The IEEE Central Texas Consultants Network

Overview of HALT and HASS: A Paradigm Shift for Rapid Reliability Development

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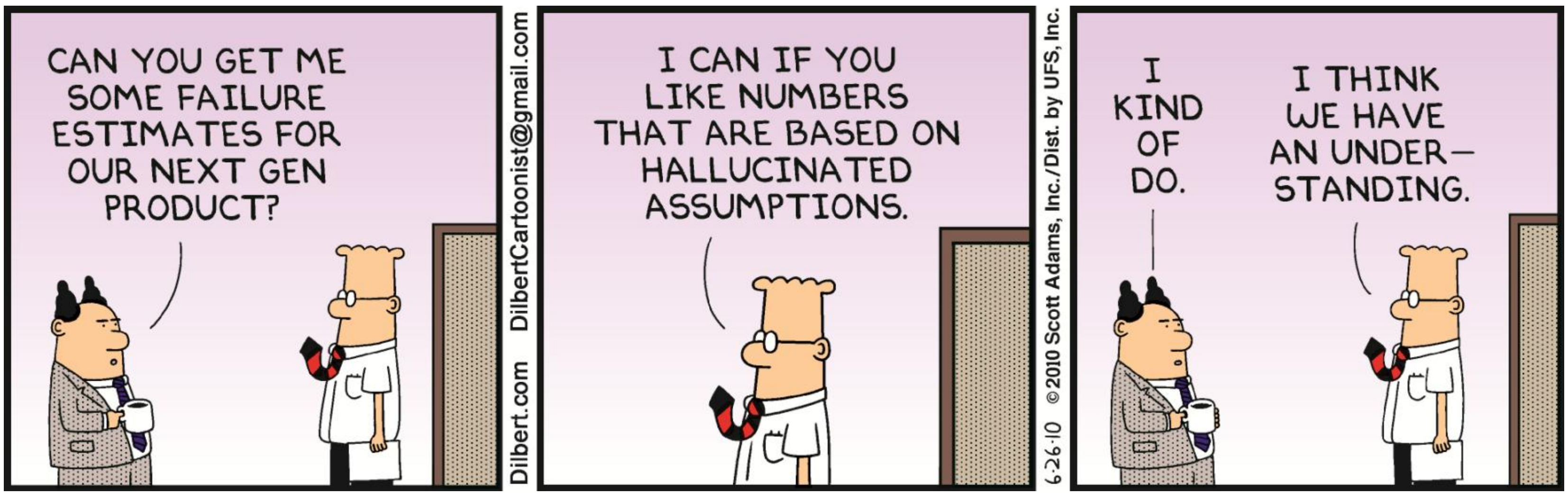
Reliability Prediction



Invalid assumptions about the causes of unreliability lead to invalid solutions to increase reliability

NTSB chairman Deborah Hersman

"The design and certification assessment and the assumptions that were made were not born out by what we saw," …speaking about the battery fires in Boston and Japan. "We had two events in two weeks on two separate aircraft. The fleet has less than 100,000 hours and [Boeing] did not expect in their assessment to see a smoke event in but less than 1 in every 10,000,000 hours."

From NTSB Website

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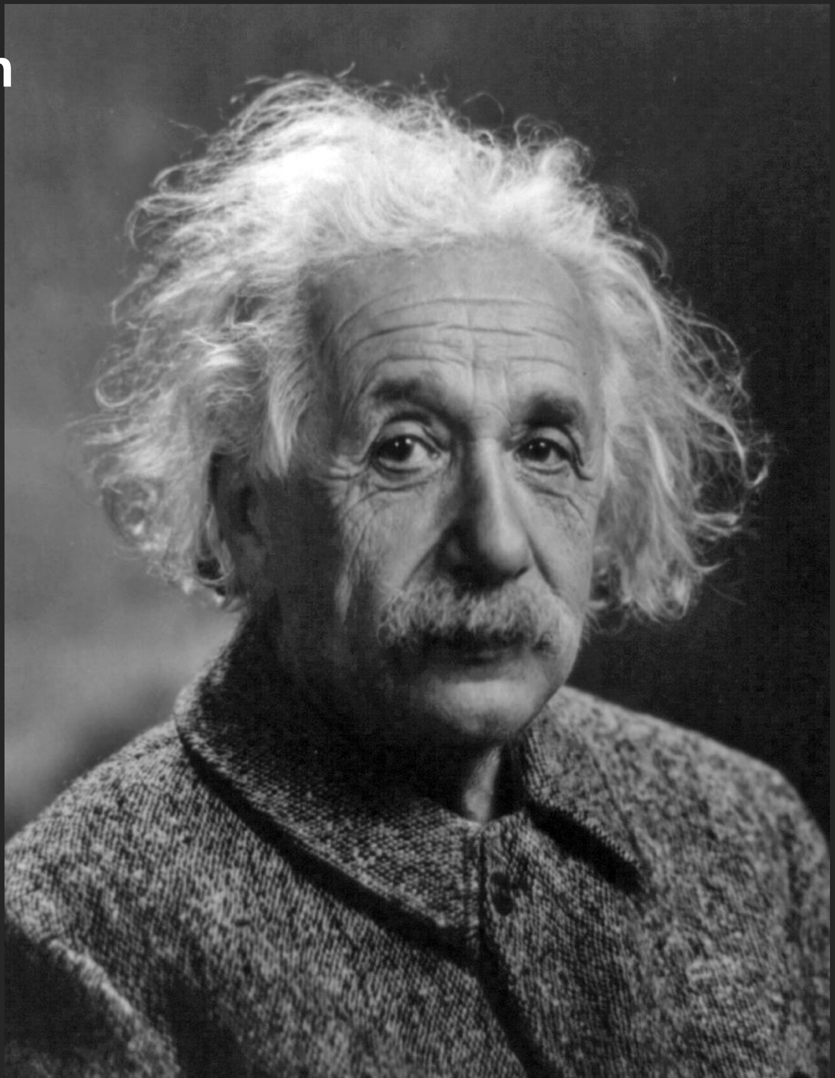
The U.S. Food and Drug Administration today issued a proposed order aimed at helping manufacturers improve the quality and reliability of automated external defibrillators

FDA has received approximately 45,000 adverse event reports between 2005 and 2012 associated with the failure of these devices

Electronics Reliability Prediction

When the number of factors coming into play in a phenomenological complex is too large scientific method in most cases fails. One need only think of the weather, in which case the prediction even for a few days ahead is impossible.”

- Albert Einstein



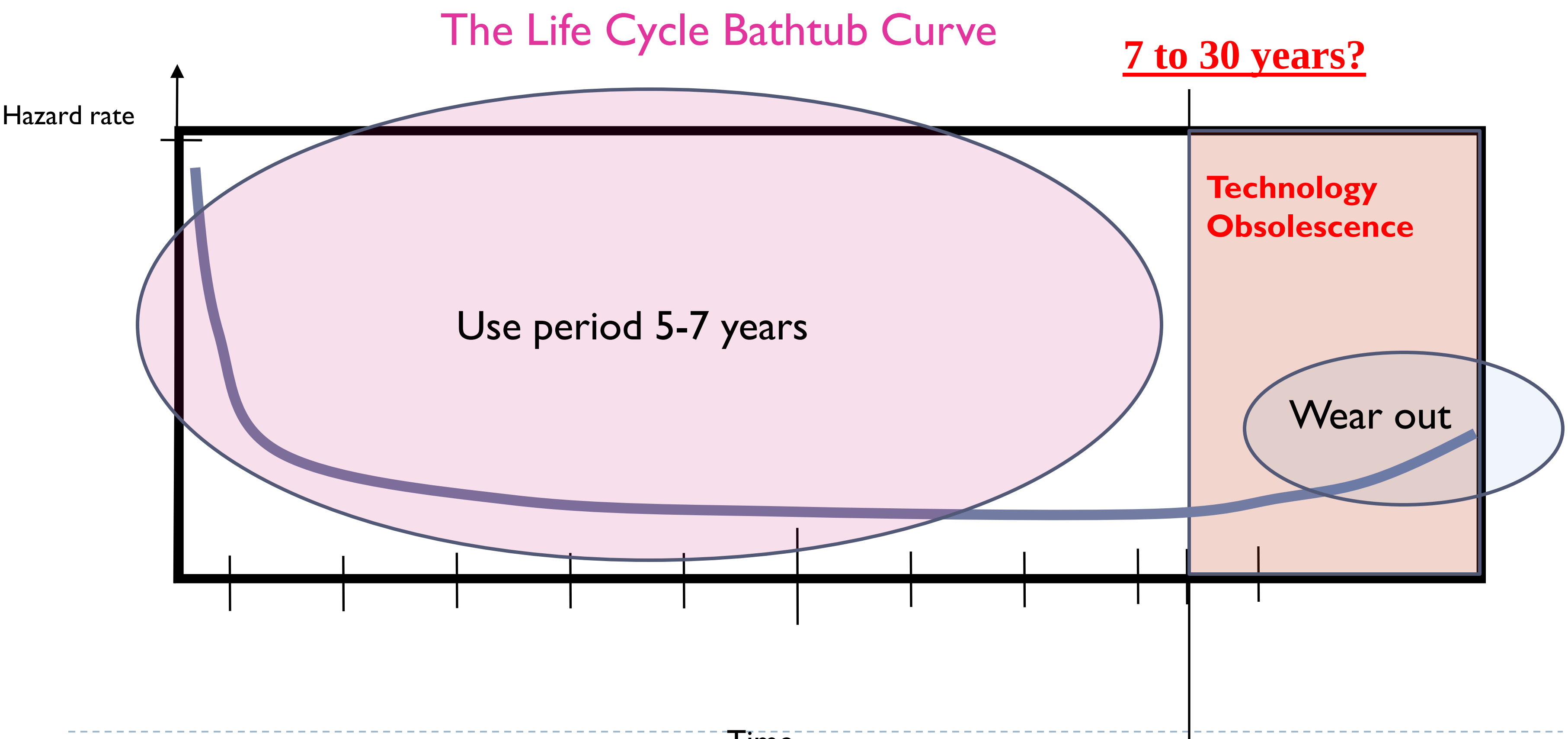
Factors contributing to the reliability of Electronics Systems is “phenomenological complex”

The Majority of Electronics Unreliability is Due to:

- Overlooked Design margin
- Error in fabrication or assembly
- Device or system misapplication
- Customer misuse or abuse

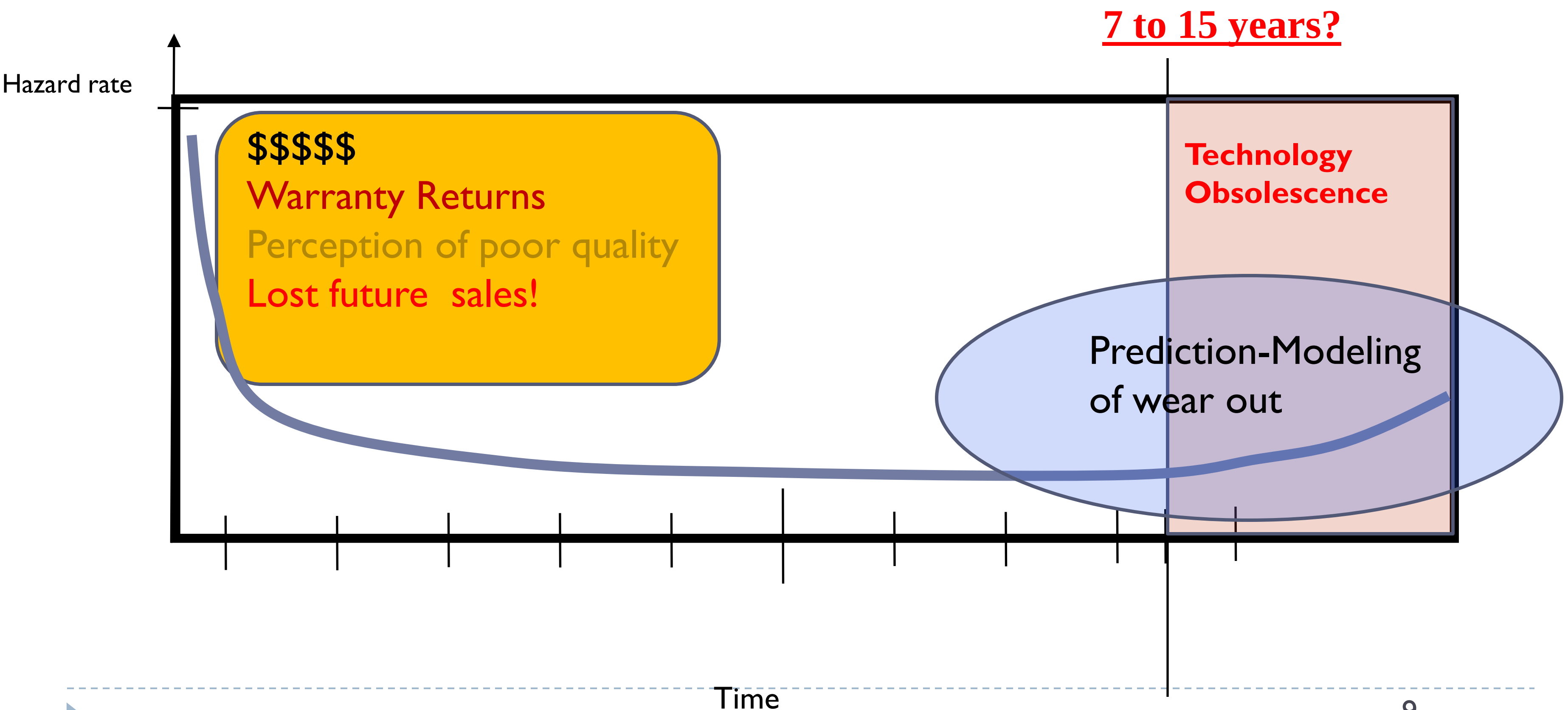
Fundamental mismatch of time scales

Wear out IS NOT a significant cause of un-reliability for vast majority of (non-mechanical) electronics assemblies



Costs and Reliability Development

Most of the costs of unreliability occur in the first several months or years

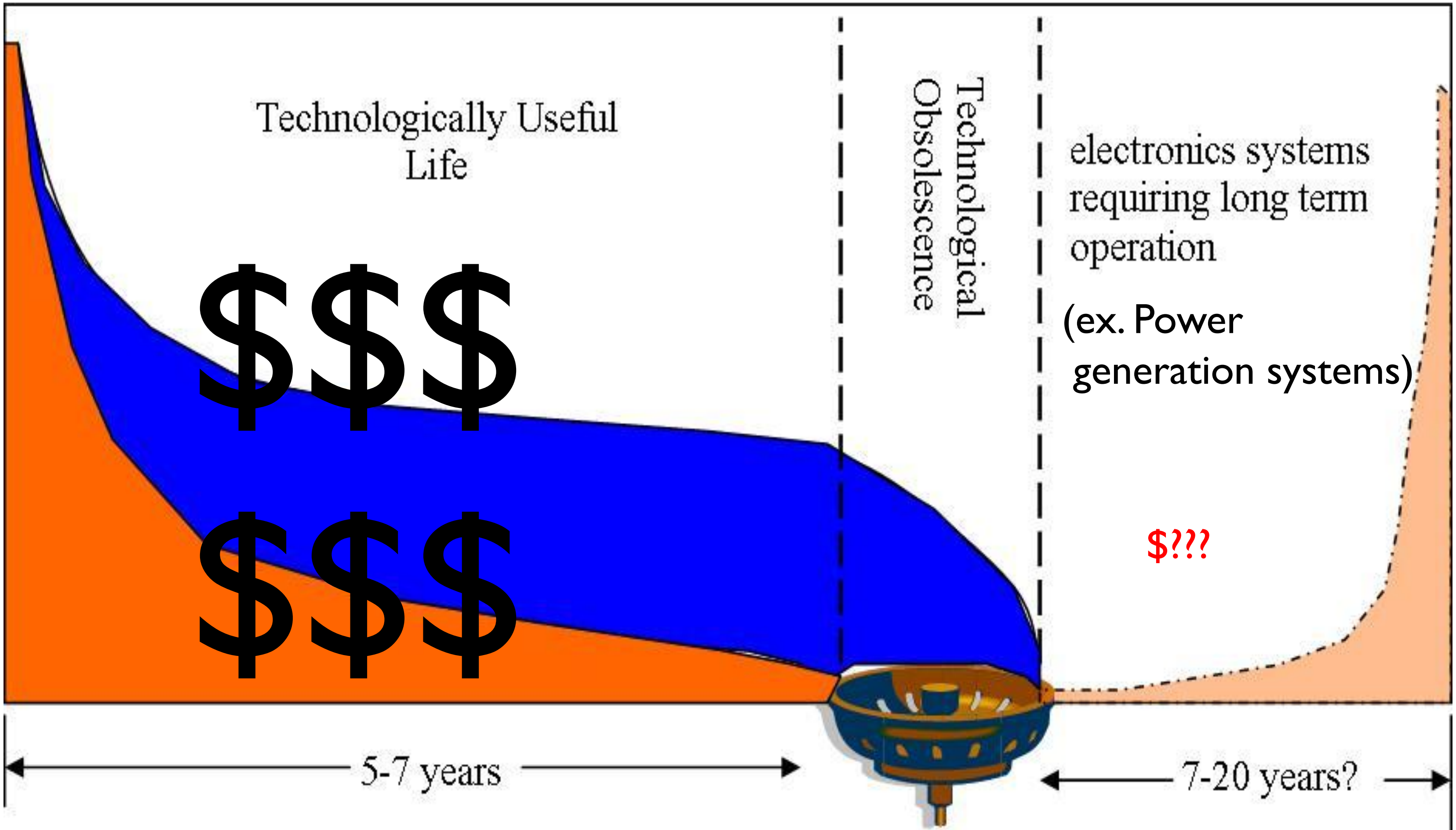


Majority of costs of unreliability occurs during market introduction

Early unreliability leads to

- Warranty expense – quantifiable
- Perception of poor quality and lost sales – not quantifiable in $$

There is a Drain in the Bathtub Curve

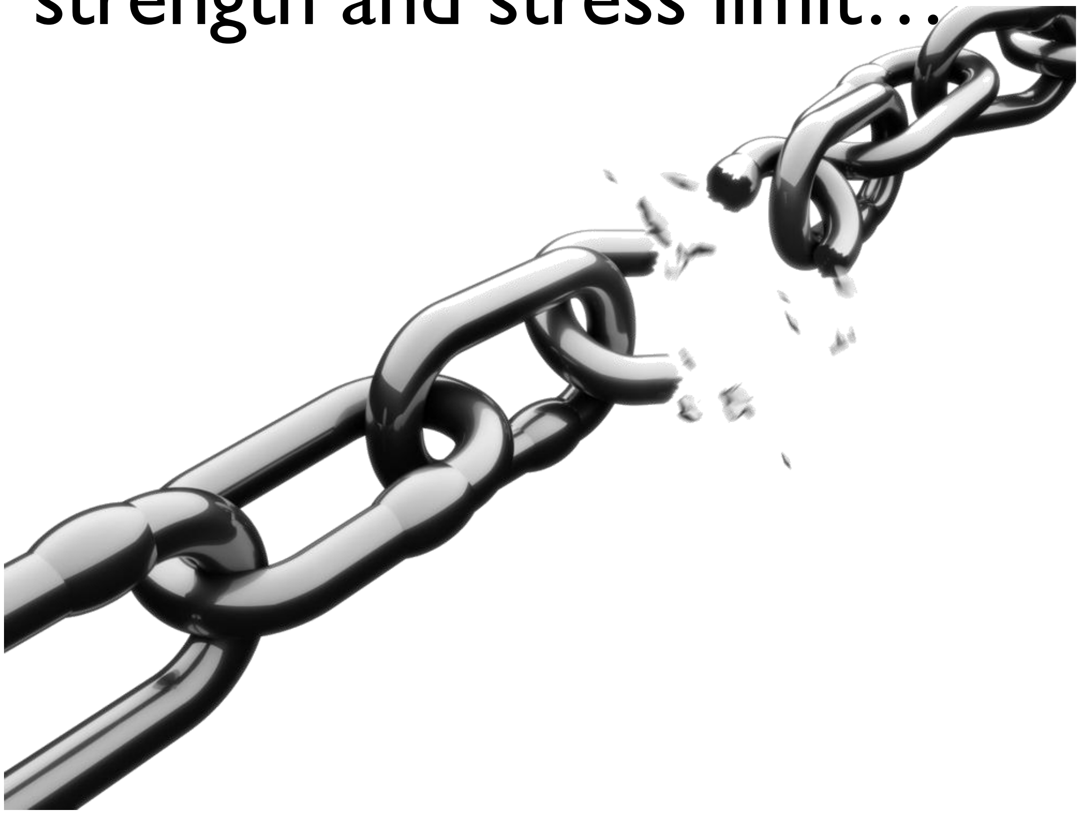


Basis for HALT

A chain is only as strong as its weakest link.

Fundamental Basis for HALT

Fastest way to find a weak link is find the strength and stress limit…

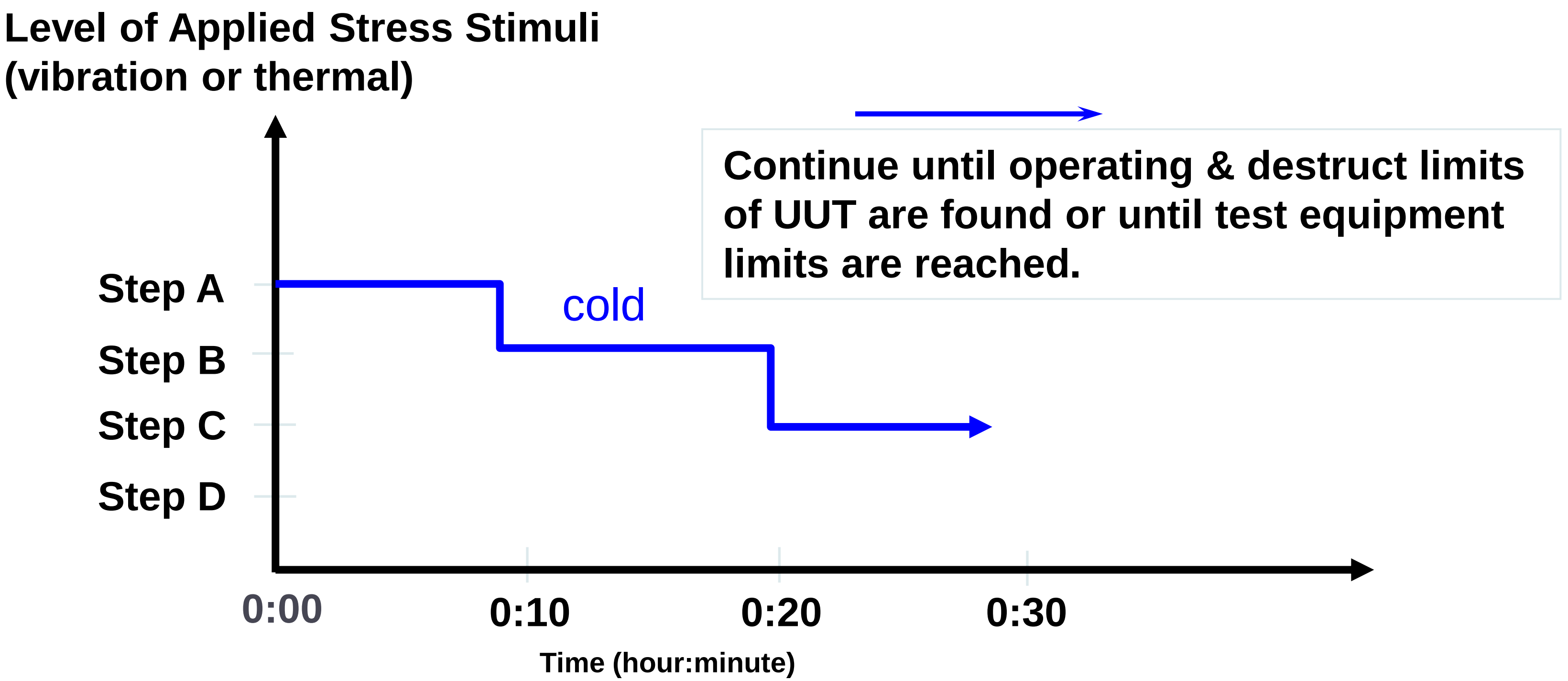


Pull until it breaks

HALT

- HALT – Highly Accelerated Life Test
  - Controlled Stepped Stress test to empirical operational and sometimes destruct limits
  - A methodology and significant reliability paradigm shift – not a type of stress or type of chamber
  - A discovery process, - a Stimulation not a *Simulation* process

The Base HALT process



Thermal Steps: typically +10ºC and -10ºC

Vibration steps: typically 5-10 Grms

After finding limits, try thermal cycling, combinations of stress

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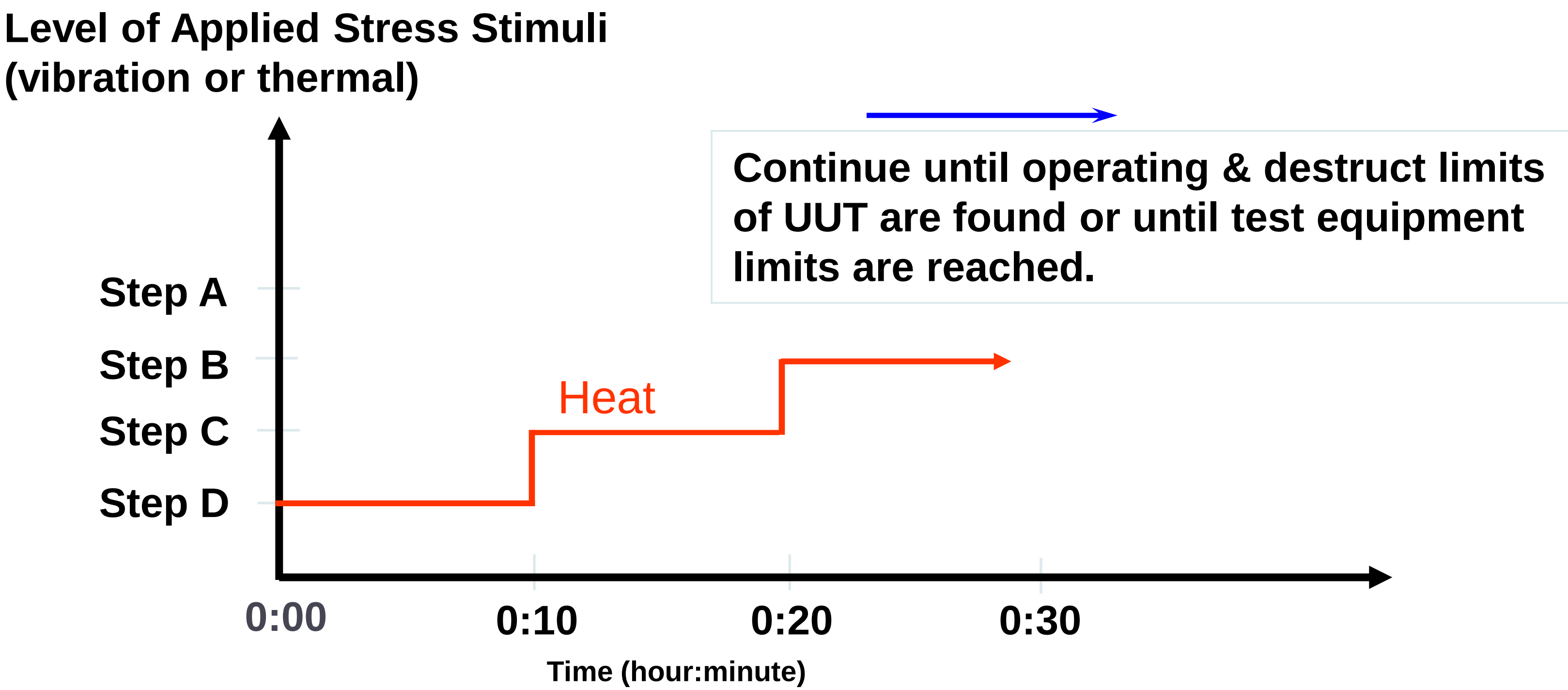

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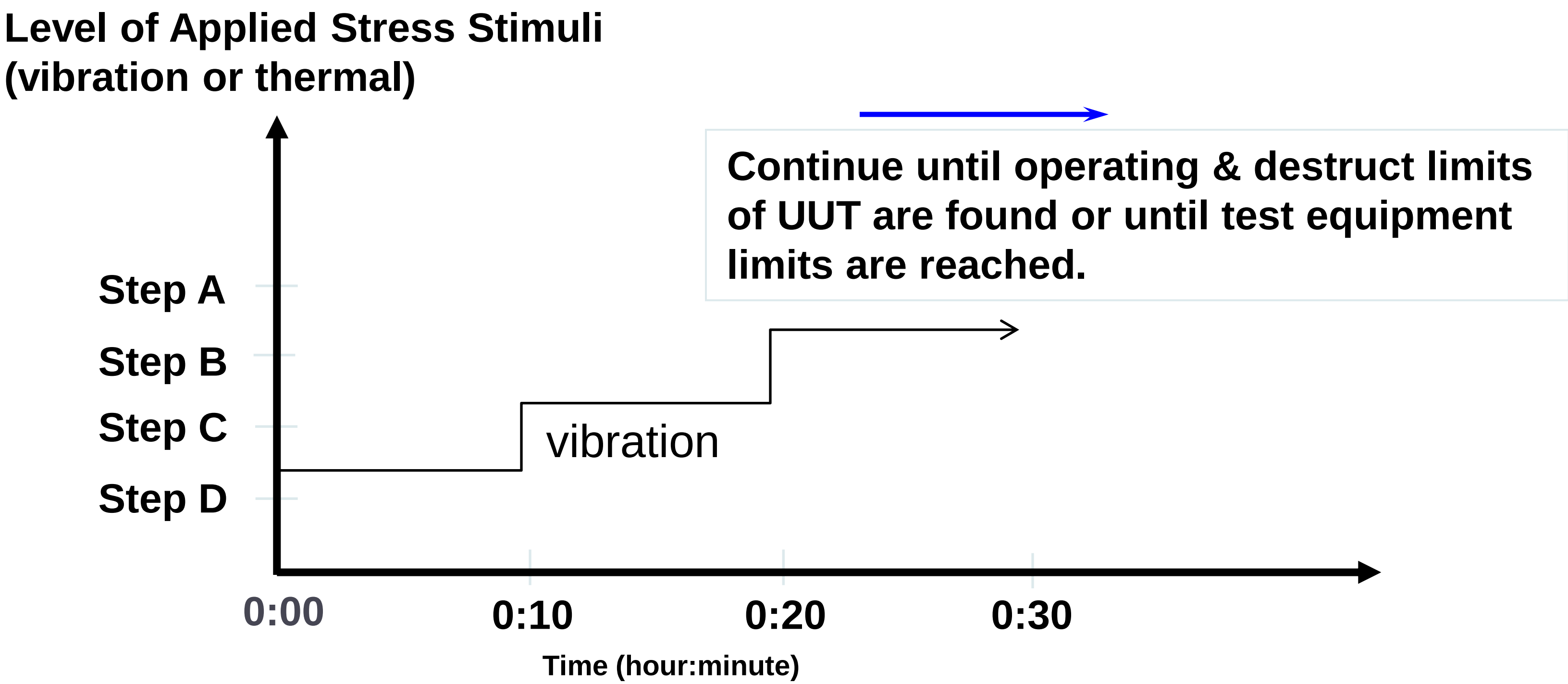

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Outputs of HALT

1) List of potential failure mechanisms, weaknesses and the relevance to field failures. Opportunity to increase reliability "tolerance" at lowest costs when done early.

2) Safe limits and stress boundaries to create a cost effective HASS processes.

HALT IS

- Deterministic- find weak links by stressing to inherent limits
- Based on fundamental limits (strength) of standard electronics and - not end-use environmental conditions
- Done with Products are powered and functionally monitored
- Not a quantifiable "life" test - no stress test for systems can accelerate all fatigue or chemical degradation mechanisms at equivalent field rates

Common Responses to HALT Discoveries

- "Of course it failed, you took it above specifications"

- "It will never see that stress level in use"

- "It wasn't designed for that vibration level"

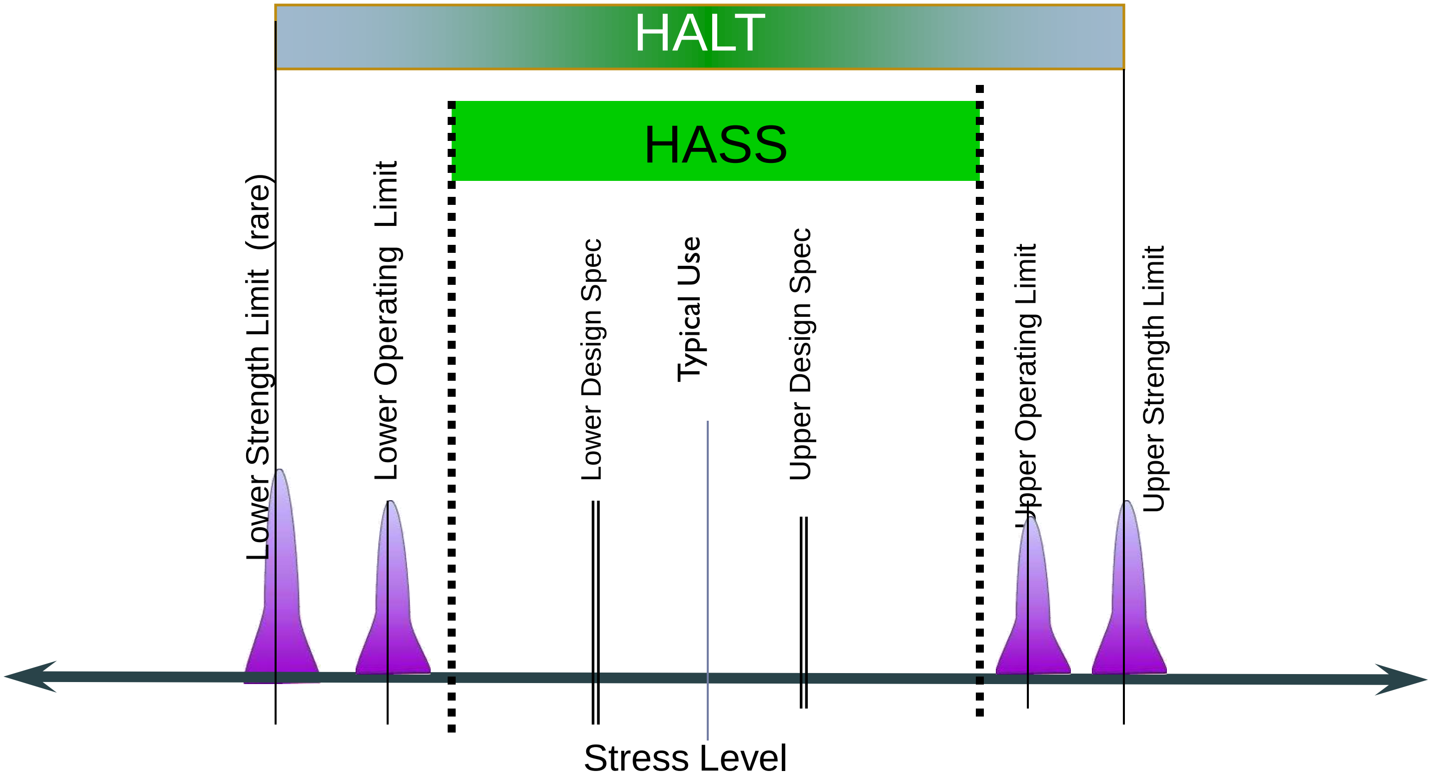
- "If you wanted it to operate in those conditions we would have designed it for those conditions"

Why many companies claiming to do "HALT" only do the first part

Purpose of HALT/HASS

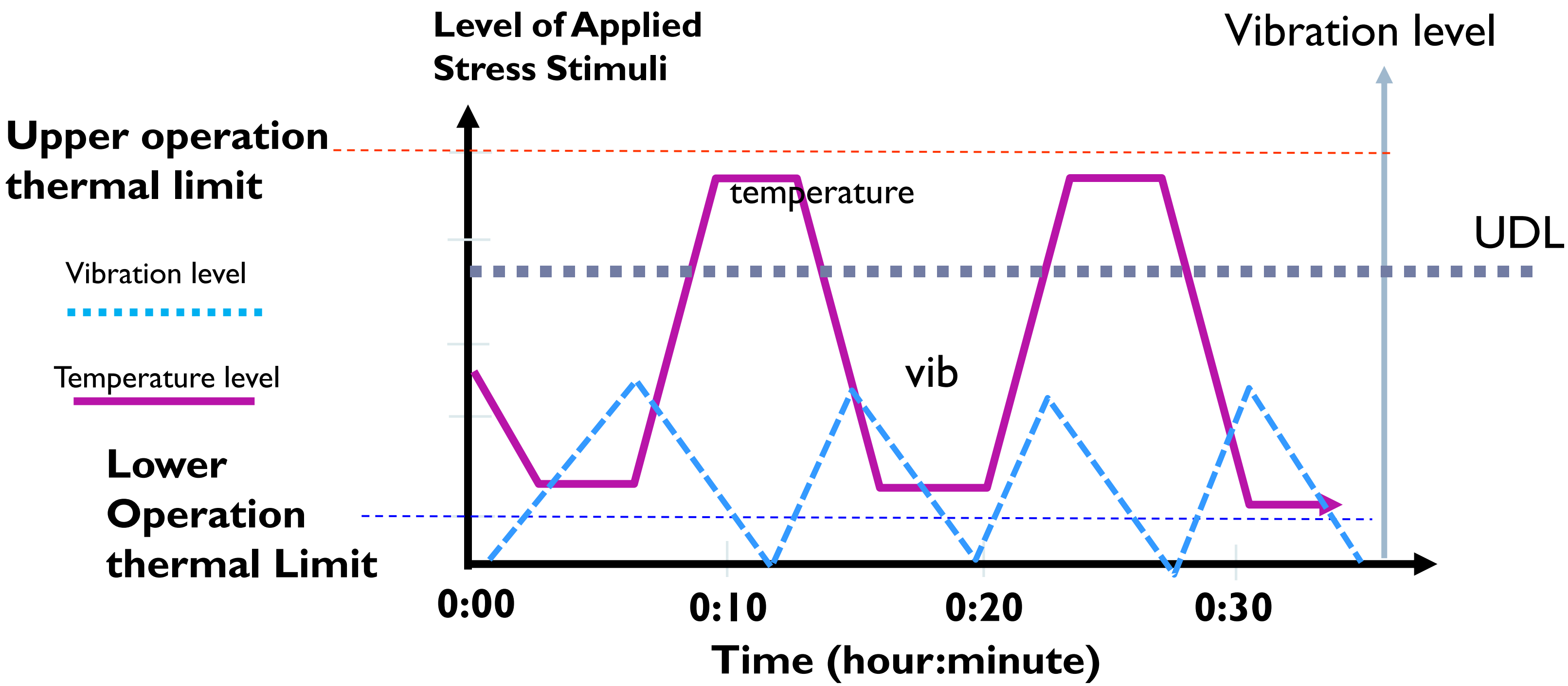
NOT to survive extreme conditions or environments

HALT vs. HASS Stress Levels



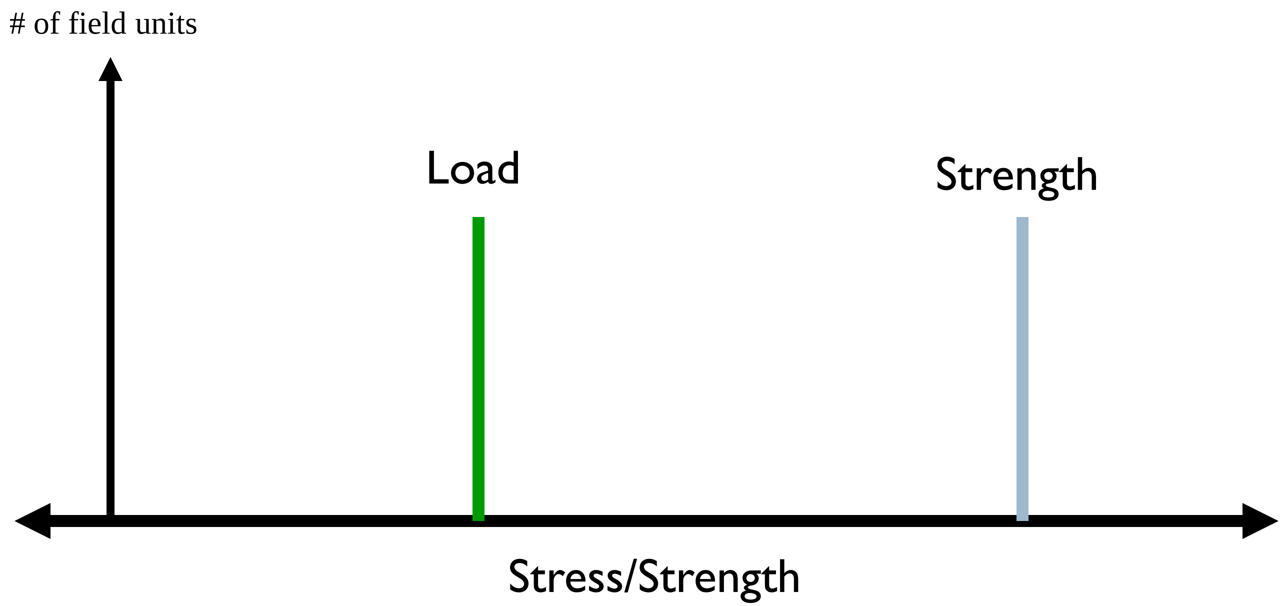
(example temperature)

HASS and HASA Process Parameters



- Rapid thermal cycling (up to 60°C/minute) – two to five thermal cycles
- Combined with multi-axis vibration – vary intensity during application
- Other stresses (power cycling, voltage margining, frequency margining)

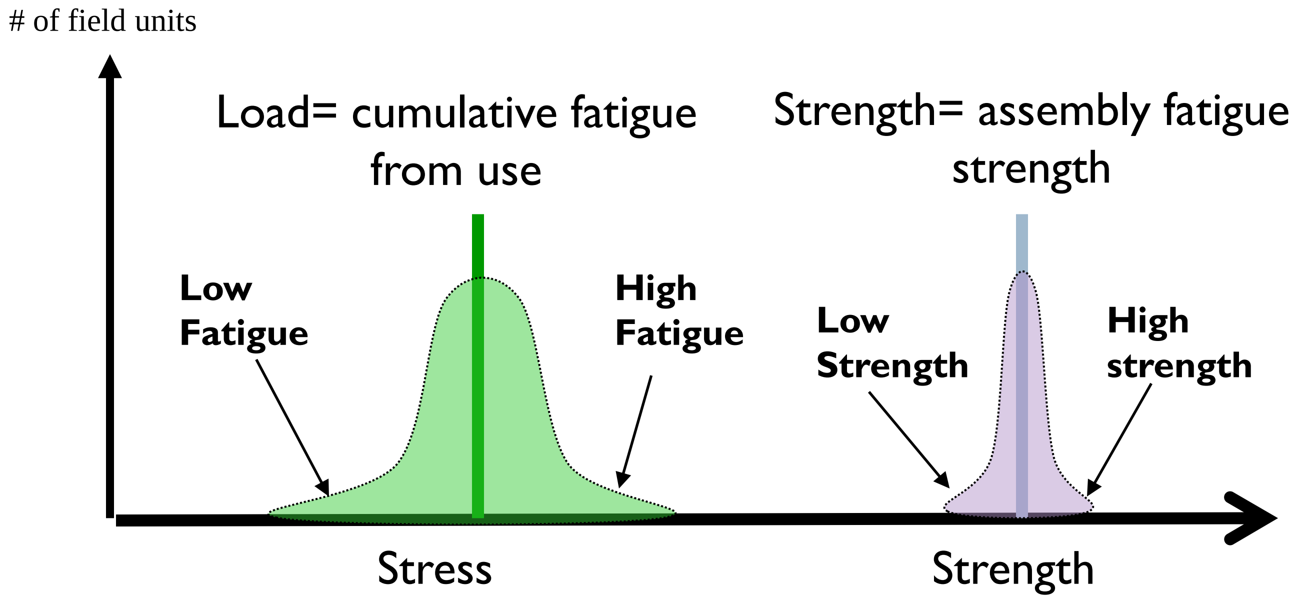
The Stress Strength Model



In assemblies and structures there is a load

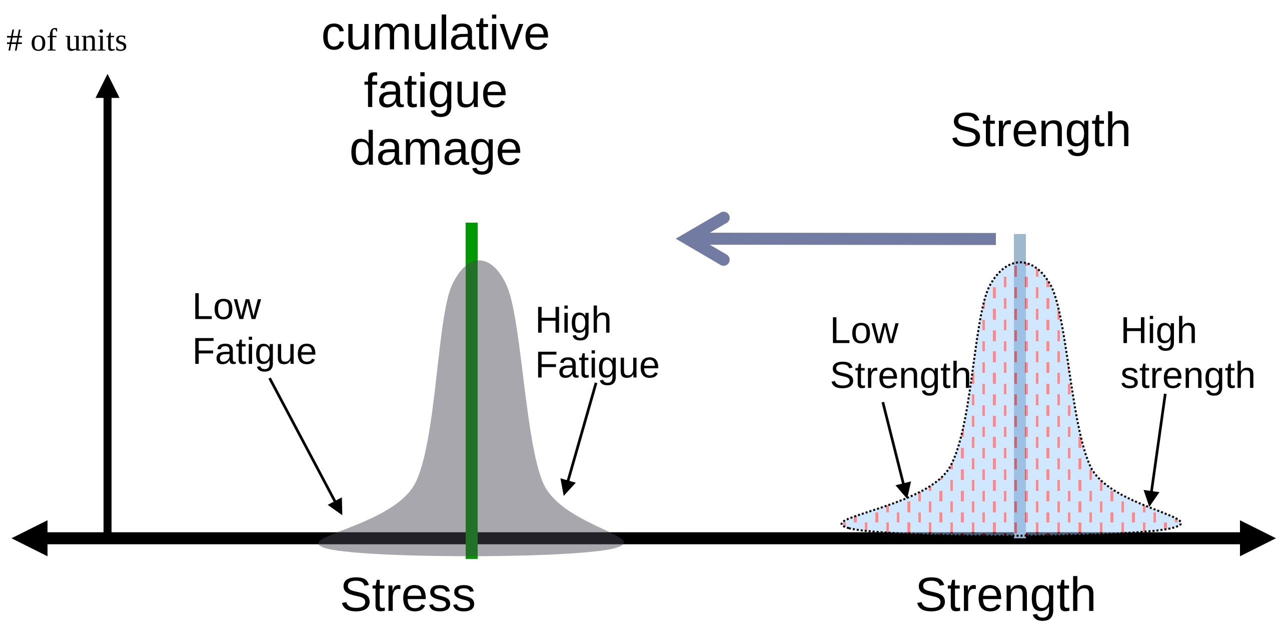
- Load = cumulative life-cycle fatigue (aging) from normal use
- Strength = the material fatigue life of electronic materials
- As Long as **Load < Strength** no failures occur

The Stress Strength Model



- For multiple units - results distribution around the nominal values
  - Variations in end-use stresses for the most part are uncontrolled
  - Variations in assembly strength
  - Also applies to thermal and electrical stress/strength

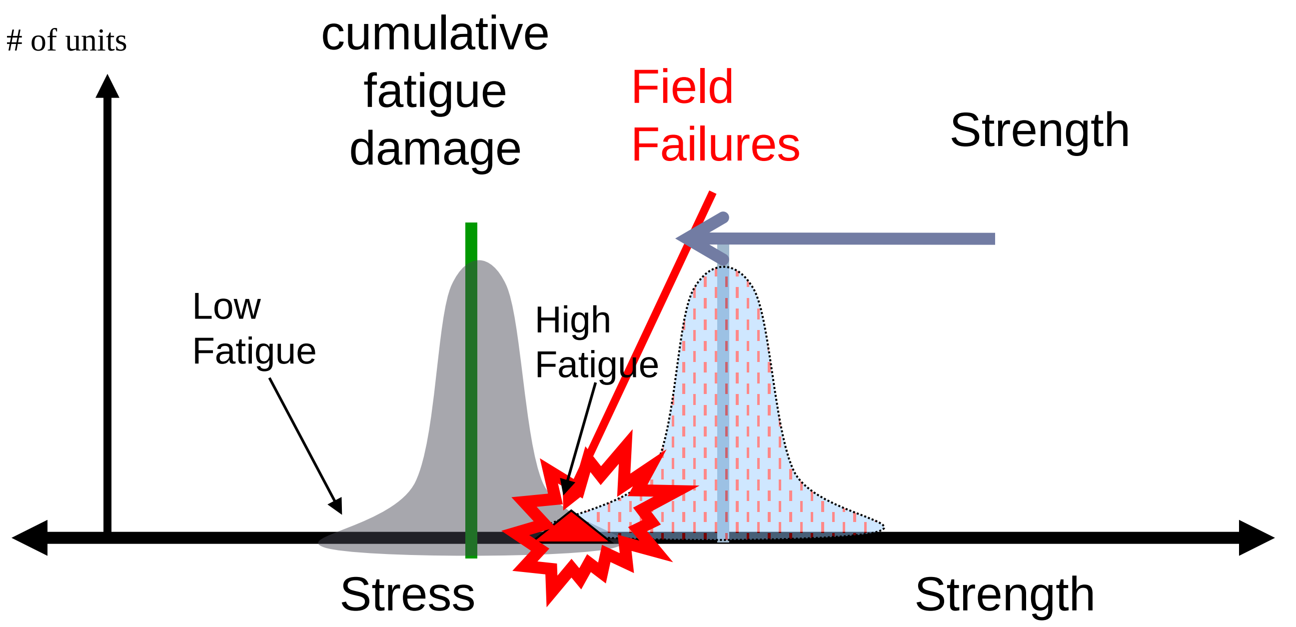
Stress/Strength Diagram and Failures



If Stress < Strength, no failures occur

- As fatigue damage (aging) accumulates, the mean of the strength shifts left
- Field failures occur when the two distributions overlap - the weakest units are subjected to the highest life cycle stresses

Stress/Strength Diagram and Failures



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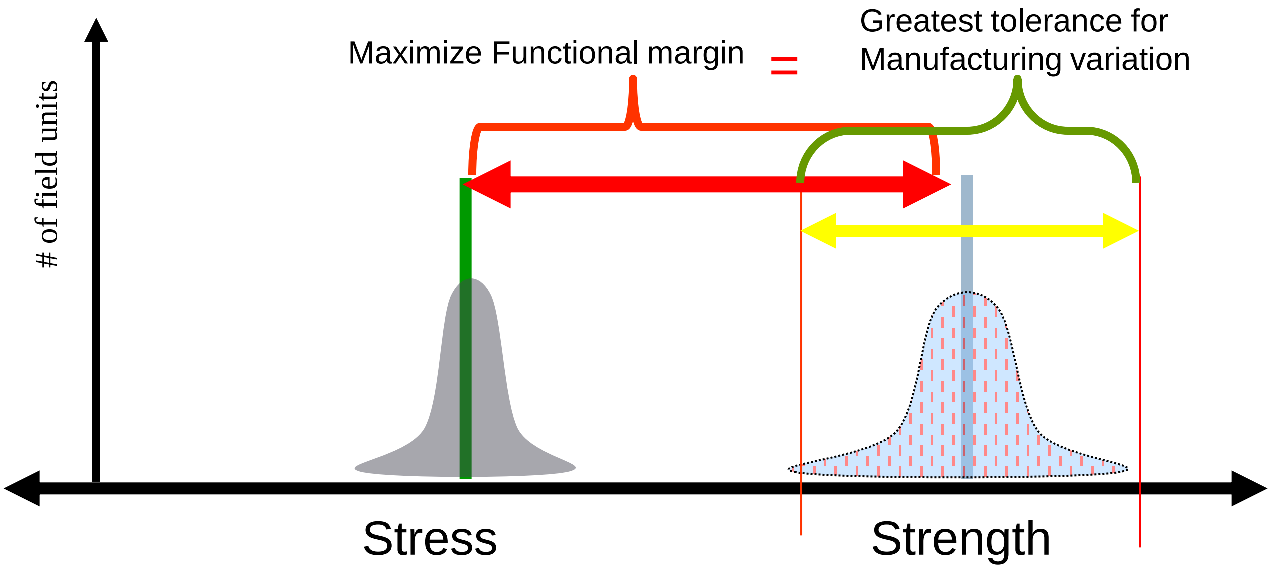
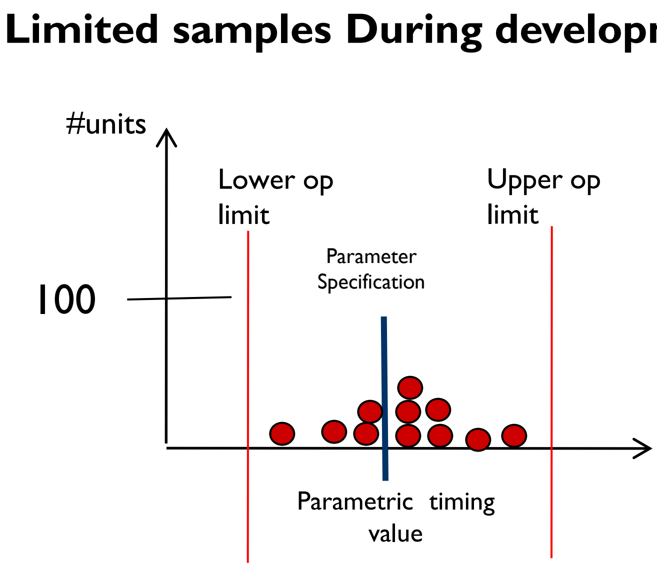
Develop Tolerance of Variations

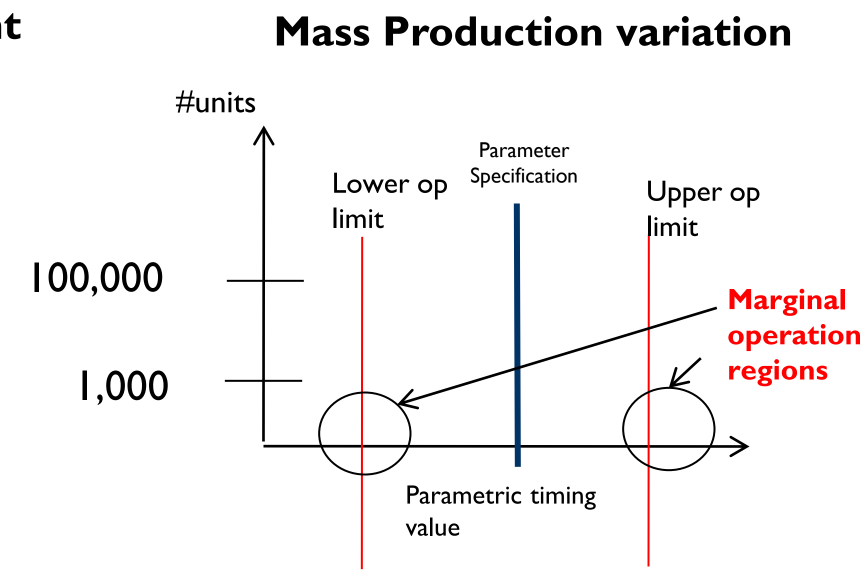


New Path to Optimal Reliability:

- Find **the functional margins by testing to absolute operational limits (thermal OTP defeated)**
- **Improve margins by finding the limiting component(s) and determining if and how the margin can be improved**
- **Small changes can result in** large margin gains

Thermal Stress to Skew Parametrics

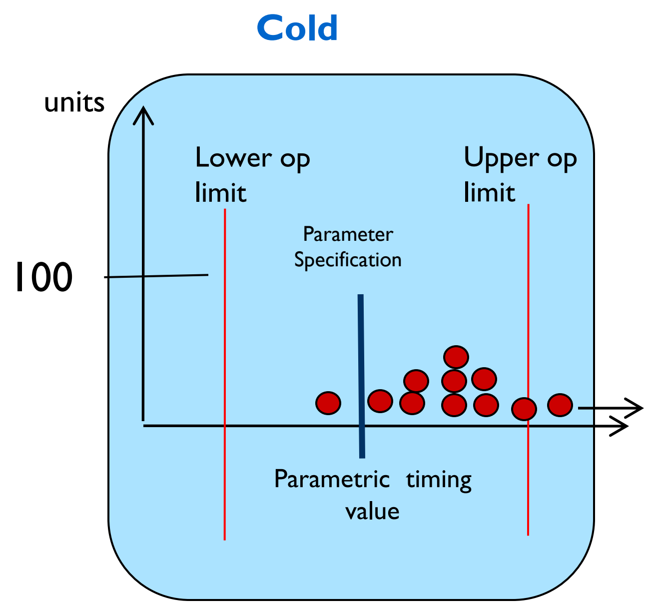




- Marginal designs may not be observable until a sufficient number of units are in the field
- The field is a costly place to find these marginal conditions

Timing Skewing from Thermal Stress

Applying thermal stress stimulates a timing shift



- Thermal Step Stress and cycling provides a much higher probability of detecting low incidence rate issues
- Cold speeds up signal propagation

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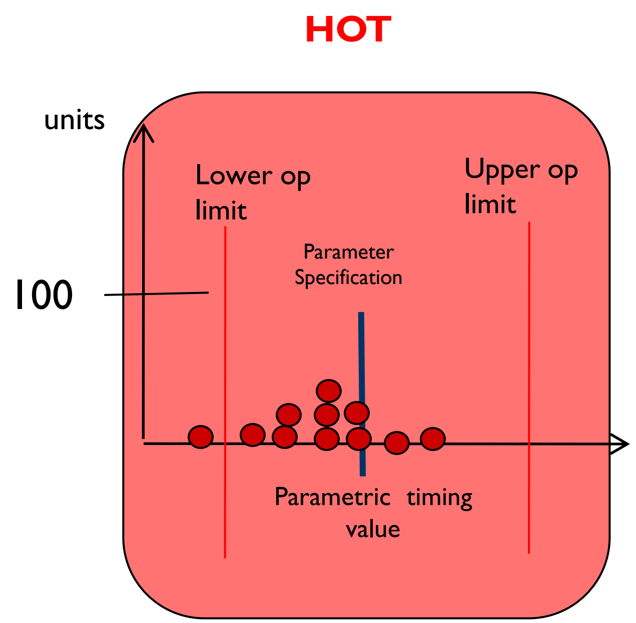

- Thermal Step Stress and cycling provides a much higher probability of detecting low incidence rate issues
- Heat slows down signal propagation

Power supply HALT and HASS Case Study

A worldwide leader in the development and marketing of power conversion and control system solutions, ion-beam sources, and plasma abatement systems wanted to improve the reliability of their High Energy Power Supplies.

Used in Capital Equipment for

- Manufacture of semiconductors
- CD-ROMs
- DVDs
- compact disks, flat panel displays, disk drives, and optical and architectural glass

First HALT and HASS Results

Results after HALT To HASS on the 6kW – 12kW PSU DC production

- Manufacturing testing for reliability cycle time was reduced from **4 days of "burn-in" to a HASS process lasting 40 minutes per 2 units.**
- Warranty returns were reduced **90% - from 5.0% to 0.5%** - within months after introduction of design change and HASS

21^{st} Century path to optimizing electronics reliability

- Design using good design practices and lessons learned
- Test to empirical operational limits and sometimes destruct
- Determine root causes of limits
- Understand the physics of failure or cause of low margin limit
- Remove or improve weak links – to make robust products
- Apply combined safe stresses to make shortest screening (HASS/HASA) processes if necessary
- Improve screens - Find best discriminators to observe failures in manufacturing capability or process control

Relevant Quote

"A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it"

-Max Planck, Scientific Autobiography

Thank You

Questions?