CENTRE FRANCAIS DE FIABILITE

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A new Reliability Methodology for the Validation of Mechatronic System

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UNION EUROPÉENNE
Ce projet est cofinancé par le Fonds européen de développement régional
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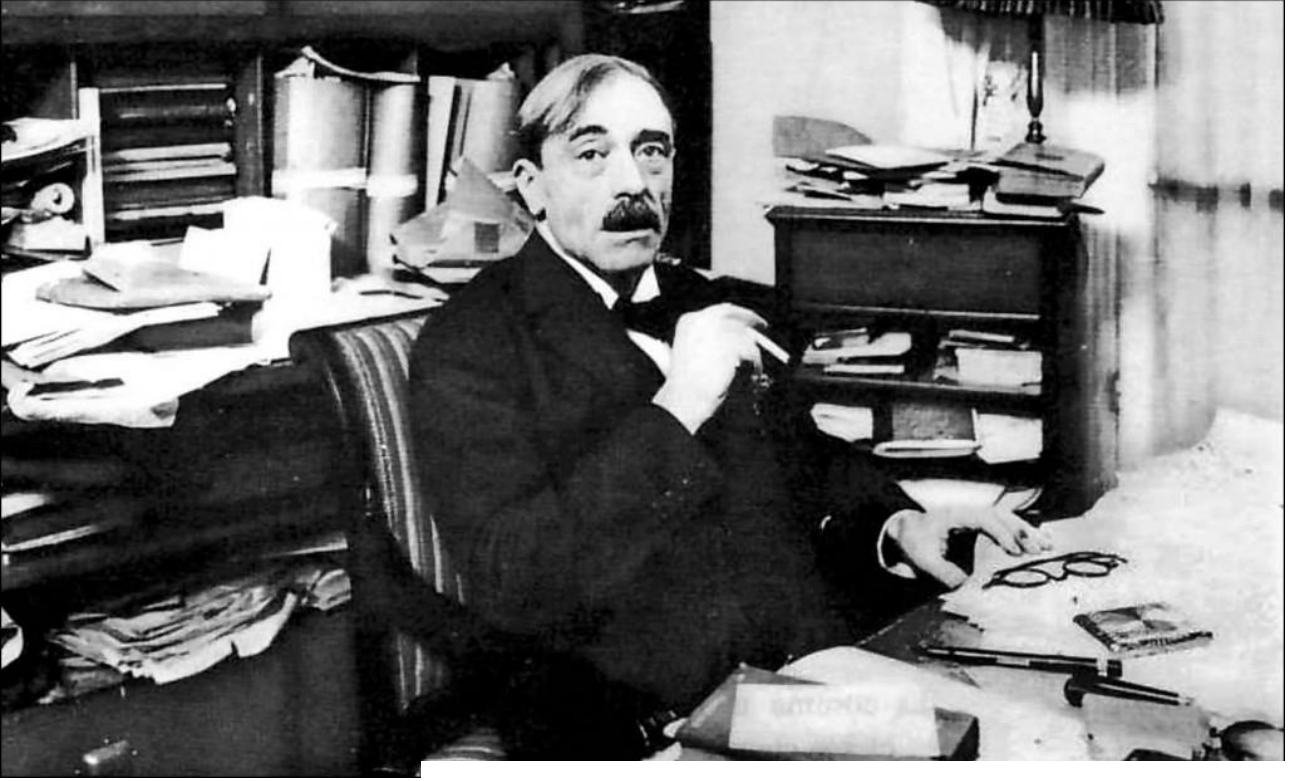
RÉPUBLIQUE FRANÇAISE
RÉGION NORMANDIE
Founded 1984



« WHAT IS SIMPLE IS ALWAYS ERRONEOUS,
WHAT IS NOT IS UNSERVICEABLE »

Paul VALERY (1871-1945)

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Agenda

1. Context & Problematic
2. Reliability tool HALT
3. Fatigue Damage Calculation
4. Conclusion

1. Mechatronic Automotive Context

Context

Reliability must take into account the complexity of systems

88 000 000

Annual World wide Production

2017

Competitive

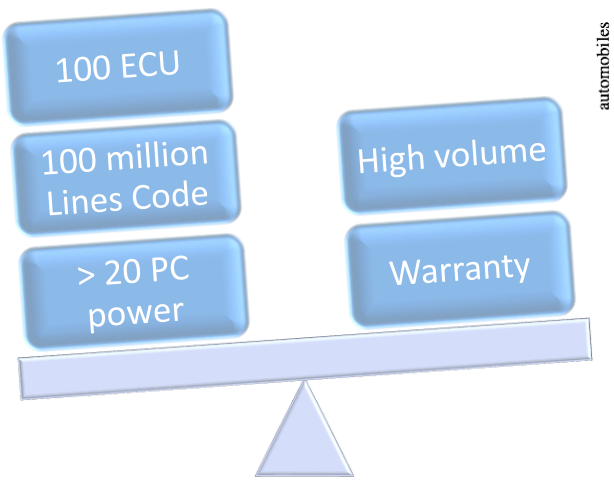
100 ECU

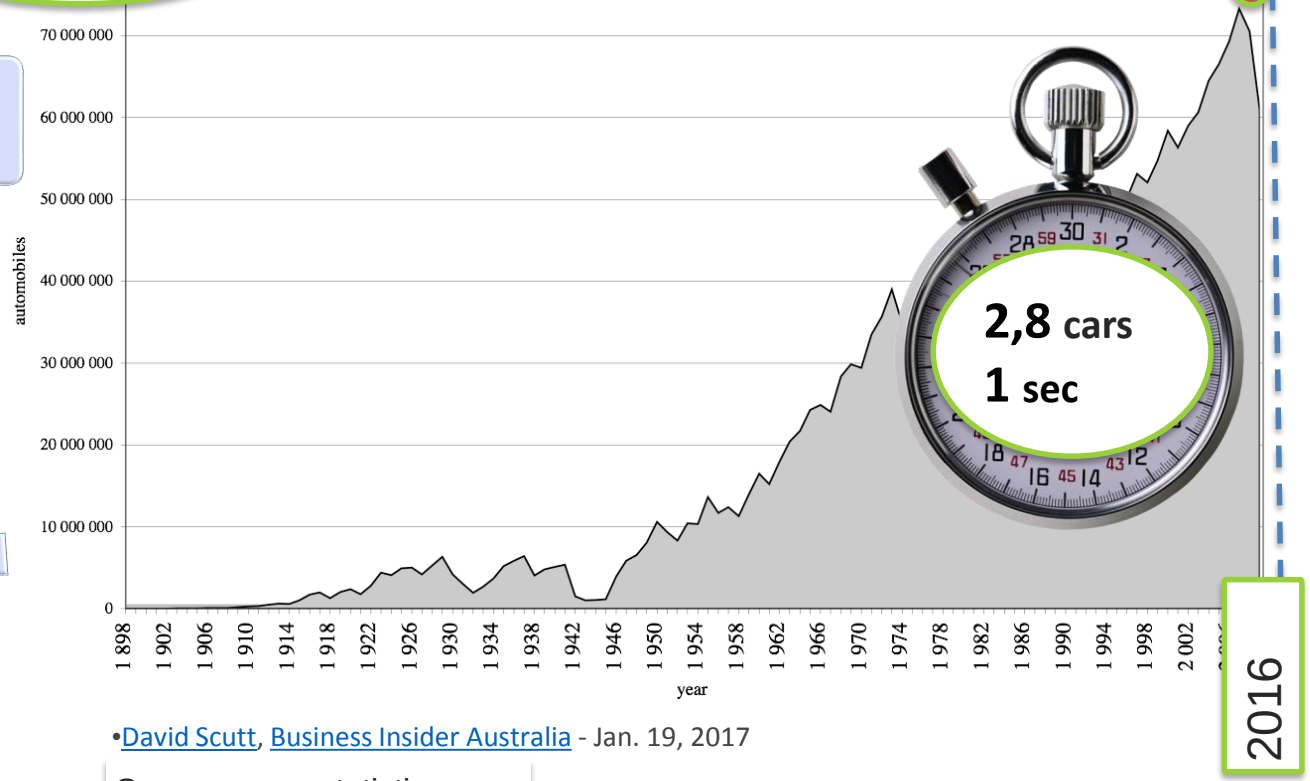
100 million Lines Code

> 20 PC power

High volume

Warranty





•David Scutt, Business Insider Australia - Jan. 19, 2017

Source : www.statistica.com

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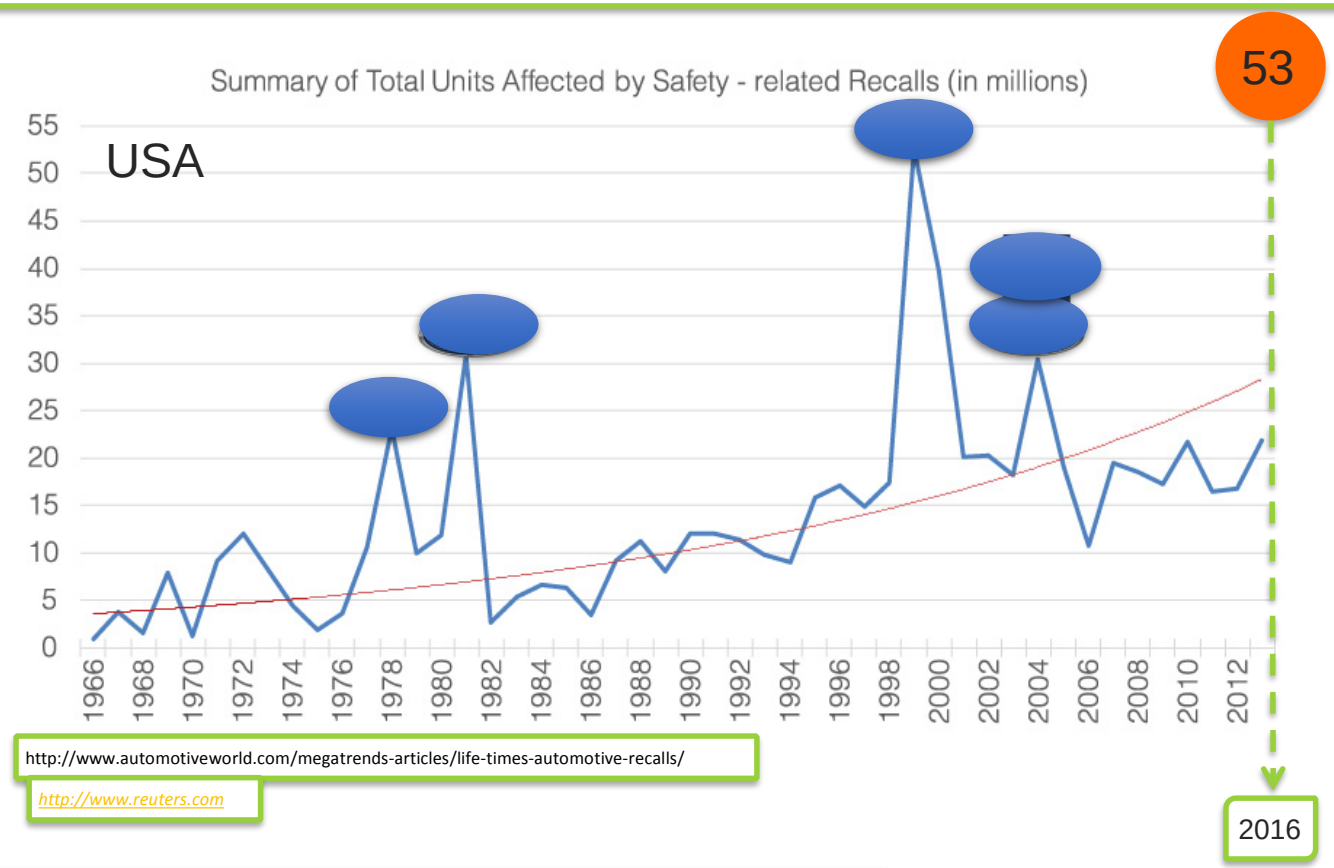
1. Mechatronic Automotive Context

Reliability must take into account the risk in the development phase

Problematic

"+45% of Japan Recall are due to optimistic evaluation criteria. The need for good Testing Criteria to Verify Design Approaches" – Japan Domestic Cars (1)



http://www.automotiveworld.com/megatrends-articles/life-times-automotive-recalls/

http://www.reuters.com

1% to 3 % sales

(*) : assumptions 2016
88 million cars produced worldwide with warranty cost of 2,28% of sales based on 15.000€ average car price

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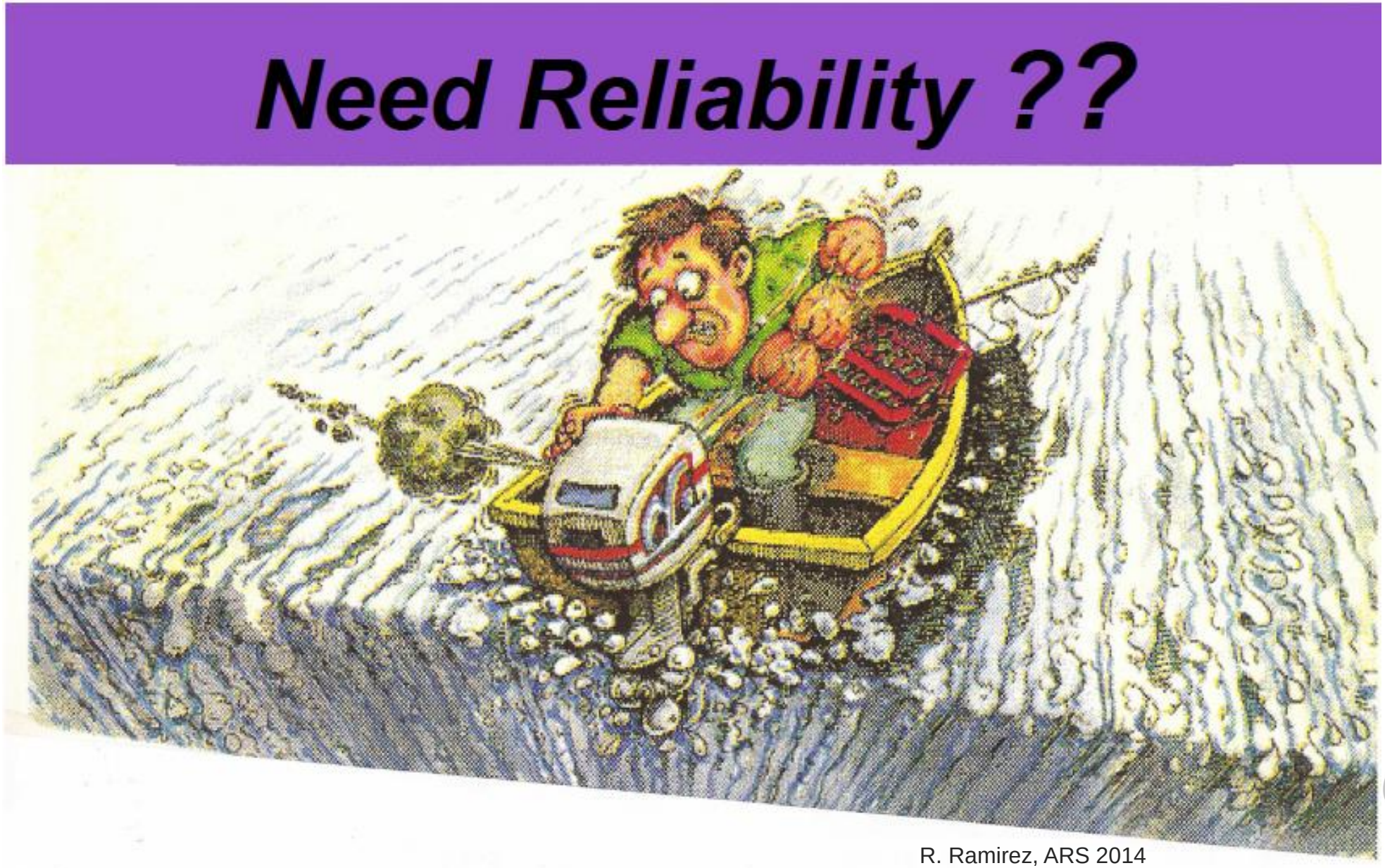
1. Mechatronic Automotive Context



R. Ramirez, ARS 2014

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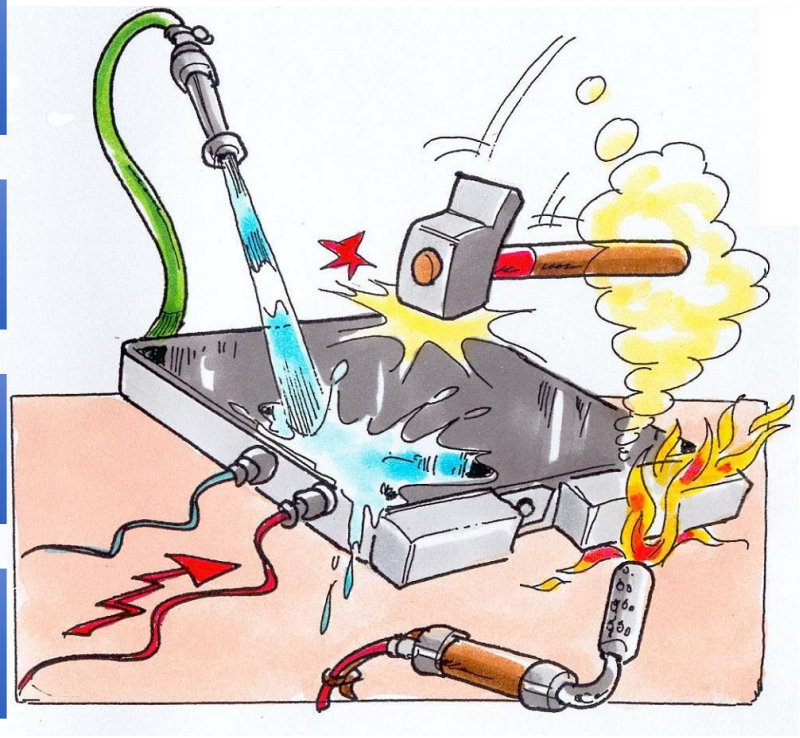
2. Mechatronic Reliability Tool : HALT

- Reveal more quickly the latent defects
- Detect more quickly the production process faults
- Identify the defects that may not have been revealed by a “conventional ESS” operation
- Reinforce the product maturity and Robustness



How can we evaluate the vehicle risk and so change the Design ?

(2) : source ASTE : “HA-ESS Guideline”

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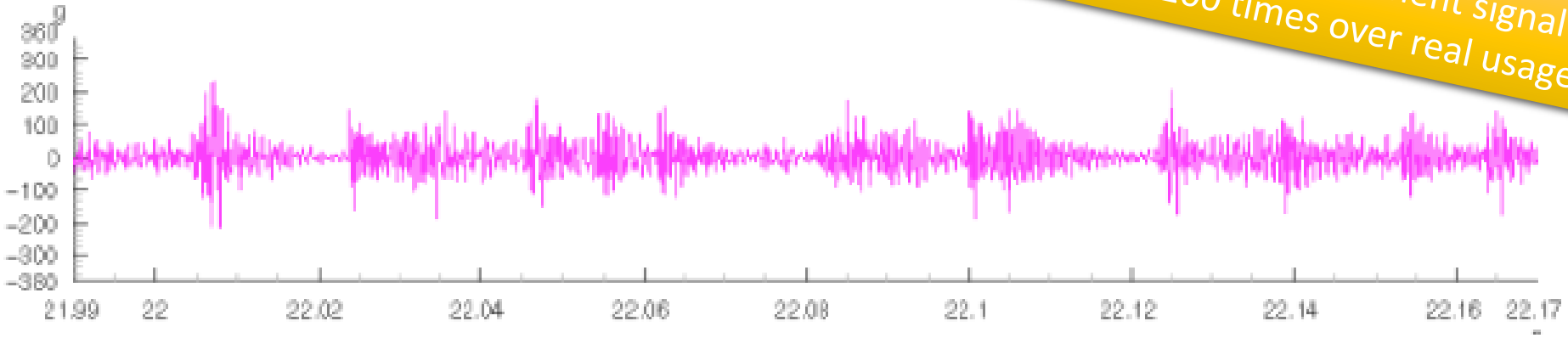
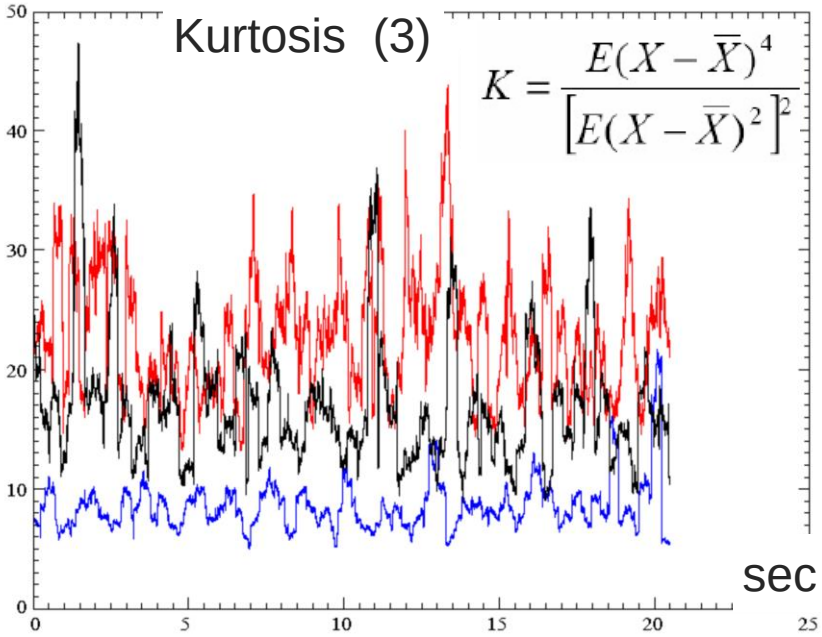
2. Mechatronic Reliability Tool : HALT

HALT vibration is a high transient signal
(lots of shocks – 200 times over real usage)





High transient signal

Pneumatic hammer

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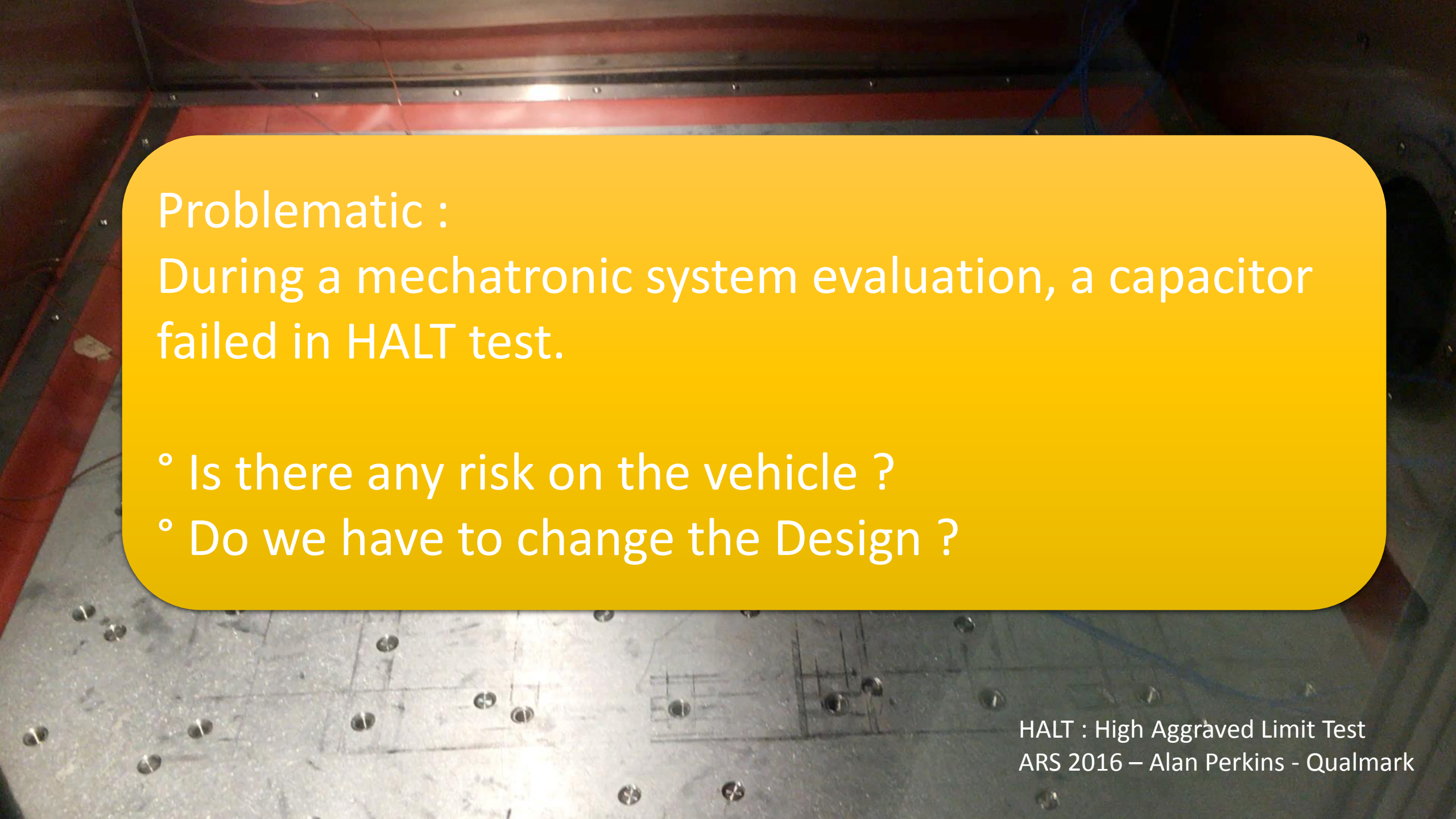
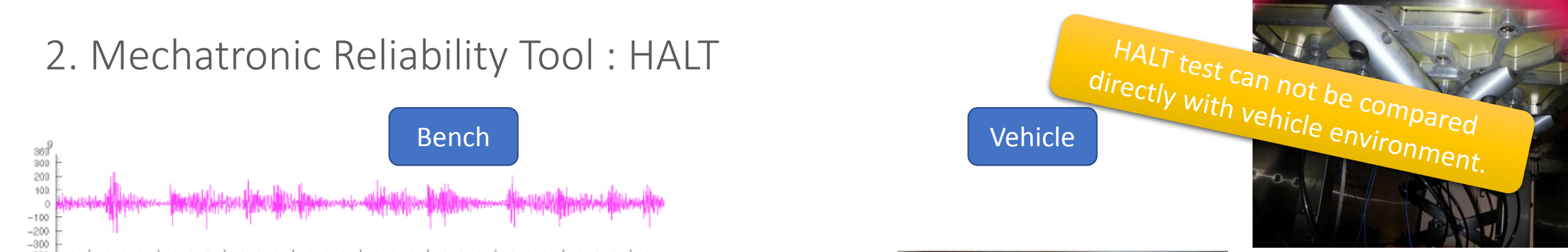


Problematic :
During a mechatronic system evaluation, a capacitor failed in HALT test.

° Is there any risk on the vehicle ?
° Do we have to change the Design ?

HALT : High Aggraved Limit Test
ARS 2016 – Alan Perkins - Qualmark

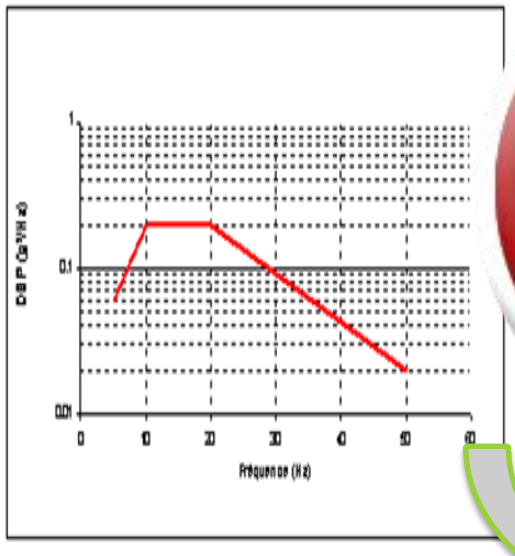
2. Mechatronic Reliability Tool : HALT

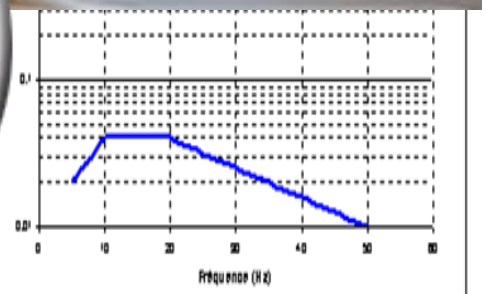


Bench

Vehicle

Fast Fourier Transform





Real vehicle needs

Evaluation of the vehicle risks : Fatigue Damage approach

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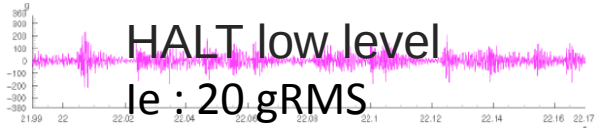
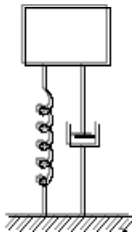
3. Fatigue Damage Computation: HALT vs Real Usage

HALT failure : ie 45gRMS capacitor

Design Change?



HALT low level
Ie : 20 gRMS

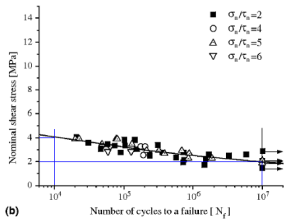


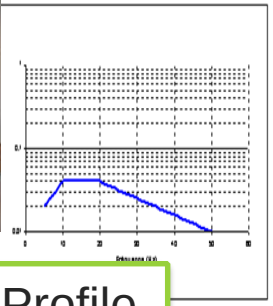
1 dof

Capacitor

Rainflow Counting

Fatigue Curve





Life Profile

FATIGUE DAMAGE
HALT 45gRMS

FATIGUE DAMAGE
LIFE PROFILE

Design Change
CRITERIA

Evaluation of the risk thanks the Fatigue Damage Method

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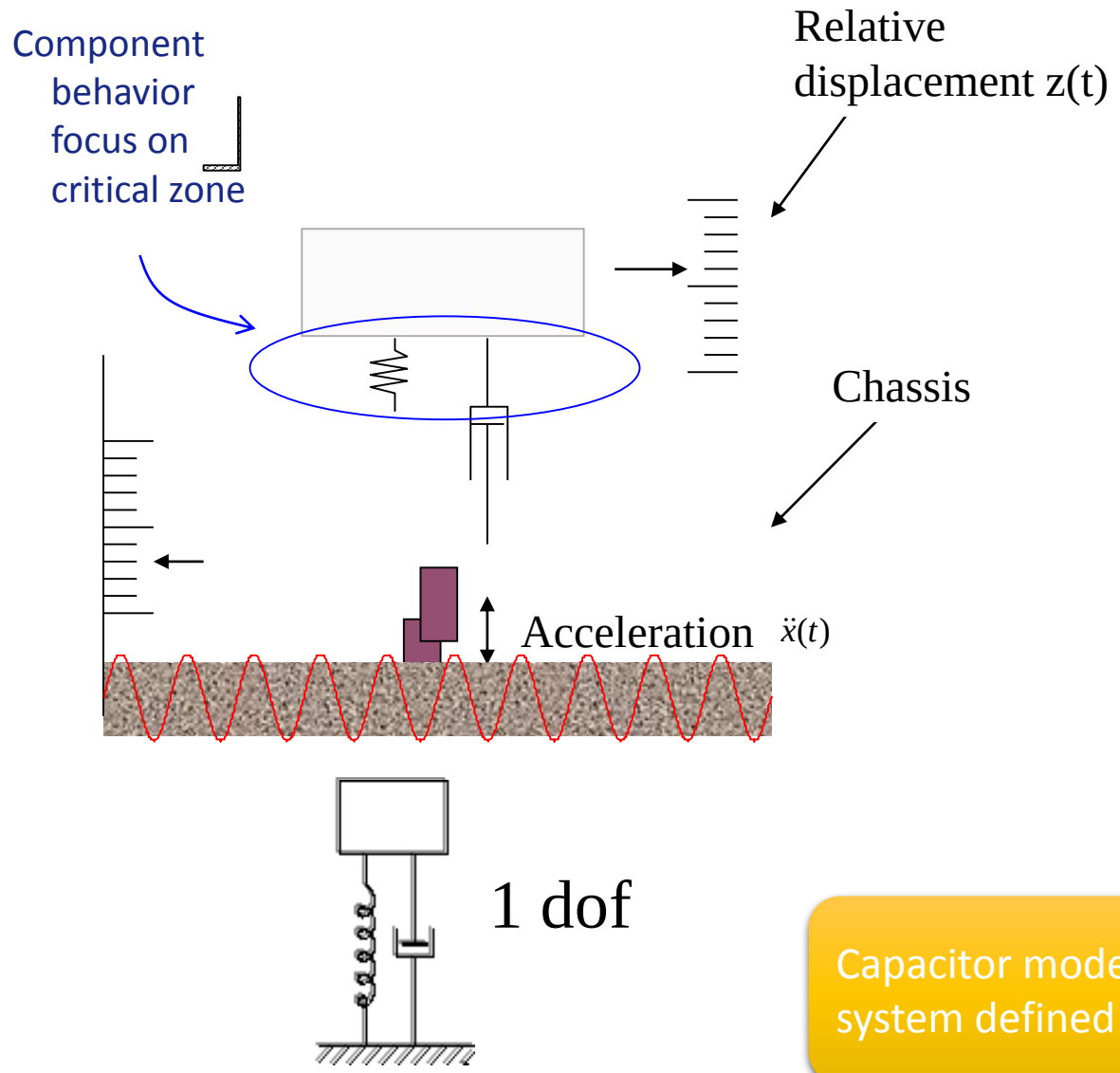
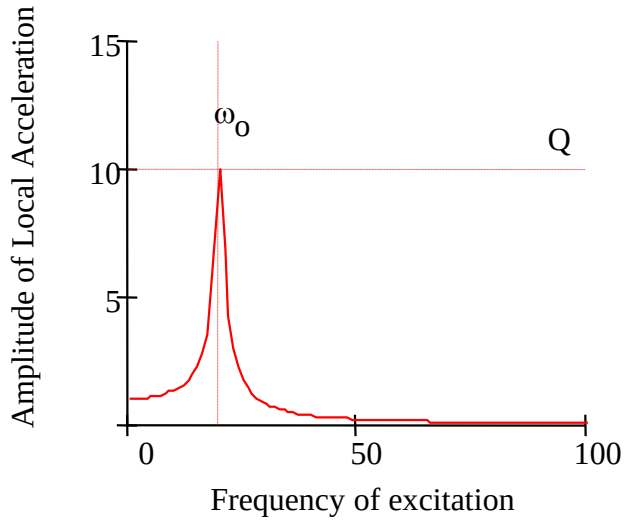
3. Fatigue Damage Computation: system equivalent to 1 Degree Of Freedom





(4)

$$Q = \frac{1}{2\zeta} \qquad \zeta = \text{damping ratio}$$

Capacitor model as a single degree of freedom system defined by its dynamic parameters

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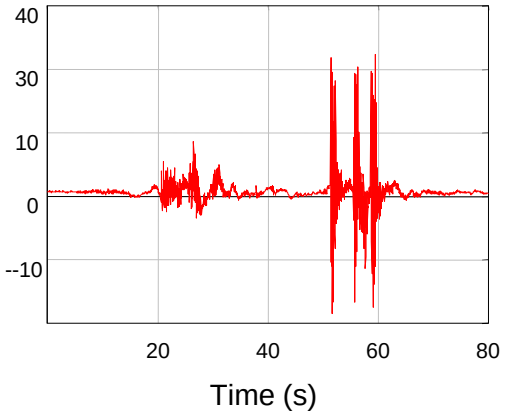
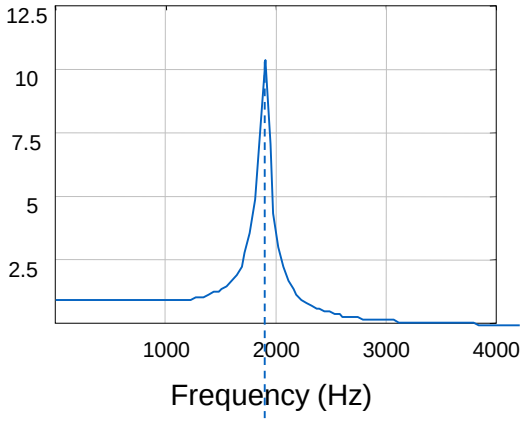
3. Fatigue Damage Computation: what is the Fatigue Damage Spectrum ?

Process to draw the Fatigue Damage Spectrum (FDS)

Acceleration (g)

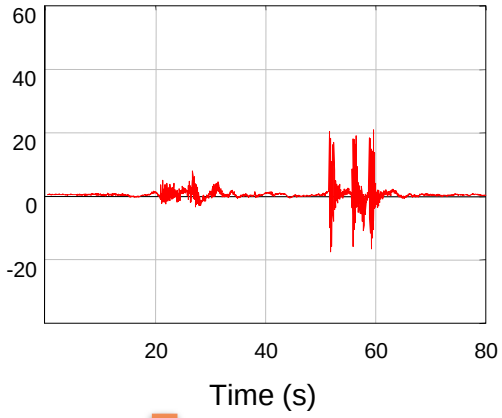


SDOF Transfer Function (fn)

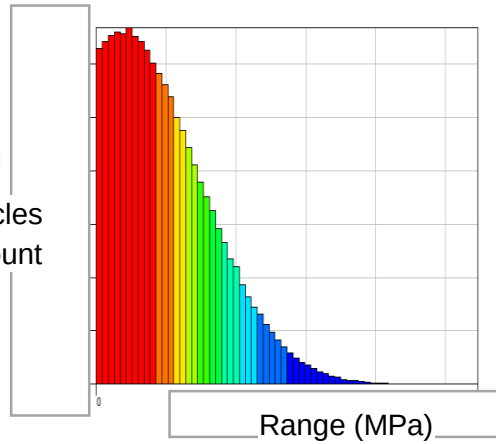


f_n

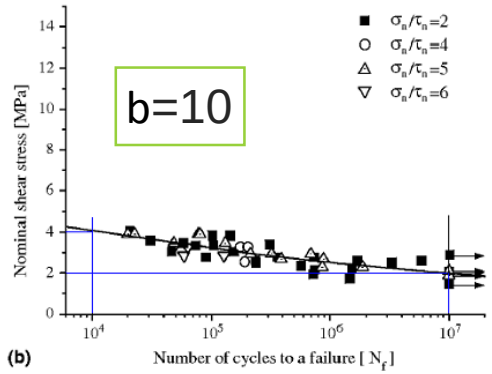
Fn Stress (Mpa)



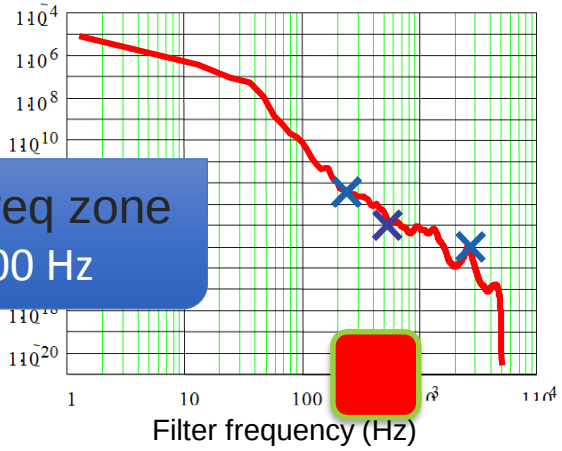
Fn Rainflow cycles count acceleration



FATIGUE CURVE
SAC305 solder (5)



Fatigue Damage Spectrum



Critical Freq zone
250-400 Hz

(4)

The Fatigue Damage Spectrum can be interpreted only in the critical Frequency zone of the component

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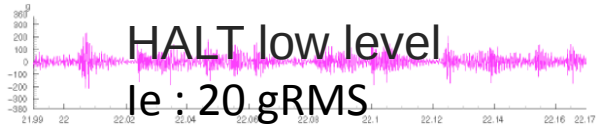
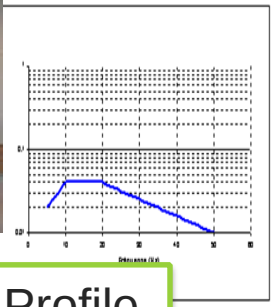
3. Fatigue Damage Computation: benefit of FDS

HALT failure : ie 45gRMS capacitor

Design Change?

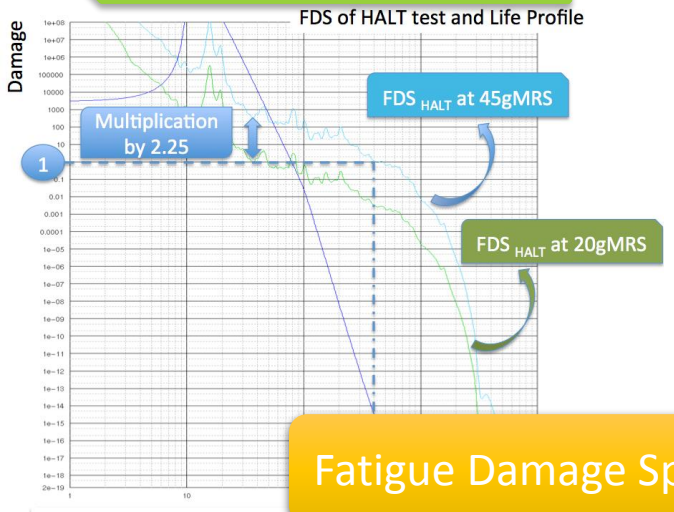


HALT low level
Ie : 20 gRMS

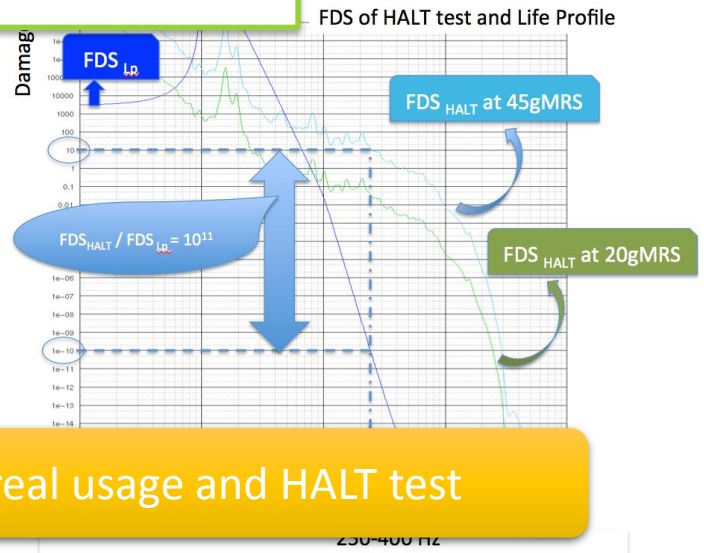


Life Profile

FATIGUE DAMAGE
HALT 45gRMS



FATIGUE DAMAGE
LIFE PROFILE



Fatigue Damage Spectrum allow to compare real usage and HALT test

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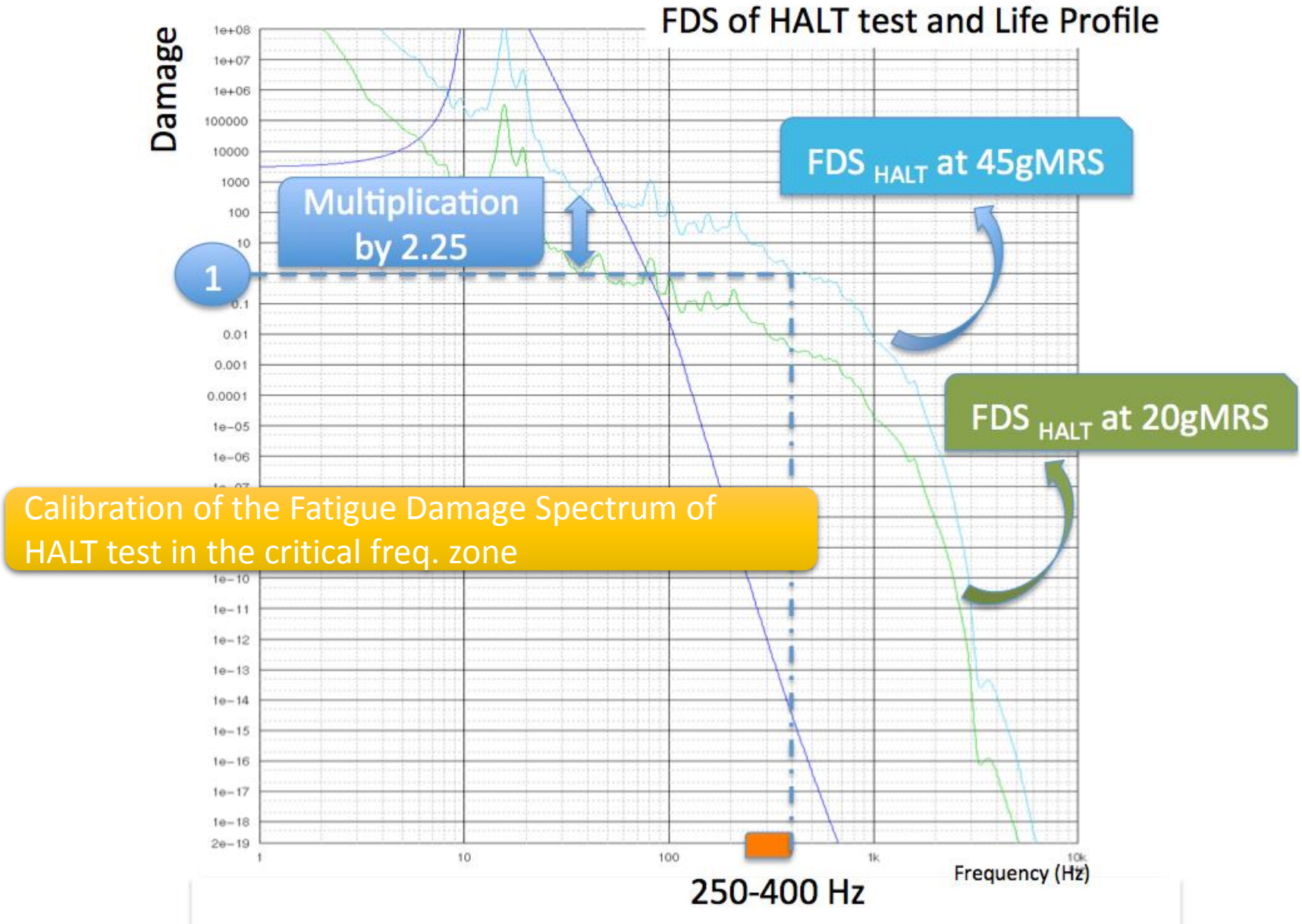
3. Fatigue Damage Computation: FDS of the HALT test



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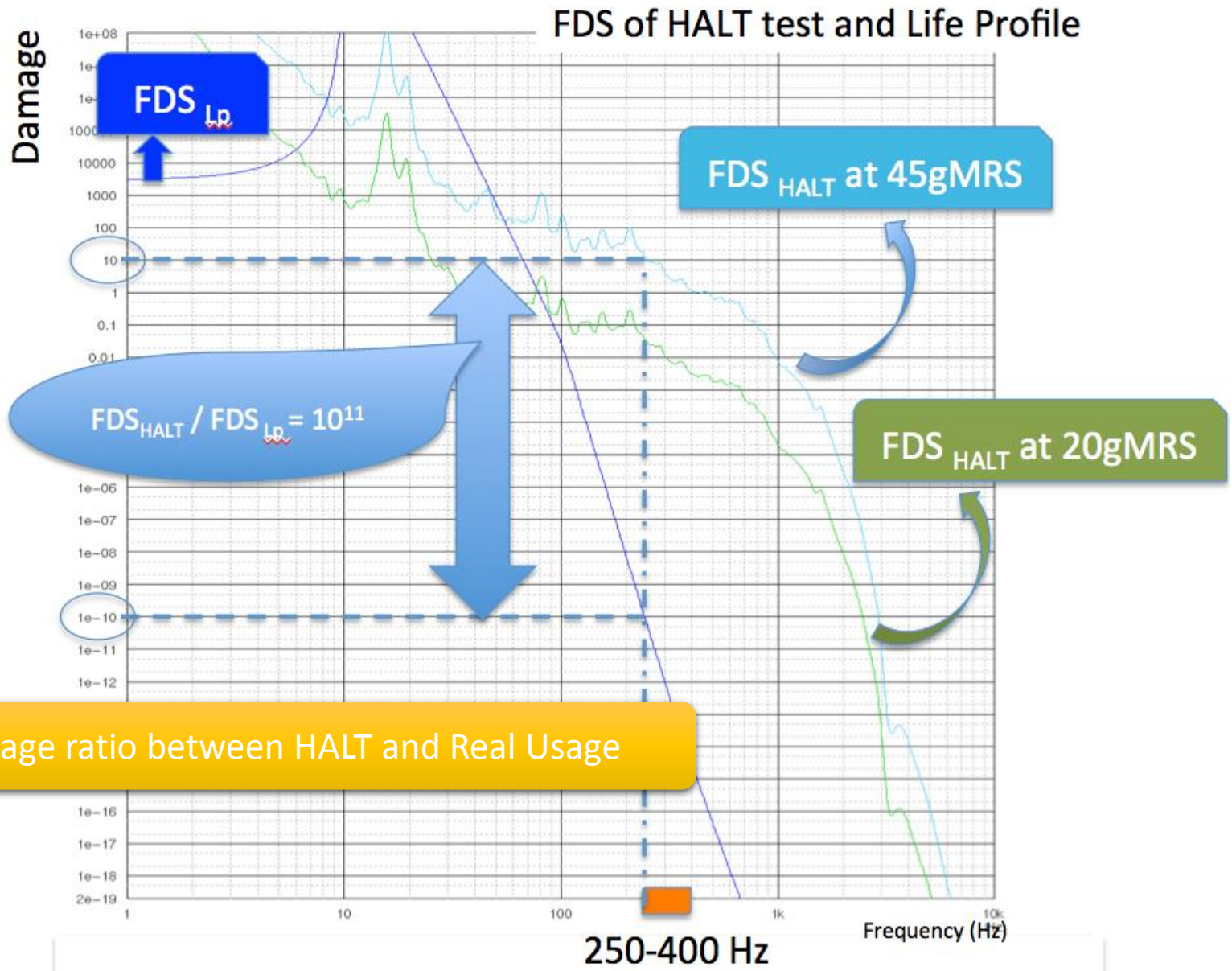
3. Fatigue Damage Computation: HALT vs Vehicle



Define the damage ratio between HALT and Real Usage

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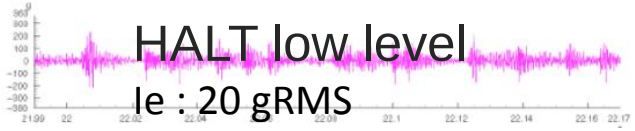
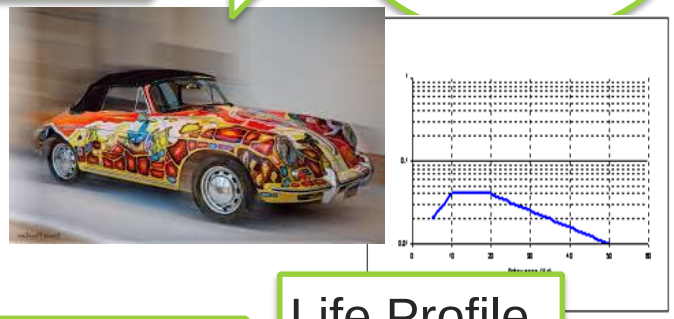
3. Fatigue Damage Computation: HALT vs Real Usage

HALT failure : ie 45gRMS capacitor

Design Change?

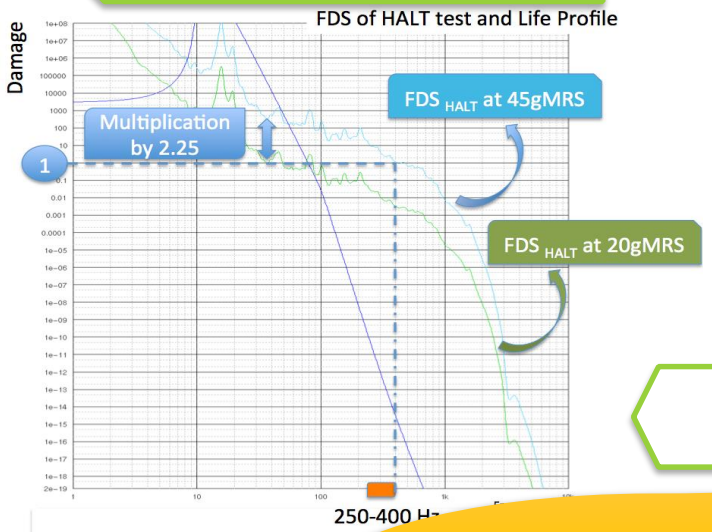


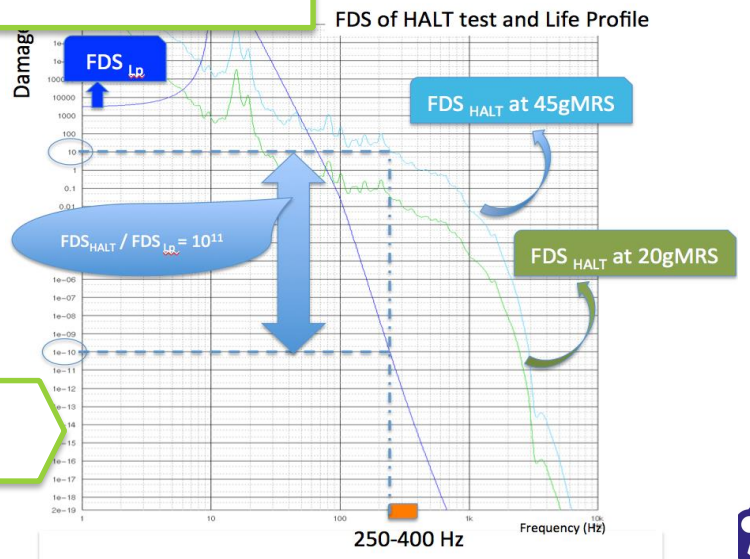


Life Profile

FATIGUE DAMAGE
HALT 45gRMS

FATIGUE DAMAGE
LIFE PROFILE





$FDS_{HALT} / FDS_{LP} = 10^{11}$

What is the Design Change CRITERIA ?

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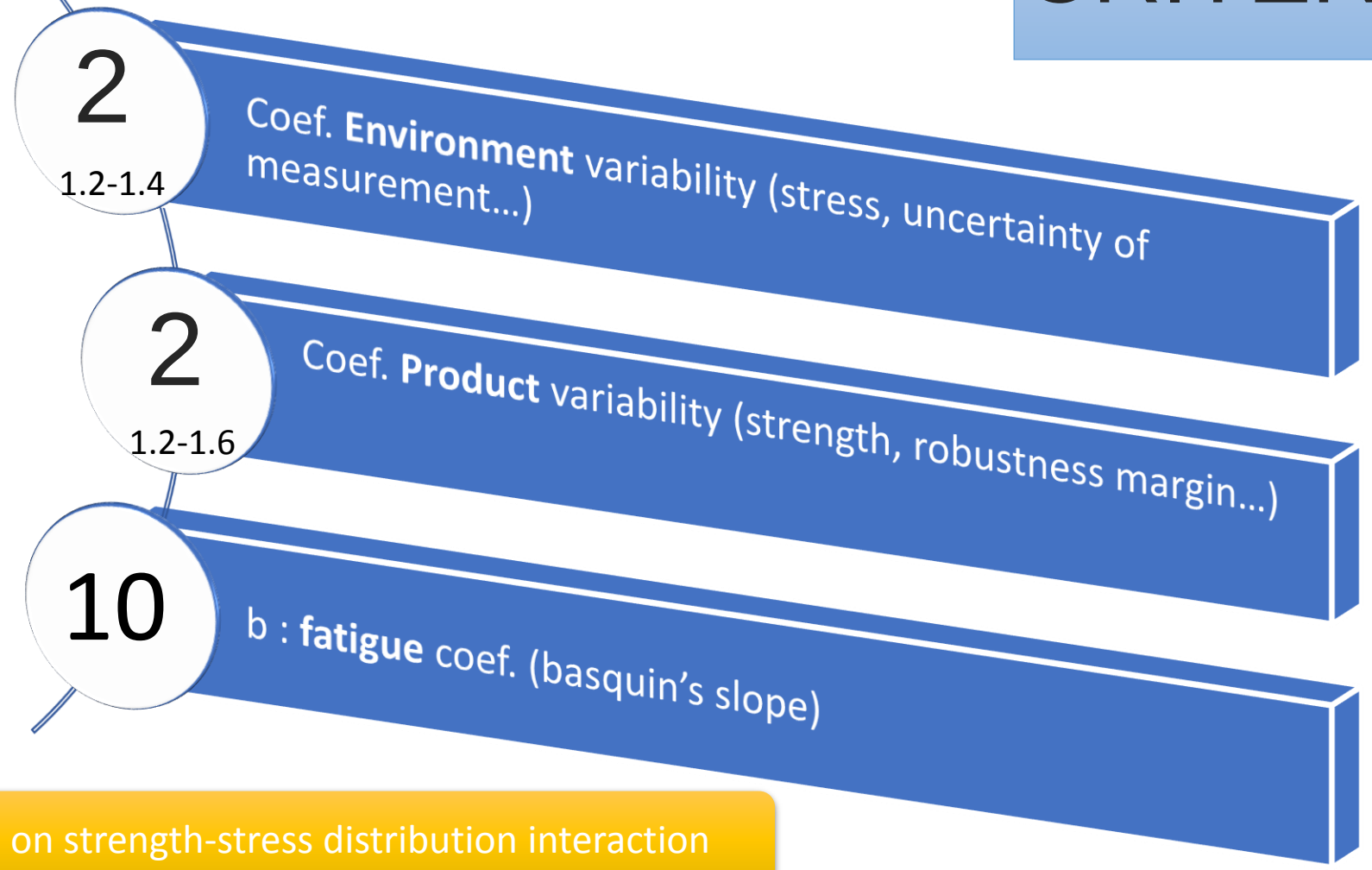
3. Fatigue Damage Computation: Design Change Criteria

CRITERIA = (Env. X Prod.) ^{b}



CRITERIA = 4^{10}

Criteria based on strength-stress distribution interaction

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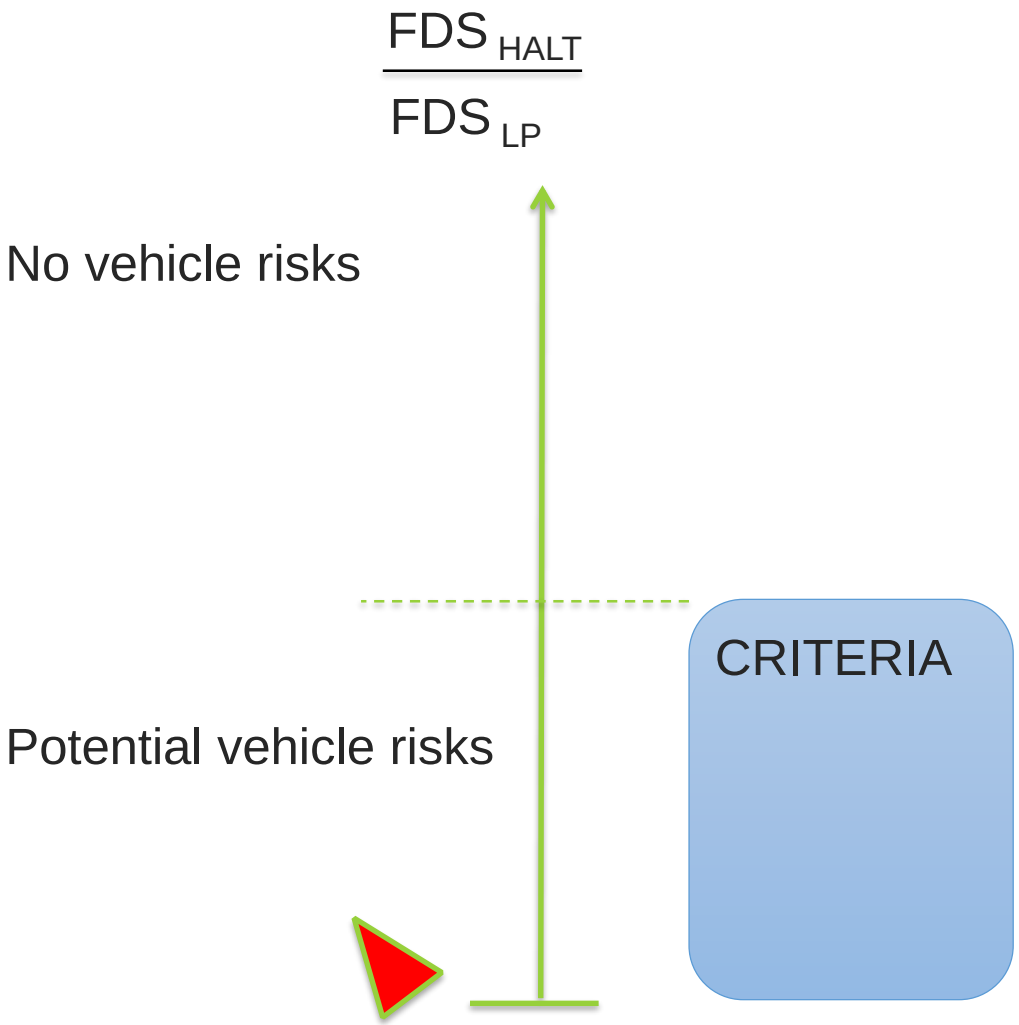
3. Fatigue Damage Computation: Risk evaluation theory

The new Criteria assess the vehicle risk



$$\frac{FDS_{HALT}}{FDS_{LP}} < CRITERIA$$ No Vehicle Risk

$$\frac{FDS_{HALT}}{FDS_{LP}} > CRITERIA$$ Vehicle Risk

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3. Fatigue Damage Computation: Risk Evaluation on the capacitor

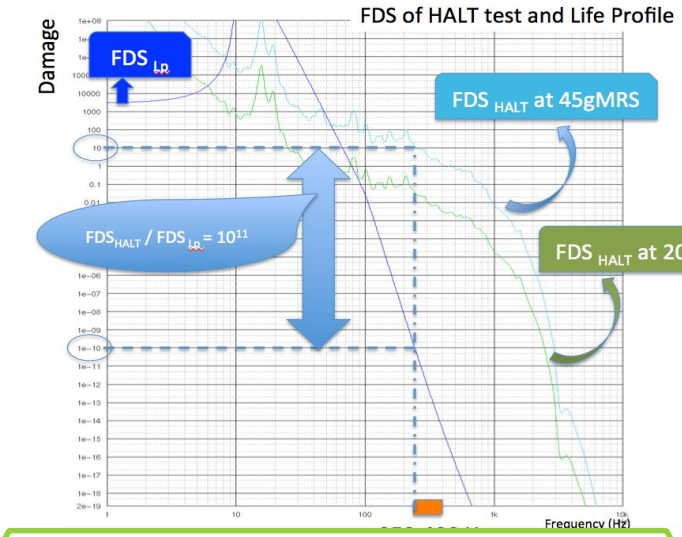
$$\frac{FDS_{HALT}}{FDS_{LP}}$$

No vehicle risks

Potential vehicle risks

CRITERIA

4^{10}



$FDS_{HALT} / FDS_{LP} = 10^{11}$

Based on this new approach, it is not necessary to change the design of the mechatronic system.

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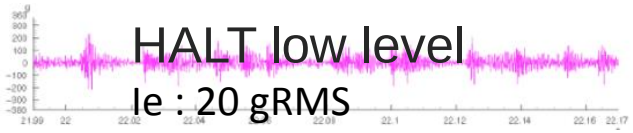
3. Fatigue Damage Computation: Overview

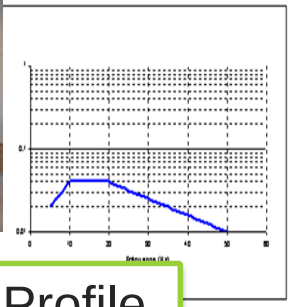
HALT failure : ie 45gRMS capacitor

Design Change?

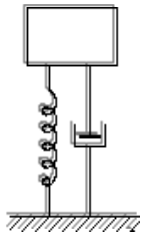


HALT low level

Ie : 20 gRMS



Life Profile

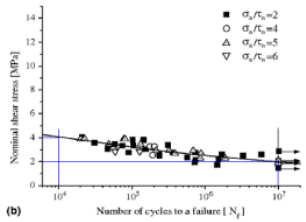


Capacitor

1 dof

Rainflow Counting

Fatigue Curve



FATIGUE DAMAGE

HALT 45gRMS

FATIGUE DAMAGE

LIFE PROFILE

New process to asses the vehicle risk.

Design Change CRITERIA

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4. Conclusion : Save Time & Money with Reliability Testing of Mechatronic Systems

Reliability Engineering must take into account :

° Product life cycle

° Complexity of Systems

° Design at the right cost

° Environmental Engineering

° …….

1. Deep understanding of Vehicle needs (ie : Mission profile)
2. Deep knowledge of product behaviour (ie : Fatigue)
3. Strong methodologies (Test tailoring approach)
4. Expert and Expertise (Humans competences)

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BIBLIOGRAPHY

(1) Japan Domestics cars, notification samples from HS.15 (2003) to HS.19 (2007)

(1) ASTE : “HA-ESS Guideline”, www.aste.asso.fr, January 2006

(2) D. Delaux: “Reliability validation of engine cooling modules with a tailoring tests of Vibration, Thermal Shock and Pressure Pulsation”, 2006 , Revue Essai & Simulation - #785 hors série

(4) M. Bonato, D. Delaux, “ Synthesis and Validation of Accelerated Vibration Durability Tests” RAMS Janv. 2015

(5) Kim, Y.B., Noguchi, H. Amagai, M. : “Vibration fatigue reliability of BGA-IC package Pb-free solder and Pb Sn Solder”, 2006, Microelectronics reliability 46, 459-466

(5) http://www.aste.asso.fr/fr/pag-488138-Guide-climatique.html

(6) http://www.aste.asso.fr/fr/pag-488138-Guide-climatique.html