Overview of HALT and HASS: A Paradigm Shift in Reliability Testing

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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.”
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
Fundamental mismatch of time scales

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

The Life Cycle Bathtub Curve

- Use period 5-7 years
- 7 to 30 years?
- Technology Obsolescence
- Wear out
Most of the costs of unreliability occur in the first several months or years.
There is a Drain in the Bathtub Curve

Technologically Useful Life

$\text{$$$}$

Technological Obsolescence

electronics systems requiring long term operation
(ex. Power generation systems)

$\text{$$$}$

5-7 years

7-20 years?
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

Continue until operating & destruct limits of UUT are found or until test equipment limits are reached.

Thermal Steps: typically +10°C and -10°C
Vibration steps: typically 5-10 Grms

After finding limits, try thermal cycling, combinations of stress
The Base HALT process

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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

HALT

Stress Level

Upper Design Spec

Typical Use

Upper Operating Limit

Upper Strength Limit

Lower Design Spec

Lower Operating Limit

Lower Strength Limit (rare)

HASS

(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

- Load = cumulative fatigue from use
- Strength = assembly fatigue strength

- Stress:
  - Low Fatigue
  - High Fatigue

- Strength:
  - Low Strength
  - High strength

# of field units
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

If Stress < Strength, no failures occur

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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
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
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
- Heat slows down signal propagation
Advanced Energy Industries is a worldwide leader in the development and marketing of power conversion and control system solutions, ion-beam sources, and plasma abatement systems.

Used in Capital Equipment for

- Manufacture of semiconductors
- CD-ROMs
- DVDs
- compact disks, flat panel displays, disk drives, and optical and architectural glass
All thermal interlocks defeated to find the inherent operational limits.

Thermocouples mounted around switch and center of unit for thermal monitoring.

6000 Watt at 465 volts

Monitored continuously during HALT
Advanced Energy 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.
21st 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 limit
- Remove or improve weak links – to make robust products
- Apply combined safe stresses to make shortest screening (HASS/HASA) processes
- 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?