Affidabilita’

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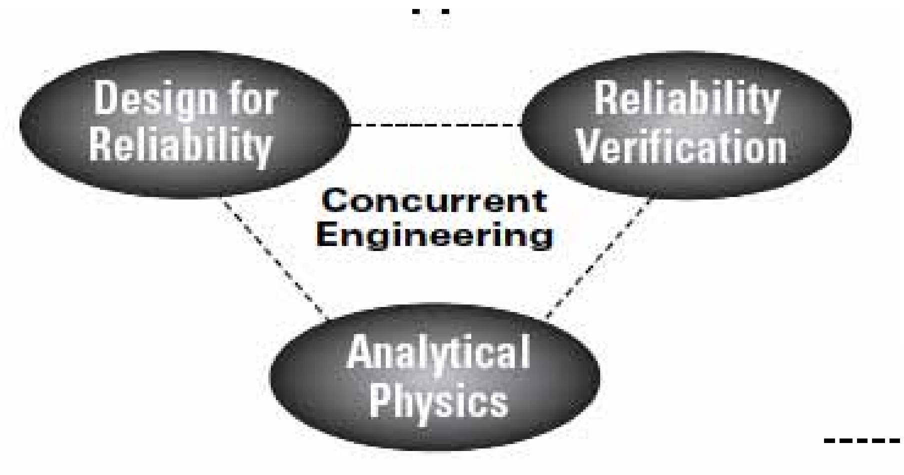
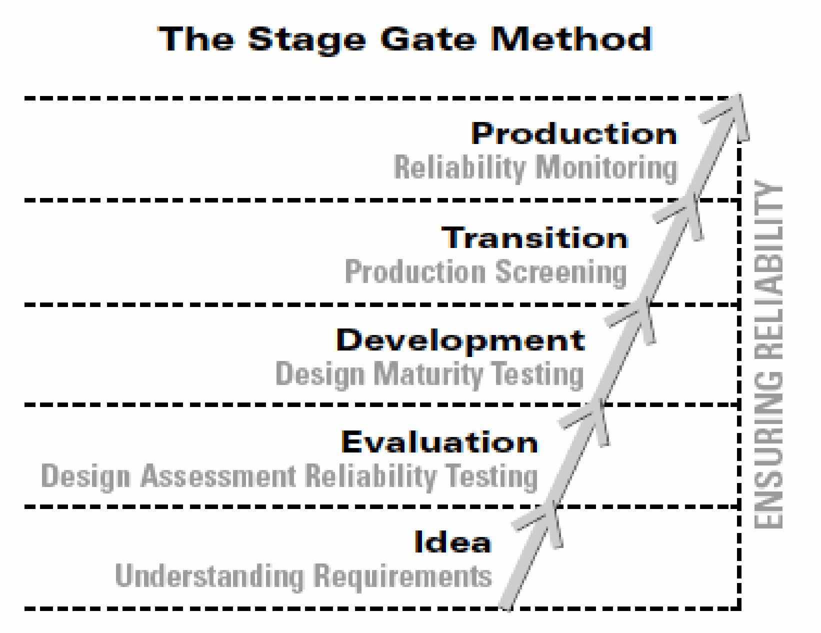
Riferimenti

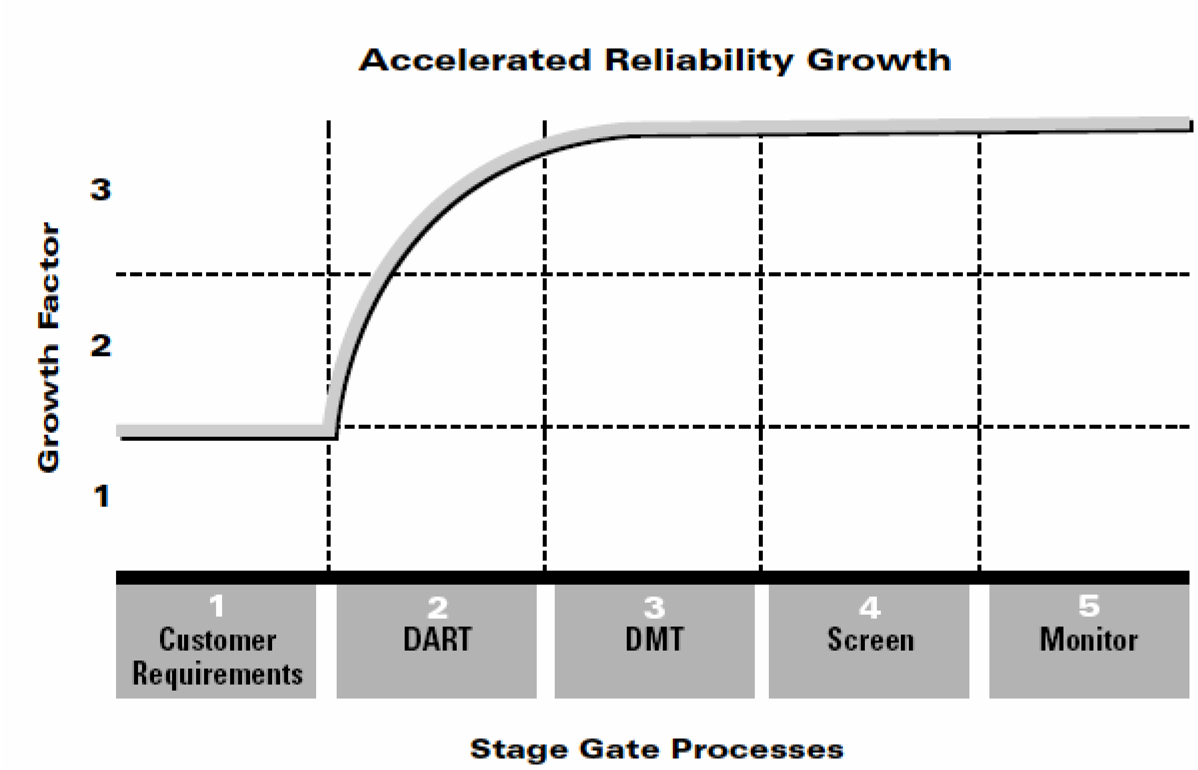
- J. Klion, “Practical Electronic Reliability Engineerging”, ISBN 0-442-00502-4
  - cap. 1-2
- “Design For Reliability”, Crowe and Feinberg editors, CRC Press, 2001

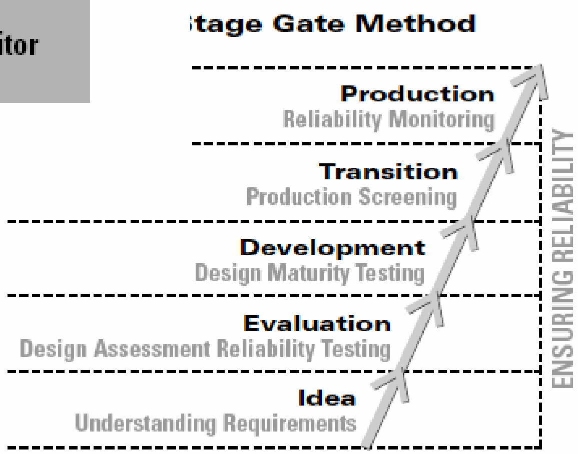
Approccio unificato



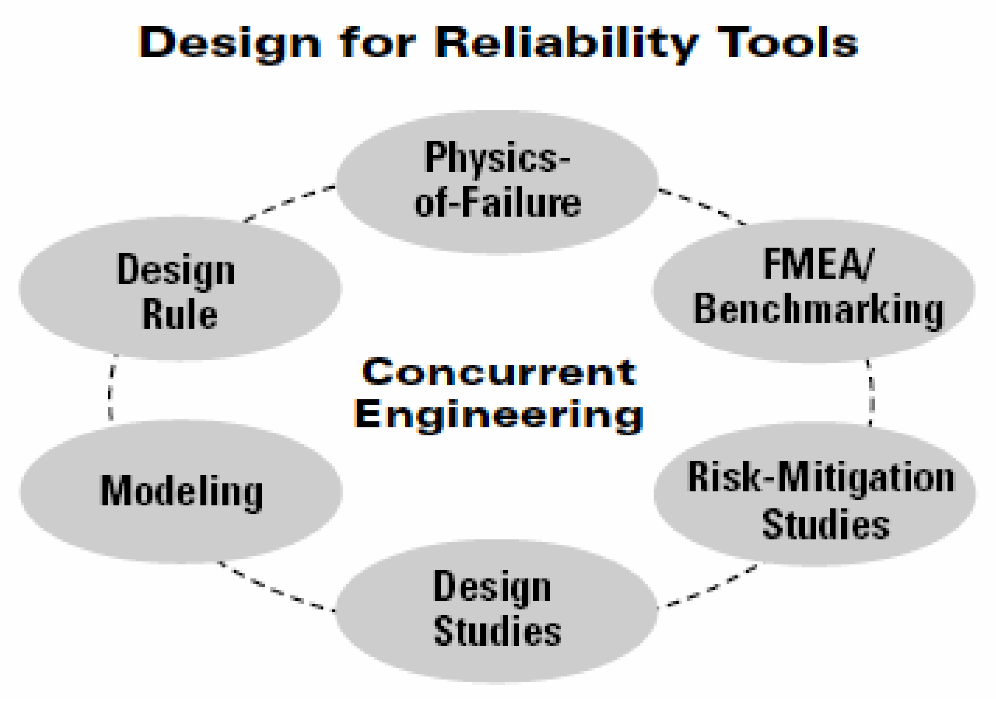


Crescita Affidabilita'





Strumenti e Metodologie



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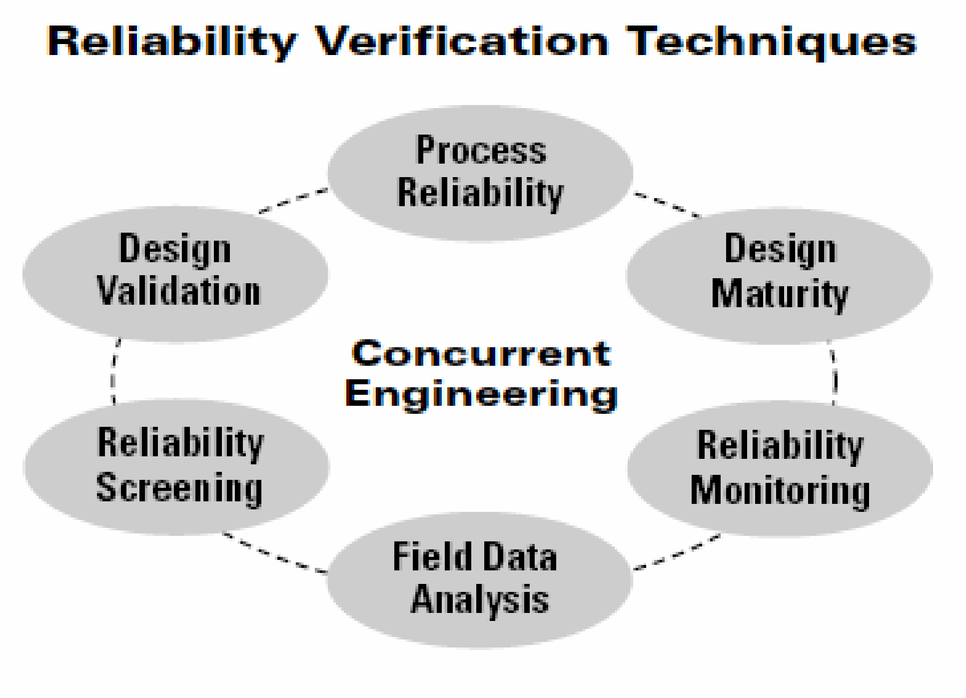

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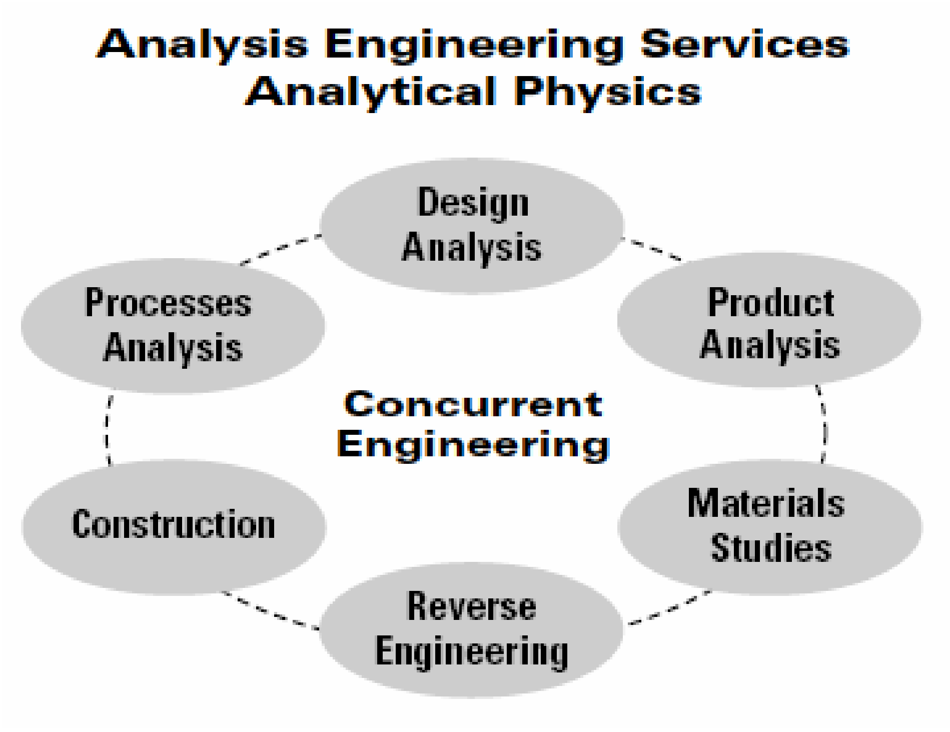


Il problema

Specified and Unspecified Requirements

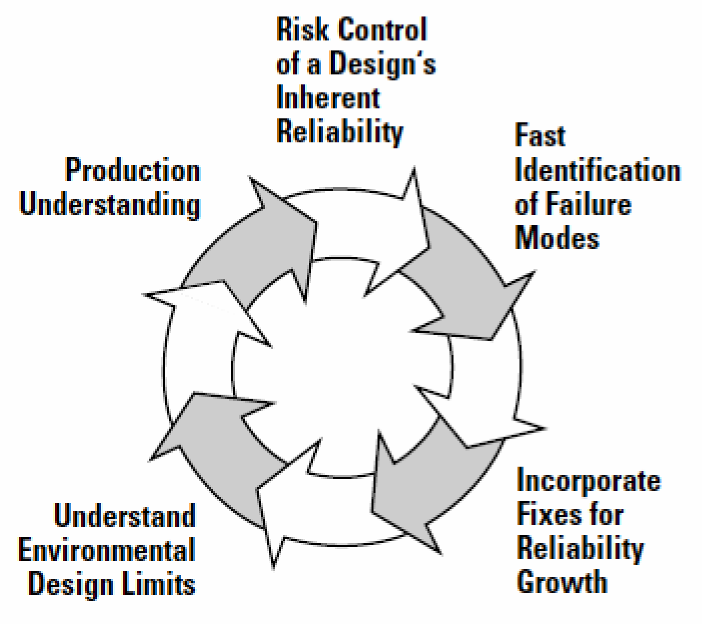
- ✓ How can the customer cause misuse?
- ✓ What are the life hazard conditions?
- ✓ What is the service life?
- ✓ What are the reliability goals?
- ✓ What are the costs associated with the goal?
- ✓ What is the customer's use plan?

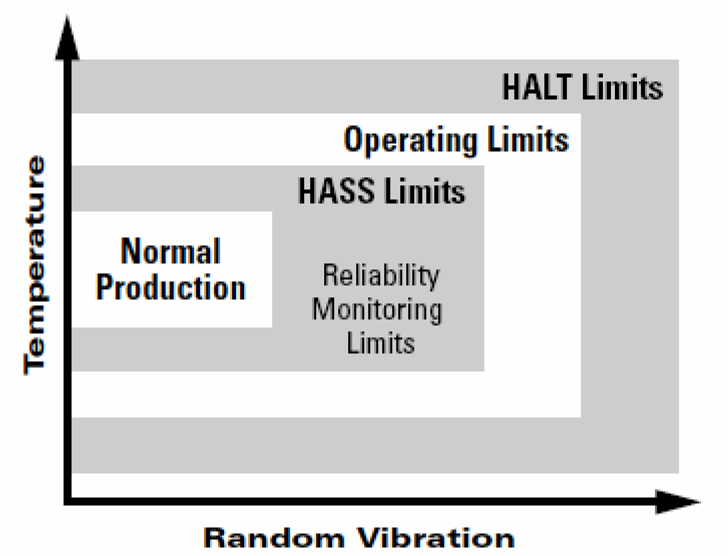
Esempio: Pager

Requirement	Useful Tool	Expectation
Customer Use Plan	Benchmarking/ FMEA	• Receives information in numerous building-type structures and environments • Audible beep • Tolerates mechanical wear and tear on beeper buttons and belt clip • State-of-the-art capability
Life Hazard Conditions	FMEA	• Survives numerous polluted environments • Withstands different temperature extremes • Withstands corrosive coastal environments
Common Misuse	FMEA	• Survives numerous shocks from being dropped from heights of up to 6 feet • Survives numerous vibration exposures from normal use and being tossed around • Survives exposure to water (being left out in the rain or dropped momentarily into a wet area, such as a sink or puddle)
Service Life Needs	Benchmarking/ FMEA	• Easy access for battery changes • Mechanical durability of battery clip
Reliability Goals	RPM	• 99% reliability for five-year life

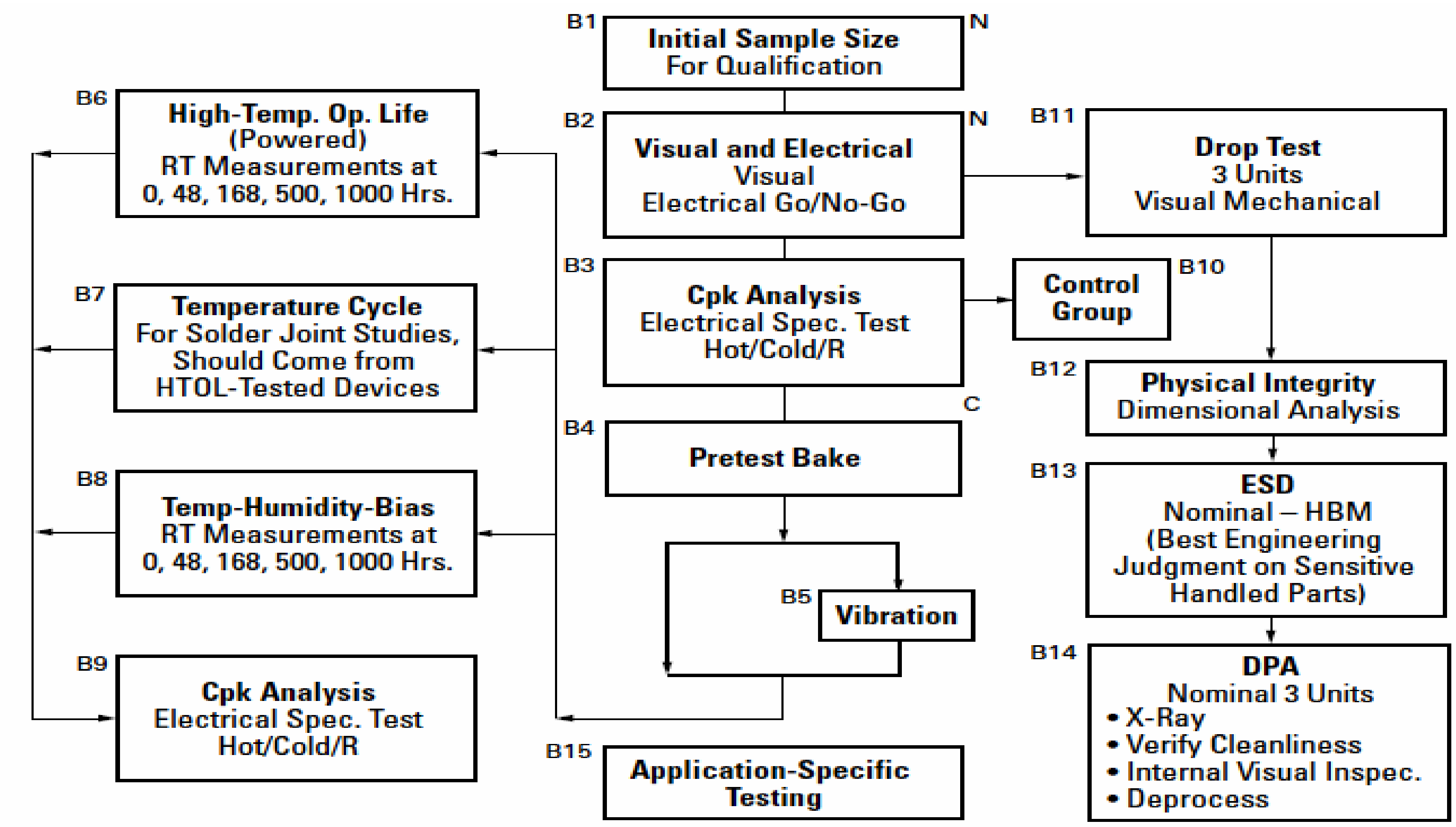
Design Assessment Reliability Testing

- Highly Accelerated Life Testing (HALT)
  - Stress termici
  - Vibrazioni
  - Temperatura e vibrazioni
  - Sbalzi termici (rapidi)



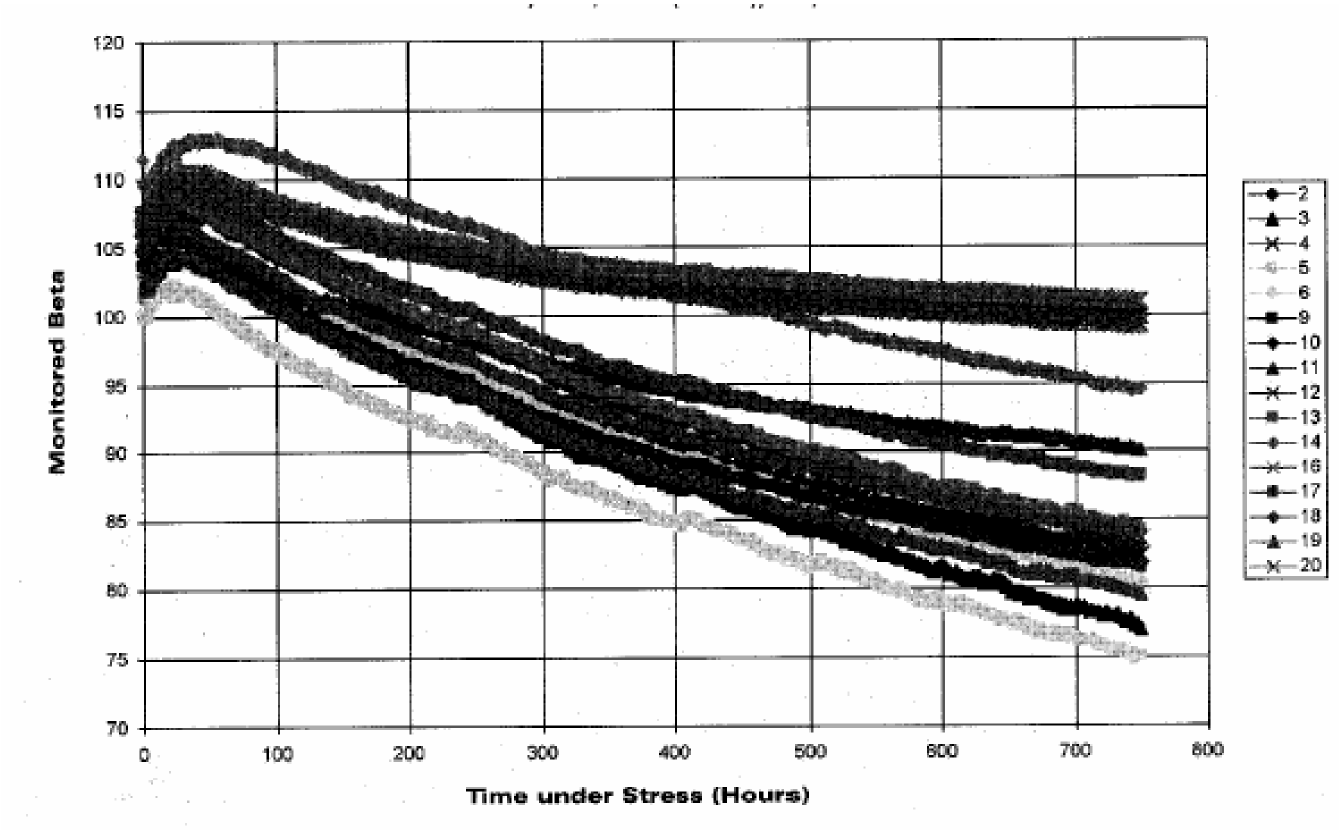


Design Maturity Testing



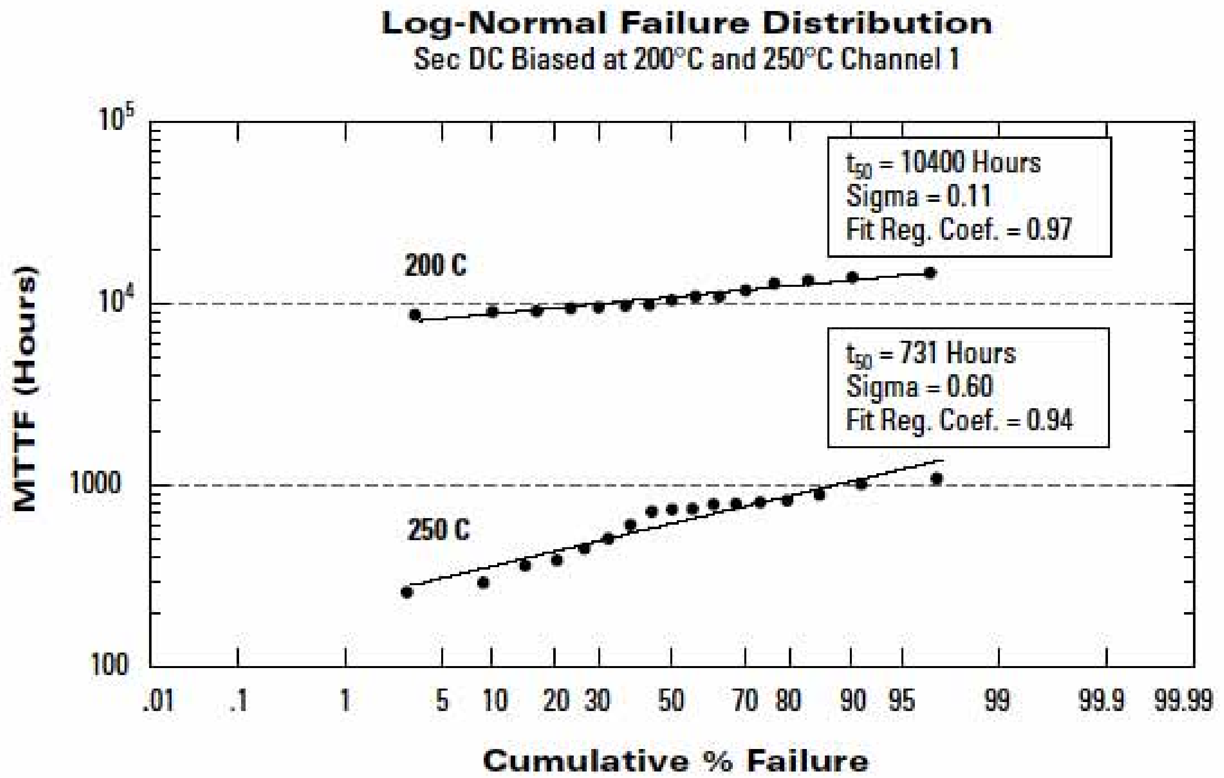
Affidabilita' Componenti Analogici

- Degradazione prestazioni



Affidabilita' Componenti Analogici

- Guasto = ?



Test Accelerati

- Comprimere e accelerare i meccanismi di guasto per rilevazioni in tempi “ragionevoli”
  - Test in parallelo su popolazioni di oggetti
- Fattore di accelerazione

$$A = \frac{t}{t'}$$

  - t = MTBF in condizioni normali
  - t’ = MTBF in condizioni accelerate
- Modello di Arrehenius

$$R = Be^{-\frac{E_A}{kT}}$$

  - E_A = energia di attivazione, B = cost., k = Boltzmann, T=temp.

Test Accelerati

- Modello di Arrehenius $R = Be^{-\frac{E_A}{kT}}$
- E' possibile predire dinamiche a diverse temperature

$$A = \frac{t}{t'} = e^{\frac{E_A}{k}\left(\frac{1}{T} - \frac{1}{T'}\right)}$$

- High Temperature Operating Life (HTOL) Acceleration Model (AM)
  - stima E_A

$$\ln(MTBF) = c + \frac{E_A}{k}\frac{1}{T}$$

Temperature-Humidity Bias AM

- THB

$$A_T = Exp\left\{\frac{E_a}{K_B}\left[\frac{1}{T_{Use}} - \frac{1}{T_{Stress}}\right]\right\}$$

$$A_H = \left(\frac{R_{Stress}}{R_{Use}}\right)^m$$

$$A_{TH} = A_T A_H$$

$$Ln(t_f) = C + \frac{E_a}{K_B T} - m \; Ln(R)$$

Notation

A_H	=	humidity acceleration factor
A_T	=	temperature acceleration factor
A_{TH}	=	temperature-humidity acceleration factor
R_{Stress}	=	relative humidity of test
R_{Use}	=	nominal use relative humidity
T_{Stress}	=	test temperature
T_{Use}	=	nominal use temperature
m	=	humidity constant
E_a	=	activation energy
t_f	=	time to fail
C	=	constant

Temperature Cycle AM

$$A_{TC} = \frac{N_{Use}}{N_{Stress}} = \left(\frac{\Delta T_{Stress}}{\Delta T_{Use}}\right)^K$$

$$Ln(N_f) = C - K \;\; Ln(\Delta T)$$

Notation

A_{TC} = temperature cycle acceleration factor
N_{Stress} = number of cycles tested
N_{Use} = equivalent number of field cycles
ΔT_{Stress} = temperature cycle test range
ΔT_{Use} = nominal daily temperature change in the field
K = temperature cycle exponent
N_f = number of cycles to failure
C = constant

Vibration Acceleration Model

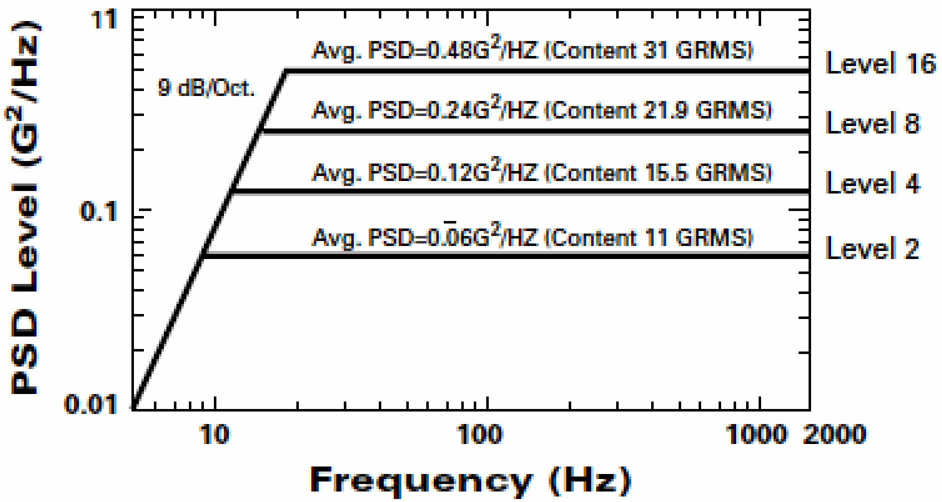
$$A_V = \frac{T_{Use}}{T_{Stress}} = \left(\frac{W_{Stress}}{W_{Use}}\right)^{M_b}$$

$$\left(\frac{W_{Stress}}{W_{Use}}\right)^{M_b} = \left(\frac{G_{f_{Stress}}}{G_{f_{Use}}}\right)^{2M_b}$$

$$Ln(t_f) = C - M_b \; Ln(W)$$

Notation

- A_V = vibration acceleration factor
- T_{Stress} = vibration duration
- T_{Use} = vibration duration (nominal)
- W = random vibration input PSD across the resonance bandwidth (G^2/Hz) W_{Stress} is the PSD test stress and W_{Use} nominal use PSD
- G_f = resonant G sinusoid vibration level
- M_b = b/2 where b is the fatigue parameter
- t_f = time to failure
- C = constant



Electromigration AM

$$A_J = \left(\frac{J_{Stress}}{J_{Use}}\right)^n Exp\left\{\frac{E_a}{K_B}\left[\frac{1}{T_{Use}} - \frac{1}{T_{Stress}}\right]\right\}$$

$$Ln(t_f) = C + \frac{E_a}{K_B T} - nLn(J)$$

Notation

A_J = electromigration acceleration factor
T_{Stress} = test temperature (°K)
T_{Use} = use temperature (°K)
E_a = activation energy
K_B = 8.6173×10^{-5} eV/°K (Boltzmann's constant)
J = current density
n = current density exponent
t_f = time to failure
C = constant

Reliability Growth

- Processo nel quale vengono identificati e risolti i meccanismi di guasto per soddisfare le specifiche sull'affidabilita'
- Principale impiego e' fornire delle linee guida per gestire il processo di miglioramento dell'affidabilita'
  - basato su dati/esperienze pregresse
  - permette di estrapolare tempi di sviluppo
- MTBF proporzionale a T^d
  - T = tempo cumulativo di test

Reliability Growth

- Il piano richiede
  - Valori per l'affidabilita' speficata e inerente
  - Criteri per stimare l'affidabilita' iniziale dell'hardware
    - e.g., in avionica sistemi appena fabricati hanno tra il 10 e il 30% dell'affidabilita' richiesta
  - Tasso di crescita dell'affidabilita'
  - Calendario dei tempi di test, correzione e riparazione
- Diversi studi mostrano tassi di crescita tra 0.1 e 0.6

Accelerated Reliability Growth

- Si utilizzano tecniche di test accelerato
- Nelle ipotesi che
  - si possa stimare A
  - il tempo sia effettivamente compresso di A
  - si possa ottenere la stessa crescita in condizioni normali/tempi non compressi

$$M(t) = M_I \qquad t \le t_1$$

$$M(t, A) = \frac{M_I}{1-\alpha}\left(\frac{t}{t_1}\right)^{\alpha} A^{\alpha} \qquad t \ge t_1$$

where

A = the effective acceleration factor,

M_I = the initial MTBF,

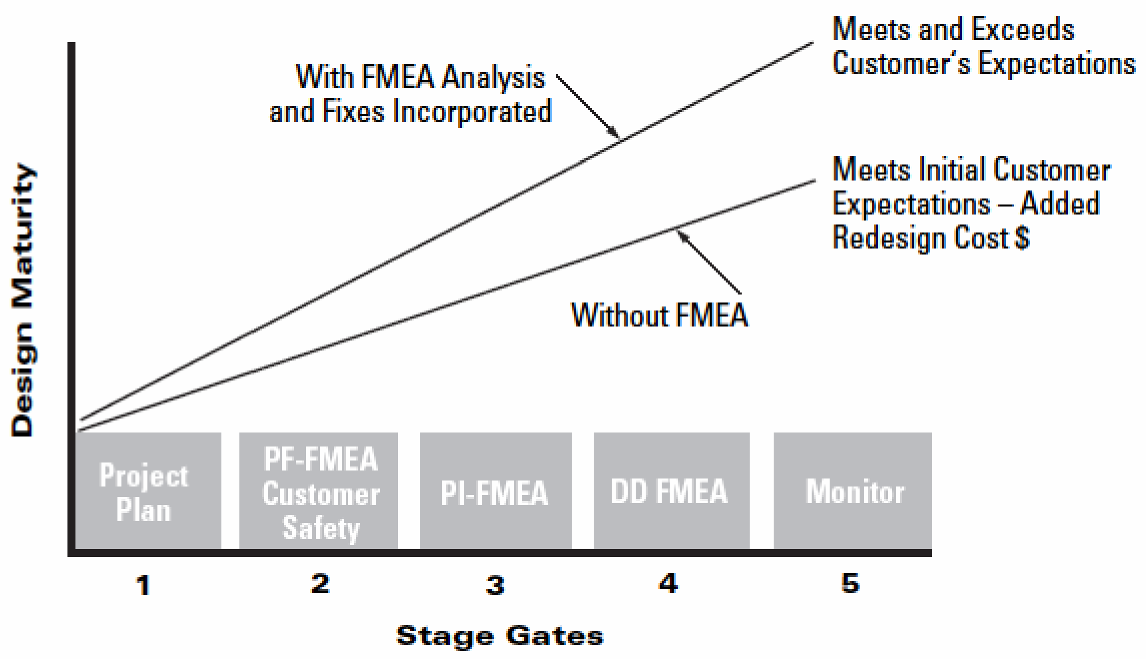
α = the growth parameter,

t = the cumulative test time under accelerated conditions, and

t_1 = the cumulative test time over the first phase.

Failure Modes and Effects Analysis

- FMEA e' una procedura documentata per identificare guasti durante la progettazione
  - Il primo passo consiste nell'identificare gli obiettivi o le attese della valutazione
  - Obiettivo chiave e' l'identificazione precoce di potenziali problemi



FMEA

- FMEA consiste di
  - Failure Mode
    - Modalita’ in cui il componente puo’ fallire il suo scopo
  - Effects
    - Come il sistema diventa non conforme con le specifiche
  - Cause
  - Analysis
    - Analisi dei rischi (Risk Priority Number)
    - RPN = Importanza*Frequenza*Rilevazione

Tipologie di FMEA

Stage Gate	FMEA Activity Expected
Idea Stage	FMEA Project Planning
Evaluate	Product Function FMEA (PF-FMEA)
Development	Product Interface FMEA (PI-FMEA)
Transition	Detail Design FMEA (DD-FMEA)
Production	Product Process FMEA (PP-FMEA)
	Updates if necessary

Obiettivi FMEA

- ✓ Support FMEA program vision.
- ✓ Increase activities with customer focus.
- ✓ Use a team approach.
- ✓ Support continuous improvement.
- ✓ Optimize lessons learned.
- ✓ Use concurrent engineering best practices.

Esempio

Failure Mode and Effect Analysis
(PI-FMEA)

System: XXX
Subsystem: XXX
Component: XXX
Model Year(s)/Vehicle(s): XXX
Core Team:

FMEA Number: XXX
Page: 1 of 2
Prepared by: XXX
FMEA Date (Orig.):
FMEA Update:

Item Function	Potential Failure Mode	Potential Effect(s) of Failure	SEV	CLASS	Potential Cause(s)/ Mechanism(s) of Failure	OCCUR	Current Design Controls	DETEC	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
												Actions Taken	SEV	OCCUR	DETEC	RPN
Electrical	open	No effect	1	c	solder joints or	1	Note 1	6	6	N/A						
Pin #1	open	for 1 of 3	1		metalization	1		6	6	N/A						
Electrical																
Ground																
Electrical	open	Loss of RF	10	c	Hot R3 or	6		3	180	Note 2						
Pin #2	open	generation	10		solder joints or	1	Note 1	6	60	N/A						
Electrical	open		10		metalization or	1		6	60	N/A						
V osc	shorted		10		FET	4		3	120	Note 3						
Electrical	open	Degradation	10	c	solder joints or	1	Note 1	6	60	N/A						
Pin #3	open	of range	10		metalization or	1		6	60	N/A						
Electrical	shorted	evaluation	10		varactor	2		2	40	N/A						
V tuning																

Severity Rating

Rating	Guideline	Rank
Very High	Indicates a potential failure mode that could cause death (9 with warning, 10 without warning).	10 9
High	High customer dissatisfaction due to the nature of the failure, such as a major system (e.g., automobile engine) function being inoperative.	8
High to Moderate	Can also be an inoperable convenience system (e.g., air-conditioning system). Do not involve safety aspects.	7
Moderate	Failure causes some customer dissatisfaction.	6
Moderate to Low	Customer is made uncomfortable or is annoyed by the failure.	5
Low	Customer will notice some subsystem or vehicle performance deterioration.	4
Low to Minor	The nature of failure causes only slight annoyance. The customer will probably only notice a slight deterioration of the performance.	3
Minor	Unreasonable to expect that the minor nature of this failure would cause any real effect on the system performance.	2
Very Minor	Most customers would probably not even notice the failure.	1

Occurrence Rating

Failure Rate	Likelihood of Failure	Ranking	Occurrence per Unit Time	
Very High	Failure is almost inevitable.	10 9	1 in 2 1 in 3	(50%) (33%)
High	Repeated failures.	8 7	1 in 8 1 in 20	(12.5%) (5%)
Moderate	Occasional failures.	6 5 4	1 in 80 1 in 400 1 in 2,000	(1.25%) (0.25%) (0.05%)
Low	Relatively few failures.	3 2	1 in 1,500 1 in 150,000	(666 PPM) (6.66 PPM)
Remote	Failure is unlikely.	1	1 in 1,500,000	(0.66 PPM)

Detection Rating

Rating	Guideline	Rank
Certainty of Nondetection	Screening cannot detect a potential failure mechanism, or there is no screen.	10
Very Low	Screening probably will not detect a potential failure mechanism.	9
Low	Screening not likely to detect a potential failure mechanism.	8 7
Moderate	Screening may detect a potential failure mechanism.	6 5
High	Screening has a good chance of detecting a potential failure mechanism.	4 3
Very High	Screening will almost certainly detect a potential failure mechanism.	2 1