Reliability Program Overview for Developers
Metrics

Amnon Ganot - October, 2010

"You cannot manage what you cannot control, and you cannot control what you cannot measure"

Source unknown

Metrics

- By quantifying reliability metrics, we can measure and define a target value.
- Meeting or exciding the target value is then our product reliability objective

Agenda

- *Metrics*
  - Reliability
  - Failure Rate
  - MTTF / MTBF
  - Expected Life
  - MTTR
  - Testability
  - Availability
  - Reliability Growth

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Reliability

- Definition
  - The **probability** that equipment will perform its intended function **(mission)**, within stated conditions, for a **specified period**
- Reliability Function
  - The Probability of component/system surviving a time **t**.
  - Alternatively, the number of units surviving at time **t** divided by the initial number of units.

$$R(t)$$

Reliability

time independent

- Example
  - A nuclear submarine successfully launched a rocket 1,500 miles down the Atlantic test range to chalk up the 43rd success in the last 45 firing

$$R(t) = \frac{43}{45} = 0.96$$

Reliability

time dependent

- Example
  - 200 identical products are being reliability tested for 40 hours with the following results:
    - 10 fail just before completing 10 hours of satisfactory operation
    - 5 fail at 20 hours
    - 2 at 30 hours
    - and 3 at 40 hours

$$R(10) = \frac{190}{200} = 0.95$$

$$R(20) = \frac{185}{200} = 0.925$$

$$R(30) = \frac{183}{200} = 0.915$$

$$R(40) = \frac{180}{200} = 0.9$$

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Failure Rate

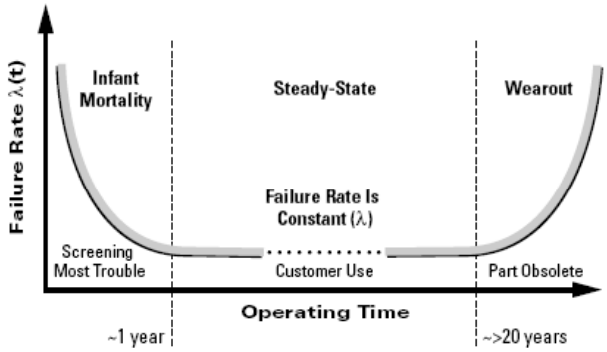
$\lambda(t)$

- Instantaneous failure rate, hazard rate, or just the failure rate:
  - Probability of failure in unit time of a device that is still working.
  - The instantaneous rate of failures for devices of population that have survived to time **t**.
- The most common reliability metrics

Failure Rate

$\lambda(t)$

- The failure rate itself is either time dependent or time-independent



Failure Rate

$\lambda(t)$

- Component Reliability (Discrete)
  - Resistors, capacitors, diodes, ICs, etc.
- System Reliability (Hybrids & Assemblies)
  - Usually, the whole is equal to the sum of the parts for the failure rate.
  - *Example: Reliability of a light bulb*
    - Failure rate = λ system
    - λ system = λ filament + λ seal + λ connections
  - The whole is not equal to the sum of the parts when there is redundancy (double filament inside).

Failure Rate

217Plus™ Transformer Failure Rate Model

Table 1: Transformer Parameters

Part Type	λ_{OB}
Audio	0.0002248
Flyback	0.0007482
Isolation	0.0150145
Power	0.0001214
Pulse	0.0002470
RF	0.0000913

λ_{OB} = Base failure rate, operating

Table 2: Optoelectronic Device Parameters

Part Type	λ_{OB}
LED	0.0000312
Optoisolator	0.0032244
Photodiode	0.0000269
Phototransistor	0.0012884

Table 1: Integrated Circuit, Nonhermetic Parameters

Part Type	λ_{OB}	λ_{EB}
Digital, Nonhermetic	0.000007	0.000385
Linear, Nonhermetic	0.000013	0.001997
Memory/Microprocessor, Nonhermetic	0.000008	0.000634

Predicted failure rate, failures per million calendar hours

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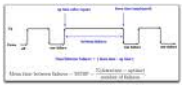
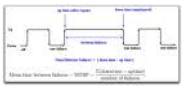
MTBF / MTTF



- MTBF/MTTF Definition
  - Mean productive Time Between *equipment-related Failures*
  - Mean productive Time To *equipment-related Failures*
  - Productive Time
    - The time when the equipment is performing its intended function
  - Equipment Related Failures
    - Any unplanned event that changes the equipment to a condition where it cannot perform its intended function solely caused by the equipment

MTBF / MTTF



- MTBF is the preferred term instead of MTTF when repairs are involved.
- Both are the inverse of the failure rate when the failures rate is constant

$$MTBF = \frac{1}{Constant\ Failure\ Rate}$$

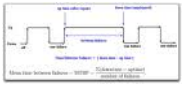
$$MTBF = \frac{1}{\lambda}$$

MTBF Vs MTTF

- Non-Repairable
  - MTTF – Mean Time To Failure

- Repairable
  - MTBF – Mean Time Between Failures

M(C)BF



- M(C)BF Definition
  - Mean (Cycles) Between *equipment-related Failures*

Failure Type	*Failure Rate*	*M(Km)BF*
Puncture	1/25,000 Km	25,000 Km
Switch Stuck	1/1E6 Cycles	1E6 Cycles
Filter Blocked	1/1000 Liter	1000 Liter

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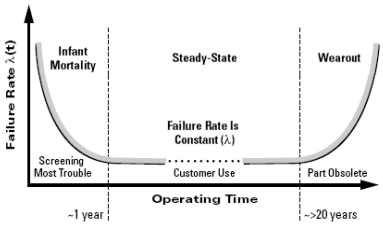
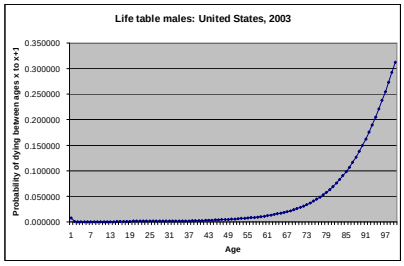
Expected Life

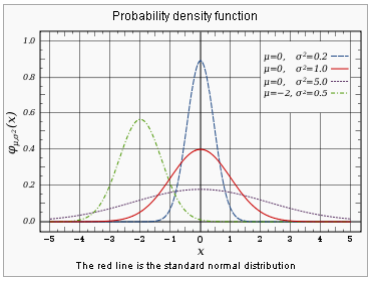
- **Expected life** corresponds to the arithmetic average of the lives of all units in a population
- The MTTF is also called the *expected life*





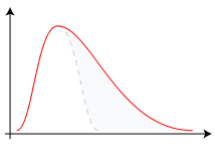
Expected Life Distribution

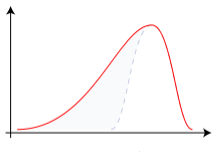
- Symmetric - Distributions that have the same shape on both sides of the center are called symmetric. A symmetric distribution with only one peak is referred to as a normal distribution.



Expected Life Distribution

- Skewness - Refers to the degree of asymmetry in a distribution. Asymmetry often reflects extreme scores in a distribution.
  - Positively skewed - A distribution is positively skewed when is has a tail extending out to the right (larger numbers). The mean is greater than the median.
  - Negatively skewed - A negatively skewed distribution has an extended tail pointing to the left (smaller numbers). The mean is smaller than the median.





Expected Life - Example

- Available from two manufacturers:
  - Manufacturer 1, $1.00 per button.
    - Spec: MTTF=2.7071E+6 Cycles
  - Manufacturer 2, $0.50 per button.
    - Spec: MTTF=2.9699E+6 Cycles
- Which design do we choose?

Expected Life - Example

The MTTF as a sole metric is flawed and misleading. It is the expected value of the random variable (mean of the probability distribution).

"There must be some mistake. According to our actuary tables I'm going to live to 83."

Expected Life - Example

"Not all that twinkles, is gold"

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Expected Life – B10/L10

- Operating time (hours or cycles) at rated load where 10% of units under test have failed
- B10 (or L10) should be interpreted very carefully! A unit with higher B10 might cause higher maintenance due to its distribution shape

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MTBF Vs Expected Life

	MTBF	*Lifetime*
LED	$100x10^6$ (hours) ~12,500 (years)	(hours) $50x10^3$ ~6 (years)
LAMP (filament)	$1x10^6$ (hours) ~125 (years)	1000 (hours) ~1.5 (month)
Capacitor (Line)	$821x10^3$ (hours) ~100 (years)	$75x10^3$ (hours) ~9 (years)
HDD	$1.2x10^6$ (hours) ~150 (years)	~5 (years)
Person	~1 (year)	~78 (years)
Car	~1 (year)	~11 (years)

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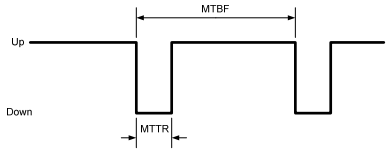
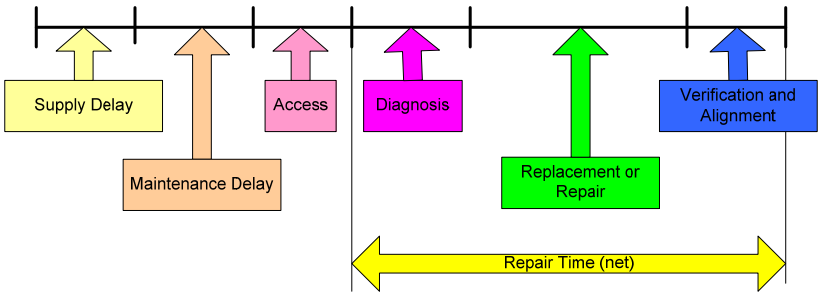
MTTR

- Weighted average time to repair *equipment-related failures*; the average time to correct an *equipment-related failure* and return the equipment to a condition where it can perform its intended function



MTTR - Timeline



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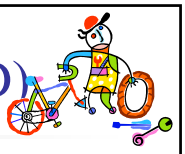
Testability

- A design characteristic which allow the status of the equipment to be confidently determined in a timely manner
- Composed of:
  - Fraction of Faults Detected (FFD)
  - Fault Isolation Resolution (FIR)
  - False Alarm Rate (FAR)

Fraction of Fault Detected (FFD)



- Achieve minimal *Fraction of Fault Detected (FFD)* level according to *Orbotech* DFM

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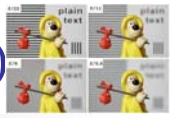
Classification	*Description*	*FFD*
Catastrophic / Safety	A failure that may cause *sever injure* or major *system damage*	100%*
Critical	A failure that may cause *minor injury* or inability to perform *primary mission*	95%
Major	A failure that may cause *degradation* in mission performance	90%
Minor	A failure that does not influence system performance but may result in *unscheduled maintenance*	85%

* Means that all safety faults will be detected!

Fault Isolation Resolution (FIR)



- Achieve minimal *Fault Isolation Resolution (FIR)* level according to *Orbotech* DFM

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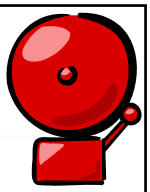
One FRU	85%
Two FRUs	10%
Three or more FRUs	5%

Example:

Number of different failures		1000
Average FFD		90%
Detected no. of failures	90% x 1000	900
FIR (one FRU)	85% x 900	765
FIR (two FRUs)	10% x 900	90
FIR (>3 FRUs)	5% x 900	45

Testability - FAR



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- The frequency of occurrence of false alarms related to equipment performance

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Availability

- The probability that the equipment will be in a condition to perform its intended function when required.
- Also named "Up-Time".

Availability - Types

- ***Inherent Availability***
  - This is the ideal state of availability
  - The only considerations are the MTBF (reliability) and the MTTR (Maintainability).
  - This measure does not take into account the time for preventive maintenance and assumes repair begins immediately upon failure of the system

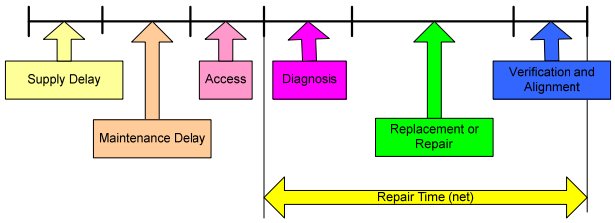
$$A_I = \frac{MTBF}{MTTR + MTBF}$$

Availability - Types

- ***Achieved Availability***
  - Achieved Availability is somewhat more realistic in that it takes preventive maintenance into account as well as corrective maintenance
  - The assumption here is that, as in Inherent Availability, there is no loss of time waiting for the maintenance action to begin

Availability - Types

- ***Operational Availability***
  - This is what generally occurs in practice
  - Operational Availability takes into account that the maintenance response is not instantaneous, repair parts may not be in stock as well as other logistics issues



Availability Vs Reliability

- There is no direct relations between Reliability and Availability!
- High Reliability does not cause high Availability!
- Example:
  - Reducing MTTR will increase Availability but will not influence the Reliability
  - Increasing frequency of Preventive Maintenance will increase Reliability but decrease Availability

$$A_I = \frac{MTBF}{MTTR + MTBF}$$

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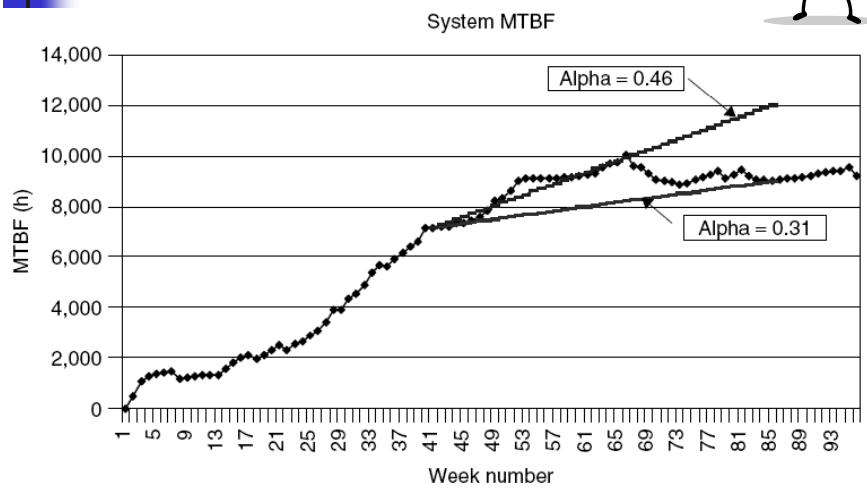
Reliability Growth – Why?

- Reliability goals become more and more demanding…
- Validating higher reliability requires much longer test time…
- Development cycles becomes more and more shorter…
- …AS a result, systems are launched with low reliability and an aggressive Reliability Growth Plan need to be enforced
- Metrics:
  - Duane Plot (Alpha)

Reliability Growth - Definition

- Reliability growth is the improvement in the reliability of a product (component, subsystem or system) over a period of time due to changes in the product's design and/or the manufacturing process

Duane Plot



Duane Plot - Alpha

α

- 0.4 ÷ 0.6 A top priority program is in effect to eliminate failure modes. Immediate attention and corrective actions prevail.
- 0.3 ÷ 0.4 An above average program on reliability improvement exists. There is a well managed plan and action on important failure modes.
- 0.2 ÷ 0.3 Routine attention is paid to reliability improvement. No environmental testing. Action taken on important failure modes only.
- 0.0 ÷ 0.2 A low priority in reliability improvement.

Summary

- Measure ⇨ Control
- Reliability Function (t)
- Failure Rate (t)
- MTBF – MTTF
- Expected Life / B10
- MTTR
- FFD / FIR / FAR
- Availability
- Reliability Growth

Questions?


Thanks for your attention
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