Accelerated Testing Technology in an Integrated Reliability Program for

CMSE
Components for Military and Space Electronics

by
Ops A La Carte

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Our Company

*OPS ALACARTE* is a reliability engineering services and management consulting firm.

We bring reliability expertise, resources and know-how together in a flexible and customized manner to improve your organization’s ability to produce reliable products.

We work closely with your team to find the most reliable and timely solution cost-effectively!

Our Team

*OPS ALACARTE* is made up of a group of highly accomplished Reliability Consultants.

Each of our consultants has 15+ years of Reliability Engineering and Reliability Management experience in various industries.

We tap a large network of labs, test facilities, and talented engineering professionals to quickly assemble resources to supplement your organization.

Our Partners

We tap a large network of labs, test facilities, and talented engineering professionals to quickly assemble resources to supplement your organization. Below is a partial list:

- Analog/Digital Design Firms – Nuvation Engineering
- Battery Design – Portable Power
- Compliance/EMI – Quanta Labs, Elliott Labs, MET Labs, UL
- Contract Manufacturer – Paramit Technologies
- Environmental Labs – Most of the Major Test Labs
- Failure Analysis Labs – DfR Solutions, Exponent, Ratronix
- Fiber Optics – MCH Engineering, SV Photonics
- HALT Facilities – QualMark, Reliant Labs, Wyle
- Mechanical Design – Fusion Design
- Power Electronics – TD Systems, EU Bloom
- Quality Training – Swartz and Associates, Peak Consulting
- RoHS/Lead Free – Design Chain Assoc., DfR Solutions, CALCE
- Safety Engineering – Exponent
- Software Reliability – Carnegie Mellon, RHM Associates
- Structural Analysis – FEC Engineering
- Thermal Consultants – eCooling
- Verification/Validation – Lynx Engineering
- Warranty Assessment and Analysis – RHM Associates
The Situation
Reliability is no longer a separate activity performed by a distinct group within the organization.
Product reliability goals, concerns and activities are integrated into nearly every function and process of an organization.
Senior management must foster an environment where the team keeps reliability and quality as defined by the customer clearly in mind.

The Situation
Engineering teams must balance cost, time-to-market, performance and reliability to achieve optimal product designs.
The organization structure must encourage all members of the team to apply appropriate reliability methods and principles.

Our Solution
Ops A La Carte offers a wide range of Reliability Services to help assess your situation, develop goals, and then execute programs to deliver high reliability.
Customizing our Solution

At the Organizational Level, Reliability Program Assessment is a great starting point to determine priorities for improving the reliability program. The assessment reveals areas of strengths, weaknesses and opportunities, plus the organization’s reliability maturity level.

At the Product Level, we offer a wide range of services across a Product’s Life Cycle. Our expertise in selecting, applying, and integrating to match your product requirements, plus our skill in educating and mentoring your team gives you the ability to achieve phenomenal reliability growth.

Integrating our Solution

OPS ALACARTE® pioneered “Reliability Integration”

Reliability Integration is the process of using multiple reliability tools and techniques in conjunction throughout each client’s organization to greatly increase the power and value of any Reliability Program.

Reliability at the Organizational Level

At the Organizational Level, Reliability Program Assessment is a great starting point to determine priorities for improving the reliability program. The assessment reveals areas of strengths, weaknesses and opportunities, plus the organization’s reliability maturity level.
Reliability Integration Services for the Organization

- Reliability Program Assessment
- Organization Reliability Goal Setting/Metrics
- Competitive Analysis
- Restriction of Hazardous Substances (RoHS)/Lead Free
- WEEE

Reliability at the Product Level

At the Product Level, we offer a wide range of services across a Product's Life Cycle. Our expertise in selecting, applying, and integrating to match your product requirements, plus our skill in educating and mentoring your team gives you the ability to achieve phenomenal reliability growth.

Reliability Integration for the Product

Once we have assessed the situation, now it is time to develop a customized Reliability Program for your Product.
Reliability Goal Setting and establishing a plan to achieve the goals characterize this phase. Reliability goals are part business decision, part technology capability and part customer driven.
Reliability Integration Services in the Concept Phase

- Reliability Goal Setting
- Benchmarking & Gap Analysis
- Technology Risk Assessment
- Reliability Program and Integration Plan

Executing the Reliability Program Plan

Once we have set our goals and developed our Reliability Program Plan, now it is time to execute the Plan through the Product Life Cycle, including the:

- Design Phase
- Prototype Phase
- Manufacturing Phase

Reliability Integration in the Design Phase

Key to a reliable product is the many design decisions, and for each decision, designers balance reliability with cost, time-to-market and performance objectives.
Reliability Integration Services in the Design Phase

- Reliability Models and Predictions (MTBF)
- Reliability Block Diagramming (RBD)
- Fault Tree Analysis (FTA)
- Failure Modes and Effects Analysis (FMEA)
- Thermal Analysis
- Derating Analysis / Component Selection
- Tolerance / Worst Case Analysis
- Material Selection
- Design of Experiments (DOE)
- Finite Element Analysis (FEA)
- Design for Six Sigma (DFSS)
- Dynamic Analysis (modal, shock, vibration)
- Sneak Circuit Analysis (hardware or software)
- Software Reliability
- Warranty Predictions
- Maintainability/Preventive Maintenance Analysis
- Design Review and Retrospective Facilitation

Reliability Integration in the Prototype Phase

Discovering design weaknesses and verifying achievement of reliability goals becomes possible with prototypes.

Reliability Integration Services in the Prototype Phase

- Reliability Test Plan Development
- Highly Accelerated Life Testing (HALT)
- Root Cause Failure Analysis
- Fracture and Fatigue
- Design Verification Testing (DVT)
- Environmental Testing and Analysis
- Thermal Testing and Analysis
- Accelerated Life Testing (ALT)
- Reliability Demonstration Testing (RDT)
- Closed-Loop Corrective Action Process Setup
Ops A La Carte LLC is proud to announce that we now own and operate:

**HIGHLIGHTS ABOUT**

- Tested over 500 products in over 50 different industries
- Second oldest HALT facility in the world, established in 1995 (originally owned by QualMark)
- Most experienced staff with over 50 years of combined experience in HALT and HASS
- We only use degreed engineers to run all our HALT.
- HALT equipment has all latest technology – only lab in region.
- Our HALT/HASS services are fully integrated with our other consulting services.
- We provide HALT/HASS services on a world-wide basis, using partner labs for tests outside California.

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**Reliability Integration Services in the Prototype Phase**

Each failure is fully analyzed to root cause using the Closed-Loop Corrective Action process.

It is the combination of rapid discovery of flaws, careful analysis of expected failure mechanisms and thorough root cause analysis that permits the best set of final design decisions before product launch.

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**Reliability Integration in the Manufacturing Phase**

As the product transitions to manufacturing, the reliability goals, models and test results become the basis for refining reliability screening, monitoring and reporting.
Reliability Integration Services in the Manufacturing Phase

- Highly Accelerated Stress Screening (HASS)
- On-Going Reliability Testing (ORT)
- Vendor Reliability Program Assessment
- Repair Depot Setup
- Field Failure Tracking System Setup
- Warranty Performance Analysis
- Reliability Performance Reporting
- End-of-Life Assessment
- Lessons Learned Process Establishment

A Highly Accelerated Stress Screen identifies and eliminates infant mortalities.

Our Customers

We have over 200 customers across many different industries, including:

- Aerospace/Defense
- Agriculture
- Airport Security
- Audio
- Automobile Industry
- Cable Networks
- Computers
- Consulting for Societies
- Contract Manufacturers
- Control/Control Systems
- Cooling Systems
- Environmental Equipment
- Integrated Chips
- Imaging
- Law Firms
- Machinery
- Medical/Biotech
- Networking
- Network Appliances
- Oceanographic
- Oil Exploration
- Optical Components
- PCB Manufacturers
- Peripherals
- Power Supplies
- Radio/FM/Microwave/Wireless
- Relaxation/Recreational
- Research/Science
- Robotics
- Semiconductors
- Test Equipment
- Test Laboratories
- Telecom
- Train Industry
- Test & Measurement
- Video
Reliability Integration Education

1. Reliability Tools and Integration:
   1) for Overall Program - Best "A-Z" course in Reliability
   2) in Concept Phase - Goals, metrics, plans
   3) in Design Phase - Analyses: Pred, FMEA, FTA, Thermal, DOE, etc.
   4) in Prototype Phase - Tests: HALT, ALT, RDT, DVT, etc.
   5) in Manufacturing Phase - Processes: HASS, HASA, ORT, Tracker

6. Reliability Techniques for Beginners:
   - Study key concepts: distributions, modeling, predictions, data analysis.

7. Reliability Statistics:
   - Study sampling, hypotheses, confidence, and Design of Experiments.

8. FMECA:
   - Use Failure Modes Effects and Criticality Analysis to develop Risk Management Programs.

9. CRE Exam Preparation - Preparation for passing the ASQ Certified Reliability Engineer Exam.

10. CQE Exam Preparation - Preparation for passing the ASQ Certified Quality Engineer Exam.

11. Design for Reliability (DfR):
    - Learn the building block tools for reliability during the design phase.

12. Design for Manufacturing (DFM):
    - Learn about the tools for producing high-quality products.

13. Design for Testability (DfT):
    - Learn about stress-strength and failure of materials and electronics, variation and reliability, design analysis & more.

14. Design for Warranty Cost Reduction (DfW):
    - Learn about the tools for reducing warranty cost.

15. Design for 6 Sigma (DfS):
    - Learn about the tools for Six Sigma improvements.

16. Design for 'X' (DfX):
    - Learn about the best of "Design for" disciplines.

17. Mechanical Design for IC Packaging:
    - Learn about the tools for IC Packaging.

18. Design for Vibration and Shock:
    - Learn about the tools for vibration and shock.

19. Software Reliability:
    - Learn about the tools for software reliability.

20. Root Cause Analysis:
    - Learn about the tools for root cause analysis.

    - Learn about the tools for SPC.

22. Innovative Problem Solving:
    - Learn about the tools for innovative problem solving.

23. Mechanical Design for IC Packaging:
    - Learn about the tools for IC Packaging.

Further Education

- April 2007 Certified Quality Engineer Prep. Course
- May 7-11, 2007 Reliability Symposium, San Jose
  - Design for Reliability
  - HALT and ALT
  - Climatic Environments
  - Design for Manufacturing
  - Design for Warranty
  - Design for 6 Sigma
  - Design for 'X'
- June 20-22, 2007 Presentation on Competitive Analysis at the San Diego Applied Reliability Symposium
- August 2007 Certified Reliability Engineer Prep. Course

Also, we offer 27 different private and public courses and seminars in Reliability, Quality, and Technical Operations.

Please see our Educational Brochure inside your Ops A La Carte packet for more details.

ELEMENTS OF A RELIABILITY PROGRAM
What is Reliability?

Reliability is often considered quality over time.

Reliability is...

“The ability of a system or component to perform its required functions under stated conditions for a specified period of time”

- IEEE 610.12-1990

- We shall revisit this when we discuss Reliability Goal Setting.

Different Views of Reliability

- Product development teams

  View reliability as the domain to address mechanical and electrical, and manufacturing issues.

- Customers

  View reliability as a system-level issue, with minimal concern placed on the distinction into sub-domains.

  - Since the primary measure of

Role of SW in System Reliability

Reliability Myth

“When performing system reliability allocation, assume that software reliability is 1 and the software failure rate is 0.”

- This was an outdated common practice applied to embedded systems with firmware:
  - Small size (< 5K bytes)
  - Very low complexity (no RTOS’s, trivial protocols, simple algorithms)
Reliability Integration

“the process of seamlessly, cohesively integrating reliability tools together to maximize reliability and at the lowest possible cost”

Reliability vs. Cost

♦ Intuitively, the emphasis in reliability to achieve a reduction in warranty and in-service costs results in some minimal increase in development and manufacturing costs.

♦ Use of the proper tools during the proper life cycle phase will help to minimize total Life Cycle Cost (LCC).

Reliability vs. Cost, continued
Reliability vs. Cost, continued

To minimize total Life Cycle Costs (LCC), an organization must do two things:

1. Choose the best tools from all of the tools available and apply these tools at the proper phases of the product life cycle.

2. Properly integrate these tools together to assure that the proper information is fed forwards and backwards at the proper times.

Does this apply to SW Reliability? Not really

The SW impact on HW warranty costs is minimal at best?

SYSTEM RELIABILITY & COSTS

♦ SW has no associated manufacturing costs, so warranty costs and saving are almost entirely allocated to HW

♦ If there are no cost savings associated with improving software reliability, why not leave it as is and focus on improving HW reliability to save money?
  • One study found that the root causes of typical embedded system failures were SW, not HW, by a ratio of 10:1.
  • Customers buy systems, not just HW.

♦ The benefits for a SW Reliability Program are not in direct cost savings, rather in:
  • Increased SW/FW staff availability with reduced operational schedules resulting from fewer corrective maintenance content.
  • Increased customer goodwill based on improved customer
# Design for Reliability (DfR) Tools by Phase

## System DfR Tools by Phase

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activities</th>
<th>Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept</td>
<td>Define project reliability requirements (Reliability Program and Integration Plan)</td>
<td>Benchmarking - Internal Goal Setting - Gap Analysis</td>
</tr>
<tr>
<td>Design</td>
<td>Architecture &amp; HLD</td>
<td>Reliability Modeling - System Failure Predictive Analysis (FMECA &amp; FTA) - Human Factors Analysis</td>
</tr>
<tr>
<td>Operations and Maintenance</td>
<td>Continuous assessment of product reliability</td>
<td>FRACAS - RCA</td>
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## HW DfR Tools by Phase

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<td>Benchmarking - Internal Goal Setting</td>
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<tr>
<td>Design</td>
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<td>Reliability Modeling - HW Failure Predictive Analysis (FMECA &amp; FTA) - HW Fault Tolerance - Human Factors Analysis</td>
</tr>
<tr>
<td>LLD</td>
<td>Reliability Analysis</td>
<td>Human Factors Analysis - Design Analysis - Worst Case Analysis</td>
</tr>
<tr>
<td>Prototype (First time product is tested)</td>
<td>Detect design defects</td>
<td>V&amp;V, TST, DOE, Multi-variant Testing</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Identify and correct manufacturing process issues</td>
<td>DIT - V&amp;V - HASS</td>
</tr>
<tr>
<td>Operations and Maintenance</td>
<td>Continuous assessment of HW reliability</td>
<td>ORT</td>
</tr>
</tbody>
</table>
### SW DfR Tools by Phase

<table>
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<th>Tools</th>
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<tbody>
<tr>
<td>Concept</td>
<td>Define SW reliability requirements</td>
<td>- Benchmarking</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Interval Dual Bieling</td>
</tr>
<tr>
<td>Design</td>
<td>Architecture &amp; HLD</td>
<td>- SW Failure Analysis</td>
</tr>
<tr>
<td></td>
<td>Modeling &amp; Predictions</td>
<td>- SW Fault Tolerance</td>
</tr>
<tr>
<td></td>
<td>LLD</td>
<td>- Human Factors Analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Best Practice Analysis</td>
</tr>
<tr>
<td></td>
<td>Coding</td>
<td>- Static detection of coding defects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- TRACAS</td>
</tr>
<tr>
<td></td>
<td>Unit Testing</td>
<td>- JPL</td>
</tr>
<tr>
<td></td>
<td>Dynamic detection of design and coding defects</td>
<td>- SW Reliability Testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- RCA</td>
</tr>
<tr>
<td></td>
<td>Integration and System Testing</td>
<td>- SW Statistical Testing</td>
</tr>
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<td></td>
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<td>- SW Reliability Testing</td>
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<td>- RCA</td>
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</table>

### DfR Tool Selection

A reliability assessment is the recommended first step in establishing a reliability program. This mechanism is the appropriate forum for selecting the best tools for each product life cycle phase.
Reliability Program Assessment

- Initiate a Reliability Program
- Determine next best steps
- Reduce customer complaints
- Select right tools
- Improve reliability

A detailed evaluation of an organization’s approach and processes involved in creating reliable products. The assessment captures the current state and leads to an actionable reliability program plan.

Assessment Motivation

- Identify systemic changes that impact reliability
  - Tie into culture and product
  - Both enjoy benefits
- Provides roadmap for activities that achieve results
  - Matching of capabilities and expectations
  - Cooperative approach

Assessment Approach

- Preparation
- Checklist
- Who to interview in organization
- Analysis, average scores and summary of comments
Steps Involved

- selecting survey topics
- interview format
- data collection
- business unit summary
- immediate follow up
- analysis
- review
- team reporting
- key stakeholder reporting

choosing interviewees

- hw r&d manager
- hw r&d engineer
- reliability manager
- reliability engineer
- procurement
- manufacturing

Checklist

DFR Methods Survey

Scoring: 4 = 100%, top priority, always done
3 = >75%, use normally, expected
2 = 25% - 75%, variable use
1 = <25%, only occasional use
0 = not done or discontinued
- = not visible, no comment

Management:
- Goal setting for division
- Priority of quality & reliability improvement
- Management attention & follow up (goal ownership)

Design:
- Documented hardware design cycle
- Goal setting by product or module

Examples

- To what extent is FMEA used?
  - Design Engineer
    Score = 2: Used only as a troubleshooting tool
  - Manufacturing Engineer
    Score = 3: Commonly used on critical design elements
  - Procurement Engineer
    Score = 3: On socket systems and other critical systems

Result: Score 2.6
Comments: Some familiarity across organization, some regular use on high risk or critical elements of system.
Reliability Maturity Grid

- 5 levels of maturity
- Similar to Crosby's Quality Maturity
- Here's one that is based on Crosby's as an example.
- Read across each row and find the statement that seems most true for your organization.
- The center of mass of the levels is the organization's overall level.

Reliability Maturity Matrix

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
<th>Category</th>
<th>Relevance</th>
<th>Impact</th>
<th>Measurement</th>
<th>Results &amp; Meaning</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Awareness</td>
<td>Understanding and Attitude</td>
<td>Management</td>
<td>Management</td>
<td>Reliability status</td>
<td>- Looking for trends, gaps in process, skill mismatches, over analysis</td>
<td>- For rough guidance see reliability maturity grid</td>
</tr>
<tr>
<td>II</td>
<td>Understanding</td>
<td>Reliability status</td>
<td>Management</td>
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<td>Awareness</td>
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<td>- For rough guidance see reliability maturity grid</td>
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Results & Meaning

- Looking for trends, gaps in process, skill mismatches, over analysis
- Look for differences across the organization, pockets of excellence, areas with good results
- For rough guidance see reliability maturity grid

There is no optimal set of reliability activities that will work in every organization. The tools need to match the needs of the product and customers

No one tool make an entire reliability program
Results & Meaning

• Process provides snapshot of current system

• Check step is critical before moving to recommendation around improvement plan

Findings

<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>OPPORTUNITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Design Reviews</td>
<td>• Cannot convince themselves they could meet Goals.</td>
</tr>
<tr>
<td>• Simulation Models</td>
<td>• Design for Reliability lacking</td>
</tr>
<tr>
<td>• Process Data for Analysis</td>
<td>• Plan not usable</td>
</tr>
<tr>
<td>• Know what they don't know</td>
<td>• Lack of Basic Reliability Training</td>
</tr>
<tr>
<td>• Formal Processes</td>
<td>• Lack of Understanding of MTBF</td>
</tr>
</tbody>
</table>

• Unclear Goals
• No clear owner of reliability
• No experience in how to achieve S/W Reliability
• CMMI supposed to save the day

Next Steps

• Determine current state of your organization (Summary of Assessment)
  – Identify strong and weak areas
• Goal Setting
  – HW and SW reliability allocations based on RAM requirements
• Gap Analysis
• Develop a Plan
  – System, HW and SW
Reliability vs. Cost

In order to minimize total Life Cycle Costs (LCC), we must do two things:
- choose the best tools from all of the tools available and must apply these tools at the proper phases of a product life cycle.
- properly integrate these tools together to assure that the proper information is fed forward and backwards at the proper times.

As part of the integration process, we must choose a set of tools at the heart of our program in which all other tools feed to and are fed from. The tools we have chosen for this are:

HALT and ALT in development

HASS in production

HALT
Highly Accelerated Life Testing
used in DESIGN for Product Ruggedization

ALT
Accelerated Life Testing
used in DESIGN to Characterize Predominant Failure Mechanisms

HASS
Highly Accelerated Stress Screening
used in PRODUCTION for Process Monitoring
HALT, ALT & HASS Summary

- In HALT, a product is introduced to progressively higher stress levels in order to quickly uncover design weaknesses, thereby increasing the operating margins of the product, translating to higher reliability. HALT can be performed at the component, board or system level.

- In ALT, a product is characterized by accelerating the use environment. The end result is an understanding of the dominant failure mechanisms (especially ones due to wearout) as well as measuring the product life. ALT is especially good at the component level. We select the key components from the system that will dominate the failures, and perform ALT on these.

- In HASS, a product is “screened” at stress levels above specification levels in order to quickly uncover process weaknesses, thereby reducing the infant mortalities, translating to higher quality. HASS can be performed at the component, board or system level.

With these three tools, we can cover all phases of the product lifecycle.

HALT, ALT & HASS Summary

HALT helps push this line down as much as possible.

ALT can help measure where this point is and push out as much as possible.

HASS can help lower the slope of this curve and bring in the point the product reaches maturity.

Failure Rate

Time

Highly Accelerated Life Testing
**HALT**

Highly Accelerated Life Test

- Quickly discover design issues.
- Evaluate & improve design margins.
- Release mature product at market introduction.
- Reduce development time & cost.
- Eliminate design problems before release.
- Evaluate cost reductions made to product.

Developmental HALT is not really a test you pass or fail, it is a process tool for the design engineers. There are no pre-established limits.

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**HALT, How It Works**

- Start low and step up the stress, testing the product during the stressing.

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**HALT, How It Works**

- Gradually increase stress level until a failure occurs.
HALT, How It Works

Stress → Failure → Analysis

- Analyze the failure

Improve → Analysis

- Make improvements

Increase stress and start process over

Improve → Analysis
HALT, How It Works

- Fundamental
- Technological Limit

- Improve
- Analysis

HALT, Why It Works

Classic S-N Diagram
(stress vs. number of cycles)

Point at which failures become non-relevant

S<sub>1</sub>, S<sub>2</sub>, S<sub>3</sub>

N<sub>1</sub>, N<sub>2</sub>, N<sub>3</sub>

Margin Improvement Process

Lower Destruct Limit
Lower Oper. Limit
Product Oper. Specs
Upper Oper. Limit
Upper Destruct Limit
**Margin Improvement Process**

<table>
<thead>
<tr>
<th>Lower Destruct Limit</th>
<th>Lower Oper. Limit</th>
<th>Product Operational Specs</th>
<th>Upper Oper. Limit</th>
<th>Upper Destruct Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destruct Margin</td>
<td>Operating Margin</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Stress**

**Developmental HALT Process**

- Planning a HALT
- Setting up for a HALT
- Executing a HALT
- Post Testing

**STEP 1: Planning a HALT**

Meet with design engineers to discuss product.
- Determine stresses to apply.
- Determine number of samples available.
- Determine functional tests to run during Dev. HALT.

It is essential that the product being tested be fully exercised and monitored throughout HALT to detect problems.
- Determine what parameters to monitor.
- Determine what constitutes a failure.

**Develop Test Plan**
For each stress, we use the Step Stress Approach

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

**Developmental HALT Process**

Stimuli

<table>
<thead>
<tr>
<th>STIMULI</th>
<th>VIBRATION</th>
<th>HIGH TEMP</th>
<th>LOW TEMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>START</td>
<td>3-5 G's</td>
<td>+20°C</td>
<td>+20°C</td>
</tr>
<tr>
<td>INCREMENT</td>
<td>3-5 G's</td>
<td>5 to 10°C</td>
<td>5 to 10°C</td>
</tr>
<tr>
<td>DWELL TIME</td>
<td>10 min*</td>
<td>10 min*</td>
<td>10 min*</td>
</tr>
<tr>
<td>END</td>
<td>3-5 G's</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Destruct Limit or Test Equipment Limitation*

* In addition to functional test time

**OTHER STIMULI:**
- Voltage/frequency margining
- Power cycling
- Combined environment (Temp/Vib)
- Rapid transitions up to 60°C/min on the product

**STEP 2: Setting up for HALT**

Setup
- Design vibration fixture to ensure energy transmission to the product (different from electrodynamic vibration fixtures).
- Design air ducting to ensure maximum thermal transitions on the product.
- Tune chamber for product to be tested.
- Apply thermocouples to product to be tested.
- Setup all functional test equipment and cabling.
STEP 3: Executing a HALT

Thermal Step Stress
- Begin with cold step stress and then hot step stress.
- Step in 10°C increments, as approach “limits” reduce to 5°C.
- Dwell time minimum of 10 minutes + time to run functional tests to ensure product is still functional. Start dwell once product reaches temperature setpoint, begin functional tests after 10 minute dwell.
- Continue until fundamental limit of technology is reached.

(If circuits have thermal safeties, ensure operation & then defeat to determine actual operating & destruct limits.)
- Apply additional product stresses during process:
  - Power Supplies: Power cycling during cold step stress.
  - Input voltage variation. Load variations.
  - Frequency variation of clocks.

Fast Thermal Transitions
- Transition temperature as fast as chamber will allow.
- Select temperature range within 5° of the operating limits found during thermal step stress.
- If product cannot withstand maximum thermal transitions, decrease transition rate by 10°C per minute until operating limit is found.
- Continue series of transitions for a minimum of 10 minutes (or time it takes to run set of functional tests).
- Apply additional product stresses during process.

Vibration Step Stress
- Understand vibration response of product (i.e. how does product respond to increases in vibration input).
- Determine Grms increments (usually 3-5 Grms on product).
- Dwell time minimum of 10 minutes + time to run functional tests to ensure product is still functional. Start dwell once product reaches vibration setpoint.
- Continue until reach fundamental limit of technology.
- Apply additional product stresses during process.
STEP 3: Executing a HALT

**Combined Environment**
- Develop thermal profile using thermal operating limits, dwell times and transition rates used during thermal step stress & fast thermal transitions.
- Incorporate additional product stresses into profile such as power cycling.
- The first run through the profile, run a constant vibration level of approx. 5 Grms. Step in same increments determined during vibration step stress.
- When reach higher Grms levels (approx. 20 Grms) add tickle vibration (approx. 5 Grms) to determine if failures were precipitated at high G level but only detectable at lower G level.

STEP 4: Post Testing

- Determine root cause of all failures that occurred.
- Meet with design engineers to discuss results of Developmental HALT and root cause analysis.
- Determine and implement corrective action.
- Perform Verification HALT to ensure problems fixed and new problems not introduced.
- Periodically evaluate product as it is subjected to engineering changes.

**Traditional vs HALT Engineering Needs**

**Product Development Manpower Requirements**
HALT - Advantages over Traditional Testing

- Uncovers flaws typically not found before product introduction
- Discovers and improves design margins
- Reduces overall development time and cost
- Provides information for developing accelerated manufacturing screens (HASS)

HALT vs Traditional Testing

Comparison of Test Methods

HALT
- “Test to Failure, Improve, Test Further”
- Gathers info on Product Limitations
- Focus on Design Weakness & Failures
- 6 DoF Vibrations
- High Thermal Rate of Change
- Loosely Defined - Modified “On the Fly”
- Not a “Pass/Fail” Test
- Results used as basis for HASS or ESS

Traditional Testing
- “Test, Fix, Retest”
- Simulates a “Lifetime” of use
- Focus on Finding Failures
- Single Axis Vibration
- Moderate Thermal Rate of Change
- Narrowly Defined - Rigidly Followed
- “Pass/Fail” Test
- Results typically not used in ESS

HALT vs Traditional Testing

Comparison of Cost/Schedule

Product #1 - HALT
- Test facility $8,000
- Three test specimens
- One integrated test chamber
- 5 days to complete

Product #2 - Traditional
- Test facility > $65,000
- Two test specimens
- 2 thermal chambers, 2 vibe tables
- Two vibe fixtures
- 7 months to complete

Conclusion:
HALT provides faster time to market (reduction in test time), reduced engineering costs, and better results than traditional testing methodologies.
HALT Implementation Requirements

- Combined stresses to technology limits
- Step stressing (individual and combined)
- Powered product with monitored tests
- Root cause failure analysis and appropriate corrective action

HALT Equipment Commonly Used

- Combined Temperature/Vibration Equipment
- Pneumatic Vibration (to provide the random vibration) with Wide Frequency Spectrum
- Fast Thermal Rates of Change and Wide Thermal Range

HALT Vibration Sub-System

- Pneumatic Vibration
- Excites six axes, 3 linear & 3 rotational
- Broadband (2 Hz to 10 kHz) random vibration on rigid shaker table
- Broadest frequency spectrum of all vibration technologies (ED, Hydraulic, etc.)
HALT Vibration Sub-System

Power Spectral Density (measured on product on QualMark OVS-2.5HP)

HALT Thermal Sub-System

- Thermal changes up to 60°C/min on a product
- Temperature range from -100°C to 200°C
- LN₂ cooling superior to refrigeration cooling in:
  - Quiet
  - Low cost
  - Reliable

HALT Cost Benefits

- Reduced product time to market
- Lowered warranty cost through higher MTBF
- Faster DVT with fewer product samples
- Accelerated screening (HASS) allowed
SUMMARY OF HALT RESULTS AT AN ACCELERATED RELIABILITY TEST CENTER

Summary of Customers

<table>
<thead>
<tr>
<th>Industry Types</th>
<th>Number of Companies</th>
<th>Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Networking Equipment</td>
<td>6</td>
<td>Electrical</td>
</tr>
<tr>
<td>2 Defense Electronics</td>
<td>4</td>
<td>Electrical</td>
</tr>
<tr>
<td>3 Microwave Equipment</td>
<td>4</td>
<td>Electrical</td>
</tr>
<tr>
<td>4 Filters</td>
<td>2</td>
<td>Electrical</td>
</tr>
<tr>
<td>5 Remote Measuring Equipment</td>
<td>2</td>
<td>Electrical</td>
</tr>
<tr>
<td>6 Computers</td>
<td>2</td>
<td>Electrical</td>
</tr>
<tr>
<td>7 Vehicle/Trucking Equipment</td>
<td>1</td>
<td>Electro-mechanical</td>
</tr>
<tr>
<td>8 Ultra-Processing Equipment</td>
<td>1</td>
<td>Electrical</td>
</tr>
<tr>
<td>9 Medical Instrument</td>
<td>2</td>
<td>Electrical</td>
</tr>
<tr>
<td>10 Handheld Computers</td>
<td>2</td>
<td>Electrical</td>
</tr>
<tr>
<td>11 Handheld Measuring Equipment</td>
<td>2</td>
<td>Electrical</td>
</tr>
<tr>
<td>12 Monitors</td>
<td>1</td>
<td>Electrical</td>
</tr>
<tr>
<td>13 Medical Devices</td>
<td>1</td>
<td>Electro-mechanical</td>
</tr>
<tr>
<td>14 Personal Computers</td>
<td>2</td>
<td>Electrical</td>
</tr>
<tr>
<td>15 Office and Places</td>
<td>2</td>
<td>Electro-mechanical</td>
</tr>
<tr>
<td>16 Portable Telephones</td>
<td>1</td>
<td>Electrical</td>
</tr>
<tr>
<td>17 Speakers</td>
<td>1</td>
<td>Electro-mechanical</td>
</tr>
<tr>
<td>18 Telephone Switching Equipment</td>
<td>1</td>
<td>Electrical</td>
</tr>
<tr>
<td>19 Semiconductor Manufacturing</td>
<td>1</td>
<td>Electro-mechanical</td>
</tr>
<tr>
<td>TOTAL</td>
<td>33</td>
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</tr>
</tbody>
</table>

Summary of Products by Customer Field Environment

<table>
<thead>
<tr>
<th>Environment Type</th>
<th>Number of Products</th>
<th>Thermal Environment</th>
<th>Vibration Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>18</td>
<td>0 to +40°C</td>
<td>Little or no vibration</td>
</tr>
<tr>
<td>Office with User</td>
<td>9</td>
<td>0 to +40°C</td>
<td>Vibration only from user of equipment</td>
</tr>
<tr>
<td>Vehicle</td>
<td>8</td>
<td>-40 to +75°C</td>
<td>1-2 Gms vibration, 0-200 Hz frequency</td>
</tr>
<tr>
<td>Field</td>
<td>7</td>
<td>-40 to +60°C</td>
<td>Little or no vibration</td>
</tr>
<tr>
<td>Field with User</td>
<td>4</td>
<td>-40 to +60°C</td>
<td>Vibration only from user of equipment</td>
</tr>
<tr>
<td>Airplane</td>
<td>1</td>
<td>-40 to +75°C</td>
<td>1-2 Gms vibration, 0-500 Hz frequency</td>
</tr>
<tr>
<td>TOTAL</td>
<td>47</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Summary of Results - by attribute -

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Thermal Data °C</th>
<th>Vibration Data, Grms</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>LOL</td>
<td>LDL</td>
</tr>
<tr>
<td>Average</td>
<td>-55</td>
<td>-73</td>
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<tr>
<td>Most Robust</td>
<td>-100</td>
<td>-100</td>
</tr>
<tr>
<td>Least Robust</td>
<td>15</td>
<td>-20</td>
</tr>
<tr>
<td>Median</td>
<td>-55</td>
<td>-80</td>
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</table>

### Summary of Results - by field environment -

<table>
<thead>
<tr>
<th>Environment</th>
<th>Thermal Data °C</th>
<th>Vibration Data, Grms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LOL</td>
<td>LDL</td>
</tr>
<tr>
<td>Office</td>
<td>-82</td>
<td>-80</td>
</tr>
<tr>
<td>Office with User</td>
<td>-21</td>
<td>-50</td>
</tr>
<tr>
<td>Vehicle</td>
<td>-69</td>
<td>-78</td>
</tr>
<tr>
<td>Field</td>
<td>-66</td>
<td>-81</td>
</tr>
<tr>
<td>Field with User</td>
<td>-49</td>
<td>-88</td>
</tr>
<tr>
<td>Airplane</td>
<td>-60</td>
<td>-90</td>
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</tbody>
</table>

### Summary of Results - by product application -

<table>
<thead>
<tr>
<th>Product Application</th>
<th>Thermal Data °C</th>
<th>Vibration Data, Grms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LOL</td>
<td>LDL</td>
</tr>
<tr>
<td>Military</td>
<td>-69</td>
<td>-78</td>
</tr>
<tr>
<td>Field</td>
<td>-57</td>
<td>-74</td>
</tr>
<tr>
<td>Commercial</td>
<td>-48</td>
<td>-73</td>
</tr>
</tbody>
</table>
Summary of Results
- by stress -

Significance:
Without Combined Environment, 20% of all failures would have been missed

Integrating Design for Reliability (DfR)
Techniques into HALT

Examples:
Reliability Predictions
FMECAs
RDTs/ALTs

Reliability Modeling and Predictions:
How to Use in Preparation for HALT
- Predictions used to identify thermocouple locations
- Predictions reveal technology-limiting components
FMECA: How to Use in Preparation for HALT

- Identify failure modes that HALT is likely to uncover
- Identify failure modes requiring extra planning to find
- Identify non-relevant failure modes
- Help to identify the number of samples

RDT/ALT: How to Drive from HALT Results

- Two of the most important pieces of information to decide upon when planning an RDT/ALT is:
  - which stresses to apply
  - how much stress to apply

From these, we can derive the acceleration factor for the test. HALT can help with both of these

HALT vs. ALT
When to Use Which Technique?
Overview

Highly Accelerated Life Testing (HALT) is a great reliability technique to use for finding predominant failure mechanisms in a hardware product.

However, in many cases, the predominant failure mechanism is wear-out.

When this is the situation, we must be able to predict or characterize this wear-out mechanism to assure that it occurs outside customer expectations and outside the warranty period.

The best technique to use for this is a slower test method, Accelerated Life Testing (ALT).

Overview

In many cases, it is best to use both because each technique is good at finding different types of failure mechanisms.

The proper use of both techniques together will offer a complete picture of the reliability of the product.

HALT
Highly Accelerated Life Testing
used in DESIGN for Product Ruggedization

ALT
Accelerated Life Testing
used in DESIGN to Characterize Predominant Failure Mechanisms, Especially for Wearout
Highly Accelerated Life Test (HALT)

- A Highly Accelerated Life Test (HALT) is the process of increasing the reliability of a product by gradually increasing stresses until the product fails.
- HALT’s are good for finding design weaknesses.
- HALT’s are usually performed on entire systems but can be performed on individual assemblies as well.
- HALT’s do not work well when there is a wear-out mechanism involved.

Accelerated Life Test (ALT)

- An Accelerated Life Test (ALT) is the process of determining the reliability of a product in a short period of time by accelerating the use environment.
- ALT’s are also good for finding dominant failure mechanisms.
- ALT’s are usually performed on individual assemblies rather than full systems.
- ALT’s are also frequently used when there is a wear-out mechanism involved.

Limitations of HALT

Classic S-N Diagram
(stress vs. number of cycles)
Advantage of ALT over HALT

- One key advantage of ALT over HALT is when we need to know the life of the product.
- In HALT, we don’t concern ourselves with this much because we are more interested in making the product as reliable as we can, and measuring the amount of reliability is not as important.
- However, with mechanical items that wear over time, it is very important to know the life of the product as accurately as possible.

ALT – Difference in Process

- Instead of stepping up to failure, we will pick a level that we know the product will survive at (within relevant failure area) and then run at this level until failure.
- This will characterize wear-out mechanisms

Advantage of ALT over HALT

Another advantage is that we often do not need any environmental equipment. Benchtop testing is often adequate.
Comparison Between ALT and HALT

HALT

1. Root Cause Analysis
2. Operating Action Specification
3. Debug No-Go/Go Determination

ALT

1. Reliability Evaluation (e.g., Failure Rate)
2. Dominant Failure Mechanism Identification

TESTING REQUIREMENTS

HALT

1. Detailed Parameters
   a) Test Length
   b) Number of Samples
   c) Confidence/Accuracy
   d) Acceleration Factors
   e) Test Environment

ALT

1. Detailed Parameters
   a) 4:2:1 Procedure Or Other
   b) Costs

ANALYTICAL MODELS

1. Weibull Distribution
2. Coffin-Manson
3. Norris-Lanzberg

Combining ALT with HALT

Often times we will run a product through HALT and then run the subassemblies through ALT that were not good candidates for HALT.

HALT on System

ALT on System

Developing ALT from HALT

And at other times, we may develop the ALT based on the HALT limits, using the same accelerants but lowering the acceleration factors to measurable levels.

HALT on System

ALT on System
ALT Parameters

In order to set up an ALT, we must know several different parameters, including:

- Length of Test
- Number of Samples
- Goal of Test
- Confidence Desired
- Accuracy Desired
- Cost
- Acceleration Factor
  - Field Environment
  - Test Environment
  - Acceleration Factor Calculation
- Slope of Weibull Distribution (Beta parameter)

Acceleration Factors

In order to measure the life of a product with ALT, one key factor we must determine is the Acceleration Factor, and this is sometimes the most difficult to obtain:

- Existing models (not very accurate)
  - Arrhenius
  - Coffin-Manson
  - Norris-Lanzber

Note that Lead Free will cause all of these to change (and we don’t know yet what they will change to)

- Determine by experimentation (lots of samples and time)
  - Divide samples into 3 Stress Levels: High Stress, Medium Stress, and Low Stress
  - Set up test to assure that failures occur at each level (same failure mechanism)
  - Calculate acceleration factor

- When the Acceleration Factor cannot be determined, often times we are left with only being able to accelerate the duty cycle
  - Increase how often buttons are pushed
  - Increase speed of pump or motor
  - Etc.
Examples of Products for HALT and ALT

Automobile  Robot
Fan  Infusion Pump
Hard Drive  Medical Cabinet
Automotive Electronics  Cell Phone

These pictures are samples of products we have tested. These are not the actual products to protect the proprietary nature of the products we test.

Automobile

<table>
<thead>
<tr>
<th>Test</th>
<th>Accelerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics</td>
<td>Temperature, Vibration, Humidity, Contamination</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Repetitive cycling test</td>
</tr>
</tbody>
</table>

Fan

<table>
<thead>
<tr>
<th>Test</th>
<th>Accelerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinning</td>
<td>Duty Cycle, Speed, Torque, Backpressure</td>
</tr>
<tr>
<td>Lubricant Longevity</td>
<td>Temperature, Humidity, Contamination</td>
</tr>
</tbody>
</table>
Hard Drive

<table>
<thead>
<tr>
<th>Test</th>
<th>Accelerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Spinning</td>
<td>Duty Cycle, Start/Stop, Speed, Temperature?, Vibration?</td>
</tr>
<tr>
<td>Contamination on Head Surface</td>
<td>Non-Operational Vibration</td>
</tr>
<tr>
<td>Board Derating</td>
<td>Temperature/Voltage</td>
</tr>
<tr>
<td>Connectors – Power, Data</td>
<td>Duty Cycle, Force, Angle</td>
</tr>
</tbody>
</table>

Robot

<table>
<thead>
<tr>
<th>Test</th>
<th>Accelerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm Movement (side to side)</td>
<td>Duty Cycle, Speed, Torque</td>
</tr>
<tr>
<td>Z-Stage (up and down)</td>
<td>Duty Cycle, Speed, Torque</td>
</tr>
<tr>
<td>Vacuum Hold-down</td>
<td>Temperature, Altitude</td>
</tr>
<tr>
<td>Repeatability</td>
<td>Duty Cycle</td>
</tr>
</tbody>
</table>

Automotive Electronics – GPS Receiver

<table>
<thead>
<tr>
<th>Test</th>
<th>Accelerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics</td>
<td>Temperature, Vibration, Humidity Contamination</td>
</tr>
<tr>
<td>Button Pushing</td>
<td>Duty Cycle, Force?, Angle</td>
</tr>
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</table>
### Infusion Pump

<table>
<thead>
<tr>
<th>Test</th>
<th>Accelerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Charging</td>
<td>Duty Cycle, Deep Discharge, Speed of Charge</td>
</tr>
<tr>
<td>Touchscreen</td>
<td>Duty Cycle, Location, Force?</td>
</tr>
<tr>
<td>Pumping</td>
<td>Duty Cycle, Rate, Plunger Force</td>
</tr>
<tr>
<td>Connectors – Battery, Charger, Pole Clamp, IV Line, Cassette</td>
<td>Duty Cycle, Force, Angle</td>
</tr>
</tbody>
</table>

### Drawer for Medical Cabinet

<table>
<thead>
<tr>
<th>Test</th>
<th>Accelerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opening/Closing of Drawer</td>
<td>Duty Cycle, Force, Angle</td>
</tr>
<tr>
<td>Locking Mechanism</td>
<td>Duty Cycle, Force, Contamination</td>
</tr>
</tbody>
</table>

### Cell Phone

<table>
<thead>
<tr>
<th>Test</th>
<th>Accelerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Button Pushing</td>
<td>Duty Cycle, Force?, Angle</td>
</tr>
<tr>
<td>Touchscreen</td>
<td>Duty Cycle, Location, Force?</td>
</tr>
<tr>
<td>Connectors – Headset, Battery, Charger</td>
<td>Duty Cycle, Force, Angle</td>
</tr>
</tbody>
</table>
HALT vs. ALT Summary

- When wear-out is not a dominant failure mechanism, HALT is an excellent tool for finding product weaknesses in a short period of time.
- When wear-out is a dominant failure mechanism, we must be able to predict or characterize this wear-out mechanism to assure that it occurs outside customer expectations and outside the warranty period.
- ALT is an excellent method for doing this.

Reliability Process Flow:
Accelerated Stress Testing (AST) or "HALT"

Reliability - Reliability Stress Test (AST) Flow

Reliability Process Flow:
Accelerated Life Test or Reliability Demonstration Test

Reliability - Reliability Demonstration Testing Flow
WHAT ABOUT HASS?

Now that we've matured the design and characterized the wear, it is time to work on the manufacturing process with HASS.

HASS

Highly Accelerated Stress Screening

- Detect & correct design & process changes.
- Reduce production time & cost.
- Increase out-of-box quality & field reliability.
- Decrease field service & warranty costs.
- Reduce infant mortality rate at product introduction.
- Finds failures that are not found with burn-in
- Accelerates ability to discover process and component problems.

HASS is not a test, it's a process. Each product has its own process.
HASS Process Is Begun Early

- Even before HALT is complete, we should
  - determine production needs and throughput
  - start designing and building fixture
  - obtain functional and environmental equipment
  - understand manpower needs
  - determine what level HASS will be performed (assembly or system)
  - determine location of HASS (in-house or at an outside lab or contract manufacturer)
  - for high volume products, determine when to switch to an audit and what goals should be put in place to trigger this

HASS Development

- After HALT is complete, we must
  - assure Root Cause Analysis (RCA) completed on all failures uncovered
  - determine which stresses to apply
  - develop initial screen based on HALT results
  - map production fixture (thermal/vibration)
  - run proof-of-screen
  - start designing and building fixture
HASS Development

- Proof-of-Screen Criteria
  - Assure that screen leaves sufficient life in product
  - Assure that screen is effective

Assuring the Screen Leaves Sufficient Life

Make dwells long enough to execute diagnostic suite. Execute diagnostics during entire profile.

- It is highly recommended to combine six-axis vibration, shock vibration, power cycling, other stresses with thermal. Powered on monitoring is essential.

- Minimum 20 passes

We run for X times more than proposed screen
- When we reach end-of-life, then we can say that one screen will leave 1 – 1/x left in the product.
- Example: We recommend testing for a minimum of 20 times the proposed screen length. A failure after 20 HASS screens tells us that one screen will leave the product with 1 – 1/20 or 95% of its life.
The “Ideal” HASS Profile for wide operating limits

HASS Process for Narrow Operating Limits

HASS Process for Wide Operating Limits

Precipitation Screen Detection Screen
It is highly recommended to combine six-axis vibration, tickle vibration, power cycling, other stresses with thermal. Powered on monitoring is essential.

Assuring the Screen is Effective
- During HASS Development
  - Seeded samples. Actually insert a failure site and then run the proposed screen to see if it can find the failure
  - Use No Trouble Founds (NTFs) from similar products
- During Production HASS
  - Start screening process with 4x the number of screen cycles intended for long-term HASS
  - During production screening (after each production run), adjust screen limits up and cycles down until 90% of the defects are discovered in the first 1-2 cycles.
  - Monitor field results to determine effectiveness of screen. Again, adjust screen limits as necessary to decrease “escapes” to the field.
  - Add other stresses, as necessary, if it is impractical to adjust screen limits any further.

HASS Results
- Poor solder quality
- Socket failures
- Component failures
- Bent IC leads
- Incorrect components
- Improper component placement
- Test fixture/program errors

PCBAs went through ATE and functional testing at our supplier’s facility. PCBAs were delivered to Array Technology and went through HASS. Array saw yields from 90% down to 17%.
HASS Advantages over “Burn-In”

- Finds flaws typically found by customers
- Reduces production time and costs
- Lowers warranty costs

HASS Defects by Environment

- Combined Temperature and 6 Degree-of-Freedom Vibration: 46%
- Extreme Temperature Transitions: 29%
- High Temp Extreme: 13%
- Low Temp Extreme: 12%

Data from Array Technology (1993).

HASS - Implementation Requirements

- HALT for margin discovery
- Screen development
- Powered product with monitored tests
- Fixturing to allow required throughput
HASS
Cost Benefits

- Greatly reduced test time
- Reduction in test equipment
- Lower warranty costs
- Minimized chance of product recalls

HASS Dilemma

- Difficult to implement without impacting production
- Expensive to implement across many CM’s.
- Difficult to cost-justify

HASA Solves All These Issues

HASA

Highly Accelerated Stress Auditing
What is HASA

- HASA is an effective audit process for manufacturing.
- HASA combines the best screening tools with the best auditing tools.
- Better than ORT in improving the shipped product because it leverages off of HALT and HASS to apply a screen tailored to the product.
- Better than HASS in high volume because it is much cheaper and easier to implement and “almost” as effective.

When to switch from HASS to HASA?

- HASS ROI turns negative
- Failure rates are acceptable
- Manufacturing processes are under control

HASA Example

Example from HP Vancouver

# units shipped per day = 1000
# units tested per day = 64

90% probability of detecting a rate shift from 1% to 3% by sampling 112 units in just under 2 days
Integrating Design for Reliability (DfR) Techniques into HASS

Examples:
- Predictions
- FMECAs
- HALT
- ALT

HASS: How to Use the Results of Reliability Predictions in Planning HASS

- Using Reliability Prediction results to determine how much screening is necessary
  - One of the parameters of a reliability prediction is the First Year Multiplier factor. This is a factor applied to a product based on how much manufacturing screening is being performed (or is planned for) to take into account infant mortality failures.
  - The factor is on a scale between 1 and 4. No screening yields a factor of 4, and 10,000 hours of “effective” screening yields a factor of 1 (the scale is logarithmic).

HASS: How to Use the Results of Reliability Predictions in Planning HASS

- Using Reliability Prediction results to determine how much screening is necessary, continued
  - Effective screening allows for accelerants such as temperature and temperature cycling.
  - HASS offers the best acceleration of any known screen. Therefore, HASS is the perfect vehicle for helping to keep this factor low in a reliability prediction.
HASS: How to Use the Results of FMECA in Planning HASS

- Using FMECA results to identify possible wearout mechanisms that need to be taken into account for HASS
  - As we discussed in the FMECA section, certain wearout failure modes are not easily detectable in HALT or even in HASS Development. Therefore, when wearout failure modes are present, we must rely on the results of a FMECA to help determine appropriate screen parameters.

HASS: How to Use the Results of HALT in Planning HASS

- Using the HALT Results, we then run a HASS Development process
  - The process must prove there is significant life left in the product
  - The process must prove that it is effective at finding defects.

HASS: How to Use the Results of ALT in Planning HASS

- How to use the results of ALT in planning a HASS
  - ALT can confirm specific characteristics of components and stresses to avoid as a result, especially wearout.
Reliability Process Flow:
Environmental Stress Screening (ESS) or “HASS/HASA”

- Develop ESS Profile that matches Product Performance
- Prove Profile Using Iterative Process of Increasing Stress to Maximum Possible without Weakening Product
- Perform ESS and Collect Data
- Do Results Warrant Staying with Sample ESS?
- Has Product Undergone a Change that Could Affect Performance?
- Data from Accelerated Stress Testing
- Analyze Repair Data to Determine if ESS Profile Needs to Be Strengthened
- Perform ESS on Material from Repair Center

HALT/ALT/HASS – Where to go to get it done?
- Buy a chamber.
- Get more in-depth training
- Go to a HALT Lab and start testing
  - HALT and HASS Labs in Santa Clara, CA
  - Other Labs in US
    - Huntington Beach, Boston, Austin, Denver, and more
  - Labs in Asia
    - Shenzhen China, Taiwan, Singapore
  - Labs in Europe
    - Netherlands, France, Ireland, Italy, UK
  - Many other labs around the world (see us for locations)
- A test is only as good as its Plan. Make sure to write a good plan!

What are your QUESTIONS?
Presenter's Biographical Sketch

Mike Silverman is founder and managing partner at Ops A La Carte, a Professional Consulting Company that has an intense focus on helping customers with end-to-end reliability. Through Ops A La Carte, Mike has had extensive experience as a consultant to high-tech companies, and has consulted for over 300 companies including Cisco, Ciena, Siemens, Abbott Labs, and Applied Materials. He has consulted in a variety of different industries including power electronics, telecommunications, networking, medical, semiconductor, semiconductor equipment, consumer electronics, and defense.

Mike has 20 years of reliability and quality experience. He is also an expert in accelerated reliability techniques, including HALT/HASS, testing over 500 products for 100 companies in 40 different industries. Mike has authored and published 7 papers on reliability techniques and has presented these around the world including China, Germany, and Canada. He has also developed and currently teaches 10 courses on reliability techniques.

Mike has a BS degree in Electrical and Computer Engineering from the University of Colorado at Boulder, and is both a Certified Reliability Engineer and a course instructor through the American Society for Quality (ASQ), IEEE, Effective Training Associates, and Hobbs Engineering. Mike is a member of ASQ, IEEE, SME, ASME, PATCA, and IEEE Consulting Society and is the current chapter president in the IEEE Reliability Society for Silicon Valley.