# RELIABILITY TOOLS AND INTEGRATION in the Manufacturing Phase

for


by

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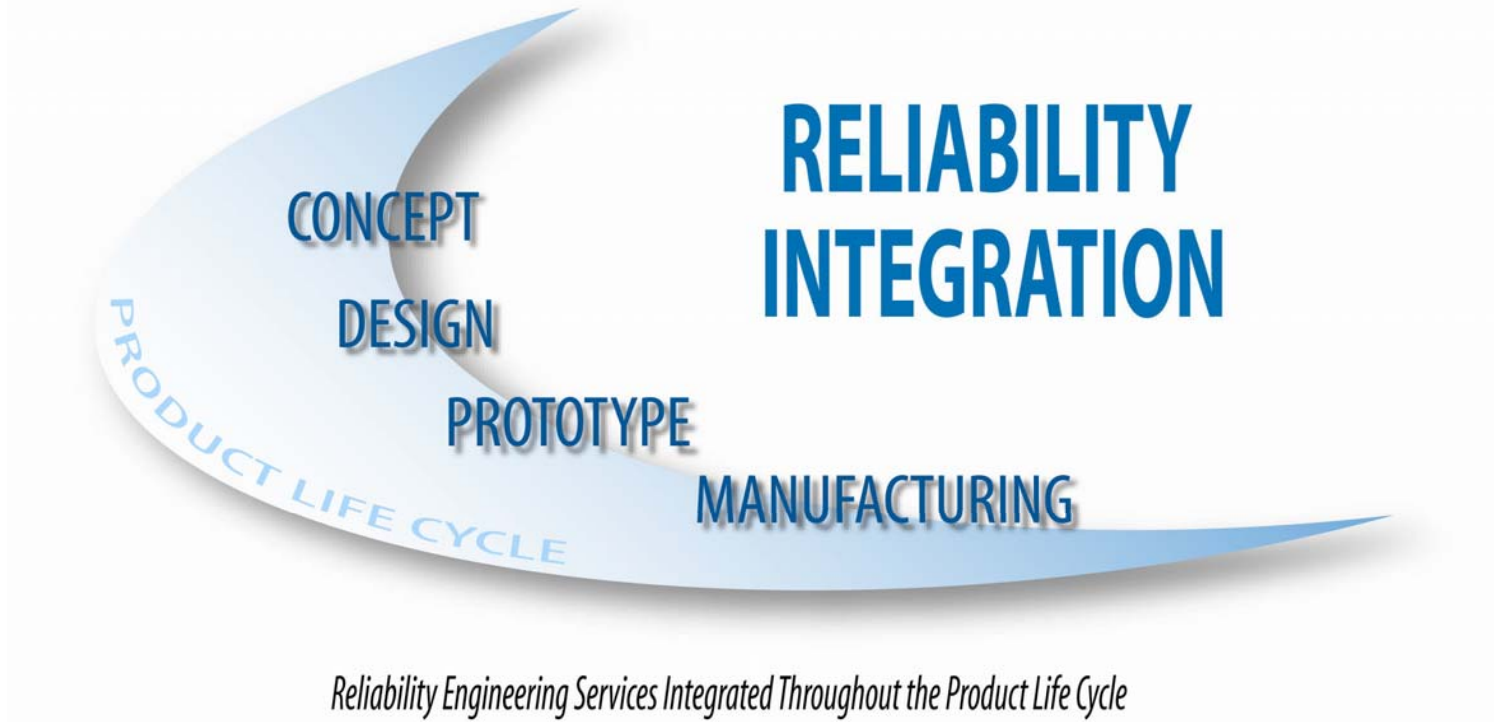
# Presenter Biography

Mike is founder and managing partner at Ops A La Carte, a Professional Consulting Company that has in 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 125 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 an officer in the IEEE Reliability Society for Silicon Valley.




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.

# Ops A La Carte Services

## Reliability Integration in the Concept Phase

1. Reliability Goal Setting
2. Review of Current Capabilities
3. Gap Analysis
4. Reliability Program and Integration Plan Development

## Reliability Integration in the Design Phase

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

# Ops A La Carte Services, continued

## Reliability Integration in the Prototype Phase

1. Highly Accelerated Life Testing (HALT)
2. Failure Reporting, Analysis, and Corrective Action System (FRACAS)
3. Reliability Demonstration Testing

## Reliability Integration in the Manufacturing Phase

1. Highly Accelerated Stress Screening (HASS)
2. Highly Accelerated Stress Auditing (HASA)
3. On-Going Reliability Testing
4. Repair Depot Setup
5. Field Failure Tracking System Setup
6. Reliability Performance Reporting
7. 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

# RELIABILITY INTEGRATION

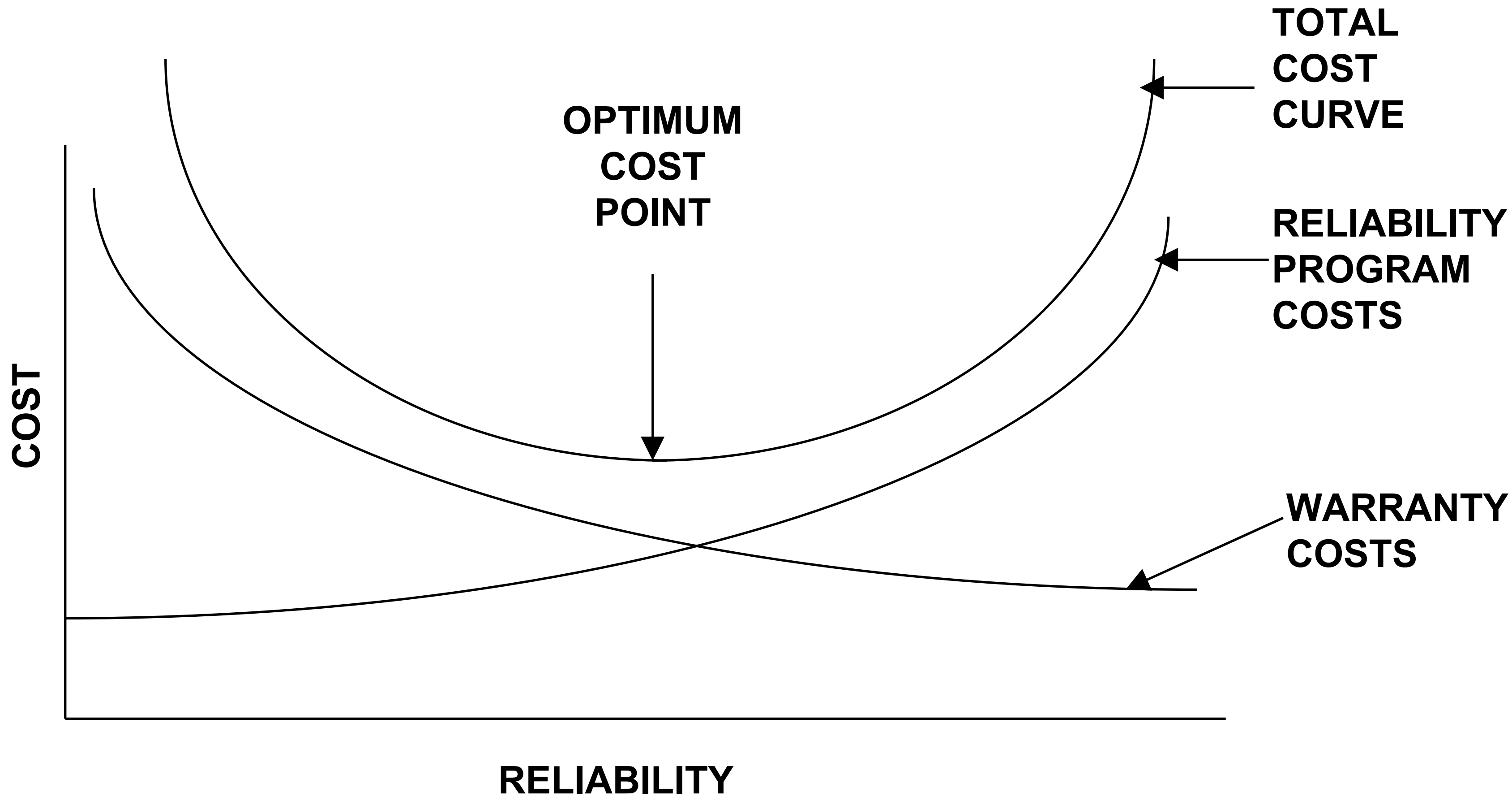
***"the process of seamlessly and cohesively integrating reliability tools together to maximize reliability at the lowest possible cost"***

# 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).

CRE Primer by QCI, 1998

# Reliability vs. Cost, continued



# Reliability vs. Cost, continued

**In order to minimize total Life Cycle Costs (LCC),**

**a Reliability Engineer 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.**

# Reliability vs. Cost, continued

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 *HASS***

# HALT and HASS Summary

- Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS) are two of the best reliability tools developed to date, and every year engineers are turning to HALT and HASS to help them achieve high reliability.

# HALT and HASS Summary, continued

- 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.
- 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.

# HALT and HASS Summary, continued

This presentation shall review the best reliability tools to use *in the Manufacturing Phase* in conjunction with HALT and HASS and how to integrate them together.

# RELIABILITY INTEGRATION TOOLS

# Reliability Integration Tools - Summary

- **PHASE I: Concept Phase**
  - Reliability Integration in the CONCEPT Phase - Tools that are used in the concept phase of a project in order to define the reliability of a program. Benchmarking is usually required. The output of this phase is the Reliability Program and Integration Plan. This plan will specify which tools to use and the goals and specifications of each. This is the plan that drives the rest of the program.

# Reliability Integration Tools - Summary

- **PHASE II: Design Phase**
  - Reliability Integration in the DESIGN Phase - Tools that are used in the design phase of a project after the reliability has been defined. Predictions and other forms of reliability analysis are performed here. These tools will only have an impact on the design if they are done very early in the design process.

# Reliability Integration Tools - Summary

- **Phase III: Prototype Phase**
  - Reliability Integration in the PROTOTYPE Phase - Tools that are used after a working prototype has been developed. This represents the first time a product will be tested.

# Reliability Integration Tools - Summary

- **Phase IV: Manufacturing Phase**
  - Reliability Integration in the MANUFACTURING Phase - Tools here are a combination of analytical and test tools that are used in the manufacturing environment to continually assess the reliability of the product.

# RELIABILITY TOOLS AND INTEGRATION IN THE MANUFACTURING PHASE

# Reliability Tools and Integration in the MANUFACTURING Phase

- Highly Accelerated Stress Screening (HASS)
- Highly Accelerated Stress Auditing (HASA)
- On-Going Reliability Testing (ORT)
- Repair Depot Setup
- Field Failure Tracking System
- Reliability Performance Reporting
- End-of-Life Assessment

# HIGHLY ACCELERATED STRESS SCREENING (HASS)

# HASS - What Is It?

- Detect & correct *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 ones ability to discover process and component problems.

**HASS is not a test, it's a process. Each product has its own process.**

***But remember...***

***...before HASS can begin, we must first HALT !!***

# Before HASS, We Must Characterize Product with HALT

- **Before HASS, we must HALT**
  - Even for mature products in which HASS is the goal, HALT must be done first to characterize the product margins.

# Once HALT Is Complete...
# WE ARE READY FOR HASS

- Begin process during HALT stage (involve mfg)
- HASS development
- Production HASS

# HASS Process Is Begun Early

- **Even <u>before</u> HALT is complete, we should**
  - determine production needs and throughput
  - start designing and building fixture
  - determine which stresses to apply
  - 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

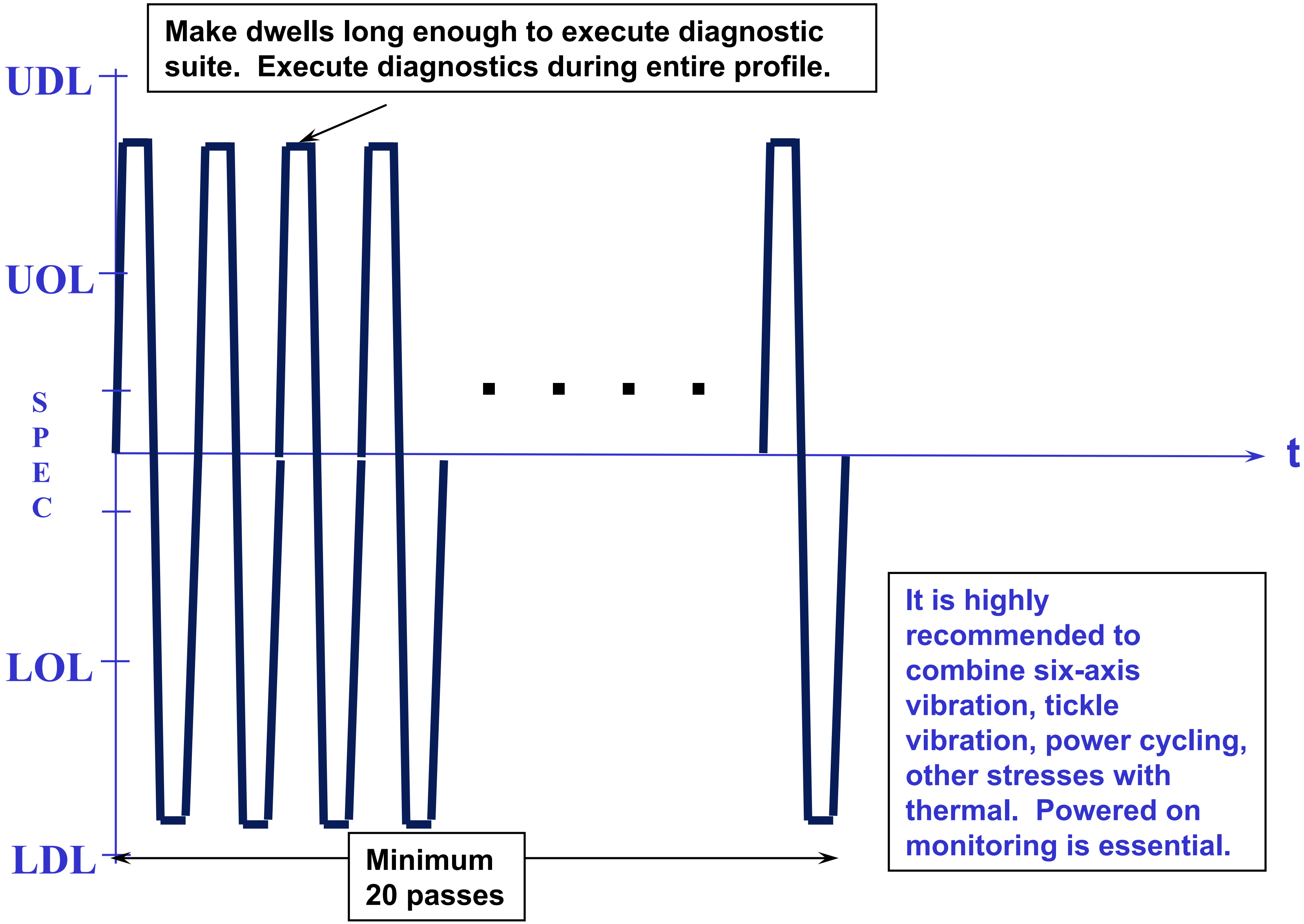
# HASS Process

- **<u>After</u> HALT is complete, we must**
  - assure Root Cause Analysis (RCA) completed on all failures uncovered
  - develop initial screen based on HALT results
  - map production fixture (thermal/vibration)
  - run proof-of-screen start designing and building fixture

# HASS Process, continued

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

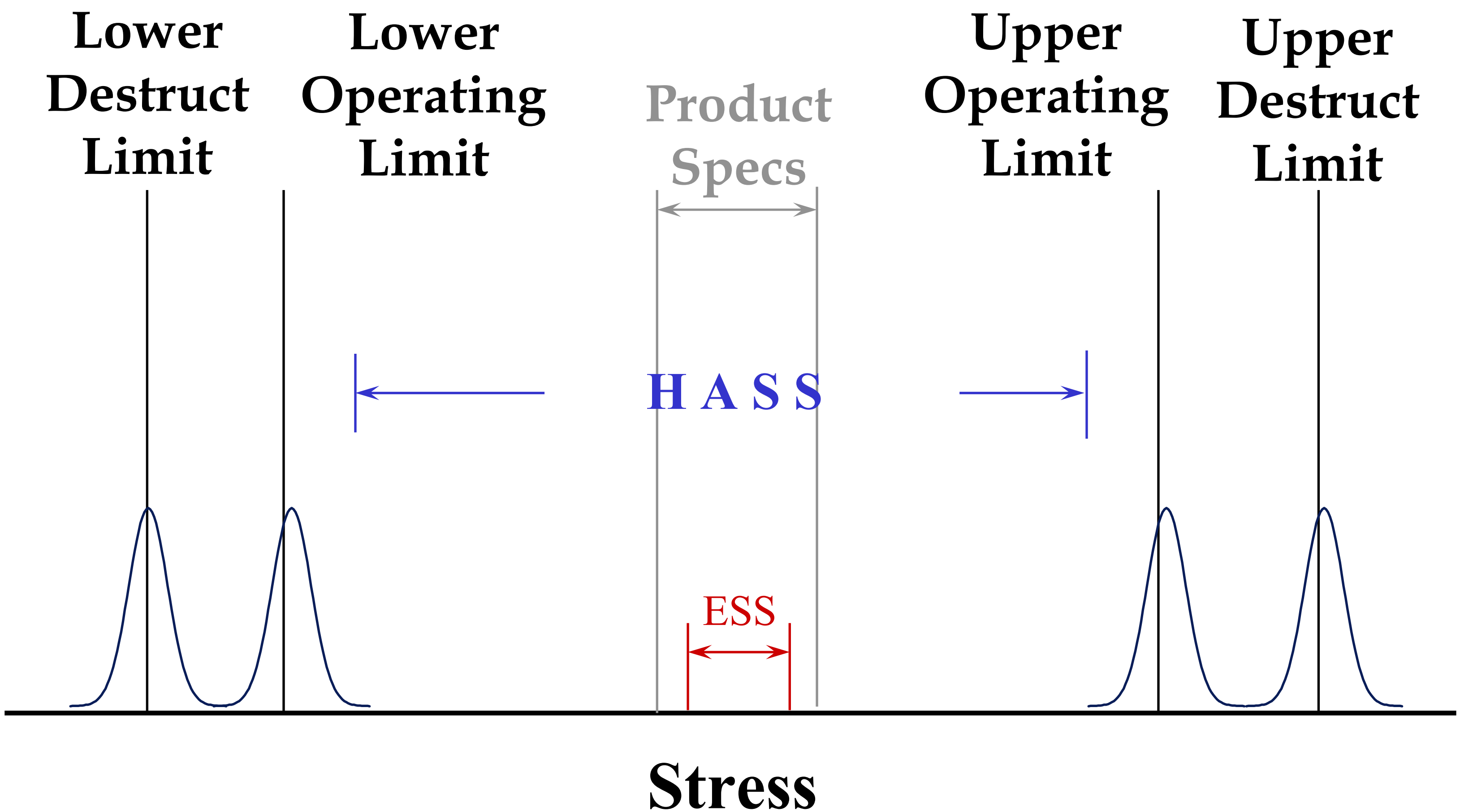
# Assuring the Screen Leaves Sufficient Life



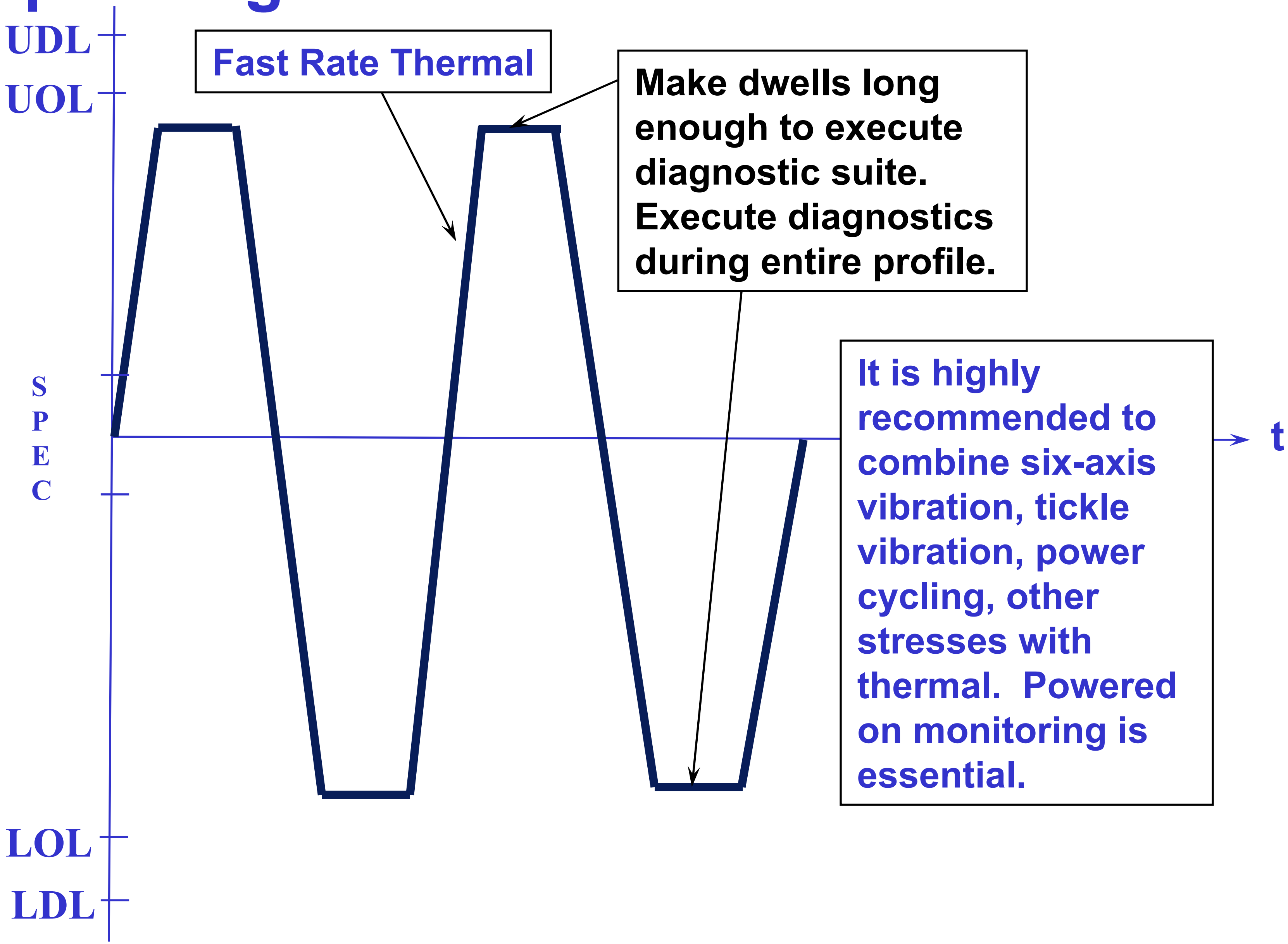
# Assuring the Screen Leaves Sufficient Life

- **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.

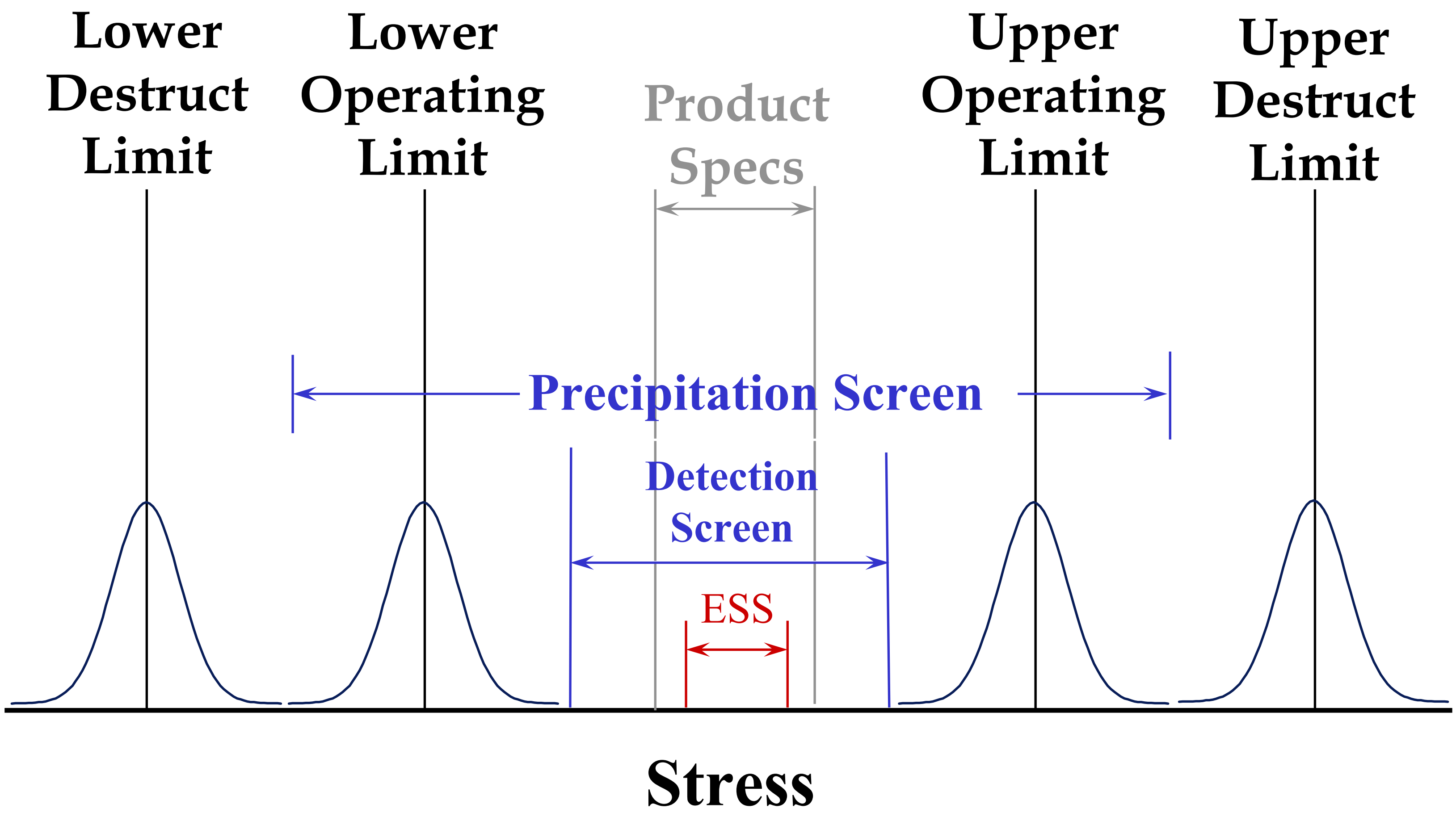
# HASS Process for Wide Operating Limits



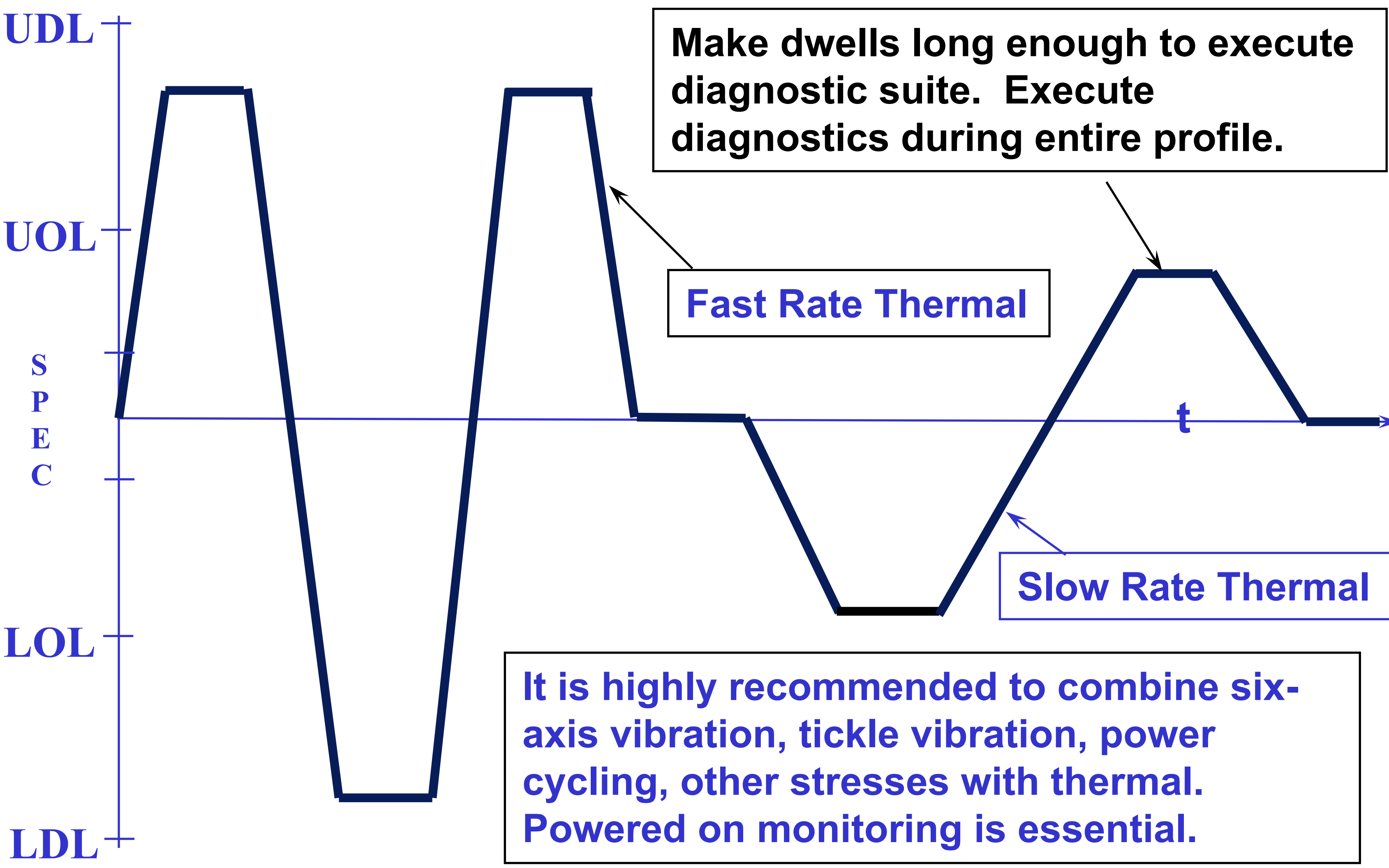
# The "Ideal" HASS Profile for wide operating limits



# HASS Process for Narrow Operating Limits



# The “Ideal” HASS Profile for narrow operating limits



# HASS Process Is Begun Early

- **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.

*It is essential that the product being tested be fully exercised and monitored for problem detection.*

# Typical HASS Failures

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

QualMark and Hobbs Seminar Notes, 1998

# HASS Advantages over "Burn-In"

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

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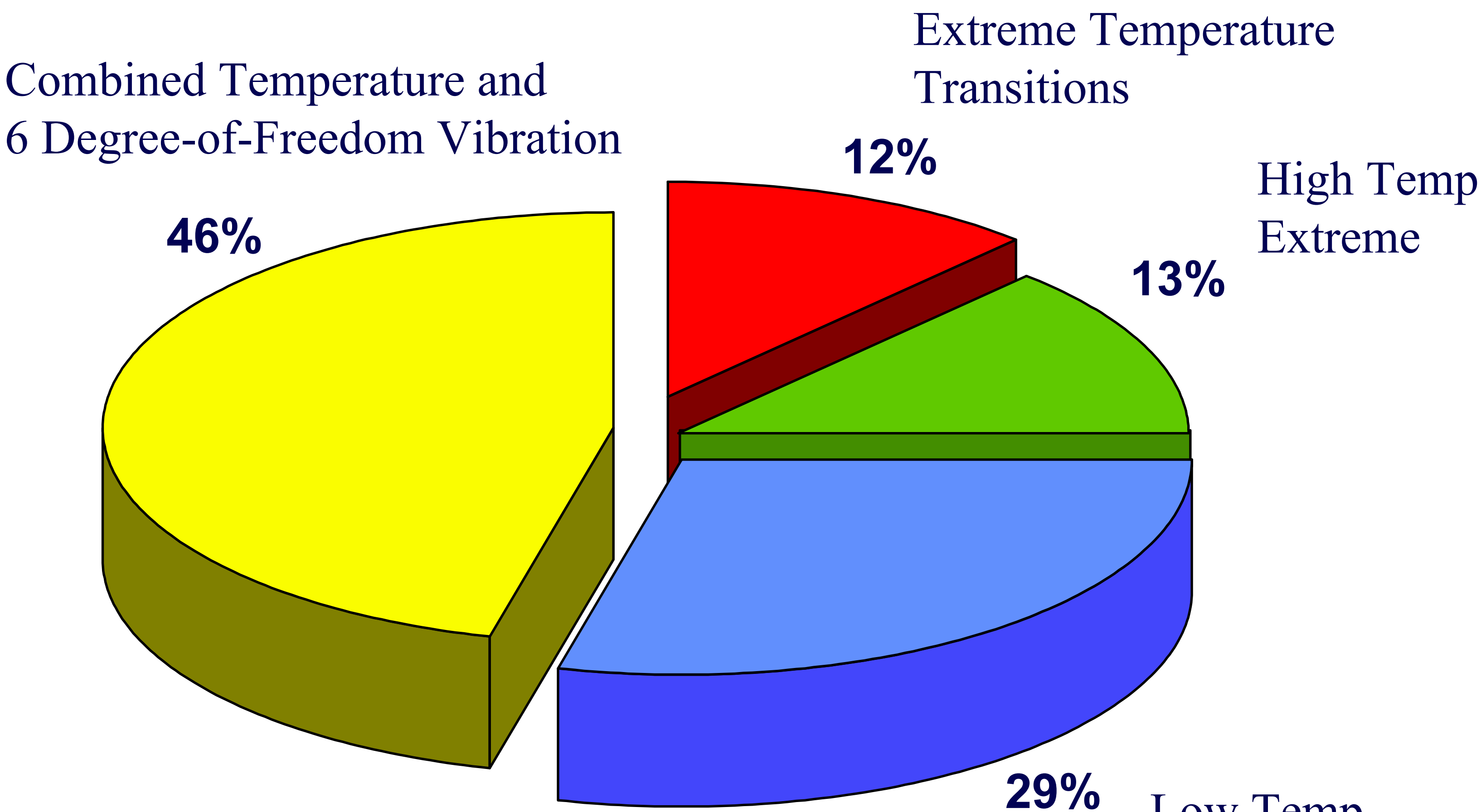
# HASS Defects by Environment




Data from Array Technology (1993).

QualMark and Hobbs Seminar Notes, 1998

# HASS – Implementation Requirements

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

QualMark and Hobbs Seminar Notes, 1998

# HASS Cost Benefits

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

QualMark and Hobbs Seminar Notes, 1998

# HASS: How to Use the Results of FMECA and a Reliability Prediction in Planning a HASS

- **How to use the results of FMECA and a Reliability Prediction in planning a HASS**
  - FMECA results can identify possible wearout mechanisms that need to be taken into account for HASS.
  - Reliability Prediction results can help determine how much screening is necessary.

# HASS: How to Use the Results of FMECA and a Reliability Prediction in Planning a HASS, continued

- **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 FMECA and a Reliability Prediction in Planning a HASS, continued

- **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 FMECA and a Reliability Prediction in Planning a HASS, continued

- **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.

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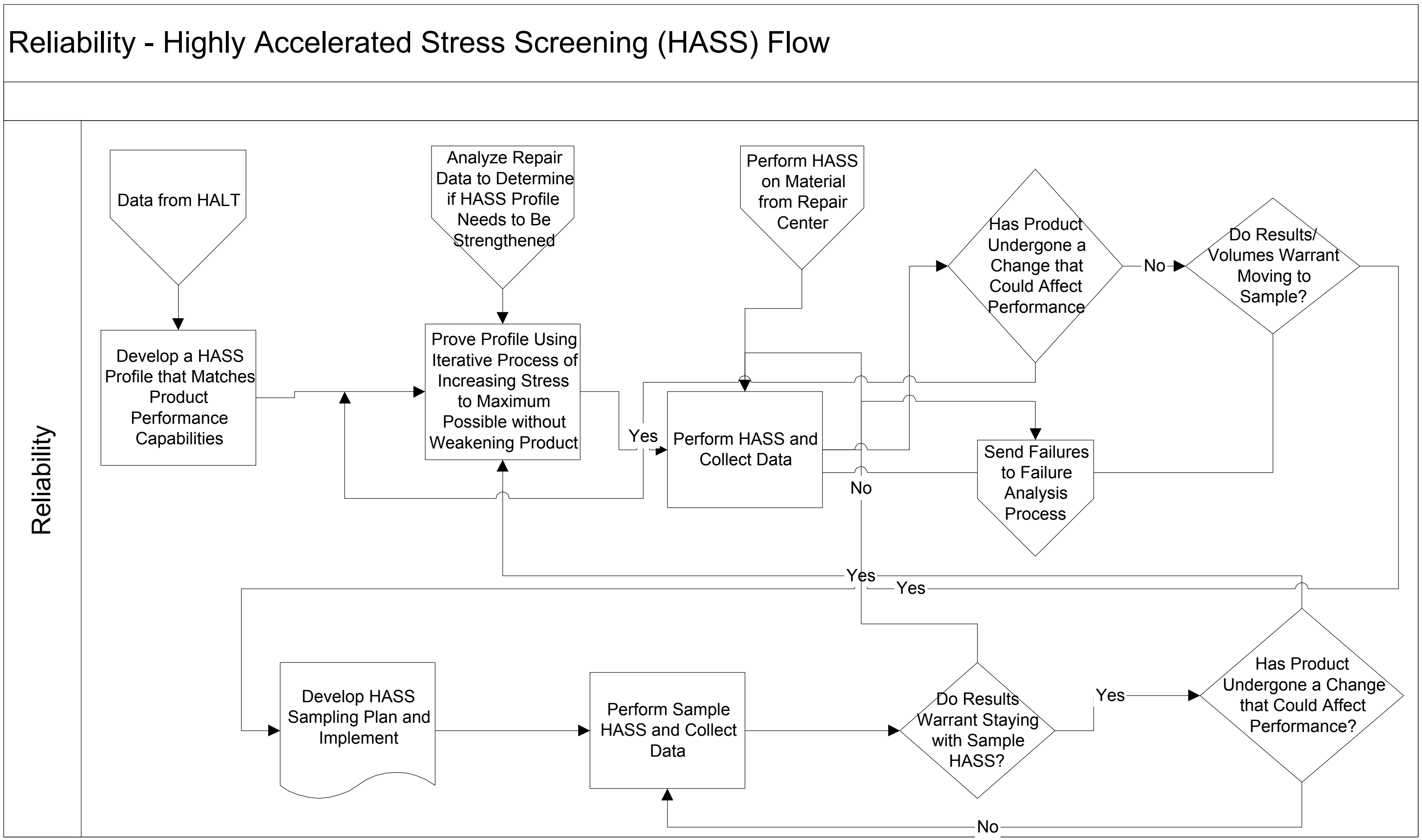
# HASS: Using the Results of HALT to Develop a HASS Profile

- **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: Linking the Repair Depot with HASS by Sending "NTF" hardware back through HASS

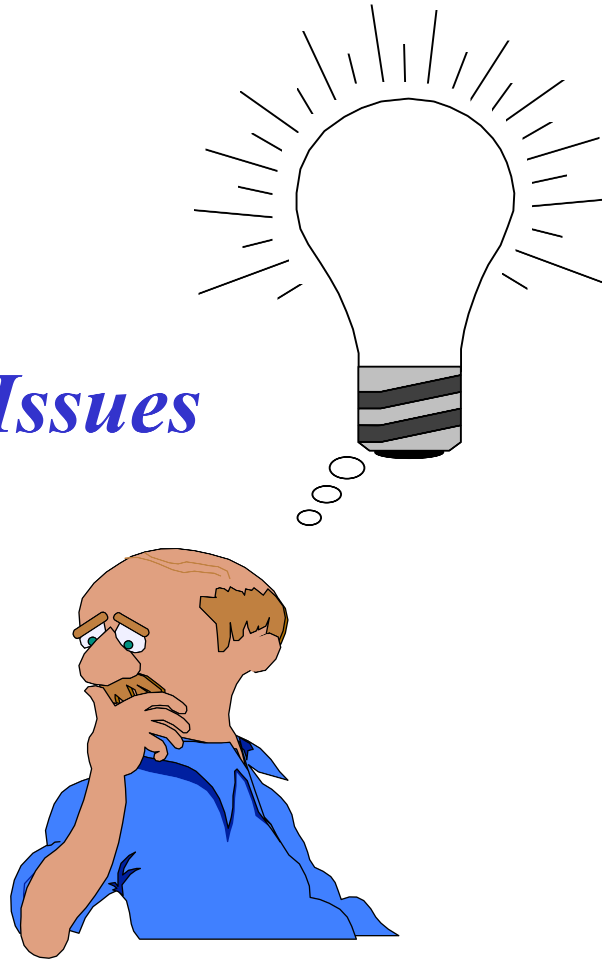
- During the repair process, we may identify a large number of "No Trouble Founds" or NTFs. HASS is the perfect vehicle for identifying if these NTFs are truly intermittent hardware problems or due to something else. Using HASS to assist with the "No Trouble Found (NTF)" issue at the Repair Depot.

# HASS Flow Chart



# HASS Dilemma

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



***HASA Solves All These Issues***

# HIGHLY ACCELERATED STRESS AUDITING (HASA)

# What is HASA

- HASA is a Highly Accelerated Stress Audit
- HASA is an effective audit process for manufacturing.

# HASA Advantages

- HASA combines the best screening tools with the best auditing tools.
- Better than ORT because it leverages off of HALT and HASS to apply a screen tailored to the product
- Better than HASS because it is much cheaper and easier to implement and "almost" as effective.

# Steps to HASA

- HALT
- HASS Development
- Pilot HASS
- HASA

# What is HASA

- HASA is an audit or sampling procedure
- HASA is intended for high volume applications in which the emphasis is not on catching every defect but rather detecting process shifts

# Advantage of switching from HASS to HASA?

- To achieve cost efficiency for High Volume production, reducing manpower, equipment, utilities, and space costs.

# Risks in switching from HASS to HASA?

- Some defective units will be shipped to the field.
- Corrective actions must be fast and accurate.

# Review of HASA

- **When can HASA be used?**
  - Design and processes are control
  - HASS failure rate has become acceptable
- **What is the advantage of a HASA program?**
  - Cost
- **What is the risk of a HASA**
  - Statistical confidence

# When should HASA be considered as an option?

**Only if:**

**HALT is completed**

**HASS Development is completed**

**HASS is successful**

# Is HALT Completed?

If so:

Design defects have been eliminated

Margins are known

Margins are large

Design is robust

# Is HASS Development completed?

**If so:**

**Screen is effective**

**Screen is safe**

# Is HASS implementation complete?

**If so:**

**Failure rates are acceptable**

**Manufacturing processes are under control**

# HASA Plan

**Goal is to catch shifts in processes**

1. Detect degradations in process quality control
2. Compare with pre-established thresholds
3. Empower Corrective Action Team

# 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

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# HASA Choices

**Acceptable risk of allowing a "bad lot" to ship**

**Probability of detecting a process shift of some amount**

SAMPLING PLAN

- **Sample Size**
- **Decision Limits**
- **Commitment to Action**

# HASA Summary

- For high volume production, HASA is the best process monitoring tool

# ON-GOING RELIABILITY TESTING (ORT)

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# On-Going Reliability Testing (ORT)

- **ORT is a process of taking a sample of products off a production line and testing them for a period of time, adding the cumulative test time to achieve a reliability target. The samples are rotated on a periodic basis to:**
  - get an on-going indication of the reliability
  - assure that the samples are not wearing too much (because after the ORT is complete, the samples are shipped).

# ORT vs RDT

- ORT is a very similar test to the Reliability Demonstration Test (RDT) except that the RDT is usually performed once just prior to release of the product, whereas the ORT is an on-going test rotating in samples from the manufacturing line.

- An ORT consists of a Planning stage and a Testing and Continual Monitoring stage. The inputs from the customer are the number of units allocated to the test, the duration that each set of units will be in the test before being cycled through, and the stress factors to be applied.

# ORT Parameters

- **Just as in a RDT, we must choose a goal, sample size, acceleration factors, and confidence.**
- **In addition, we must choose length of time each sample will be in ORT. Because these are shippable units, we cannot risk taking significant life out.**

# ORT Goal

- **The goal of an ORT is to:**
  - Ensure that the defined reliability specification, including the MTBF, are met throughout the manufacturing life of the product.
  - Verify that infant mortalities have been removed during the standard manufacturing process.

# ORT Goal, a closer look

- **The goal of an ORT is to:**
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    The answer is “yes”, but a better question is:

    Is this really the most effective method of doing this?

# ORT Goal, a closer look

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    Does it do this?

    The answer is yes, but a better question is:

    Is this really the most effective method of doing this?

    Probably Not. Wouldn't a HALT/RDT be much more effective? HALT will make the product more robust, and then RDT will measure the reliability after that. Then we perform periodic HALT's to assure the product remains robust.

# ORT Goal, a closer look

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  The answer is "NO, IT DOES NOT!"

  ORT is ineffective for process monitoring because

  a) ORT rarely finds problems because acceleration factors are typically not aggressive enough.

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    Does it do this?

    The answer is "NO, IT DOES NOT!"

    ORT is ineffective for process monitoring because

    a) ORT rarely finds problems because acceleration factors are typically not aggressive enough.

    b) when problems that are found, it may be weeks later and products from that lot have already shipped.

# Comparison Between ORT and HASA

- **ORT Benefits over HASA**
  - You can measure reliability at any given time
- **HASA Benefits over ORT**
  - Effective process monitoring tool due to ability to find failures and to timely corrective actions
  - Don’t need to measure on-going reliability because reliability measurement was already done once in RDT. Also, periodic HALT is a much better vehicle for continuously monitoring reliability over time after it has been baselined.

# ORT vs. HASA: Conclusion

| ORT = ☹ | HASA = ☺ |
| --- | --- |
| : ( | : ) |

# REPAIR DEPOT SETUP

# Repair Depot Setup

- **When setting up a Repair Depot, we must**
  - Integrate with HALT results
  - Integrate with HASS results
  - Set up to feed data to the Field Failure Tracking System

# Repair Depot Setup

- **Integrating the Repair Depot Center with HALT results**
  - If we find design issues in the field and we can duplicate these issues in the Repair Depot Center, we must feed them back into the HALT process.
  - Therefore, the Repair Depot must be set up to easily feed information back to the HALT process when issues like this arise.
  - The Corrective Action System is the perfect vehicle for linking these two together.

# Repair Depot Setup

- **Integrate the Repair Depot Center with HALT results**
  - Once the issue is fed back into the HALT process, we will review the type of failure and why HALT was not able to find the problem.
    - Under what conditions did the failure occur?
    - Was this something that HALT found but for which corrective action was not implemented?
    - Perhaps we stopped short of reaching the fundamental limit of technology.
    - Perhaps additional stresses are required.
  - This will then be used for future HALT's so that the process continually learns and adapts.

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# Repair Depot Setup

- **Integrate the Repair Depot Center with HASS results**
  - Once the issue is fed back into the HASS process, we will review the type of failure and why HASS was not able to find the problem.
    - Was the issue a DOA or did it occur into the life of the product? This will help determine why HASS did not catch.
    - Perhaps the screen limits need to be adjusted.
    - Perhaps additional stresses are required.
  - This information will then be used for future HASS'es so that the process continually learns and adapts.

# Repair Depot Setup

- **Set up the Repair Depot System to feed data to the Field Failure Tracking System**
  - The Repair Depot Center retests products returned from the field to confirm failures and determine root cause.
  - The confirmation is then fed back to the Field Failure Tracking System so that it can be properly categorized for reliability data reporting.

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# FIELD FAILURE TRACKING SYSTEM

# Field Failure Tracking System

- **When setting up a Field Failure Tracking System, we must**
  - Integrate with sales support and customer service to assure data integrity
  - Set up to easily collect data to calculate Field MTBF
  - Integrate with the Repair Depot to assure issues are fed into the Corrective Action System

# Field Failure Tracking System

- **Setting up the Field Failure Tracking System to integrate with sales support and customer service to assure data integrity**
  - Data Integrity is key to a good Field Failure Tracking System. We must be able to accurately determine
    - Date product was put into service
    - Date of failure
    - Circumstances around failure and solution

# Field Failure Tracking System

- **Data Integrity – Date product was put into service**
  - This is not the same as the date of shipment
  - Often we have an "adder" to the ship date (e.g. ship date + 30 days) but we must verify this is accurate
    - Sales support will help define this since they know the customer installation process best
  - From this we need to be able to accurately determine DOAs from products that failed soon after installation.
  - We need to come up with "Definition of DOA", or how many days after installation is a failure considered a DOA.

# Field Failure Tracking System

- **Data Integrity – Date of failure**
  - The failure date is equally as critical and not always easy to determine because the customer sometimes only indicates the date the product was returned and not the date it failed
    - Customer service can help work with the customers to assure that we get accurate information here

# Field Failure Tracking System

- **Data Integrity – Circumstances around failure and solution**
  - The key to each field issue is the actual failure itself and how it was solved.
  - Tags on product with failure information is essential
  - RMA numbers should also be on these tags and these RMA numbers should tie back to database
  - The database should be linked to the Field Failure Tracking Database so that all of the circumstances around the failure are known before trying to repair.
    - Often we will find that the true problem was identified after hardware was returned
    - Sometimes numerous pieces of hardware are pulled to solve a single problem – "Shotgunning"

# Field Failure Tracking System

- **Set up to easily collect data to calculate Field MTBF**
  - Once we have assured data integrity, then we can use the Field Failure Tracking System to calculate reliability of the product on-going, including
    - DOA rates
    - MTBF
    - Warranty returns
    - End-of-Life Issues (see EOL Assessment for more details)

# Field Failure Tracking System

- **Set up to easily collect data to calculate Field MTBF**
  - All of these reliability calculations can be presented using
    - total over time
    - point estimates
    - rolling averages
      - 3 month rolling average
      - 12 month rolling average

# Field Failure Tracking System

- **Set up to easily collect data to calculate Field MTBF**
  - Rolling averages are typically the best because
    - they show the reliability trend
    - they make for an easy comparison from the time a product starts shipping to present to show reliability growth
    - they can show effectiveness of a corrective action by comparing from the time a failure is discovered to after a corrective action has been implemented.

# Field Failure Tracking System

- **Integrating the Field Failure Tracking System with the Repair Depot Center**
  - Failed products from the field are returned to the Repair Depot Center for confirm and to determine root cause.
  - The confirmation is then fed back to the Field Failure Tracking System so that it can be properly categorized for reliability data reporting.

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# RELIABILITY PERFORMANCE REPORTING

# Reliability Performance Reporting

- Reliability Performance Reporting essentially is the "report card" against the Reliability Program and Integration Plan
- Let's quickly review the Reliability Program and Integration Plan to better understand how to set up a Reliability Performance Report.

# A Review of the Reliability Program Plan

- **A Reliability Program and Integration Plan is crucial at the beginning of the product life cycle because in this plan, we define:**
  - What are the overall goals of the product and of each assembly that makes up the product ?
  - What has been the past performance of the product ?
  - What is the size of the <u>gap</u> ?
  - What reliability elements/tools will be used ?
  - How will each tool be implemented and integrated to achieve the goals ?
  - What is our schedule for meeting these goals ?

# Reliability Performance Reporting

- **Reliability Performance Reporting in its simplest form is just reporting back how we are doing against our plan. In this report, we must capture**
  - how we are doing against our goals and against our schedule to meet our goals ?
  - how well we are integrating each tool together ?
  - what modifications we may need to make to our plan ?
- **In the report, we can also add information on specific issues, progress on failure analyses, and paretos and trend charts**

# Reliability Performance Reporting

- **How we are doing against our goals and against our schedule to meet our goals ?**
  - After collecting the field data, we then compare with our goals and estimate how we are doing.
  - If we are achieving a specific goal element, we explain what pieces are working and the steps we are going to take to assure that this continues
  - If we are not achieving a specific goal element, we must understand what contributed to this and what steps we are going to take to change this
    - As part of this, we must understand the major contributors to each goal element through trend plotting and failure analyses

# Reliability Performance Reporting

- **How well we are integrating each tool together ?**
  - As part of an understanding the effectiveness of our reliability program, we must look at the overall program
  - For example, if we stated in the plan that we were going to use the results of the prediction as input to HALT, we must describe here how we accomplished this
    - This can help explain the effectiveness of the HALT so that its results can be repeated
    - This can help explain how the HALT can be more effective in future programs if we overlooked or skipped some of the integration
    - This will serve as documentation for future programs

# Reliability Performance Reporting

- **What modifications we may need to make to our plan ?**
  - Occasionally, we may need to modify the plan
    - Goals may change due to new customer/marketing requirements
    - We may have discovered new tools or new approaches to using existing tools based on research
    - We may have developed new methods of integration based on experimentation and research
    - Schedule may have changed

# Reliability Performance Reporting

- **What modifications we may need to make to our plan ?**
  - If this occurs, we need to
    - Re-write the plan
    - Summarize the changes in our Reliability Performance Report so that we can accurately capture these new elements going forward

# END-OF-LIFE ASSESSMENT

# End-of-Life (EOL) Assessment

- **We Perform End-of-Life Assessments to**
  - Determine when a product is starting to wear out in case product needs to be discontinued
  - Monitor preventive maintenance strategy and modify as needed
  - Monitor spares requirements to determine if a change in allocation is necessary
  - Tie back to End-of-Life Analysis done in the Design Phase to determine accuracy of analysis

# End-of-Life (EOL) Assessment

- **Determining when a product is starting to wear out in case product needs to be discontinued**
  - In most market segments, customers don't expect products to last forever and would gladly replace if technological advances dictate it
  - Therefore, discontinuing a product and offering an upgrade/replacement is common
  - If we can calculate when a product is starting to reach end-of-life, this will help provide the cost justification for both us and our customer

# End-of-Life (EOL) Assessment

- **Monitor preventive maintenance strategy and modify as needed**
  - If we decide to continue supporting the product, we may determine our preventive maintenance strategy needs to be modified
    - Perhaps we didn’t anticipate a wearout mechanism that now needs to be dealt with
    - Perhaps we estimated incorrectly the length of time before wearout would begin

# End-of-Life (EOL) Assessment

- **Monitor spares requirements to determine if a change in allocation is necessary**
  - Our spares allocation is partly based on our initial Reliability Prediction and End-of-Life (EOL) Analysis.
  - If our EOL Assessment is showing something that we did not predict in our EOL Analysis, then our spares allocation will need to be adjusted as a result.

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# End-of-Life (EOL) Assessment

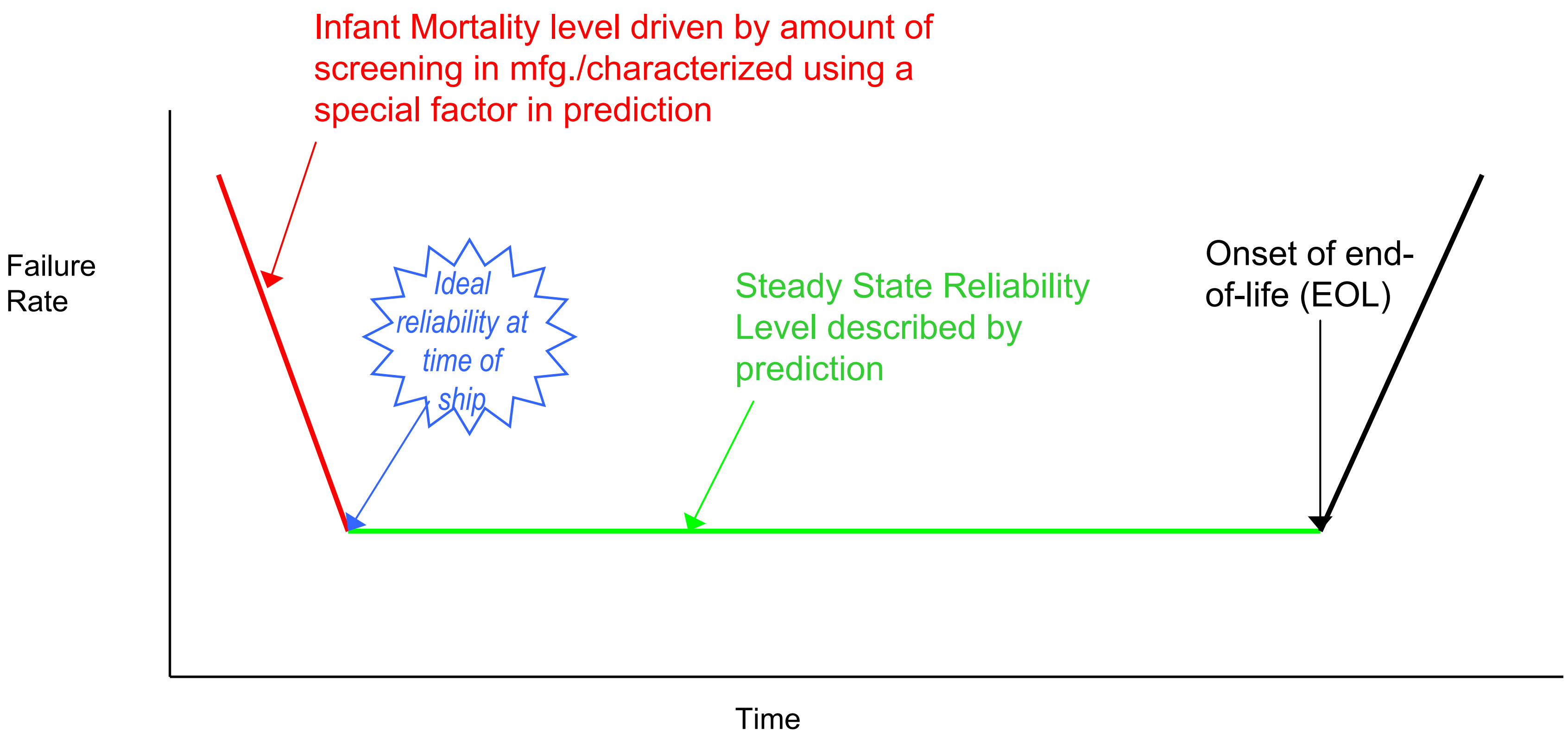
- **Tie back to End-of-Life Analysis done in the Design Phase to determine accuracy of analysis**
  - For future programs, this comparison between EOL analysis and EOL assessment is critical to understand how to modify.
  - In some cases, our EOL analysis may differ because of analytical techniques. If this is the case, we can develop an adjustment factor between EOL analysis and EOL assessment and carry forward to new programs.

# End-of-Life (EOL) Assessment

- **So now that we understand how to use EOL Assessments, how to we actually perform one ?**
  - An EOL Assessment uses Weibull-plotting techniques to determine where on the “bathtub” curve we are

# End-of-Life (EOL) Assessment

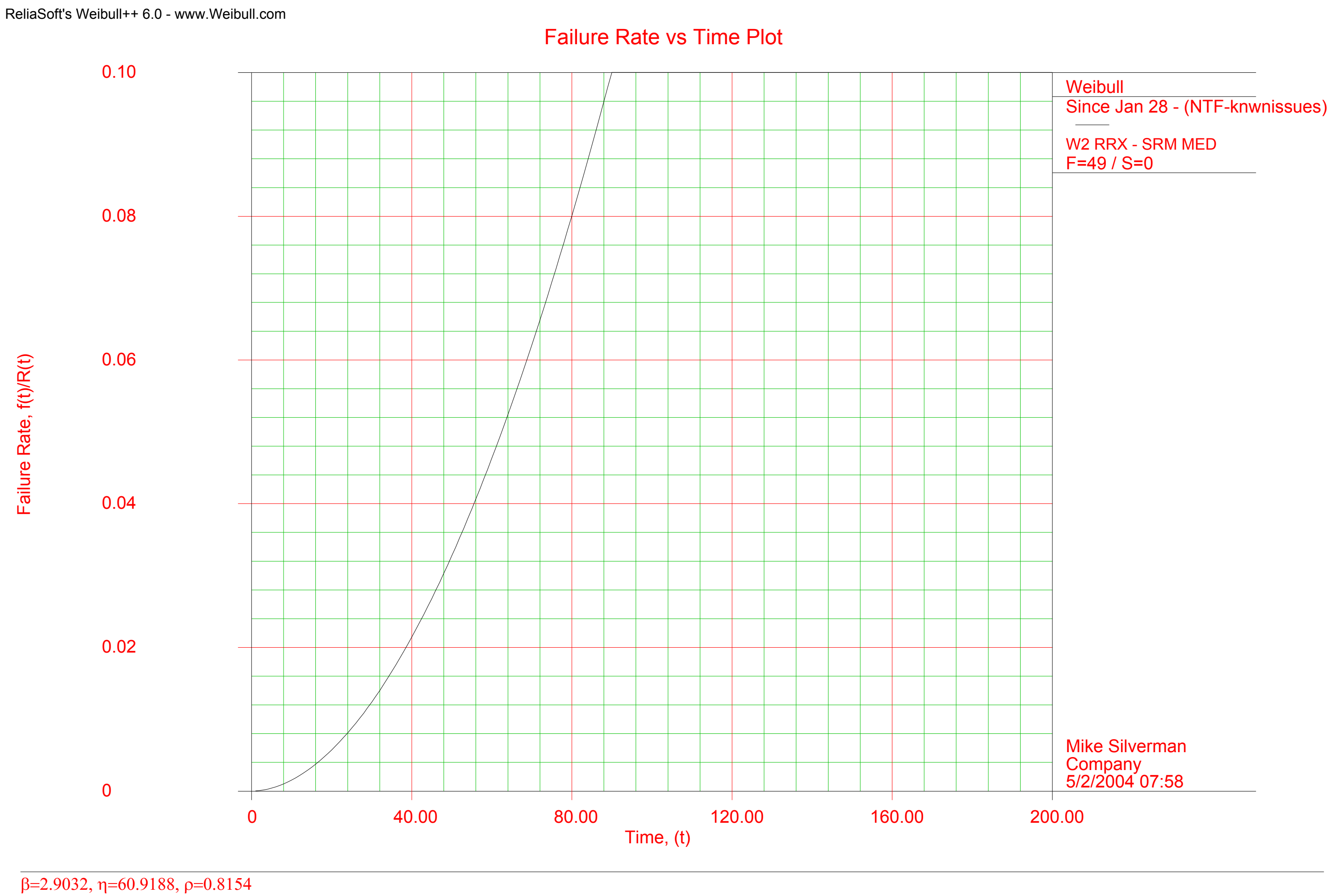
- A review of the "bathtub" curve



# End-of-Life (EOL) Assessment

- **To figure out where we are, we plot the field data**
  - We must "scrub" the data to
    - accurately determine the number of days in use before failure
    - properly categorize the failure
  - We must be careful and plot data by assembly type, especially if different assemblies have different wearout mechanisms. Otherwise, it will be impossible to determine a pattern

# End-of-Life (EOL) Assessment



# Presentation Summary

- This seminar has given you an overview of many of the tools we use in the manufacturing phase of a product life cycle.
- This seminar has shown how to integrate tools in the manufacturing phase together and with tools from other phases.
- This seminar has shown how to collect and present reliability data and how to link to the Reliability Program Plan.
- This seminar has shown the power of HASA over ORT.

# PRESENTATION SUMMARY

# Presentation Summary

ANY QUESTIONS ?

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# Further Education

- For a more In-depth view of this topic and more, Mike will be teaching at:
  - Oct 5th: "Mandated Pb-Free Solder Assemblies: Exploring the Transition's Impact on Product Reliability" sponsored by IEEE, Ops A La Carte, and QualMark.
  - Oct 12th – Nov 30th: "Certified Quality Engineer (CQE) Preparation Course" to prepare for taking the ASQ CQE Exam
  - Oct 28th and 29th: "Reliability Analysis Tools: A look at the best reliability tools being used"
  - January, 2005: "Certified Reliability Engineer (CRE) Preparation Course" to prepare for taking the ASQ CRE Exam

# For more information...

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