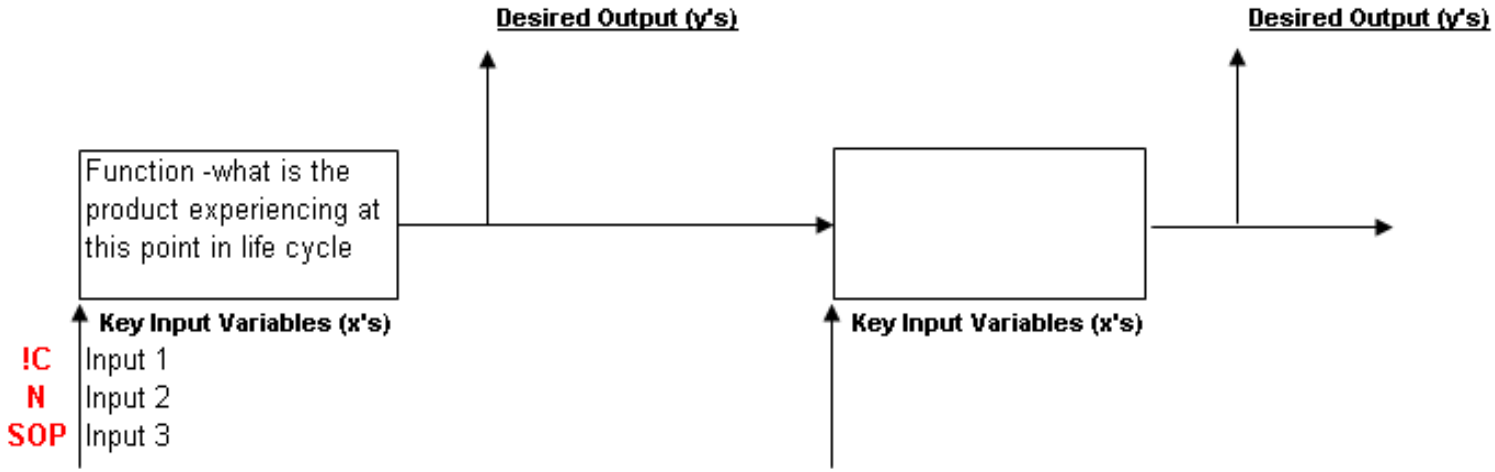
Product Life Cycle

- **A** Acquire/Transport Raw Materials
- **B** Create Primary Part
- **C** Create Saleable Unit
- **D** Distribute to OEM
- **E** Installation into System
- **F** Distribute to End-User
- **G** Use of Product (QRDP)
- **E** Serviceability of Product
- **F** End of Life

Process/Physical Map: Walk the Item through the Process



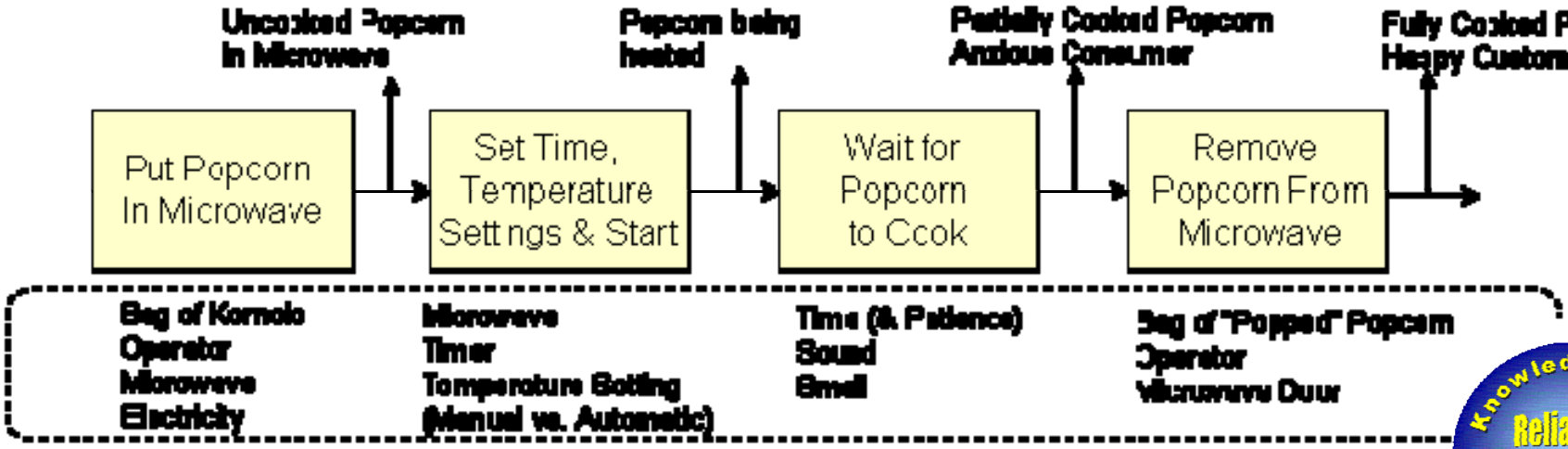
Functional Map: Be the Item In the Process



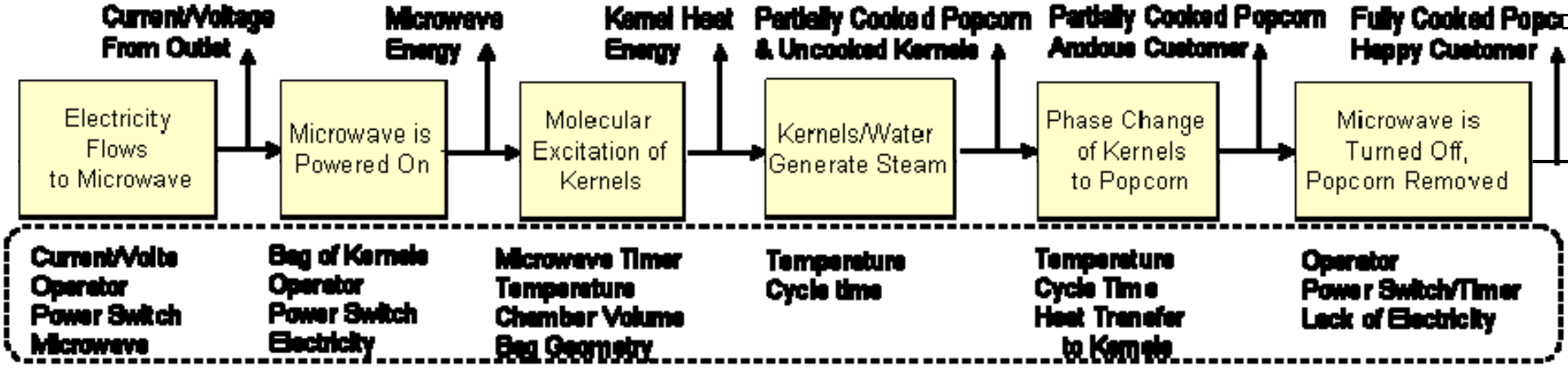
Mapping Example

- ✓Makes FMEA easy
- ✓Defines initial DOE factors
- ✓Supports Physics of failur

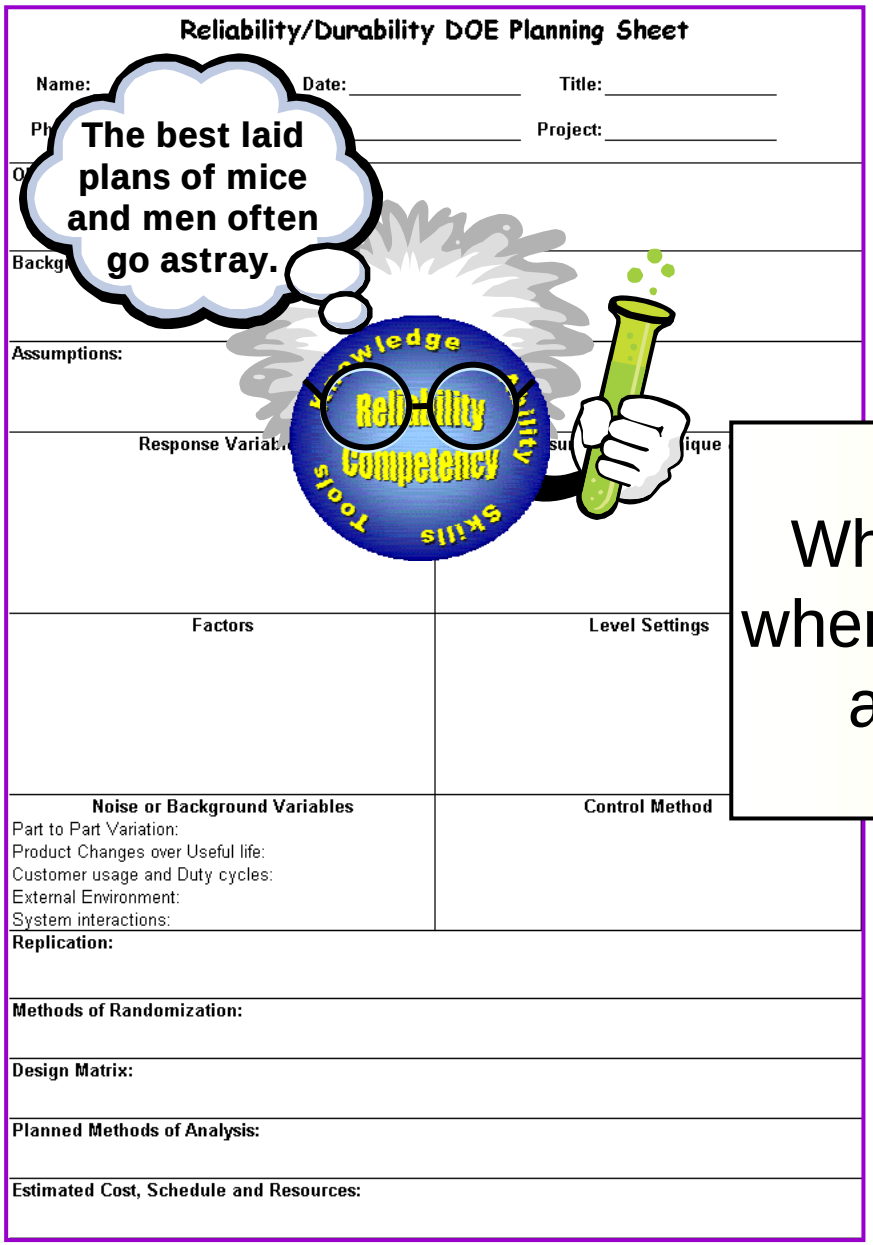
P-Map



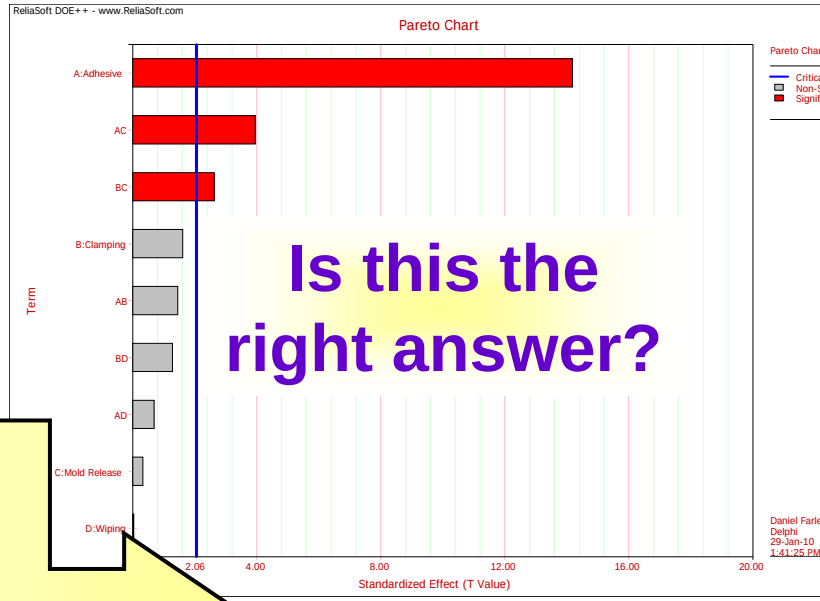
Functional P-Map

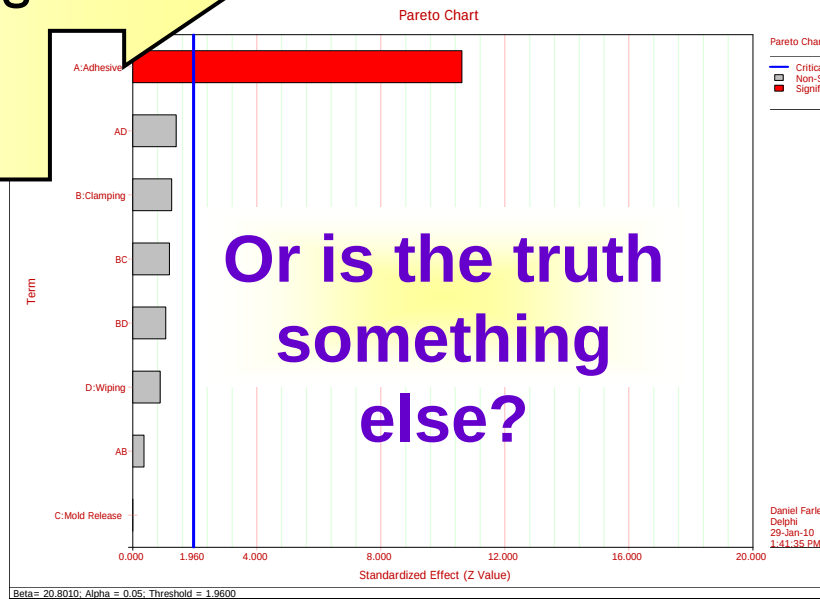


DOE for Reliability



What happens when DOE results are messy?





Validate

- In engineering or as part of a quality management system, validation confirms that the needs of an external customer or user of a product, service, or system are met.
  - Validation is confirming that it satisfies stakeholder's or user's needs.
  - Verification is a quality process of determining compliance with a regulation, standard, or specification.
  - An easy way of recalling the difference between validation and verification is that validation is ensuring "you designed and built the right product" and verification is ensuring "you built the product as intended."

DV / PV Plans and Report Summaries

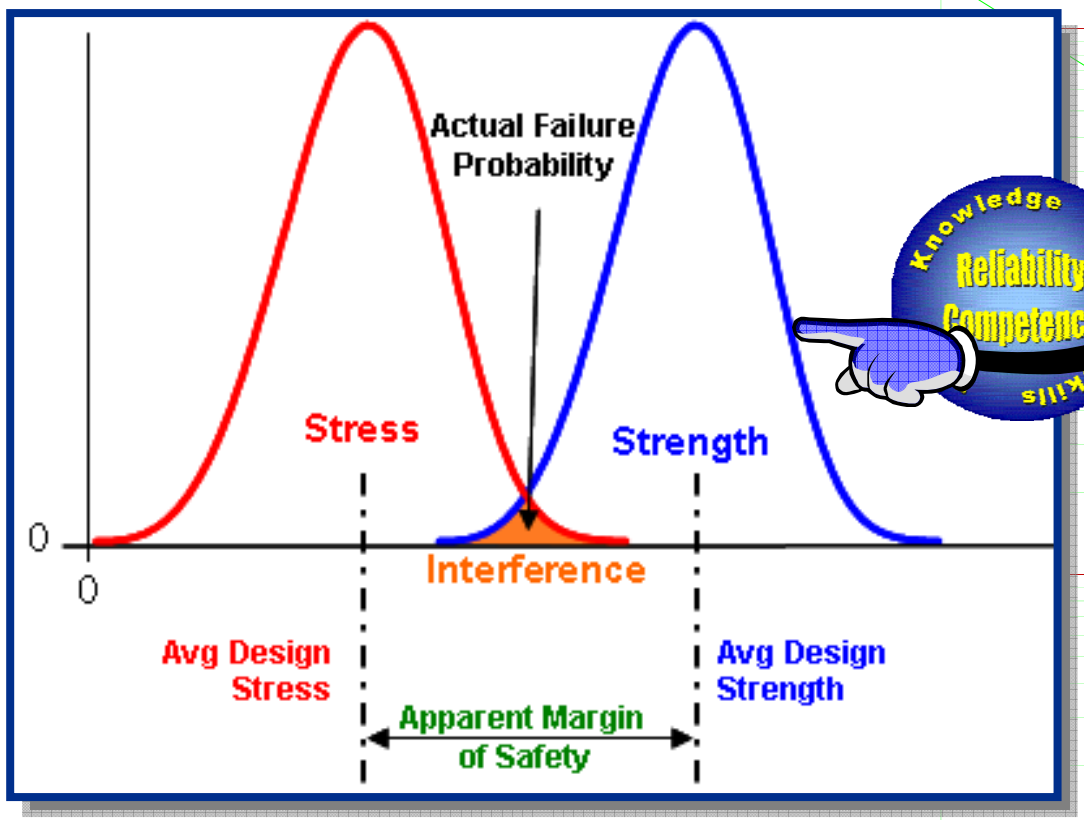
Customer Spec Section	Customer Spec Requirement	Component	Delphi Reliab Procedure o

Due Date	R Test Plan Submitted to Customer	R Test Plan Approved by Customer	ADVP&R Updated with RPP	Start Date	Reliability Test Plan Comments or Actions Needed	R Test Plan Actions Completed	R Test Completed	Cor Dat

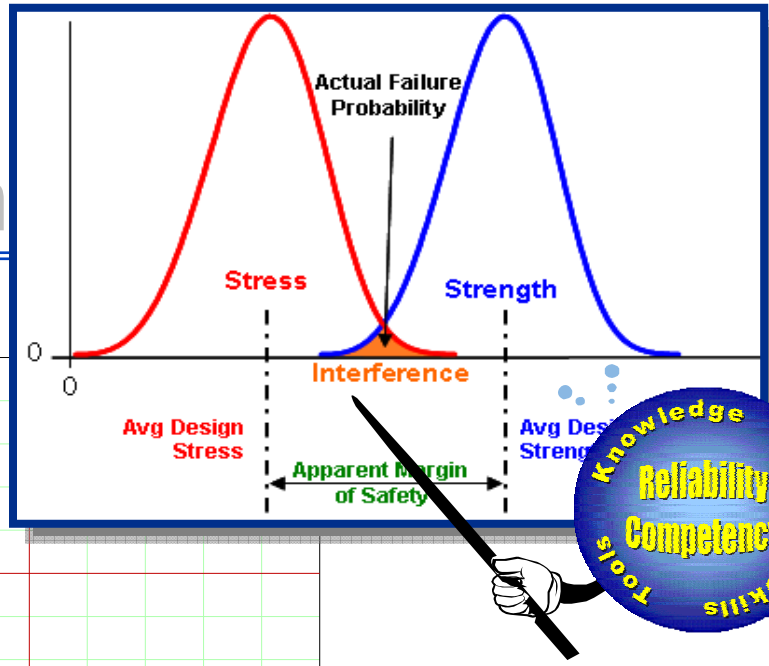
Program
Component
Reliability/Durability Test
Delphi Reliability Engineer
Report Date
Phase and Report Content
Test Purpose
Test Procedure
Environmental Conditions
Test Operating Conditions
Test Duration
Sample Size
Acceptance Criteria
Test Equivalent Target Life (10 yrs, 160,000 kilometers)
Number of Lives on Test:
Customer Usage Severity of Test
Customer Usage Source
Assumptions
Reliability Method
Reliability Demonstrated
References
Comments

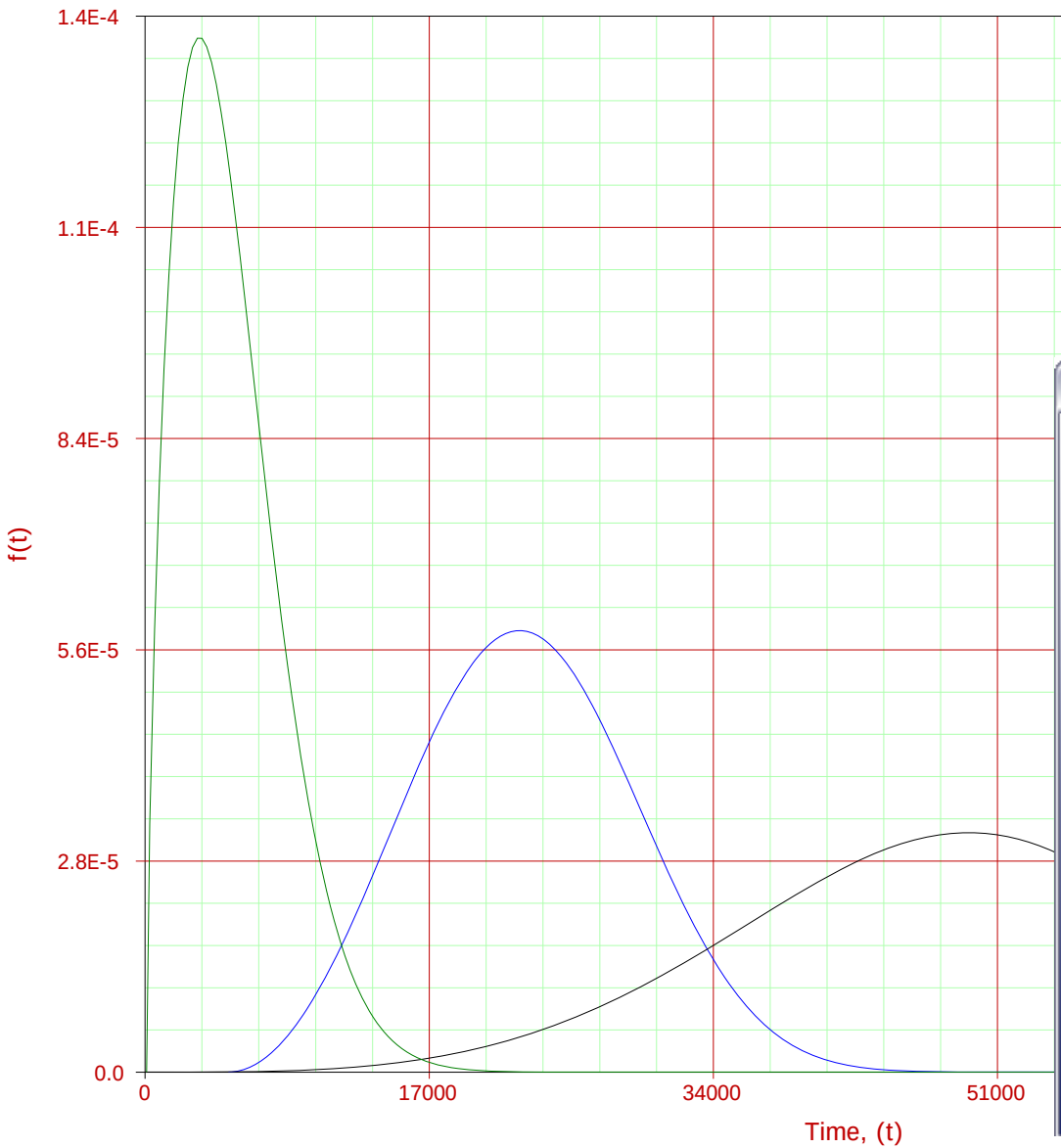
ALT
for Understanding Strength

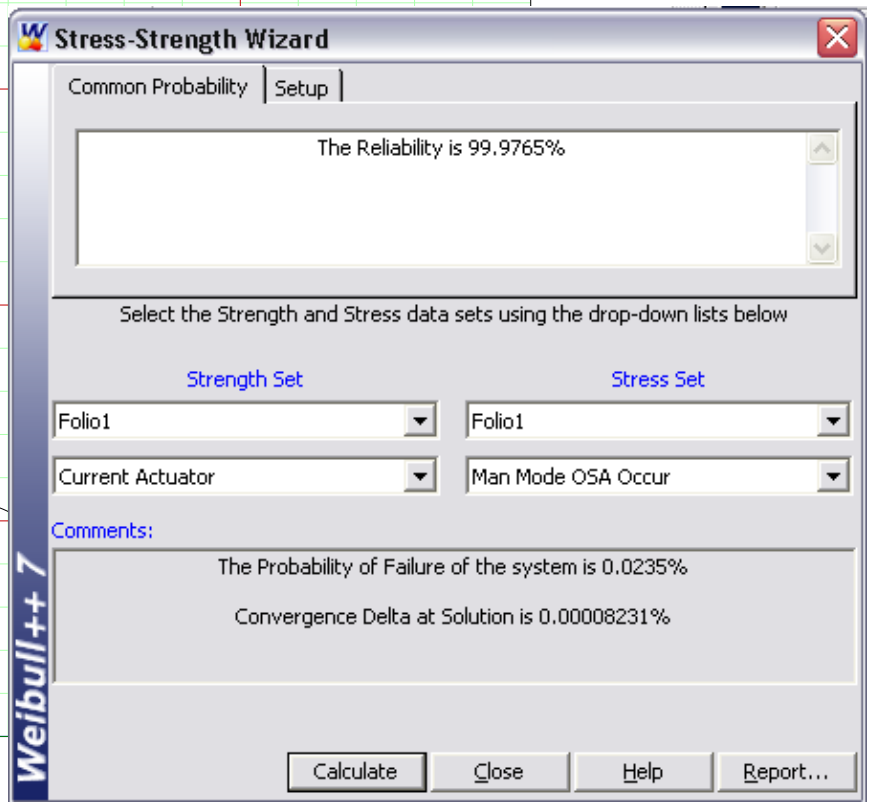
S-N Curves
Wöhler Curves



SSI
Knowing You're Good Enough



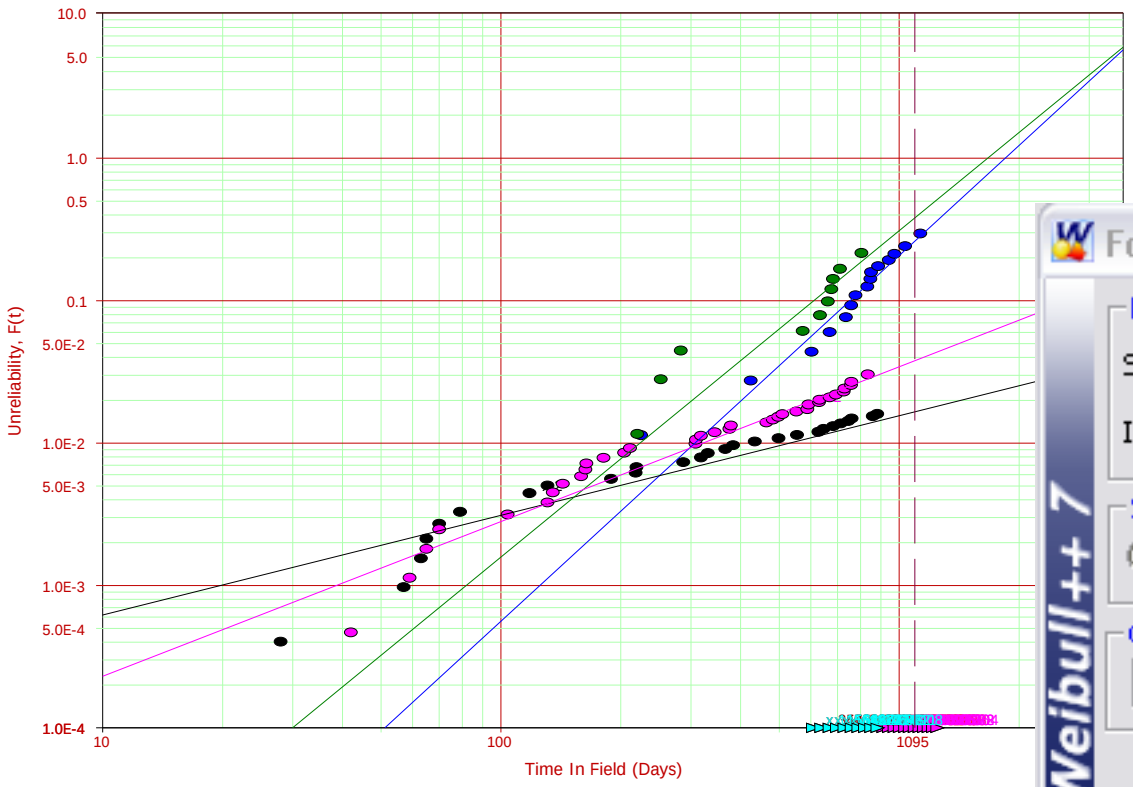


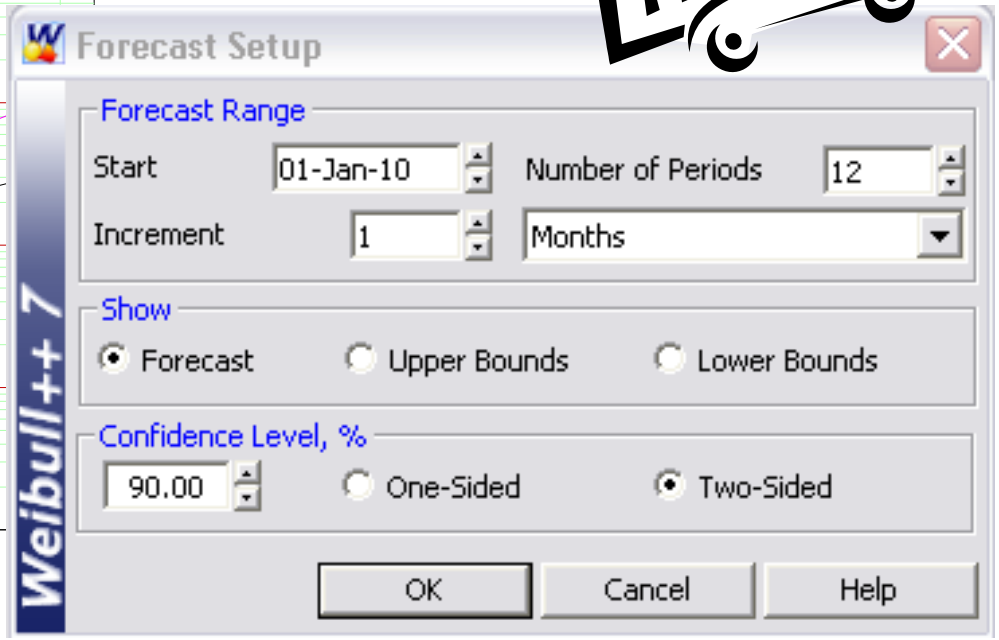


Monitor and Control

- Ensuring Reliable Performance: The reliability engineer when required provides guidance in planning and implementing actions that will ensure a product achieves and maintains an acceptable level of reliability performance over its entire life cycle.
  - The reliability engineer will more directly be involved in monitoring field results and work with product engineering to improve existing and new designs to be more robust.
  - The Monitor and Control phase begins with establishing Production Reliability Acceptance testing and continues with warranty result analysis.
- It is also important at this stage to ensure all lessons learned have been updated in appropriate engineering standard work elements for use and reuse by other and future product programs.

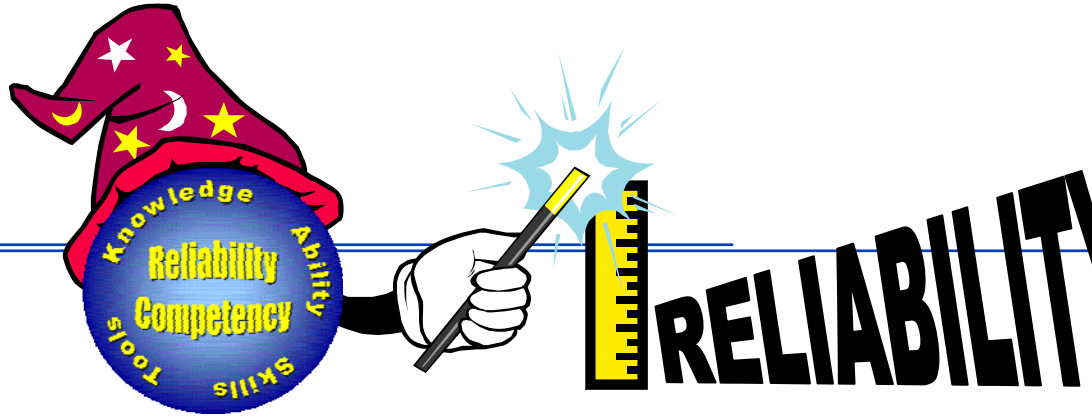
Warranty Analysis

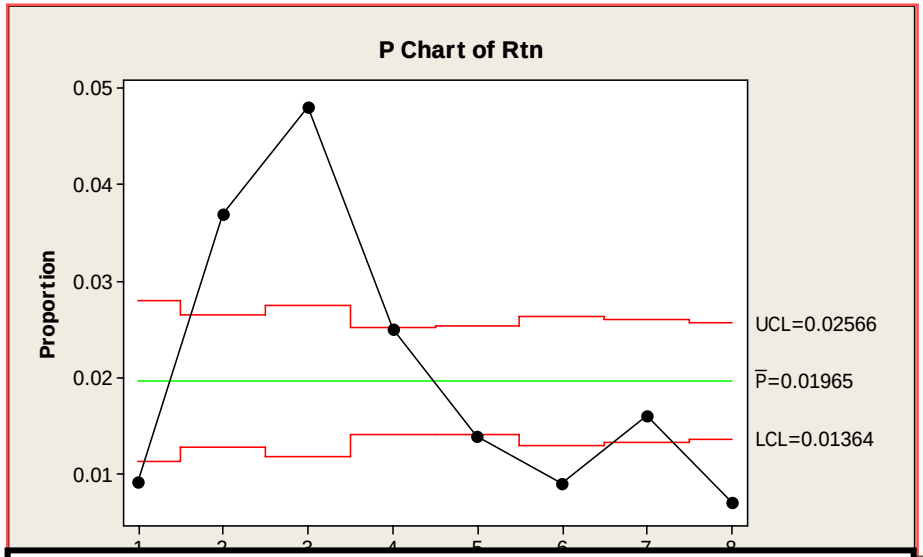


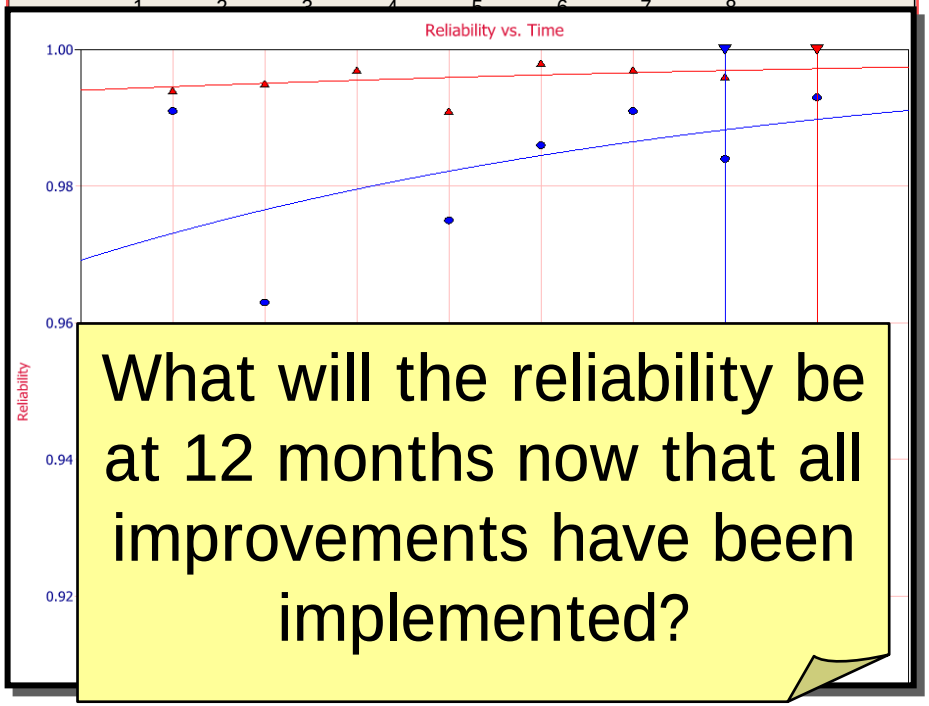


	Quantity In-Service	Date In-Service	Subset ID	Jan 01, 2010	Feb 01, 2010	Mar 01, 2010	Apr 01, 2010	May 01, 2010	Jun 01, 2010	Jul
43	15643	01-Apr-08	2008ML	0.01	0.17	0.16	0.18	0.17	0.18	
44	11589	01-May-08	2008ML	0.01	0.13	0.12	0.13	0.13	0.13	
Total				**0.00**	**3.00**	**3.00**	**3.00**	**3.00**	**3.00**	

Reliability Growth

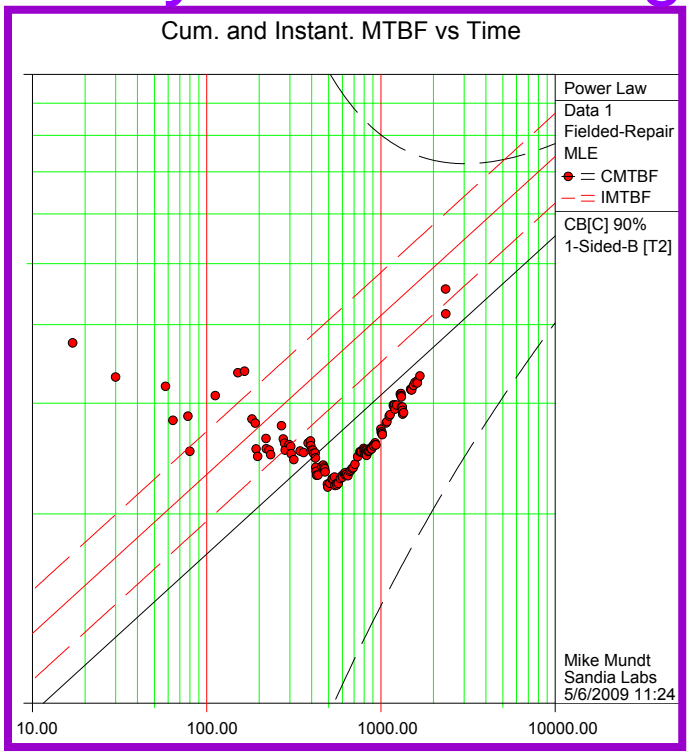






What will the reliability be at 12 months now that all improvements have been implemented?

PV System Thinking



Predictable reliability growth is occurring with field repair by finding problems and applying fixes to all the inverters.

Summary

- What works?
  - Customize DfR and RPP to fit your Product Development Process
    - Have a map so you know where you are going.
  - Global Standards for Training and Work
  - Strategic Competency Partnership
  - Common tool set
  - Change Point

- What needs improvement?
  - Developing the right Reliability Support Model for the business
  - Getting internal resources to Complete Certification
  - Application to non-Automotive
    - Improve understanding of usage / stress
  - Proactively establish S-N / Wöhler curves for products

Where to Get More Information

- ReliaSoft Design for Reliability (DfR)
  - http://www.reliasoft.com/
- Reliability Engineering Resource
  - http://www.weibull.com/
- SAE Reliability Program Standard Implementation Guide (SAE JA1000-1)
  - *SAE* International
    http://www.sae.org/
- SRC-HDBK-1001: Blueprints for Product Reliability (RBPR 1-6)
  - Alion System Reliability Center (SRC)
    http://src.alionscience.com/
- Practical Reliability Engineering: O'Connor

Questions

Do you have any questions?

Thank You

धन्यवाद

Danke

TACK

Arigato

Gracias

Σε ευχαριστώ

Thank you for your attention!

Спасибо

شكرا لك

grazie!

Dziękuję

Takk

Merci

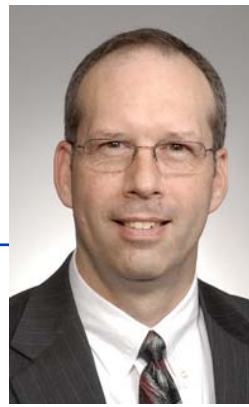
Thanks

Köszönöm

תודה

Mahalo

Daniel Farley



- Dan is the Manager and Global Competency Owner of Reliability and ICIM for Engineering at Delphi Thermal Systems.
- Dan joined Delphi in March 1984 and is currently responsible for leading the global competency development and deployment of best practices in reliability and ICIM for Thermal Engineering. (ICIM are Delphi's Innovation and Continuous Improvement Methods for achieving excellence, ICIM includes Six Sigma, Design for Six Sigma, Robust Engineering and Problem Solving toolsets.)
- Dan's experiences span almost 30 years in problem solving and problem prevention. He lead the development and implementation of customer-based engineering and reliability engineering, was the divisional global ICIM deployment champion and lead the effort to have internal self-sufficient Six Sigma and Design for Six Sigma programs at Delphi Thermal.
- Dan is a Certified Reliability Professional, Delphi Six Sigma and Design for Six Sigma Master Black Belt.
- Additional information on LinkedIn: http://www.linkedin.com/in/danielfarley

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