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HALT vs. ALT

When to Use Which Technique?

**A presentation for the IEEE Reliability Society
April 27, 2005**

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Overview

HALT and ALT are two of the most popular testing methods but often times engineers are confused about which to use when.

Overview

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

However, in many cases, the predominant failure mechanism is wearout.

When this is the situation, we must be able to predict or characterize this wearout 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)***.

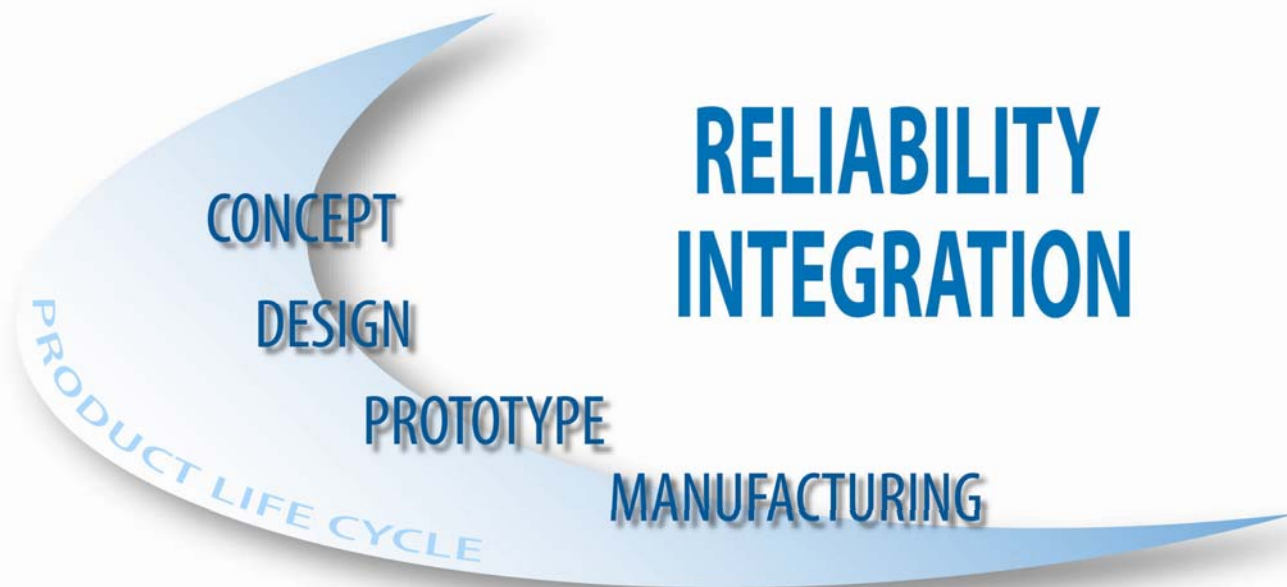
Overview

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.

Presenter Biography

- Mike Silverman, (408) 472-3889, mikes@opsalacarte.com
- Mike is founder and managing partner at Ops A La Carte, a Professional Business Operations Company that offers a broad array of expert services in support of new product development and production initiatives. The primary set of services currently being offered are in the area of reliability. Through Ops A La Carte, Mike has had extensive experience as a consultant to high-tech companies, and has consulted for over 200 companies including Cisco, Ciena, Apple, Siemens, Intuitive Surgical, Abbott Labs, and Applied Materials. He has consulted in a variety of different industries including telecommunications, networking, medical, semiconductor, semiconductor equipment, consumer electronics, and defense electronics.
- Mike has 20 years of reliability, quality, and compliance experience, the majority in start-up companies. He is also an expert in accelerated reliability techniques, including HALT and HASS. He set up and ran an accelerated reliability test lab for 5 years, testing over 300 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 8 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 currently the IEEE Reliability Society Santa Clara Valley Chapter President.



Reliability Engineering Services Integrated Throughout the Product Life Cycle

Ops A La Carte assists clients in developing and executing any and all elements of Reliability through the Product Life Cycle.

*Ops A La Carte has the unique ability to assess a product and understand the key reliability elements necessary to measure/**improve** product performance and customer satisfaction.*

Ops A La Carte pioneered "Reliability Integration" – using multiple tools in conjunction throughout each client's organization to greatly increase the power and value of any Reliability Program.

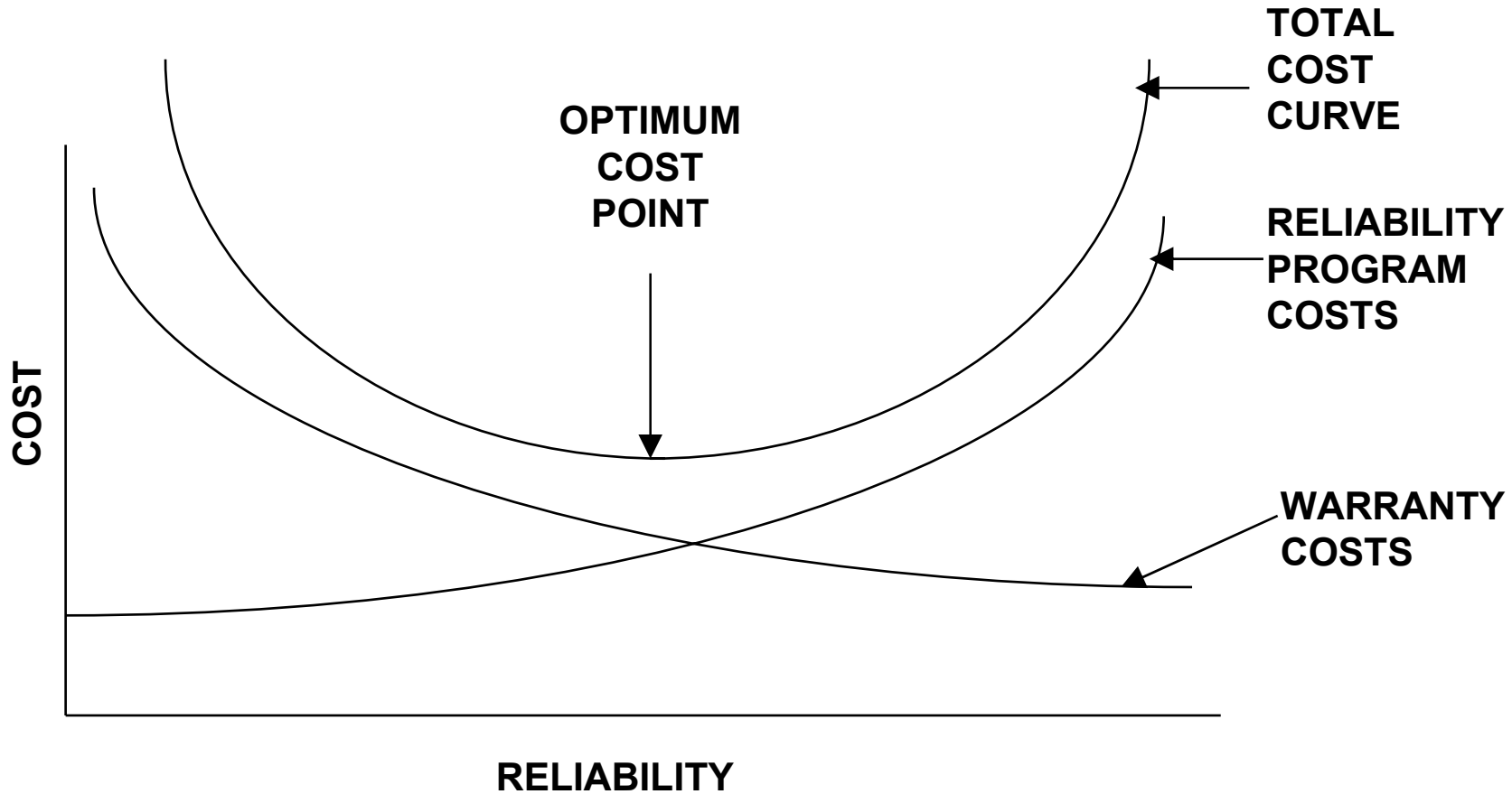
RELIABILITY INTEGRATION

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

Reliability vs. Cost

- Intuitively, one recognizes that there is some minimum total cost that will be achieved when an emphasis in reliability increases development and manufacturing costs while reducing warranty and in-service 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

Two of the best testing tools are *HALT* and *ALT*.

It is important to know when to use which tool.

It is also important to know how the two can be used in conjunction on the same product in order to get a complete picture of the reliability of a product.

HALT

Highly Accelerated Life Testing

used in **DESIGN** for Product Ruggedization

ALT

Accelerated Life Testing

used in **DESIGN** to Characterize Predominant Failure Mechanisms

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.**



ALACARTE™

Reliability Engineering Services
HALT and Classical Techniques
"Reliability Integration"™

HALT

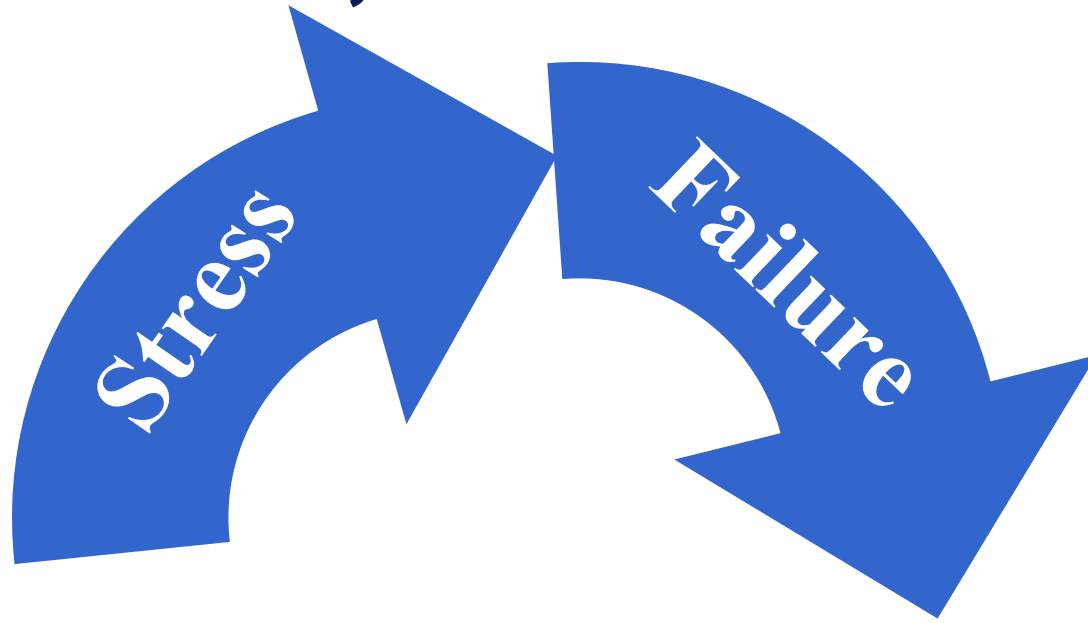
Highly Accelerated Life Testing

HALT, How It Works



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

HALT, How It Works



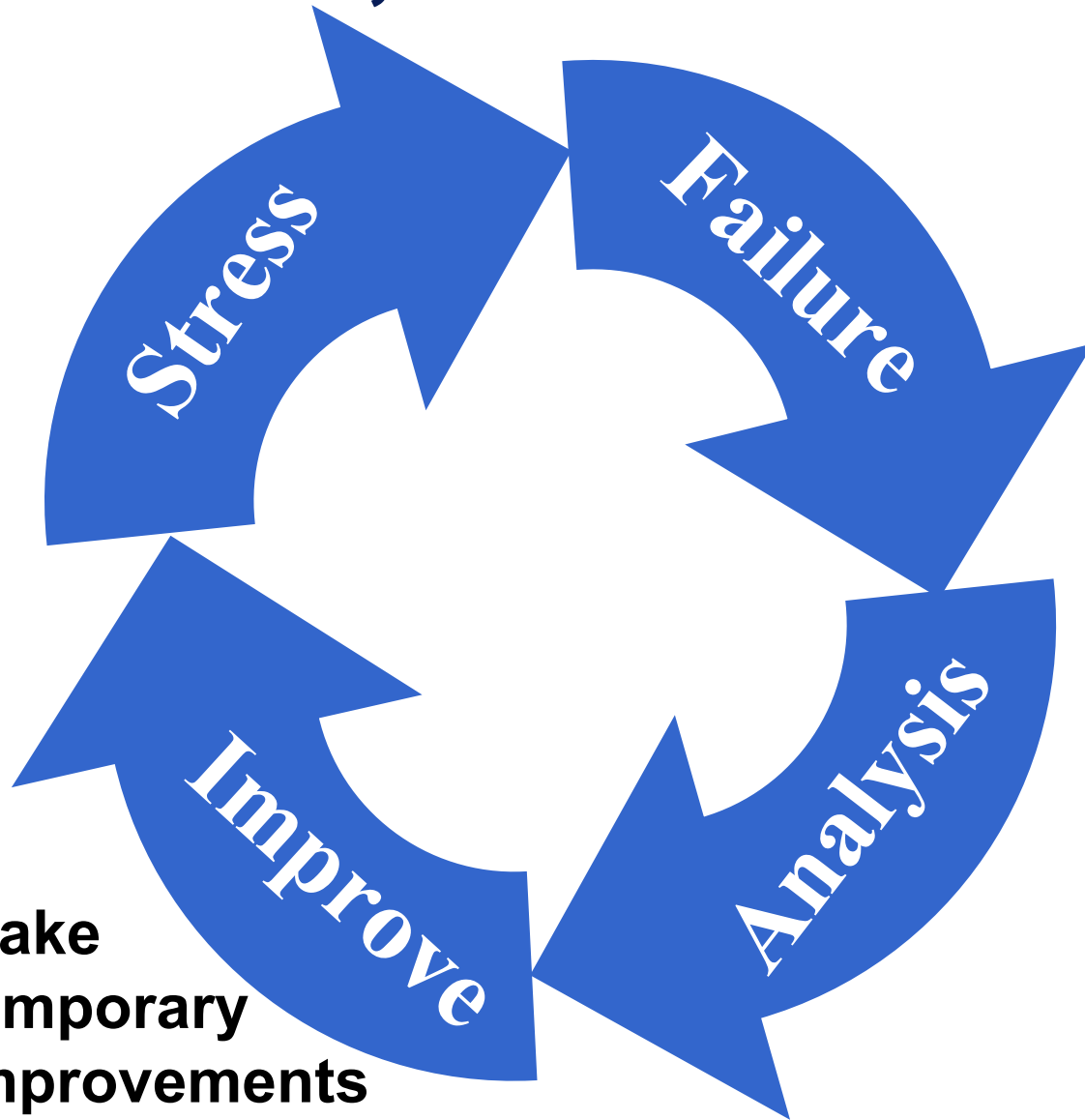
- Gradually increase stress level until a failure occurs

HALT, How It Works



● Analyze
the failure

HALT, How It Works



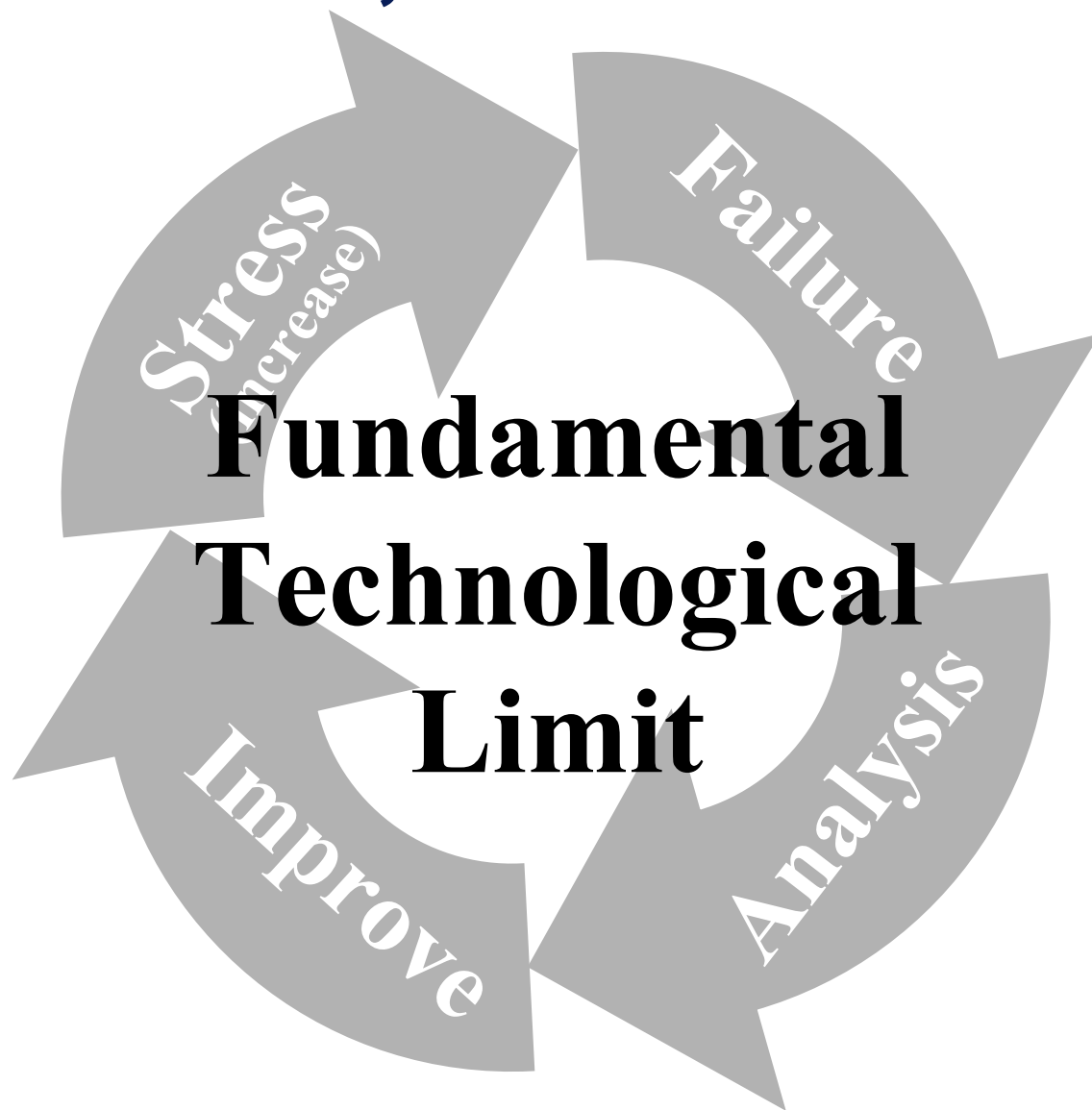
- **Make temporary improvements**

HALT, How It Works

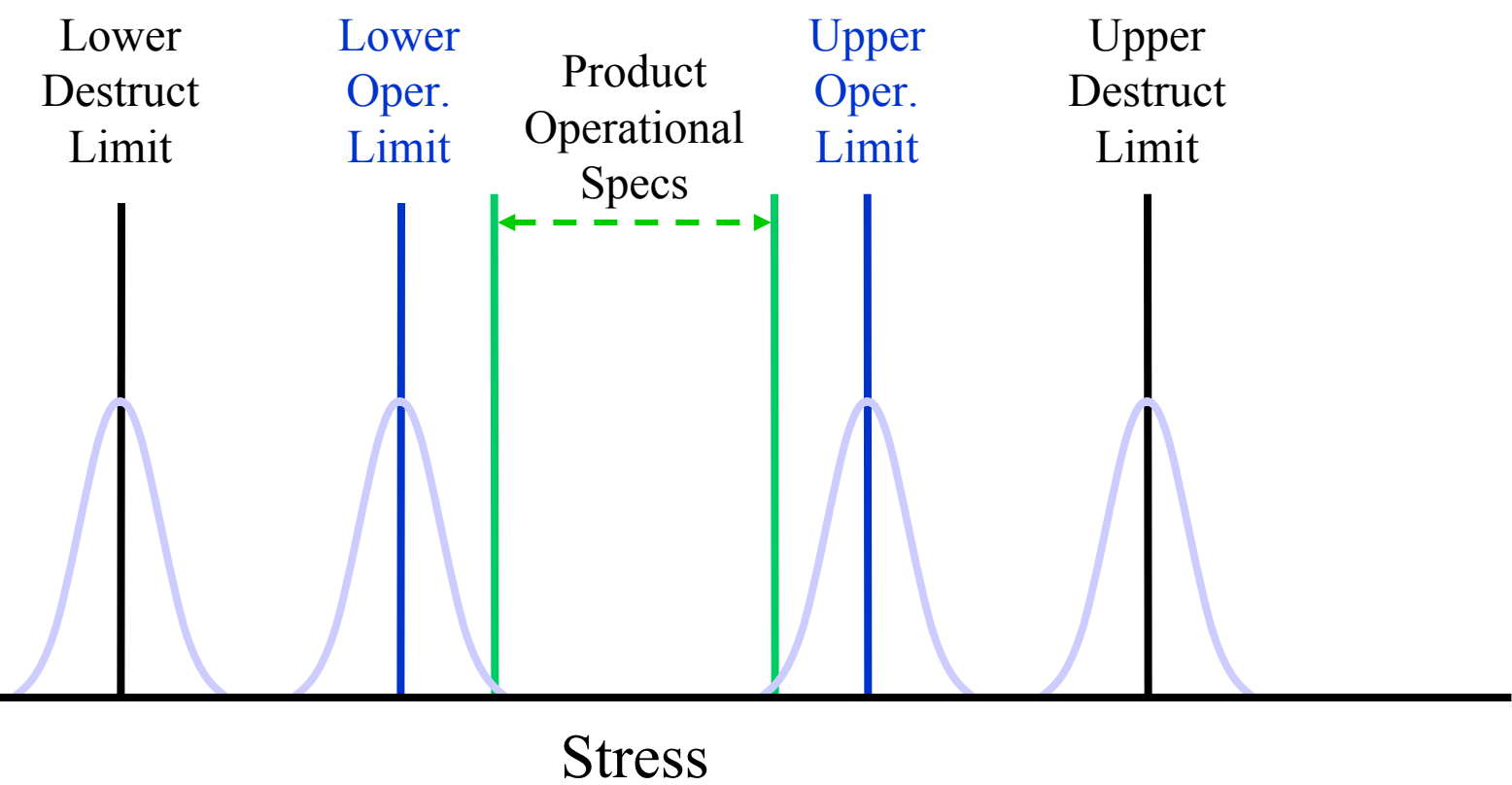
● Increase stress and start process over



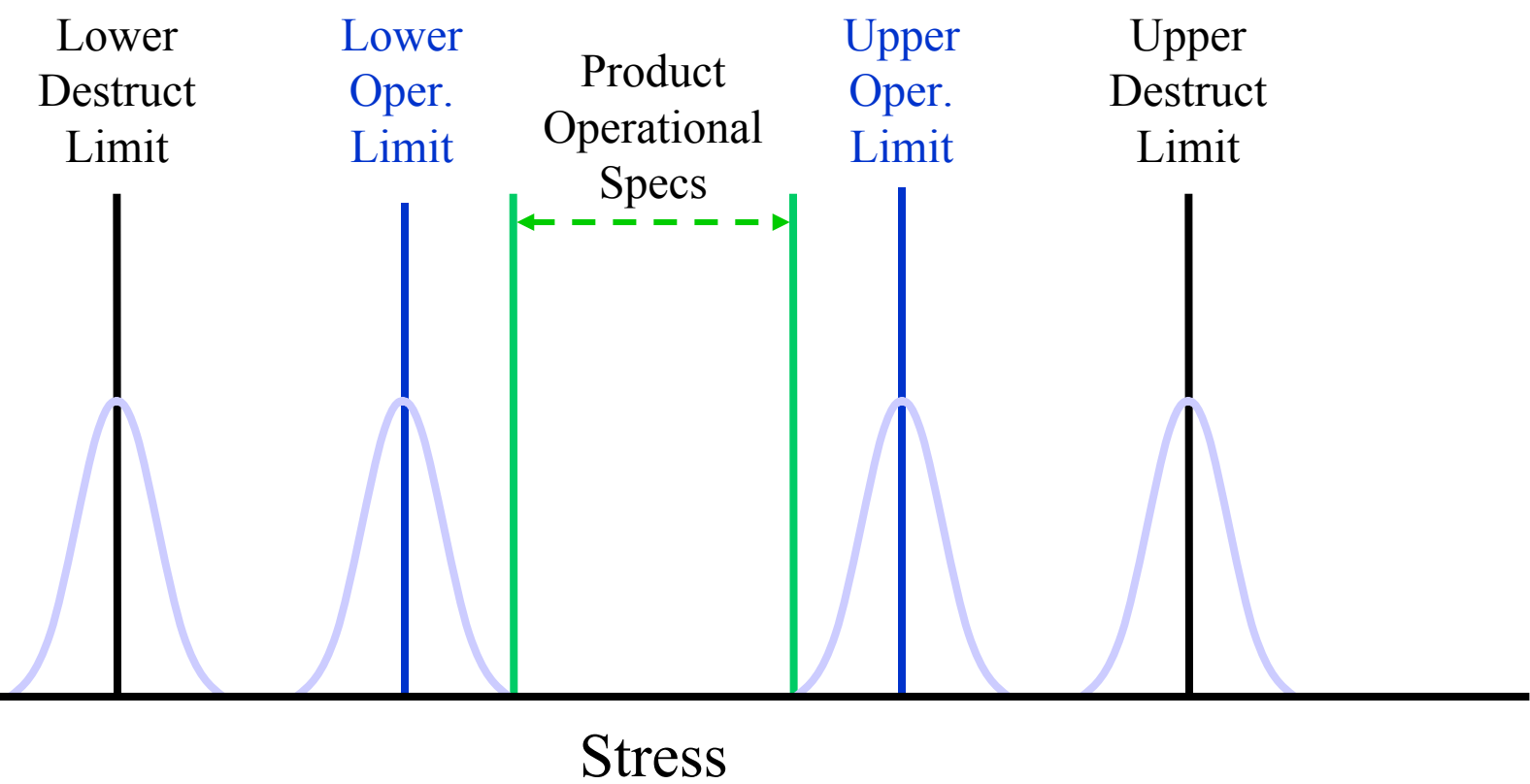
HALT, How It Works



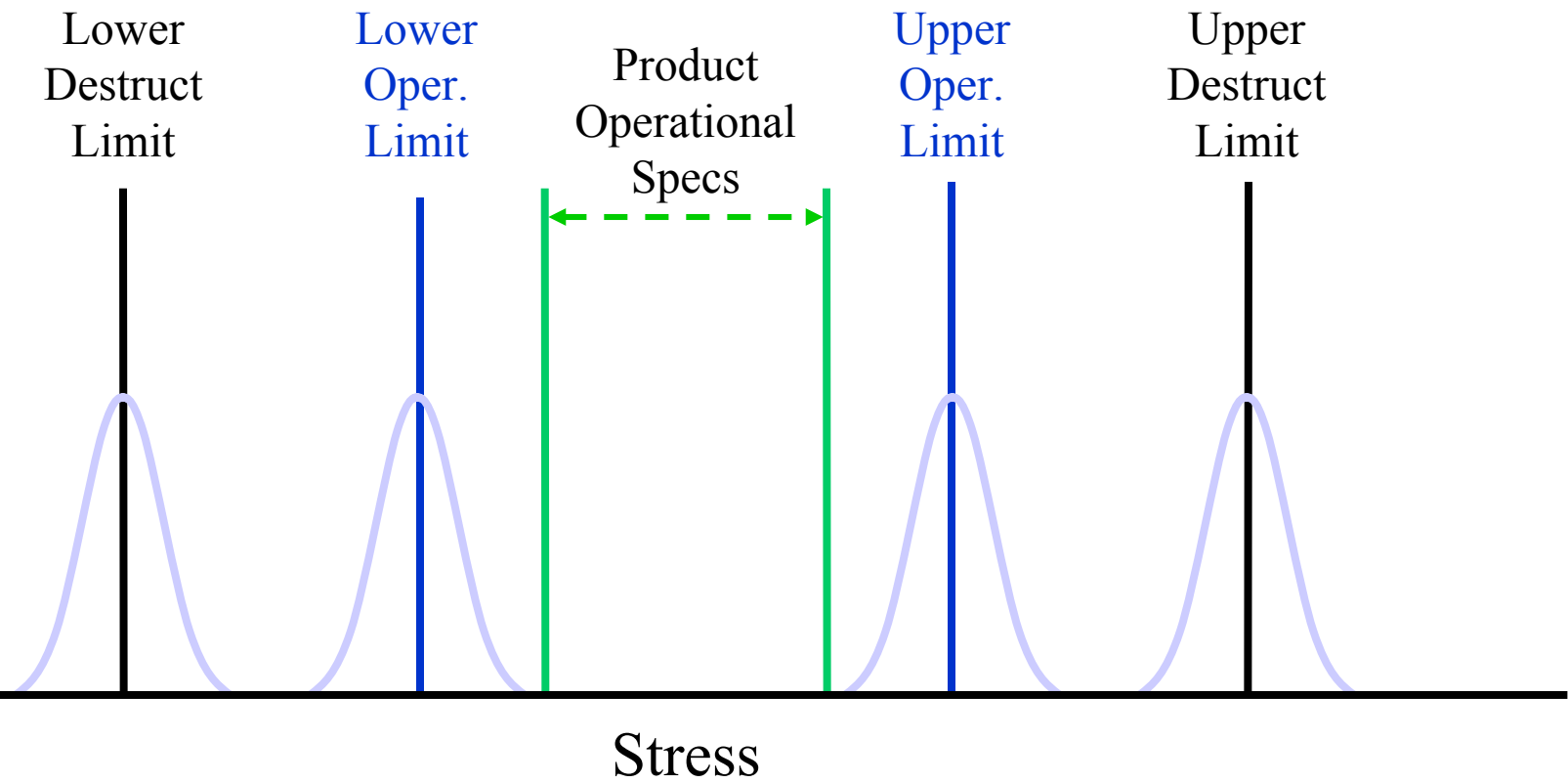
Margin Improvement Process



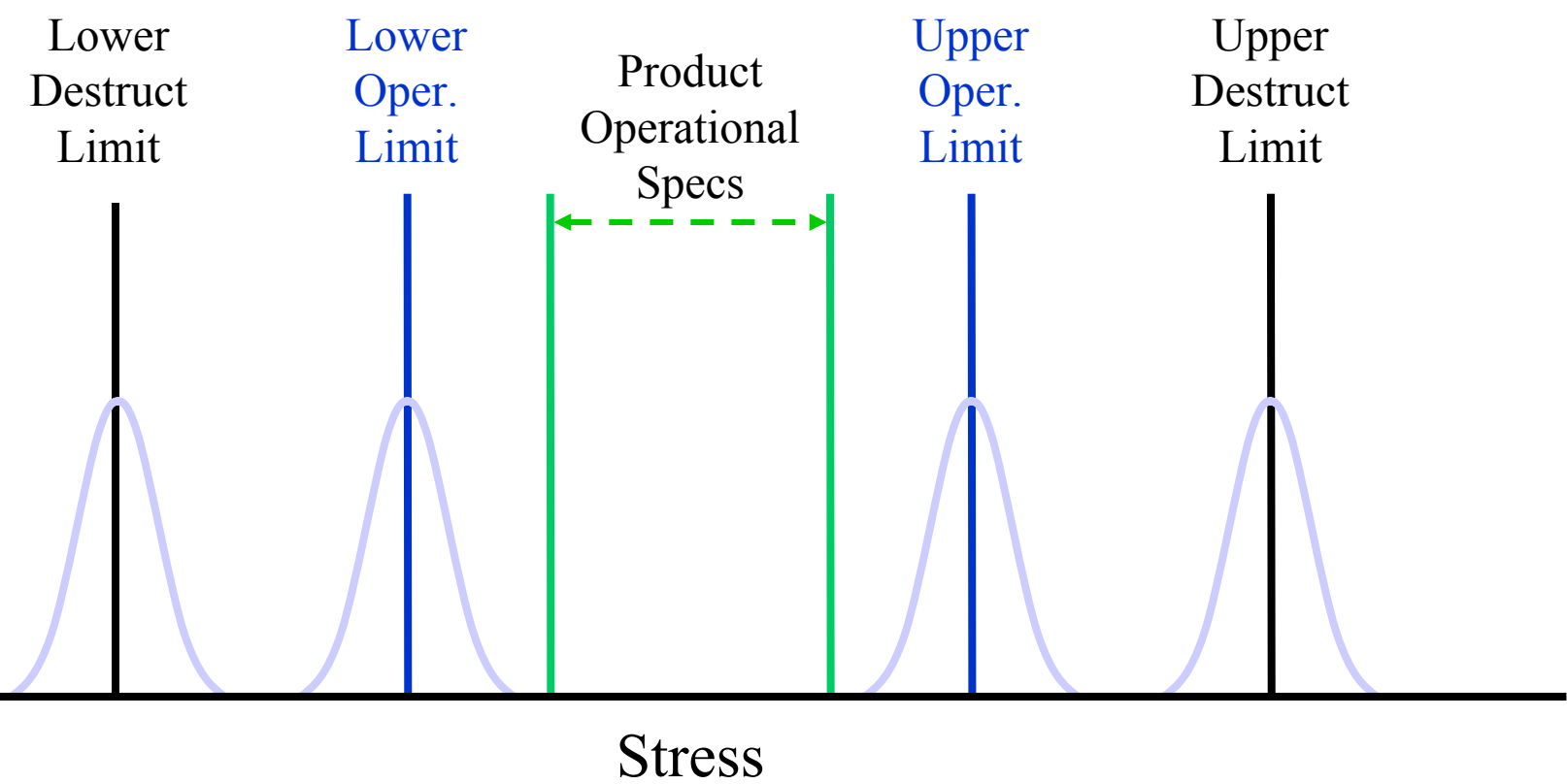
Margin Improvement Process



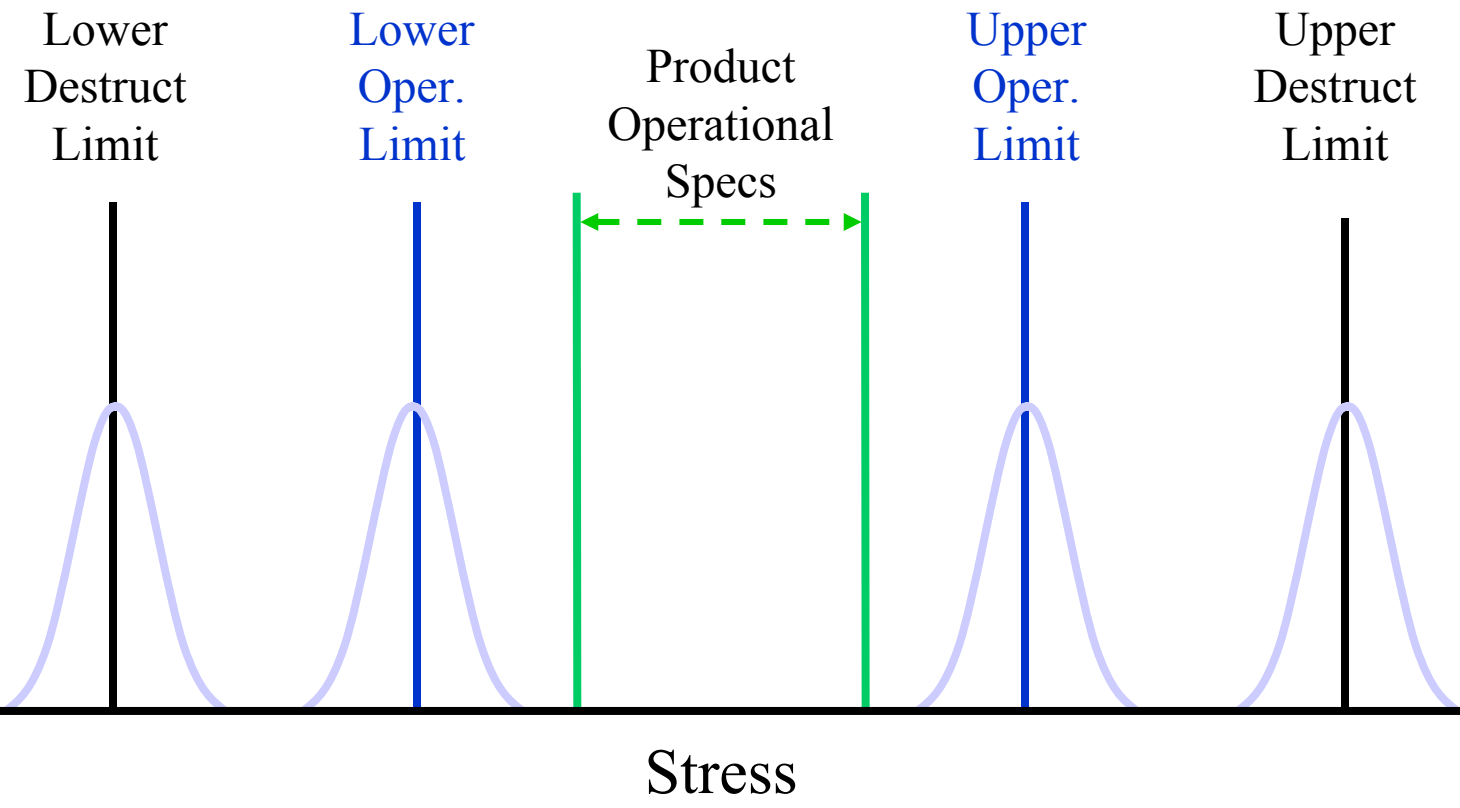
Margin Improvement Process



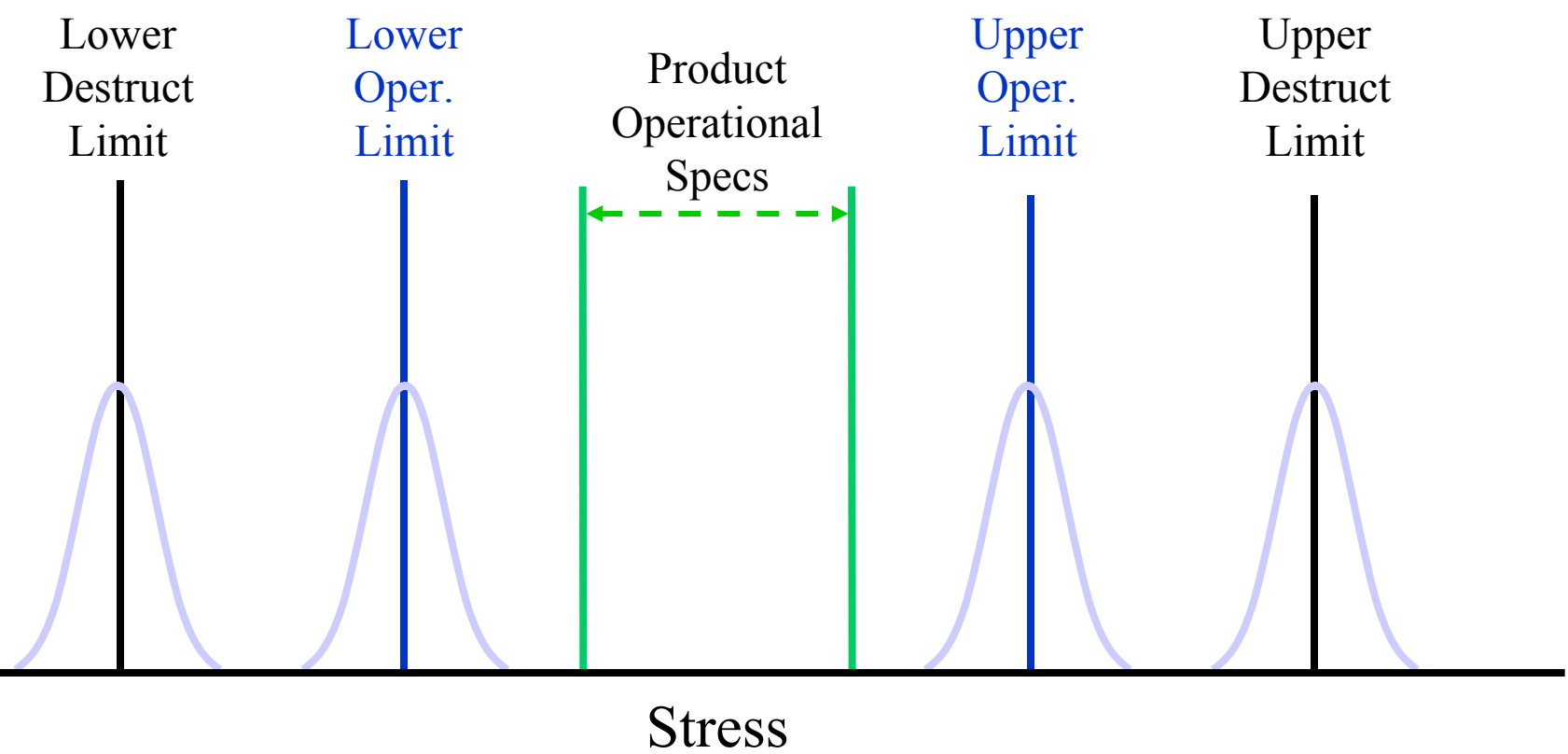
Margin Improvement Process



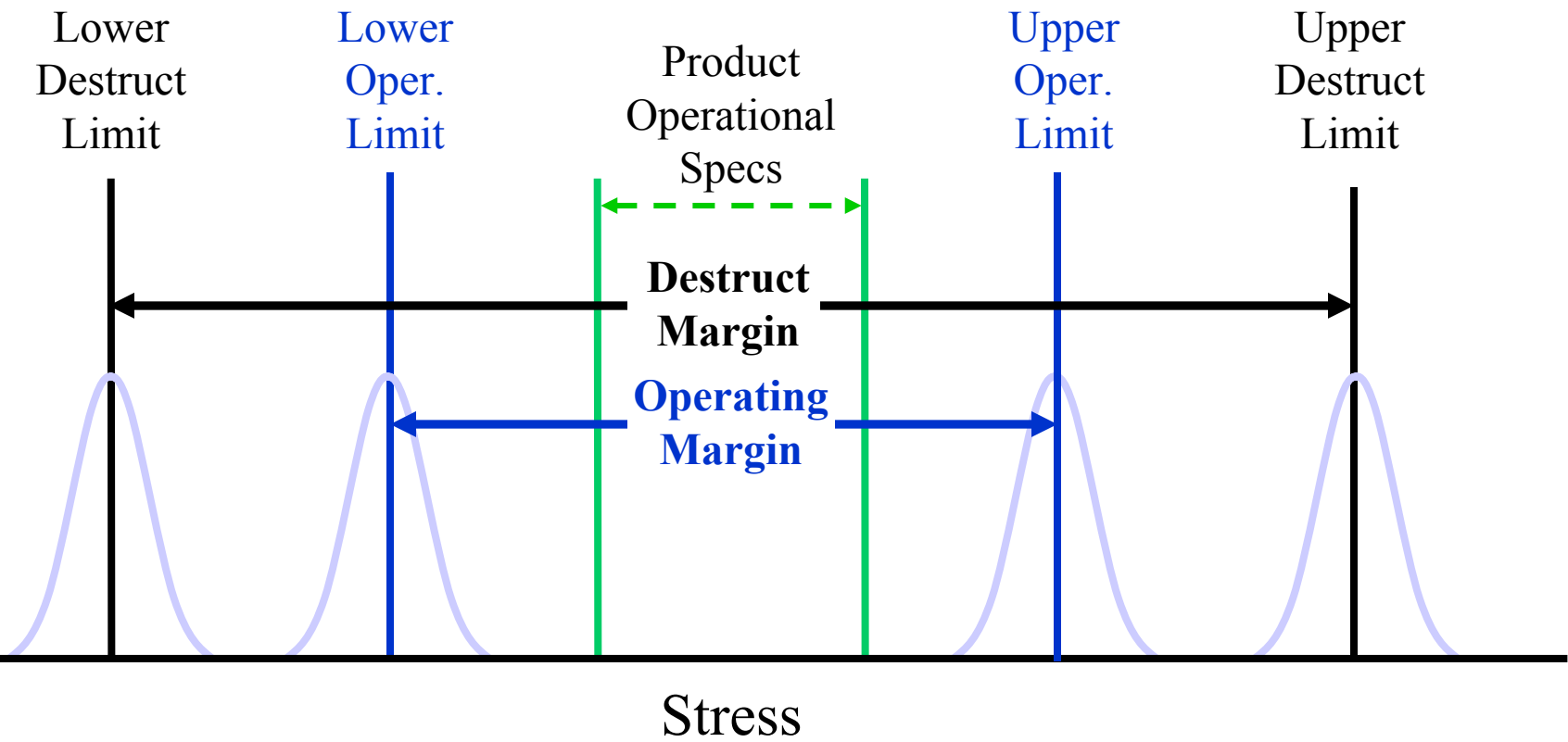
Margin Improvement Process



Margin Improvement Process



Margin Improvement Process



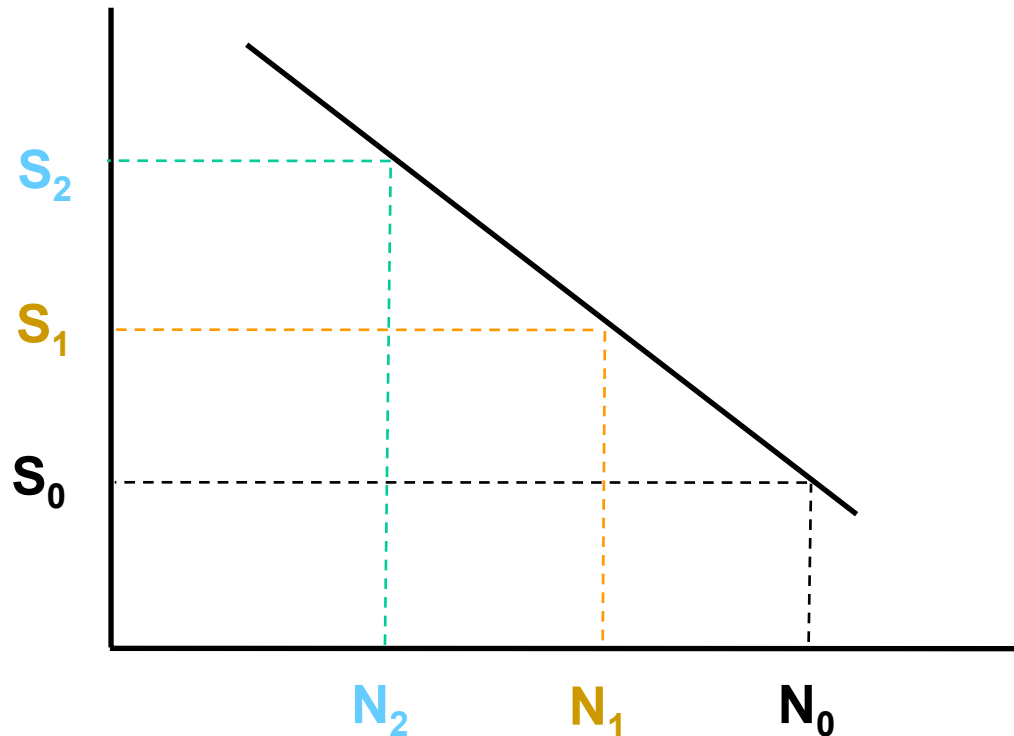
HALT Equipment Commonly Used



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

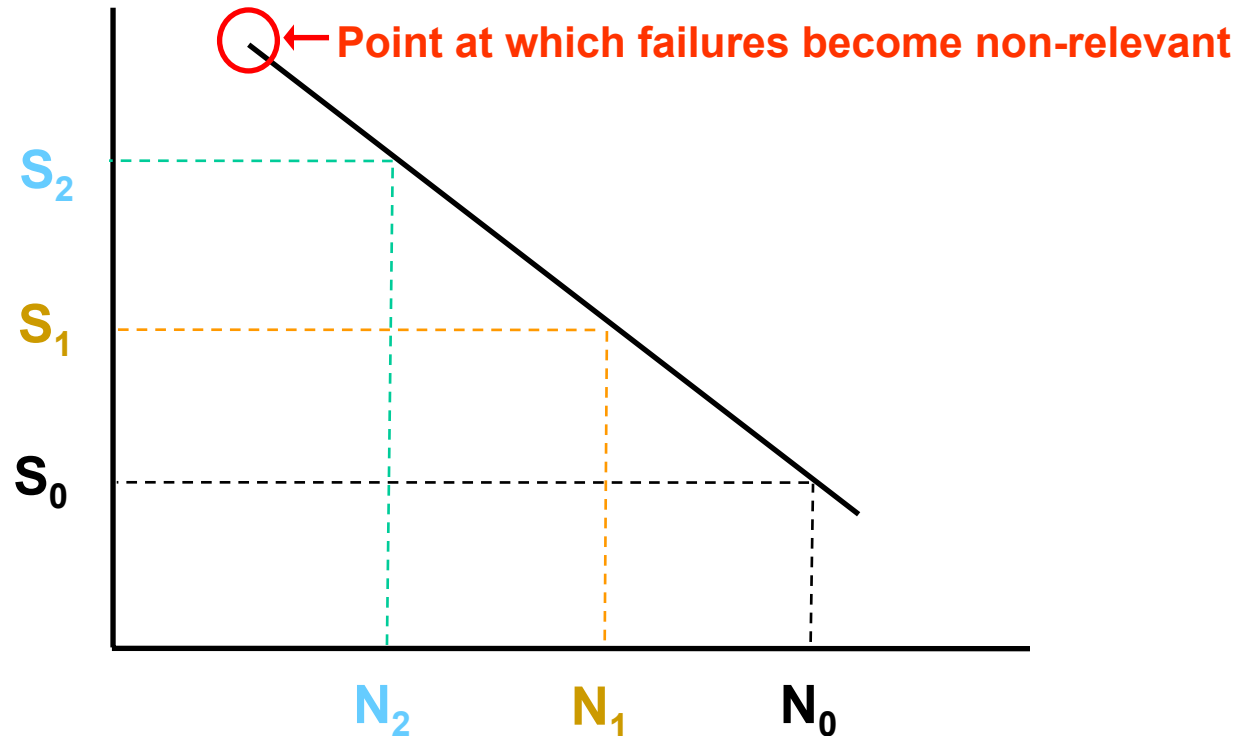
HALT, Why It Works

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



Limitations of HALT

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



ALT Advantage

- 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 wearout mechanisms

ALT

Accelerated Life Testing

Accelerated Life Testing (ALT)

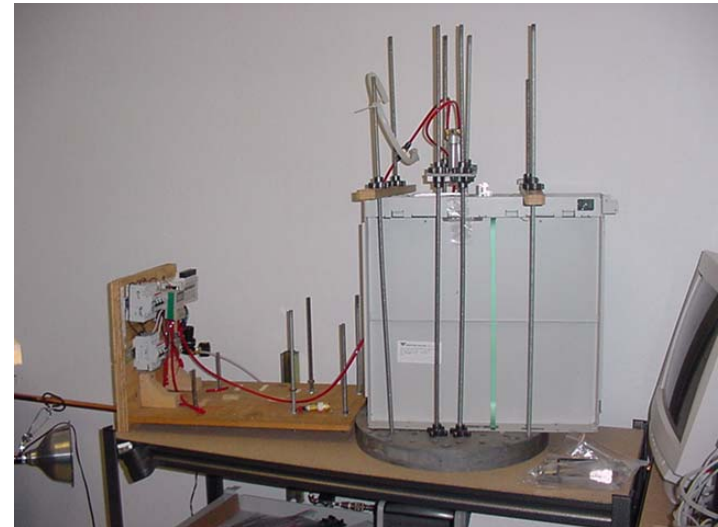
- **An Accelerated Life Test (ALT) is the process of determining the reliability of a product in a short period of time by accelerating the use environment.**
- **ALT's are also good for finding dominant failure mechanisms.**
- **ALT's are usually performed on individual assemblies rather than full systems.**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

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.**

Advantage of ALT over HALT

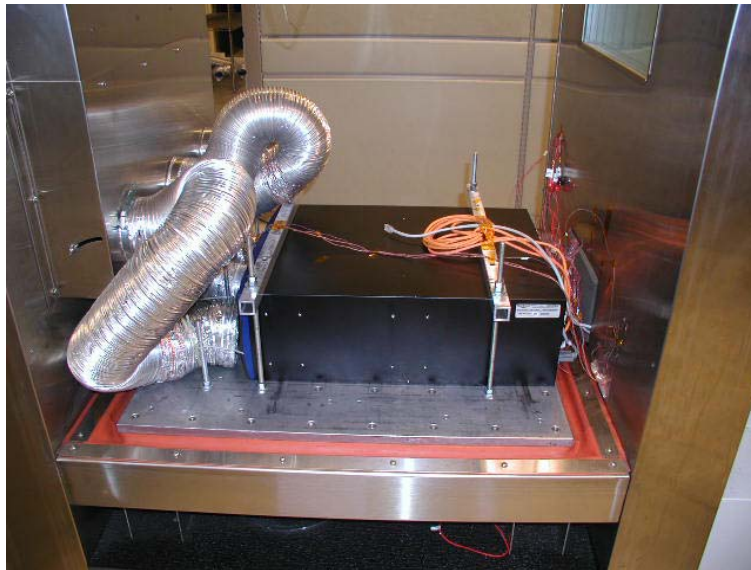
Another advantage is that we often do not need any environmental equipment. Benchtop testing is often adequate.



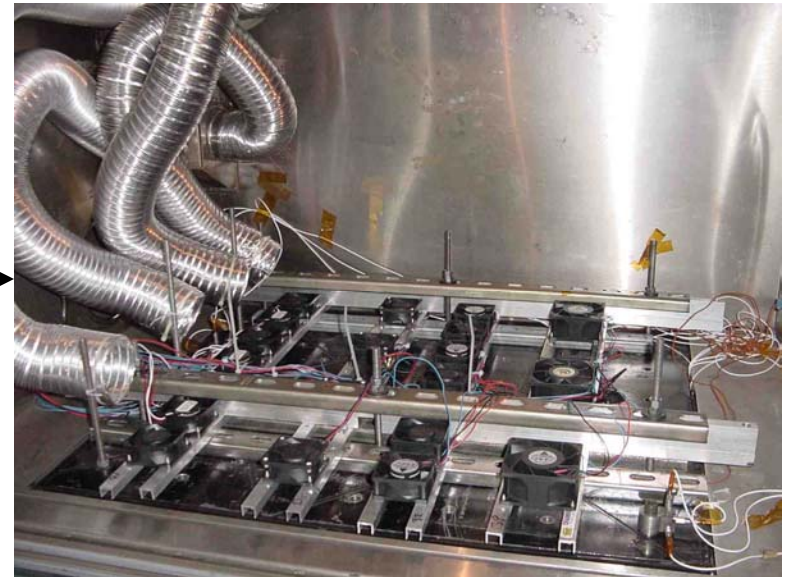
Combining ALT with HALT

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



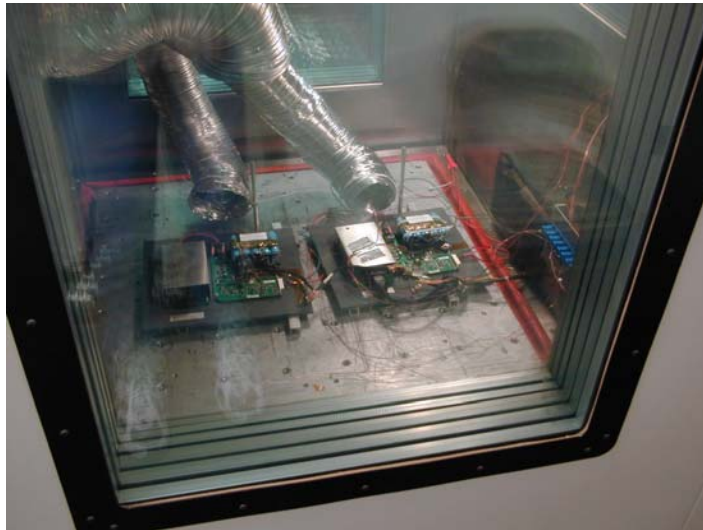
ALT on System Fan



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 factor)

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-Lanzberg

*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

Acceleration Factors

- 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 ALT

Cell Phone



Robot



Fan



Infusion Pump



Hard Drive



Medical Cabinet



Automotive Electronics



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.

Cell Phone



| Test | Accelerant |
|--|------------------------------|
| Button Pushing | Duty Cycle, Force?, Angle |
| Touchscreen | Duty Cycle, Location, Force? |
| Connectors – Headset, Battery, Charger | Duty Cycle, Force, Angle |

Fan



| Test | Accelerant |
|---------------------|---|
| Spinning | Duty Cycle, Speed, Torque, Backpressure |
| Lubricant Longevity | Temperature, Humidity, Contamination |

Hard Drive



| Test | Accelerant |
|--------------------------|---|
| Head Spinning | Duty Cycle, Start/Stop, Speed, Temperature?, Vibration? |
| Connectors – Power, Data | Duty Cycle, Force, Angle |

Robot



| Test | Accelerant |
|-----------------------------|---------------------------|
| Arm Movement (side to side) | Duty Cycle, Speed, Torque |
| Z-Stage (up and down) | Duty Cycle, Speed, Torque |

Automotive Electronics – GPS Receiver



| Test | Accelerant |
|----------------|---|
| Electronics | Temperature, Vibration, Humidity Contamination |
| Button Pushing | Duty Cycle, Force?, Angle |

Infusion Pump



| Test | Accelerant |
|--|---|
| Battery Charging | Duty Cycle, Deep Discharge, Speed of Charge |
| Touchscreen | Duty Cycle, Location, Force? |
| Pumping | Duty Cycle, Rate, Plunger Force |
| Connectors – Battery, Charger, Pole Clamp, IV Line, Cassette | Duty Cycle, Force, Angle |

Drawer for Medical Cabinet



| Test | Accelerant |
|---------------------------|----------------------------------|
| Opening/Closing of Drawer | Duty Cycle, Force, Angle |
| Locking Mechanism | Duty Cycle, Force, Contamination |

Summary

- **When wearout is *not* a dominant failure mechanism, *HALT* is an excellent tool for finding product weaknesses in a short period of time.**

Summary

- **When wearout *is* a dominant failure mechanism, we must be able to predict or characterize this wearout mechanism to assure that it occurs outside customer expectations and outside the warranty period.**
- ***ALT* is an excellent method for doing this**

Ops A La Carte Services

Reliability Integration in the Concept Phase

1. **Benchmarking**
2. **Gap Analysis**
3. **Reliability Program and Integration Plan Development**

Reliability Integration in the Design Phase

1. **Reliability Modeling and Predictions**
2. **Derating Analysis/Component Selection**
3. **Tolerance/Worst Case Analysis/Design of Experiments**
4. **Risk Management / Failure Modes, Effects, & Criticality Analysis (FMECA)**
5. **Fault Tree Analysis (FTA)**
6. **Human Factors/Maintainability/Preventive Maintenance Analysis**
7. **Software Reliability**

Ops A La Carte Services, continued

Reliability Integration in the Prototype Phase

1. **Reliability Test Plan Development**
2. **Highly Accelerated Life Testing (HALT)**
3. **Design Verification Testing (DVT)**
4. **Reliability Demonstration Testing**
5. **Failure Analysis Process Setup**

Reliability Integration in the Manufacturing Phase

1. **Highly Accelerated Stress Screening (HASS)**
2. **On-Going Reliability Testing**
3. **Repair Depot Setup**
4. **Field Failure Tracking System Setup**
5. **Reliability Performance Reporting**
6. **End-of-Life Assessment**

Ops A La Carte Services, continued

Reliability Training/Seminars

1. Reliability Tools and Integration for Overall Reliability Programs
2. Reliability Tools and Integration in the Concept Phase
3. Reliability Tools and Integration in the Design Phase
4. Reliability Tools and Integration in the Prototype Phase
5. Reliability Tools and Integration in the Manufacturing Phase
6. Reliability Techniques for Beginners
7. Reliability Statistics
8. FMECA
9. Certified Reliability Engineer (CRE) Preparation Course for ASQ
10. Certified Quality Engineer (CQE) Preparation Course for ASQ

Presentation Summary

WHAT ARE YOUR QUESTIONS ?

Further Education

For a more In-depth view of this topic and more, we will be teaching at:

- April 26th: “The Value of Warranty Data” (free webinar). Email us at freewebinar@opsalacarte.com for more details. Tape transcript is available.
- May 18th-20th: Applied Reliability Symposium, San Diego
Ops A La Carte is a proud sponsor of the 2005 ARS at the Catamaran Resort on Mission Bay in San Diego, CA.
In addition to sponsoring, we shall be giving a presentation on “Reliability Integration Across the Product Life Cycle”
- August 16th through October 4th, 2005: “Certified Reliability Engineer (CRE) Preparation Course” to prepare for taking the ASQ CRE Exam

In addition, we will be teaching two seminars out of country:

- May 12th: Transitioning from HALT to HASS to HASA, Seoul Korea
- July 28-29: Reliability Integration in Manufacturing, South Africa

Go to www.opsalacarte.com/pages/news/news_events.htm for more details

For more information...

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