Speaker's Biography

- Neill Doertenbach
- Senior Applications Engineer
- Qualmark Corporation
- Presented at ASTR last year
- Publications include:
  - The Calculation of gRMS
  - Highly Accelerated Life Testing – Testing With A Different Purpose
  - Understanding Repetitive Shock Vibration
  - A Comparison of HALT Results in 1996 and 2008
  - HALT on OEM Supplied Subassemblies

Improving Production Screening by Moving From Mil Hdbk 2164A ESS to HASS

Using the Best Tools for Reliability Improvement of Today's Electronic Assemblies

Neill Doertenbach

Mil Hdbk 2164A ESS Guidelines: An Overview

- Mil Std 2164 created in 1985
- Defines the structure and components of an effective ESS program
- Includes the thermal and vibration stresses to use during ESS
- Presented as a guideline only, not a requirement
- Later revised to Mil-Hdbk-2164, then Mil-Hdbk-2164A

MIL-HDBK-2164A

NOT MEASUREMENT SENSITIVE

MIL-HDBK-2164A
19 June 1996
SUPERSEDING
MIL-HDBK-2164(SH)
16 January 1996

DEPARTMENT OF DEFENSE HANDBOOK

ENVIRONMENTAL STRESS SCREENING PROCESS FOR ELECTRONIC EQUIPMENT

THIS HANDBOOK IS FOR GUIDANCE ONLY. DO NOT CITE THIS DOCUMENT AS A REQUIREMENT.

Mil Hdbk 2164A ESS Guidelines: An Overview

- States that the operating thermal limits for the ESS should be set at the thermal specs of the product
  - Thermal stress should cycle at ramp rates of at least 10°C per minute
  - A minimum of 80 hours of thermal cycling is recommended, up to 120 hours
- Vibration profile is the well-known NAVMAT profile
  - A total of 10 minutes of vibration is recommended, in two five minute bursts

Purpose of 2164A

- Standard states:
  - "This handbook provides guidelines that will help in the Environmental Stress Screening (ESS) of electronic equipment so that latent defects may be located and eliminated before the equipment is accepted."
- There is no question it is critical that ESS fills this purpose to ensure product reliability in the field
- Stresses used in HASS more effectively meet this purpose versus 2164A methods

Screening Results Can Be Improved By Moving From 2164A to HASS

- Stress levels used in HASS are as high as they can safely be, increasing the likelihood that defective components will fail in the screen
- Vibration used in HASS is different, and more effective than NAVMAT
- Thermal stresses used in HASS shorten test time and are more effective
- The effects of each of these differences will be evaluated here

A Key Difference – The Method Of Determining Stress Levels

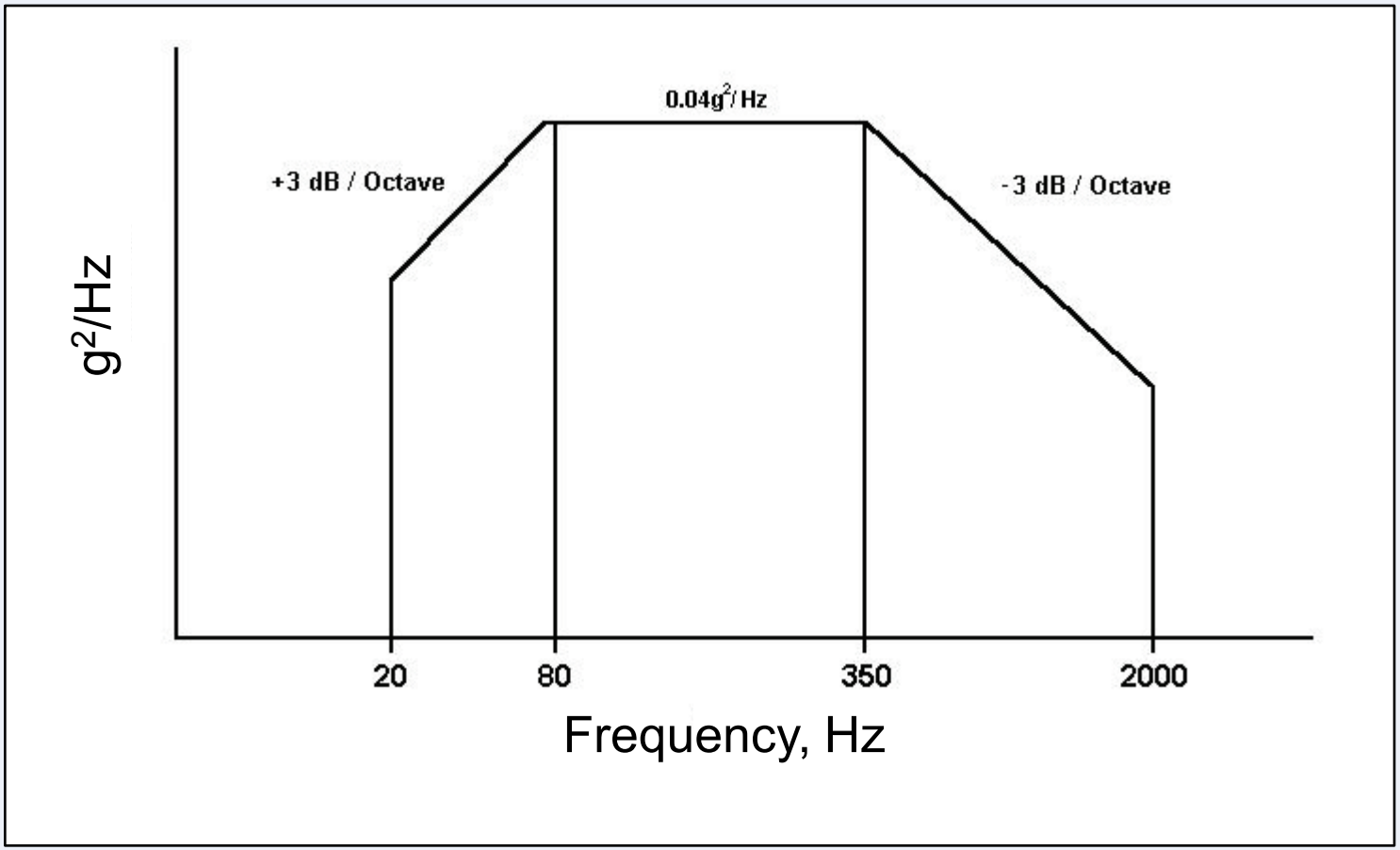
- 2164A:
  - Vibration stress levels are based on the levels defined in the NAVMAT profile
    - More on that later
  - Thermal limits based on product specifications
- HASS:
  - Vibration and thermal limits are based on HALT results, typically stressing beyond specification
  - Much more likely to drive out latent failures without damaging good product
    - HASS Proof of Screen is used to ensure this

Vibration In 2164A – The NAVMAT Profile

- Created in 1979 by Willis Willoughby of Grumman Aircraft[1]
- He was developing test spectra for Navy
- The purpose of the spectrum was to define optimum loading for equipment subjected to accelerated stress testing

[1]Henderson, G. and Burgess, W., *Comparing NAVMAT Versus 6DOF for HALT/HASS Testing*, COTS Journal, June 2009 (George Henderson, founder, President and CEO, GHI Systems, and William Burgess, Reliability Engineer, Leach International)

Vibration In 2164A – The NAVMAT Profile



20-80 Hz at 3 dB/Octave rise • 80-350 Hz at 0.04g2/Hz • 350-2,000 Hz at 3 dB/octave rolloff

Vibration In 2164A – The NAVMAT Profile

- Begins to drop off above 350 Hz, drops to 0 above 2000 Hz
- Vibration defined in only one axis, perpendicular to plane of major subassemblies
- Specification hasn't changed since 1979, technology has - *(Where were YOU in 1979?)*
  - Massive, leaded components
  - SMT
  - BGA
  - Lead-free solder

Comparing NAVMAT with Repetitive Shock HASS Vibration

- The purpose of the vibration is to fatigue the product so that weak areas fail
- Fatigue occurs when the resonant frequencies of the components and subassemblies in the product are excited
- Smaller assemblies, boards and components mean higher resonant frequencies
- RS vibration does a better job at exciting these higher frequencies

Comparing NAVMAT with Repetitive Shock HASS Vibration

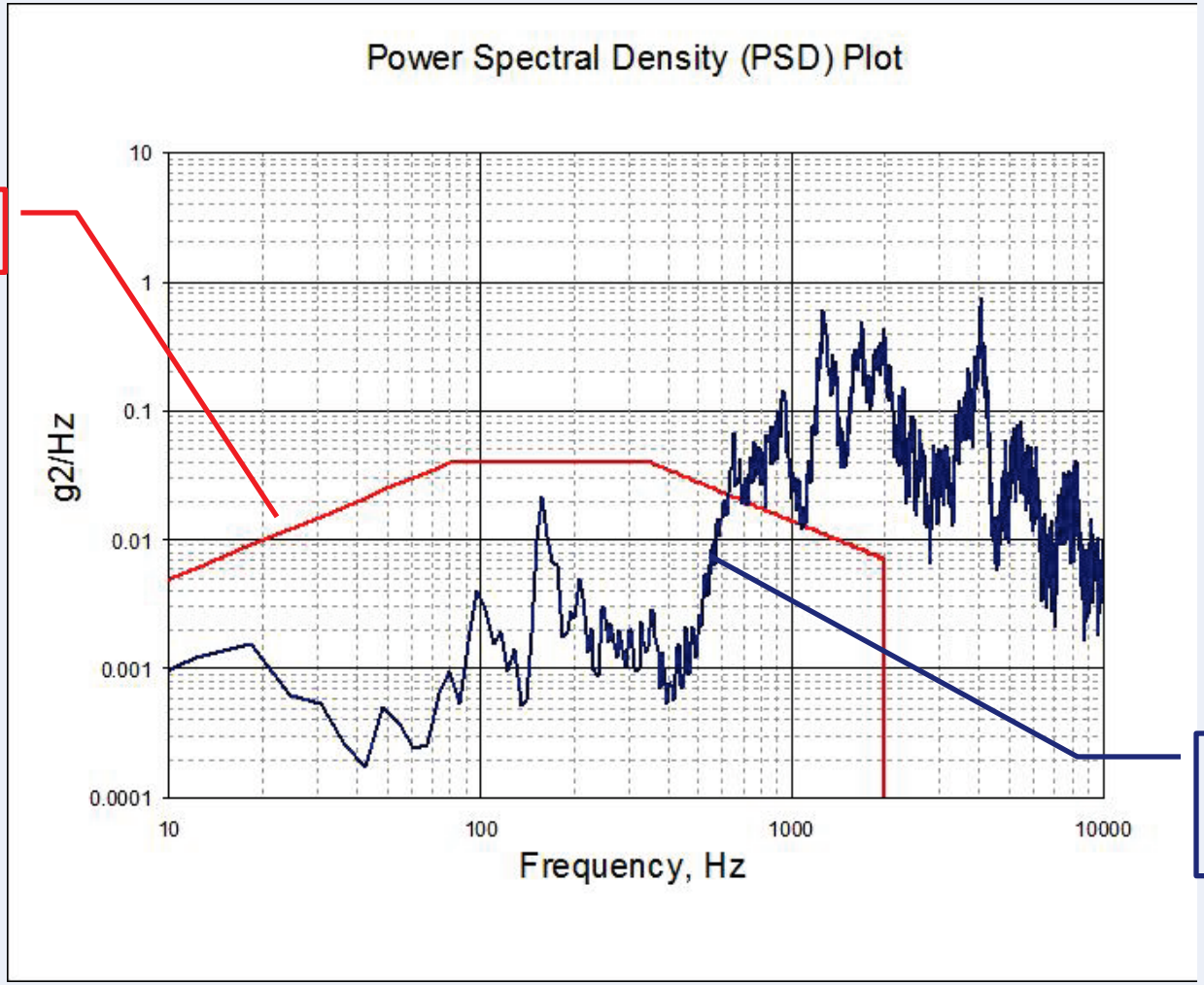
- More important than the input is the actual response of the components within the product
- The resonant characteristics of the upper level assembly shape the spectrum seen by the subassemblies
- This can make the fatigue induced in the subassemblies much less dependant on the spectrum of the input
- The response of the product is key

The NAVMAT Profile

Comparing NAVMAT with Repetitive Shock HASS Vibration

- 30” x 30” table size
- Board-level product (laptop motherboard)
- 2 locations

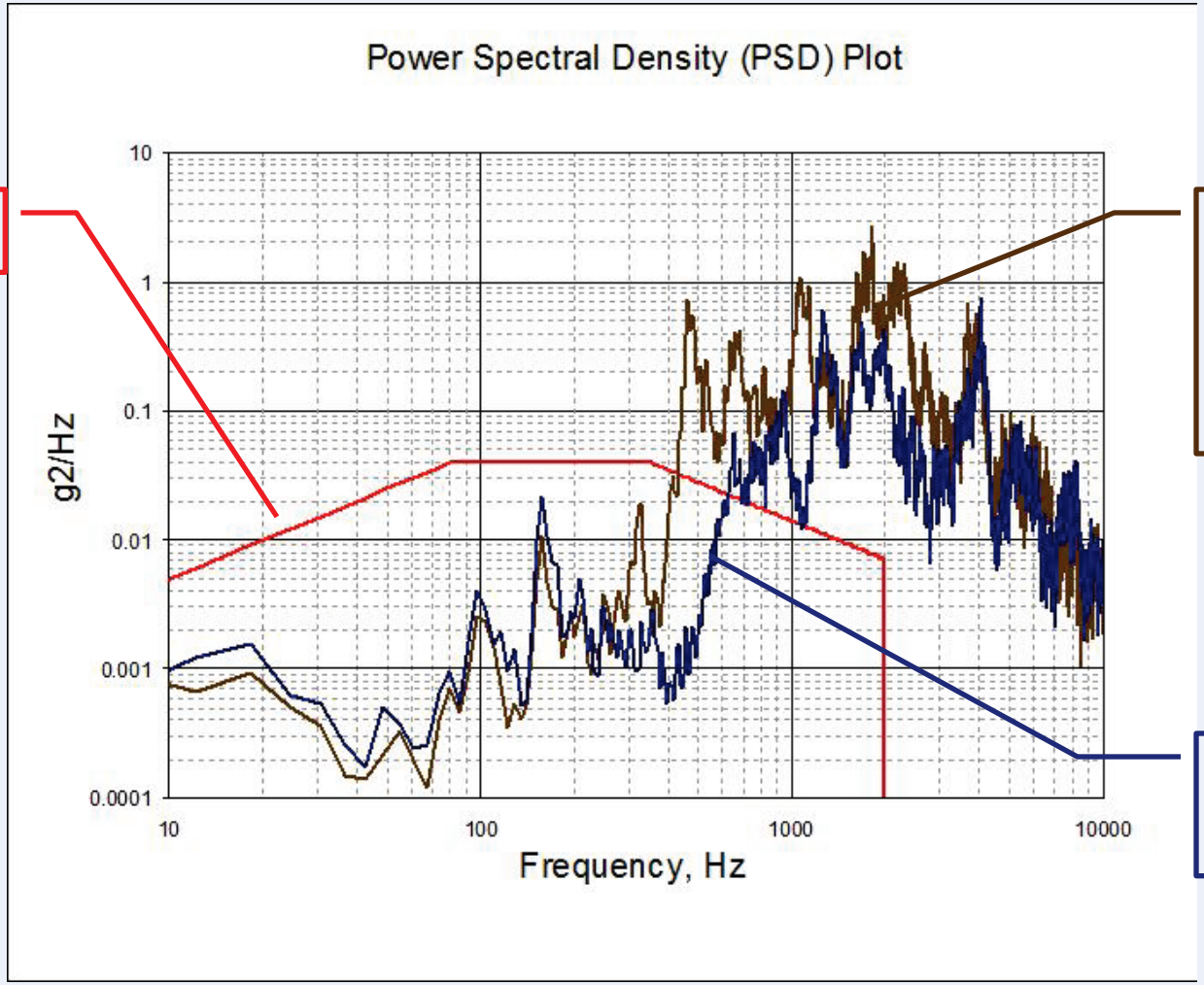
NAVMAT + RS Table PSD, 25 gRMS



NAVMAT

30" table Z axis

Product Response, Location 1, 25 gRMS

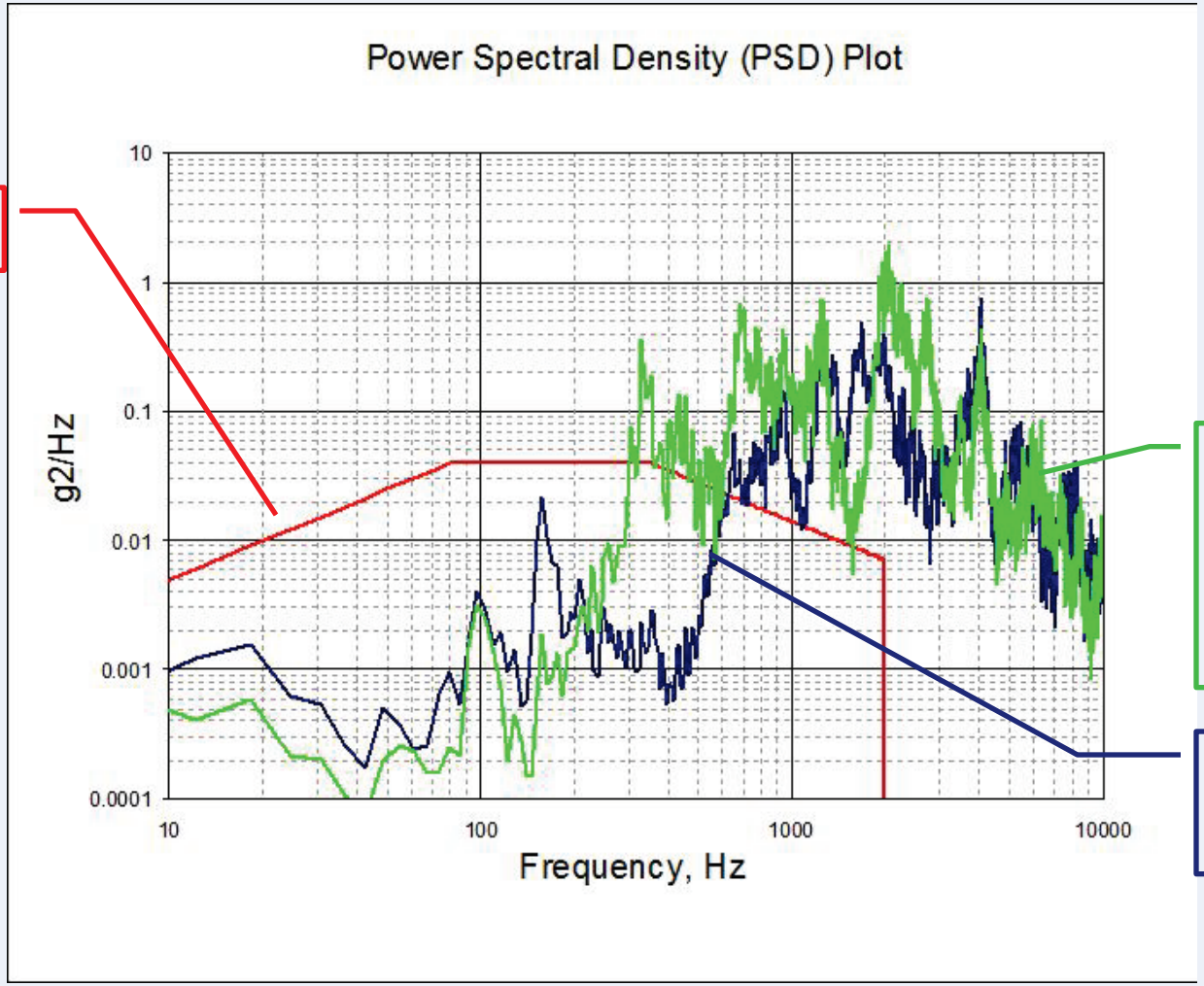


NAVMAT

Product response, location 1 Z axis

30" table Z axis

Product Response, Location 2, 25 gRMS



NAVMAT

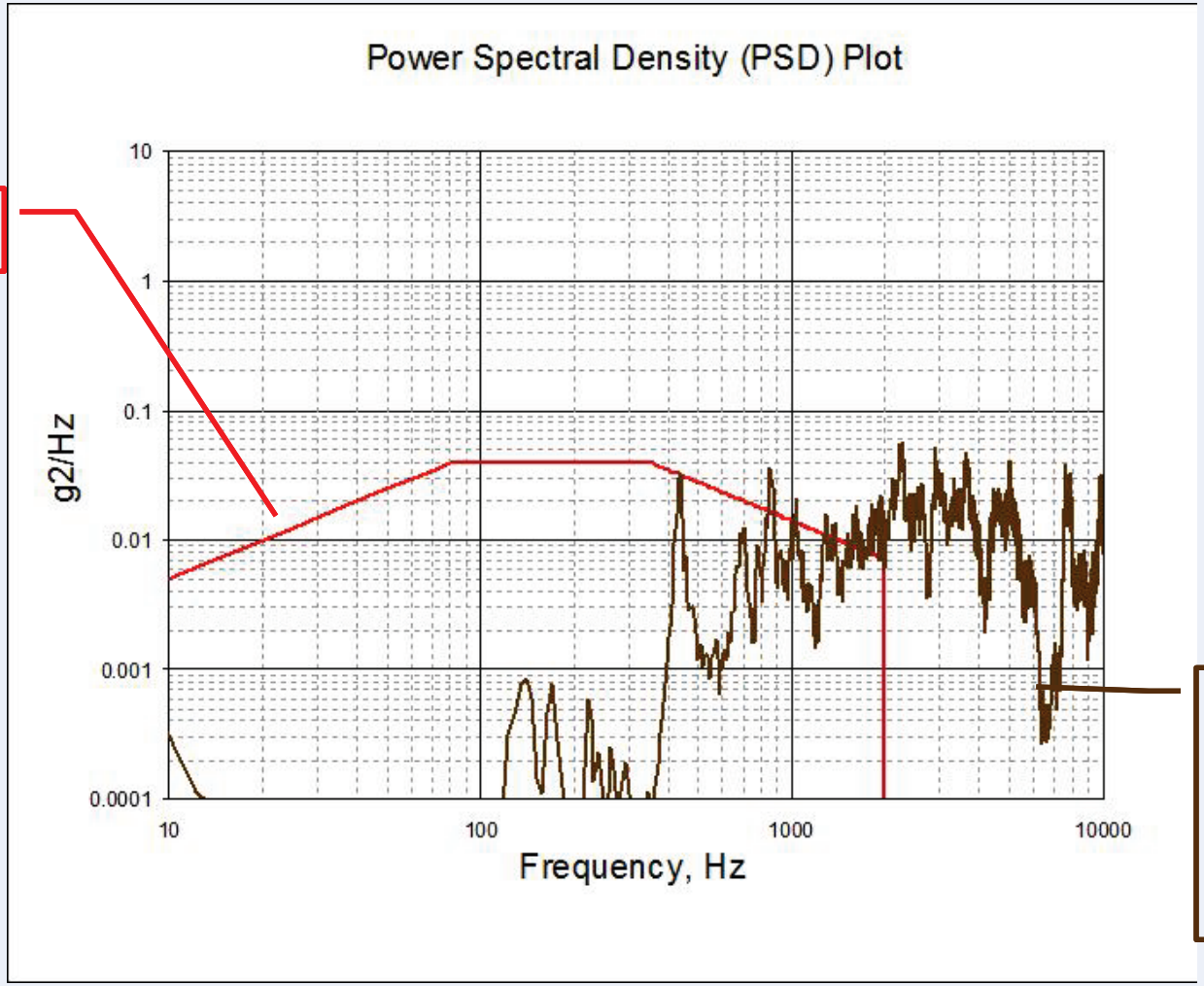
Product response, location 2 Z axis

30" table Z axis

Comparing NAVMAT with Repetitive Shock HASS Vibration

- 48” x 48” table size
- Larger product (LED street lamp assembly)
- Multiple gRMS

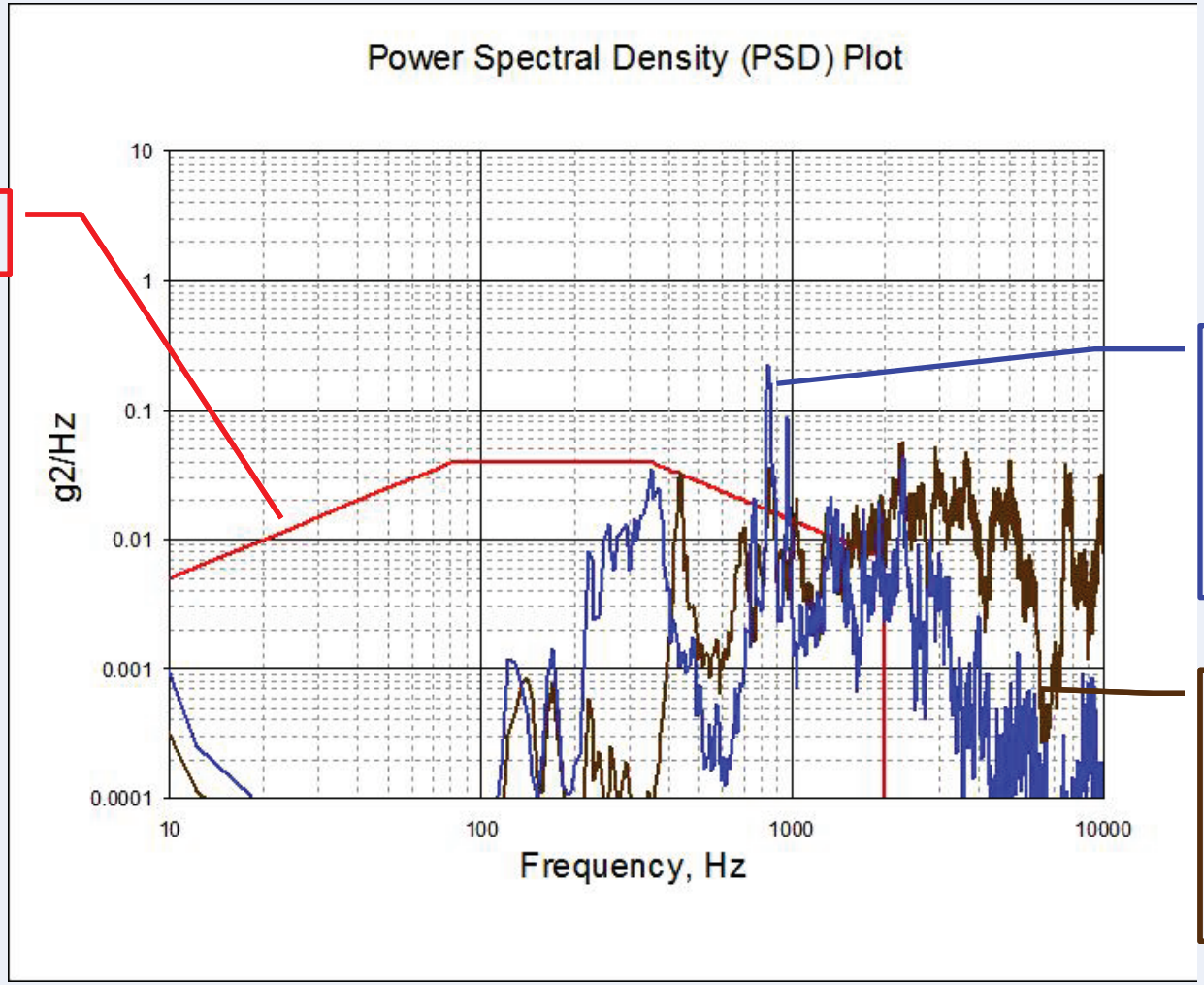
Table Response at Low (5) gRMS



NAVMAT

Table response, 48" table, Z axis

Table and Product Response at Low (5) gRMS

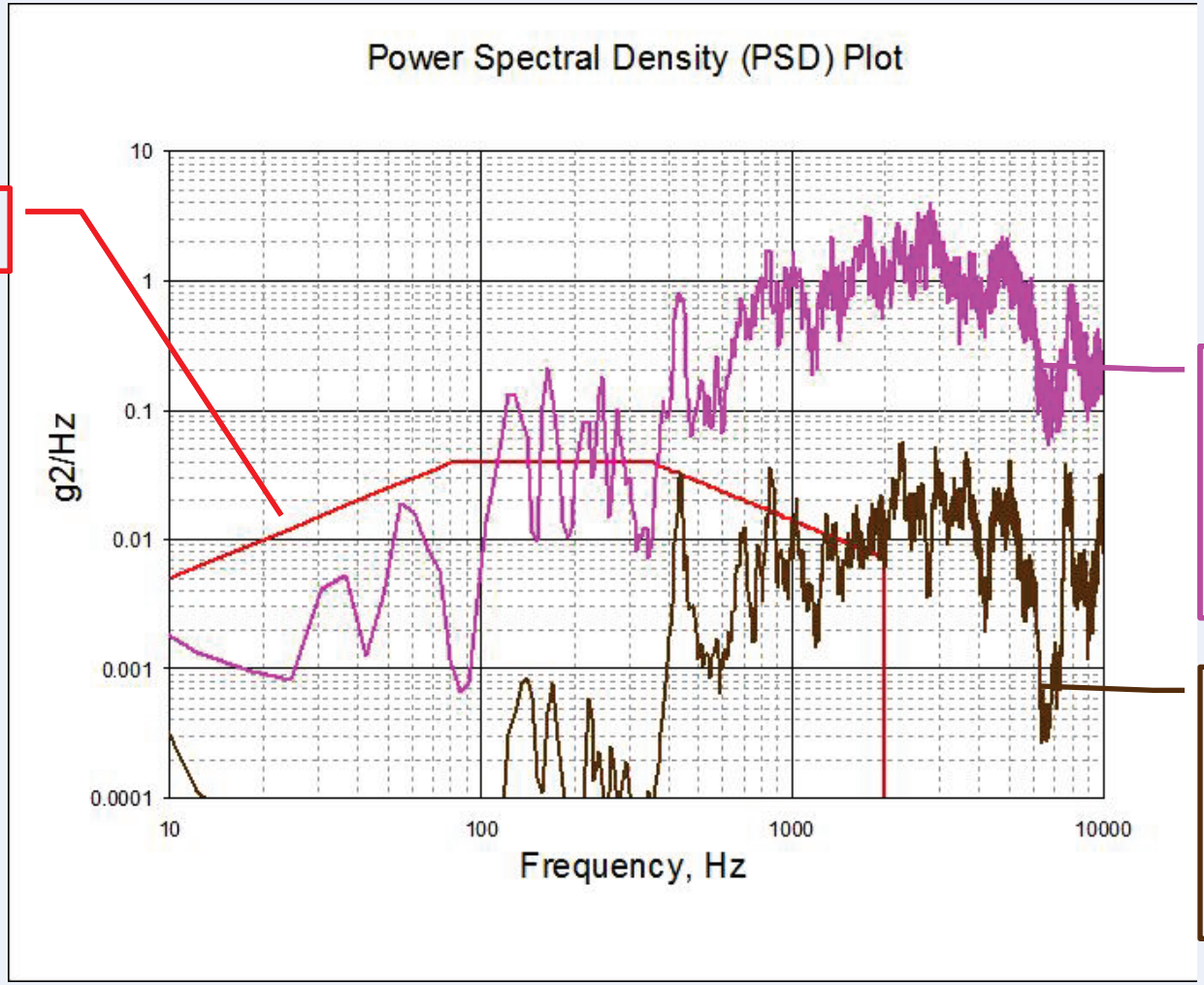


NAVMAT

Product response, 48" table, Z axis

Table response, 48" table, Z axis

Table Response at 5 gRMS and 50 gRMS

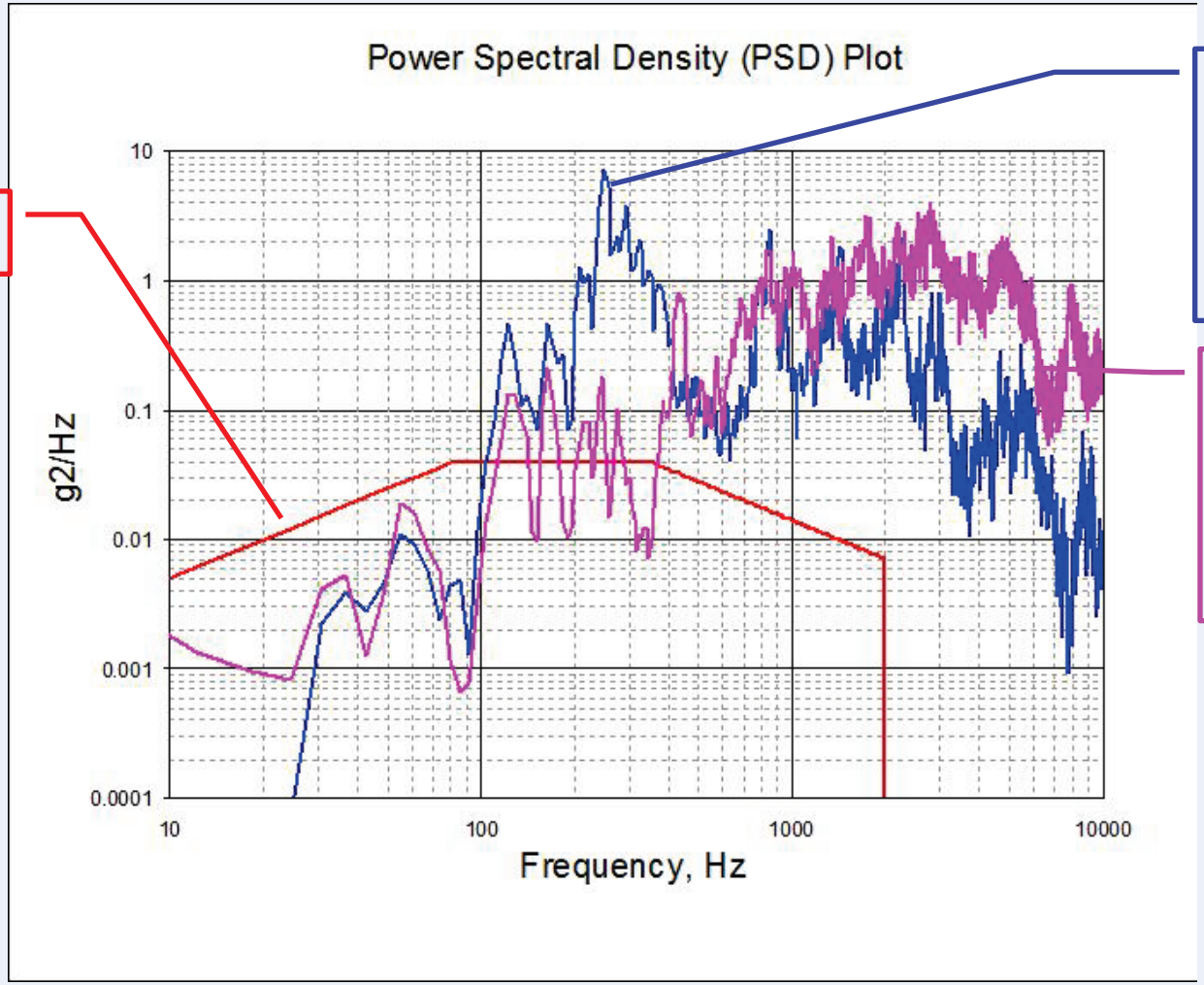


NAVMAT

Table response, 48" table, Z axis, 50 g

Table response, 48" table, Z axis, 5 g

Table and Product Response, 50 gRMS



NAVMAT

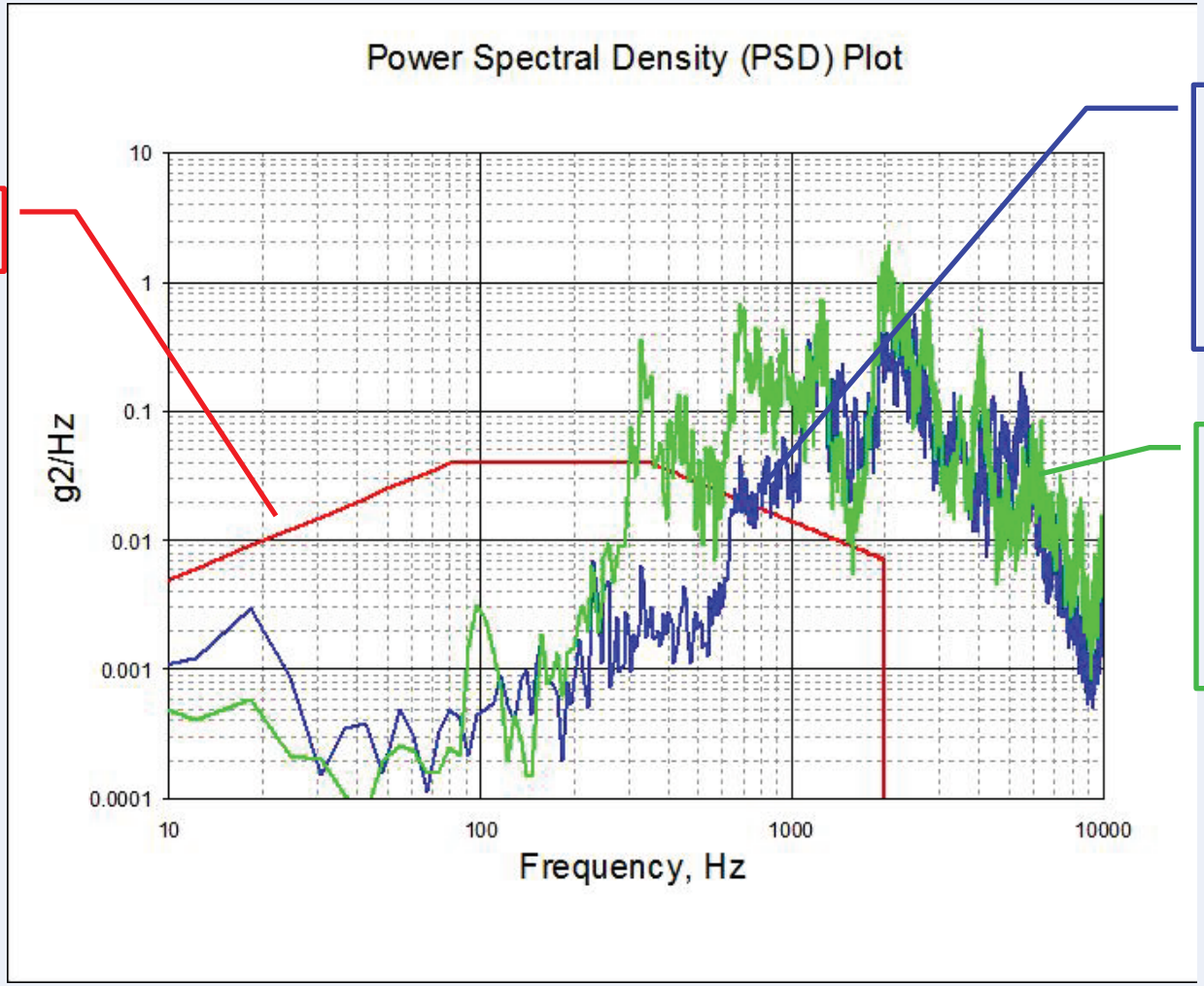
Product response, 48" table, Z axis, 50 g

Table response, 48" table, Z axis, 50 g

3-Axis RS Vibration is More Effective than NAVMAT

- Simultaneous three axis and three rotation vibration, inherent in RS systems, provides more effective stresses than single axis ED vibration
- Major circuit card assemblies may lie in a single axis, but key stress vectors for the components are typically perpendicular to that plane and are not excited with single axis vibration
  - It is not unusual for an assembly today to consist of multiple cards, some coplanar, some perpendicular

Product Response, Location 2, 25 gRMS, Y and Z



NAVMAT

Product response, location 2 Y axis

Product response, location 2 Z axis

Higher-Level Vibration is More Effective than Mil Hdbk 2164A

- More excitation is delivered to the product
  - HASS typically involves continuous vibration
    - Intensity and duration determined by actual product limitations
  - Ensures maximum tolerable vibration stresses to the product
  - Results in maximum possible defect detection

Advantages of HASS Thermal Excitation

- As in vibration, the thermal limits in HASS are based on actual product limitations
  - More aggressive thermal stressing results in better precipitation of thermally sensitive defects
- Very fast change rates make the entire test go much faster
  - The 80 to 120 hour thermal tests described in 2164A are unheard of in HASS
  - Typical screens last 2 to 6 hours

HASS Thermal Change Rate is More Effective than Mil Hdbk 2164A

- Faster change rates induce more thermal fatigue than slower rates
- mil_hdbk_344A, “ESS of Electronic Equipment”, provides an equation for calculating the ‘precipitation efficiency’ of thermal ramps
  - Based on technologies used in 1990’s, but the characteristics of thermal fatigue on mechanical assemblies due to thermal ramps are consistent enough that it should be adequate for comparison purposes
  - See equation at end of presentation

Advantages of HASS Thermal Excitation

- 2164A thermal cycle testing recommends:
  - 10°C/min minimum ramp rates
  - -54°C to +71°C typical thermal range
  - 120 hours of thermal cycle testing, resulting in 80 thermal cycles
- The precipitation efficiency of these ramps can be achieved at 60°C/minute with ¼ of the number of cycles
- Conclusion - fast HASS ramp rates are 4 times more fatiguing than slower 2164A ramp rates

Summary

- HASS provides vibration excitation much more suited to today's electronic assemblies and components
- HASS provides thermal excitation that dramatically reduces the time to do ESS
- Levels are based on actual product limitations, guaranteeing the most effective stress levels possible
- The stated goals of 2164A are met more effectively and economically by using HASS stresses

Precipitation Efficiency Calculations

- 344a Precipitation Efficiency equation
  - Precipitation Efficiency (PE) = $1 - e^{(-kt)}$
  - $k = (.0017 * (\text{Delta T} + .6)^{.6}) * (\ln(\text{rate} + 2.718))^3$
    - Delta T = total temperature change
    - t = number of cycles
    - rate = ramp rate, °C/min

Precipitation Efficiency Calculations

- Calculation assumptions:
  - 120 hour, 80 cycle screen as recommended in 1394A is used
    - Precipitation efficiency cannot be calculated for more than 20 thermal cycles of the 1394A screen, so efficiency comparisons are based on this number.
  - Dwells are assumed at 30 minutes
  - Ramp rates compared are 10°C/min(1394A) and 60°C/min (typical HASS)
  - Equation from 344A is used

Precipitation Efficiency Calculations

Precipitation Efficiency Calculation Results

Equal Efficiency, 10°C/min vs 60°C/min

Low Temperature	-54	-54
High Temperature	71	71
Ramp Rate, °C/min	**10**	**60**
Number of thermal cycles	**20**	**4.6**
Precipitation Efficiency	**0.99996**	**0.99996**

Conclusion: A precipitation efficiency of 0.99996 can be achieved with 20 thermal cycles at 10 °C/min or with 4.6 thermal cycles at 60 °C/min

References:

- MIL-HDBK-2164A, June 19, 1996
- MIL-HDBK-344A, Augusts 16, 1993
- Navmat P9492A, 1982
- Tustin, W., *Multiaxis Random Vibration For HALT and HASS*, Aerospace Testing Expo 2005 NORTH AMERICA (Long Beach), November 8, 2005 (Wayne Tustin, equipment Reliability Institute, Santa Barbara, California)
- Henderson, G. and Burgess, W., *Comparing NAVMAT Versus 6DOF for HALT/HASS Testing*, COTS Journal, June 2009 (George Henderson, founder, President and CEO, GHI Systems, and William Burgess, Reliability Engineer, Leach International)