Multiaxis Random Vibration for HALT and HASS

Wayne Tustin
Equipment Reliability Institute
Santa Barbara, California

Aerospace Testing Expo 2005 NORTH AMERICA (Long Beach)

November 8, 2005

A little 1979 ESS background to introduce HASS and HALT: Willis J. Willoughby's P-9492 document, mandated ESS, environmental stress screening.

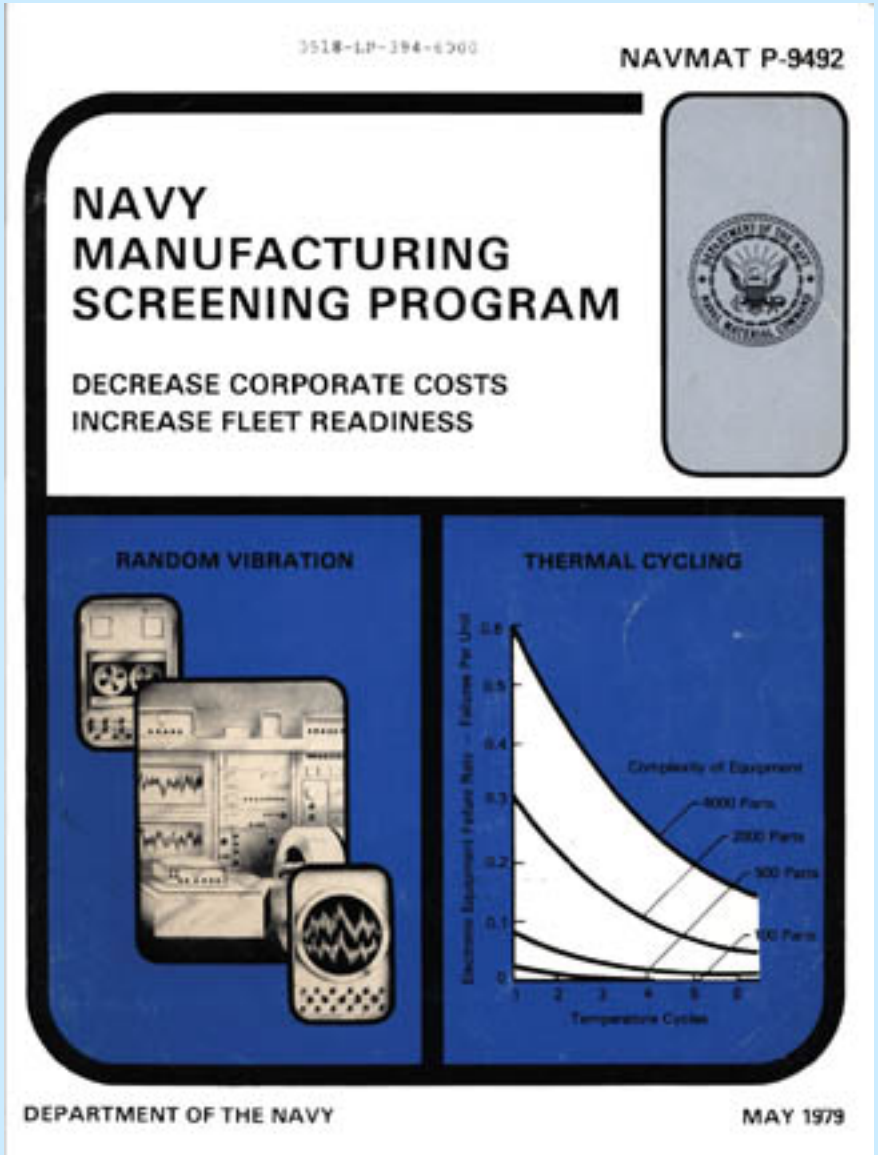


Figure 24-2
NAVMAT P-9492

Willoughby knew about ED shakers, all right. Large or small, their operating principle is exactly the same as an ED loudspeaker.

Figure 15-1 Largest and Smallest MB Shakers

Figure 15-2 Electrodynamic Shaker Principle

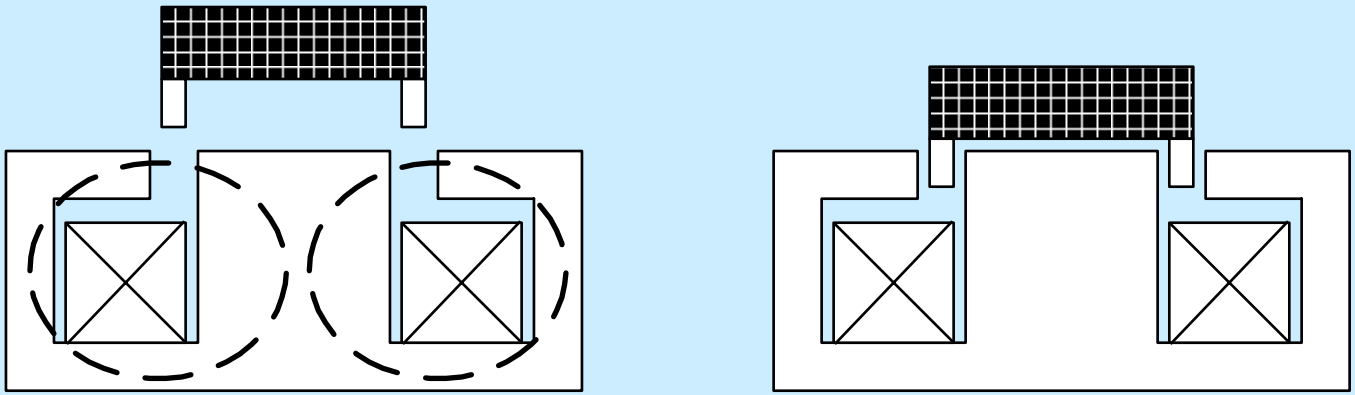
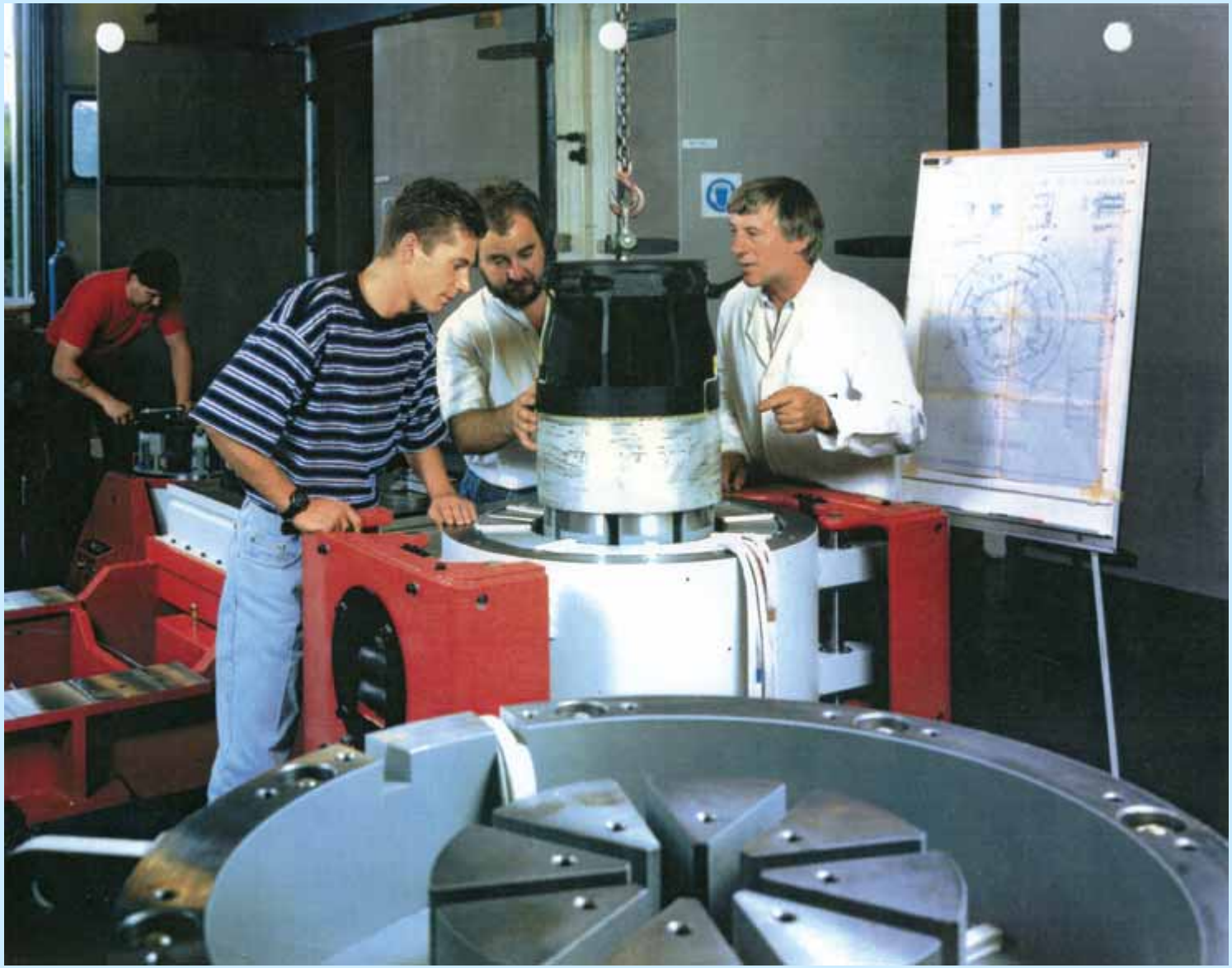


Figure 15-11 ED Shaker Assembly



DC flows in a fixed winding to create a strong magnetic field. AC for the axially-moving coil, attached to the table and DUT, comes from a power amplifier.

Figure 17-2 System Block Diagram

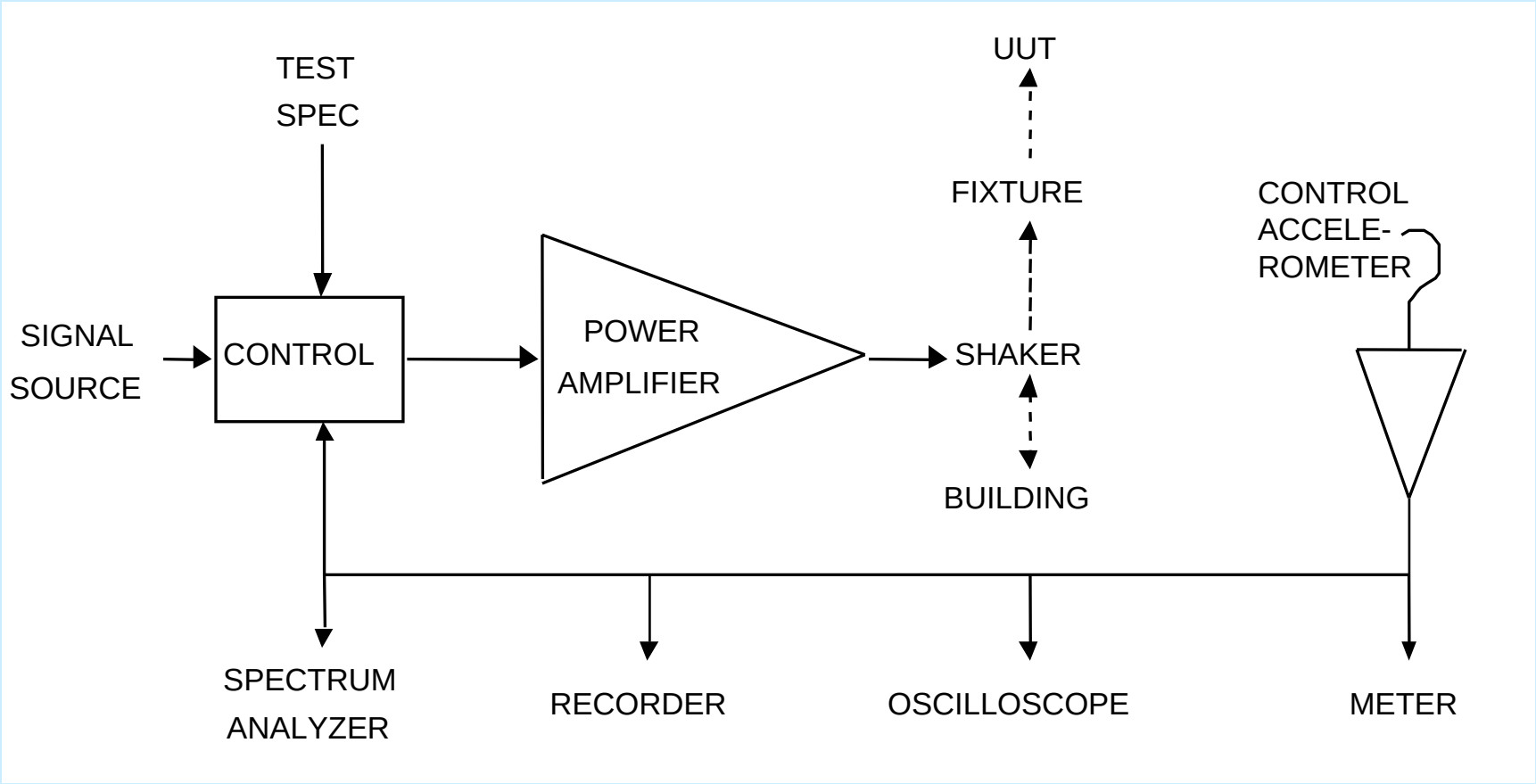
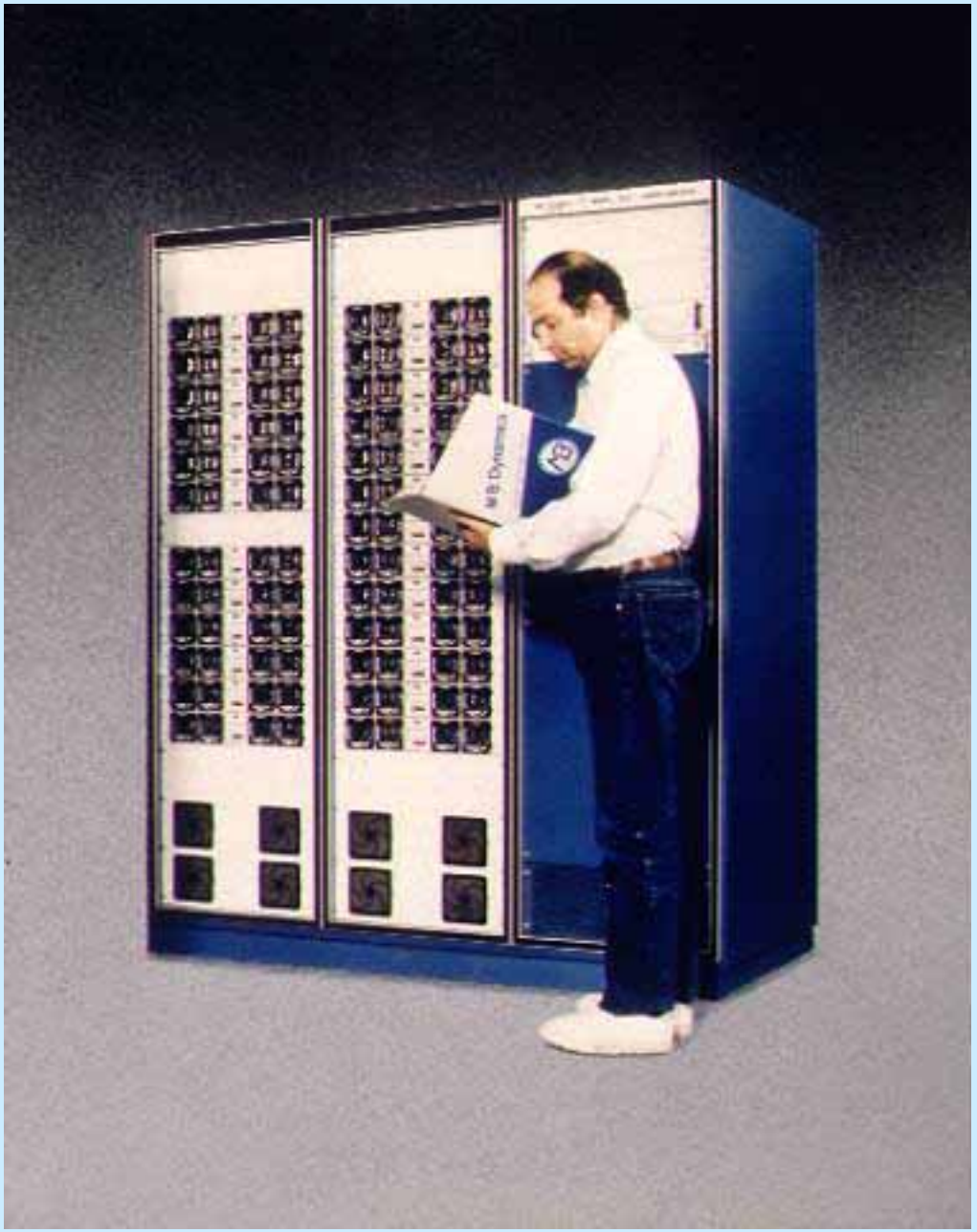


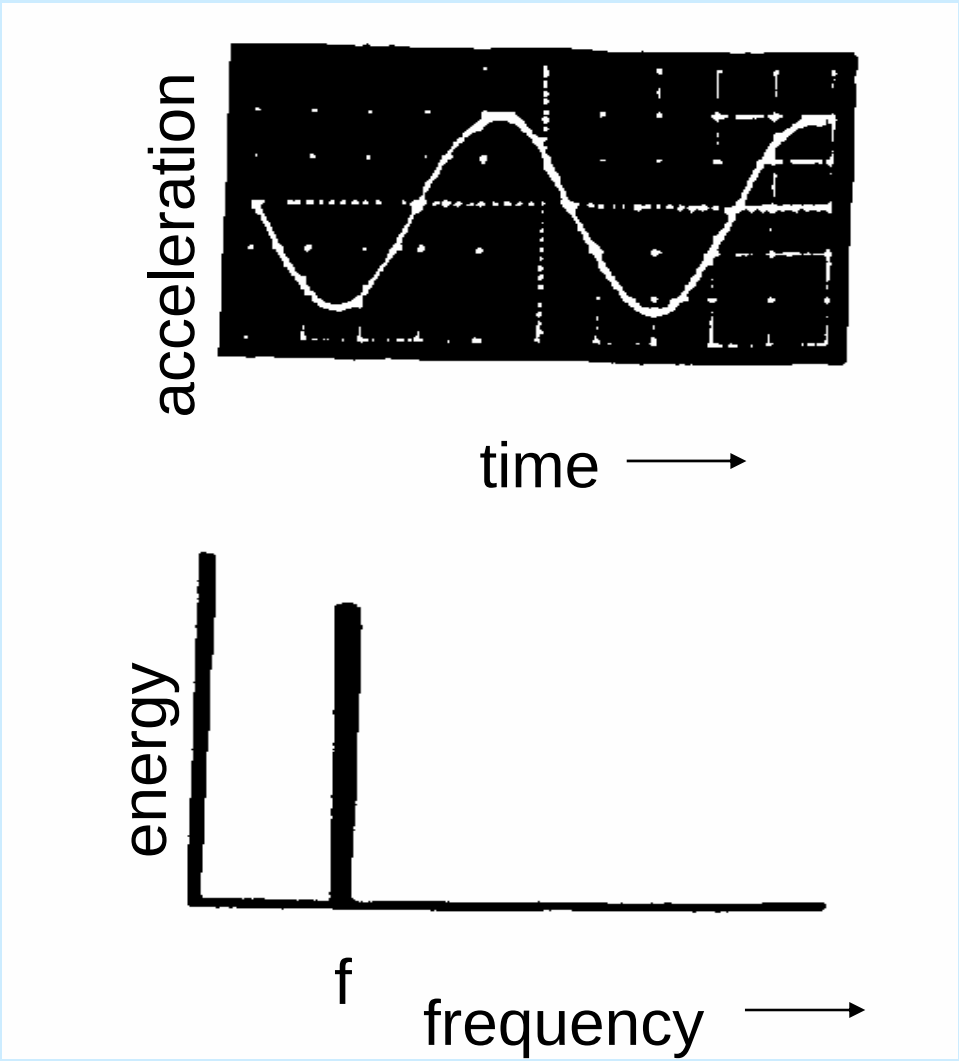
Figure 17-3 Power Amplifier

(courtesy MB Dynamics)



Early on, spec writers thought they wanted sinusoidal vibration. Means what?

Figure 11-1 Sine Wave in Two Domains



Some spec writers wanted fixed frequency, fatigue testing specific resonances, perhaps to failure.

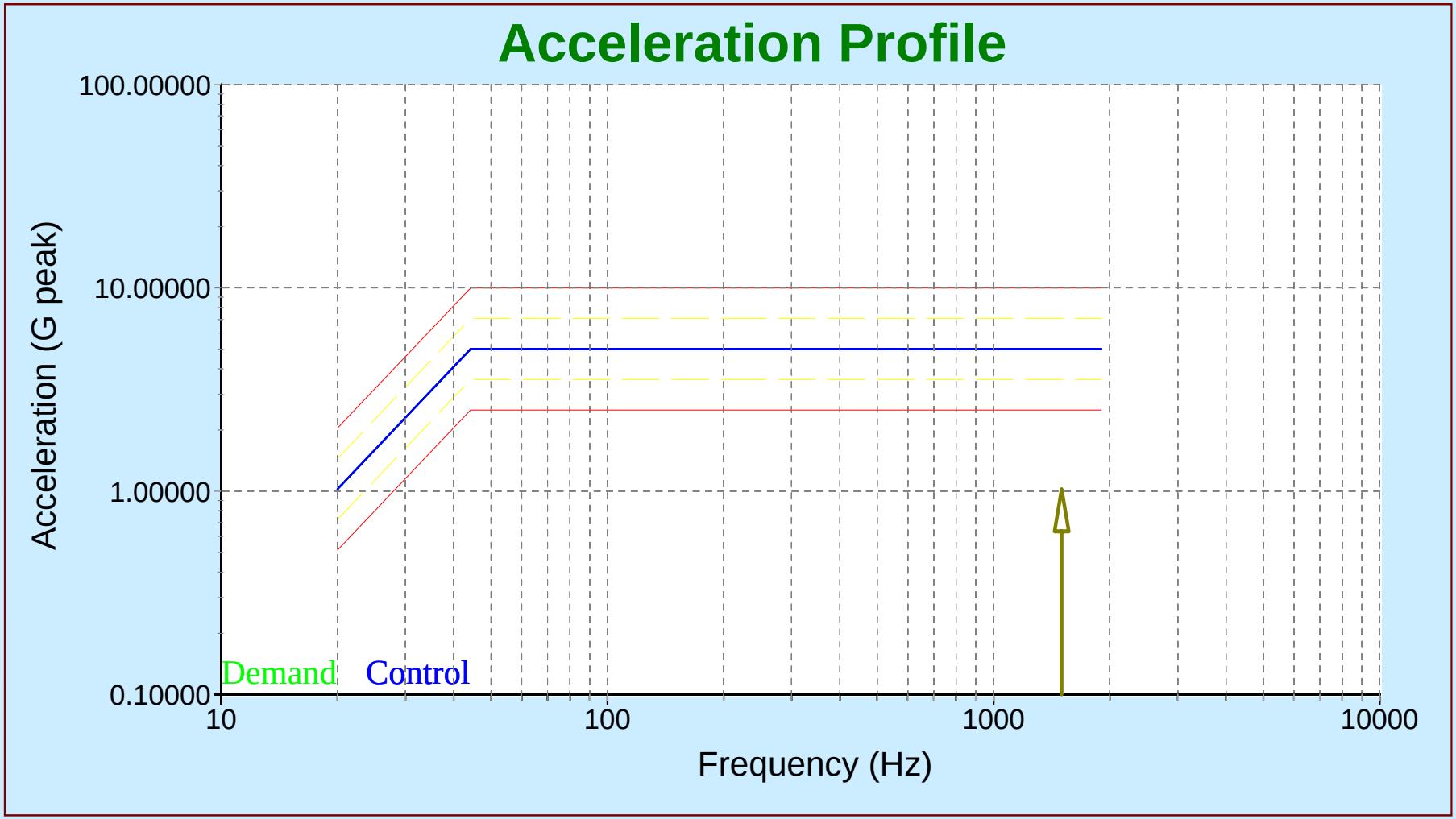
Figure 11-38 Mechanical Spectrum Analyzer

Video Clip 11-3

complex3

Other spec writers wanted to sweep a range of frequencies, exciting resonances sequentially.

Figure 18-7 Simple Profile



courtesy Vibration Research Corp.

Figure 17-2 System Block Diagram

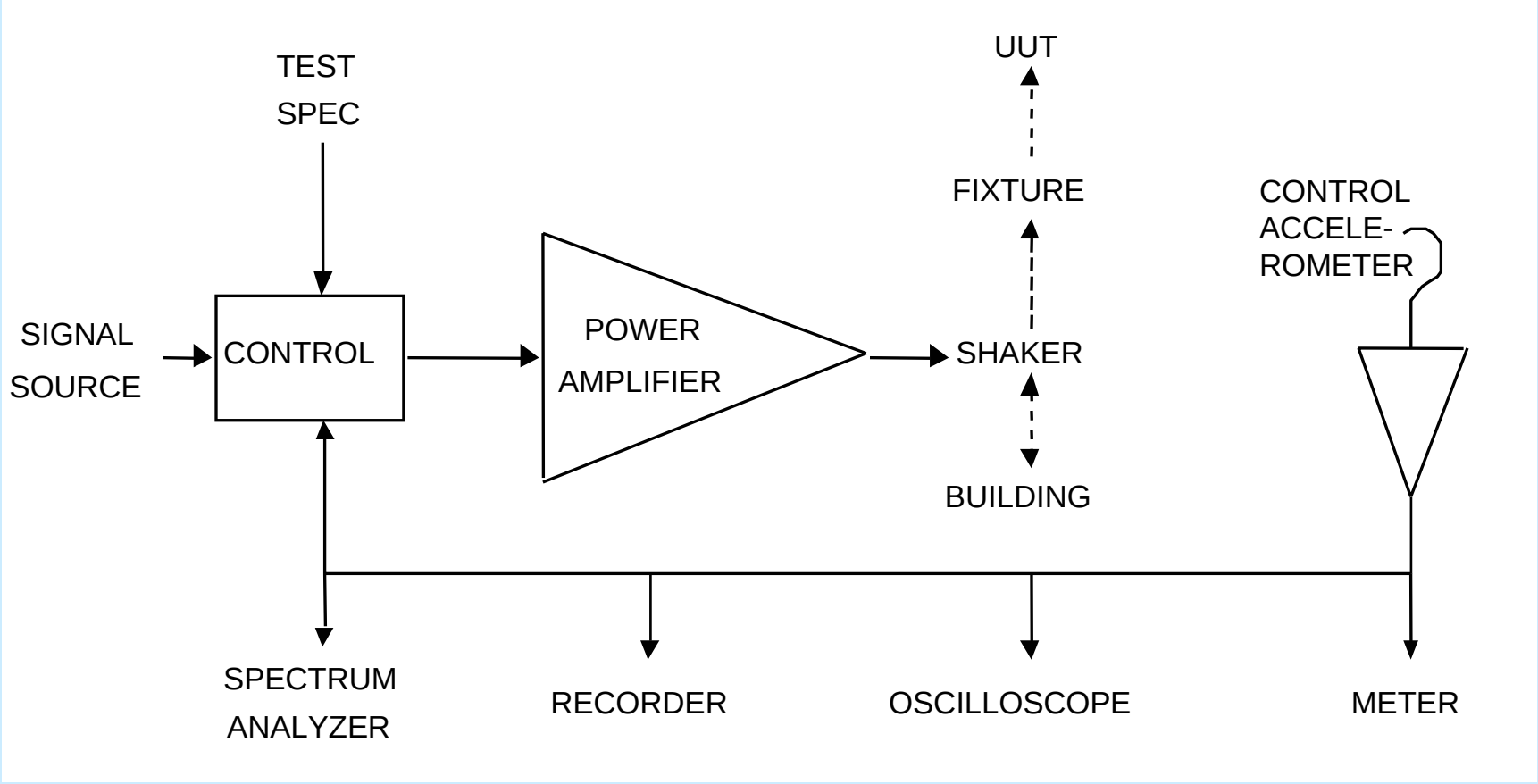


Figure 19-7 Digital Sine Test Controls

(Courtesy Data Physics)

Back to Willoughby for a moment,

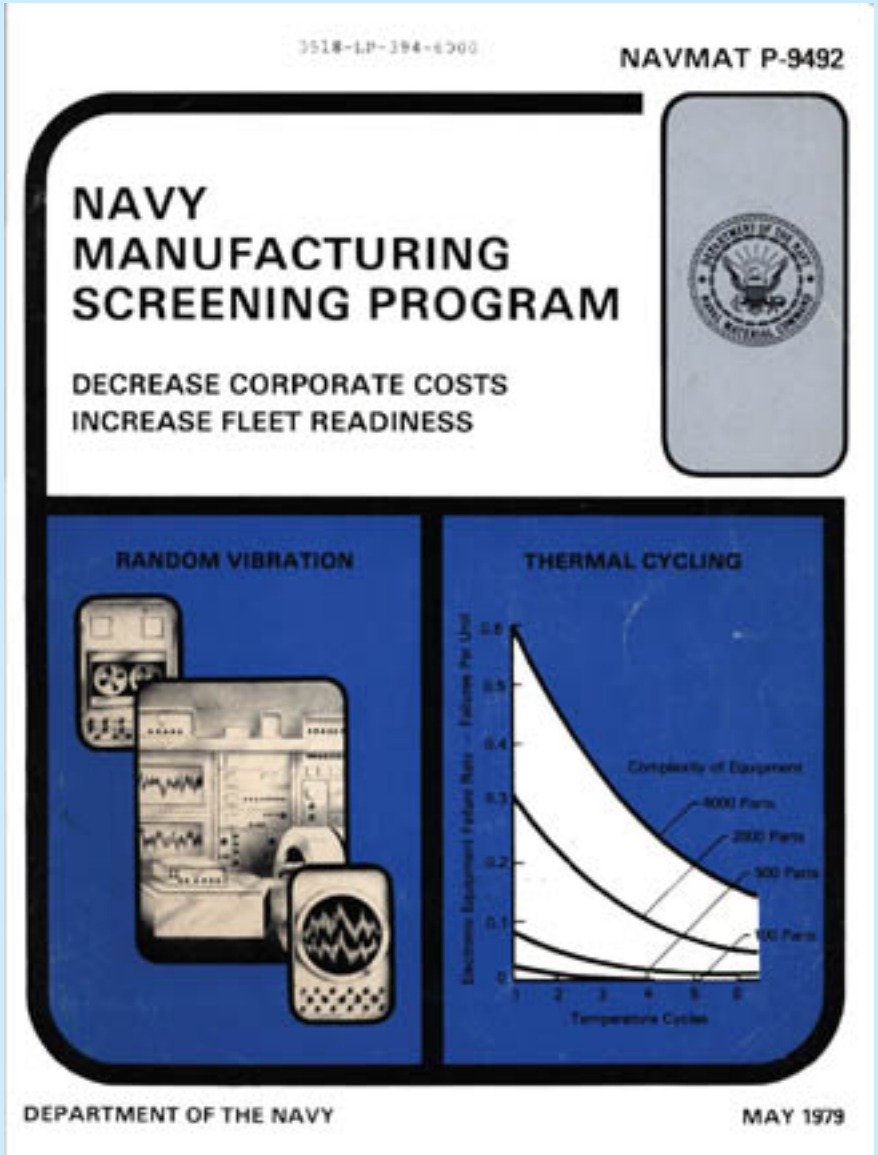


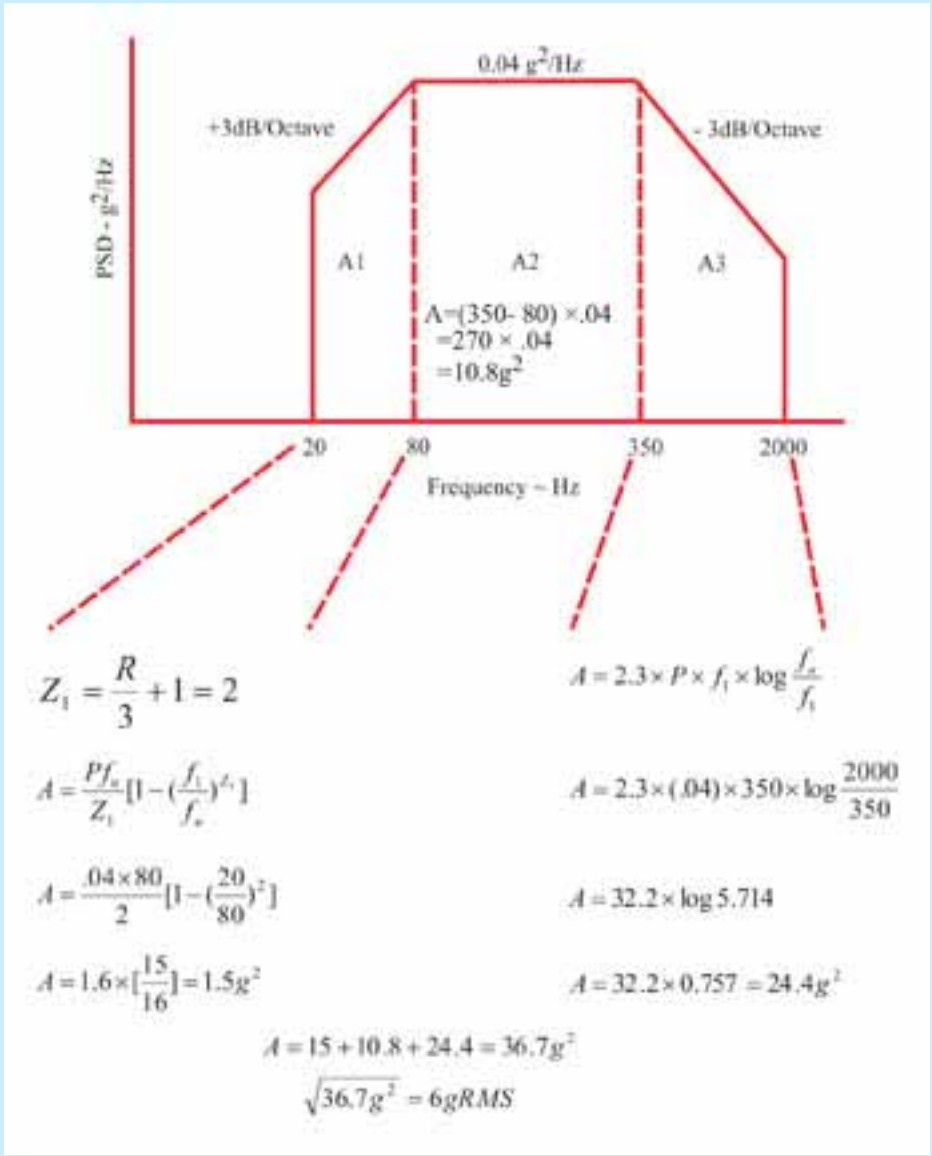
Figure 24-2
NAVMAT P-9492

Willoughby wanted ESS done not with sine vibration but rather with random.

Random vibration? What's that?

In the frequency domain, not a single line but rather a continuum

Figure 24-10 The "Willoughby" ESS Spectrum



$$Z_1 = \frac{R}{3} + 1 = 2$$

$$A = \frac{Pf_e}{Z_1}[1 - (\frac{f_1}{f_e})^{Z_1}]$$

$$A = \frac{.04 \times 80}{2}[1 - (\frac{20}{80})^2]$$

$$A = 1.6 \times [\frac{15}{16}] = 1.5g^2$$

$$A = 2.3 \times P \times f_1 \times \log \frac{f_e}{f_1}$$

$$A = 2.3 \times (.04) \times 350 \times \log \frac{2000}{350}$$

$$A = 32.2 \times \log 5.714$$

$$A = 32.2 \times 0.757 = 24.4g^2$$

$$A = 15 + 10.8 + 24.4 = 36.7g^2$$

$$\sqrt{36.7g^2} = 6gRMS$$

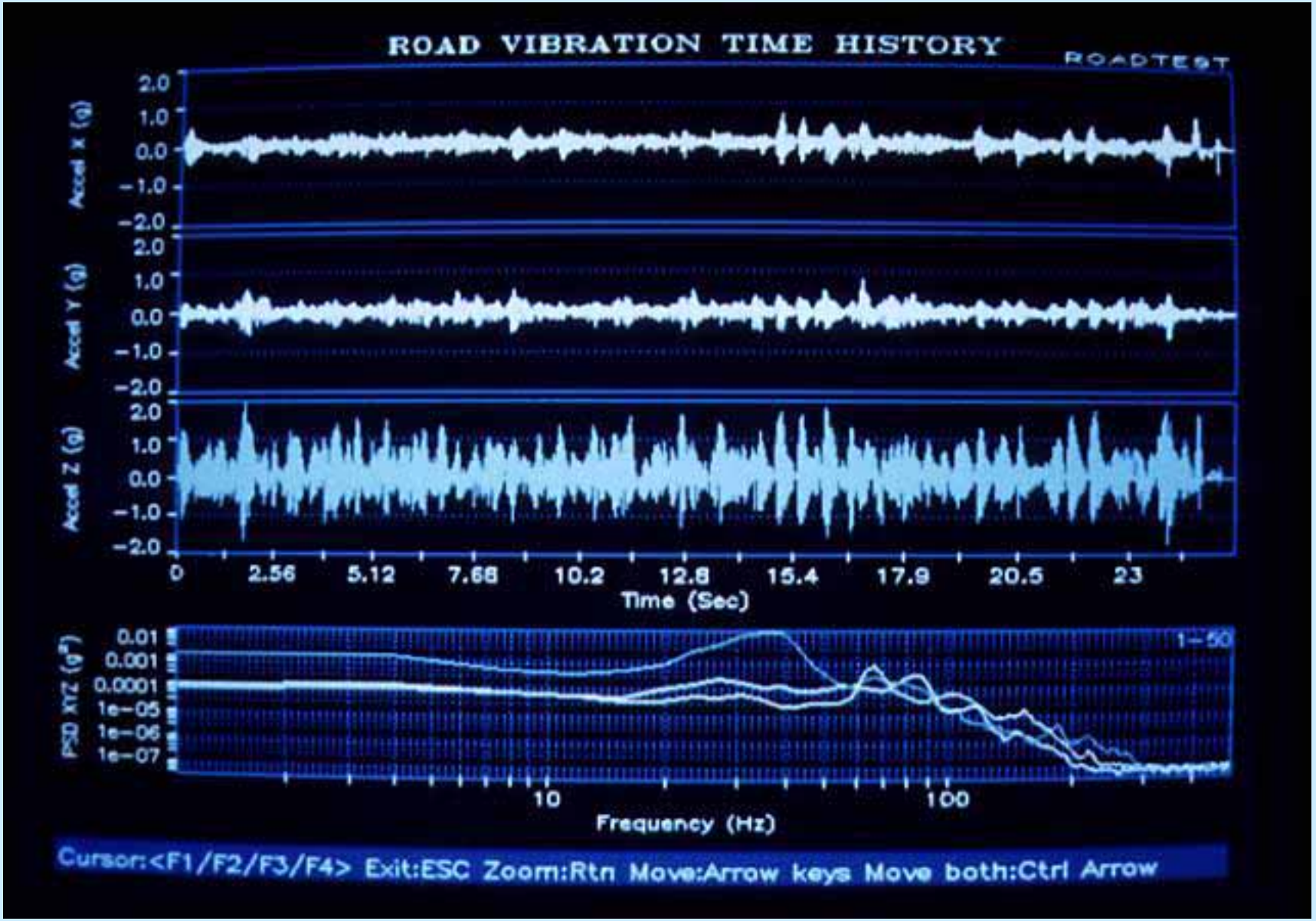
And in the time domain, something pretty messy, hard to describe but with an example that’s easy to obtain.

Video Clip 20-6 Detroit Street

detroit

On the suspension are three accelerometers. The vibration is definitely not sinusoidal.

Figure 20-12 An Analysis of Automotive Vibration

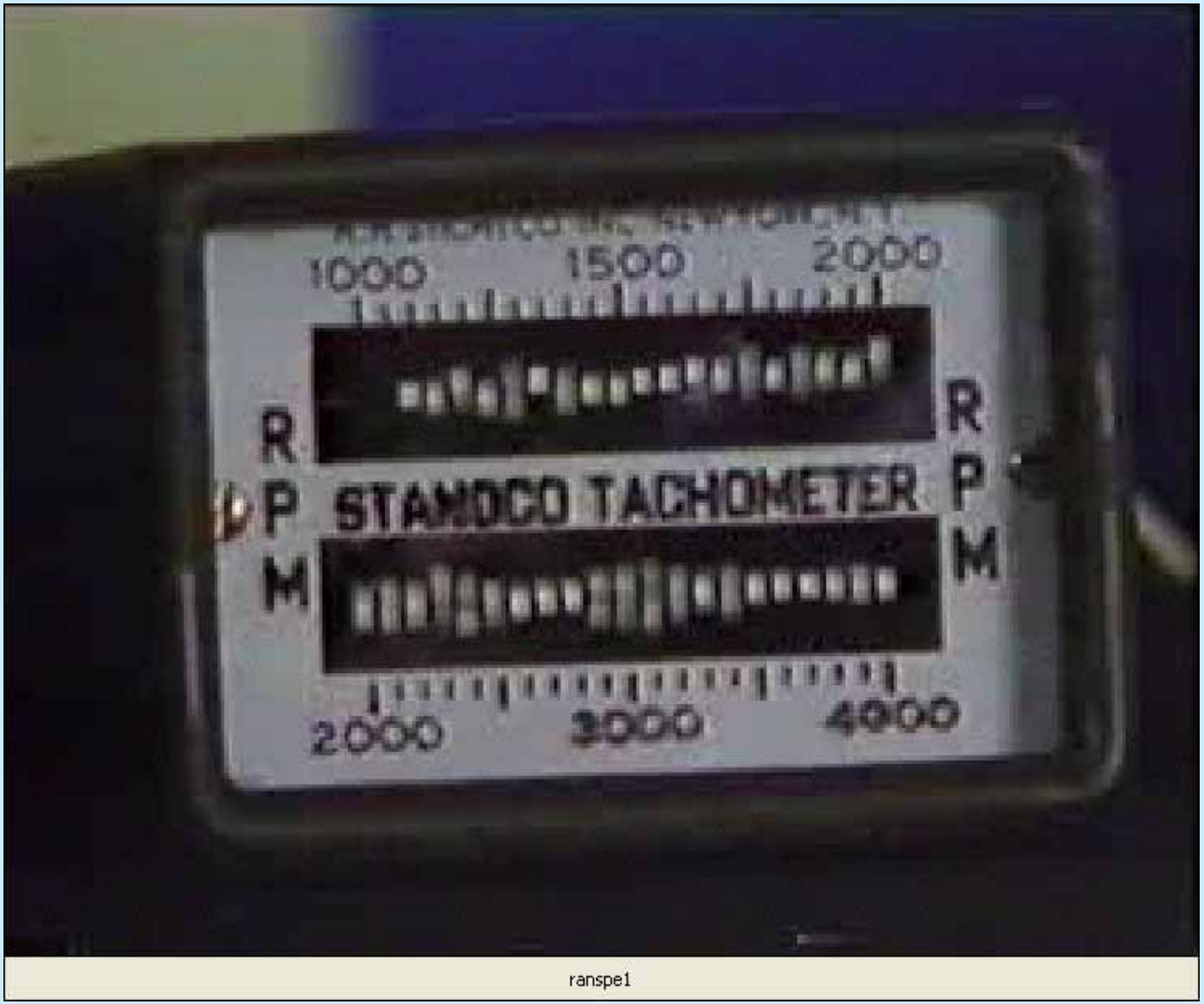


We use the same shaker, power amplifier and control as for sine testing. But now we have adjusted our controller for the kind of random vibration needed to simultaneously excite all your resonances for ESS, HALT and HASS.

Figure 23-12 A Windows-based Digital Controller

Courtesy Data Physics

Video Clip 21-1 Multi-reed Tachometer

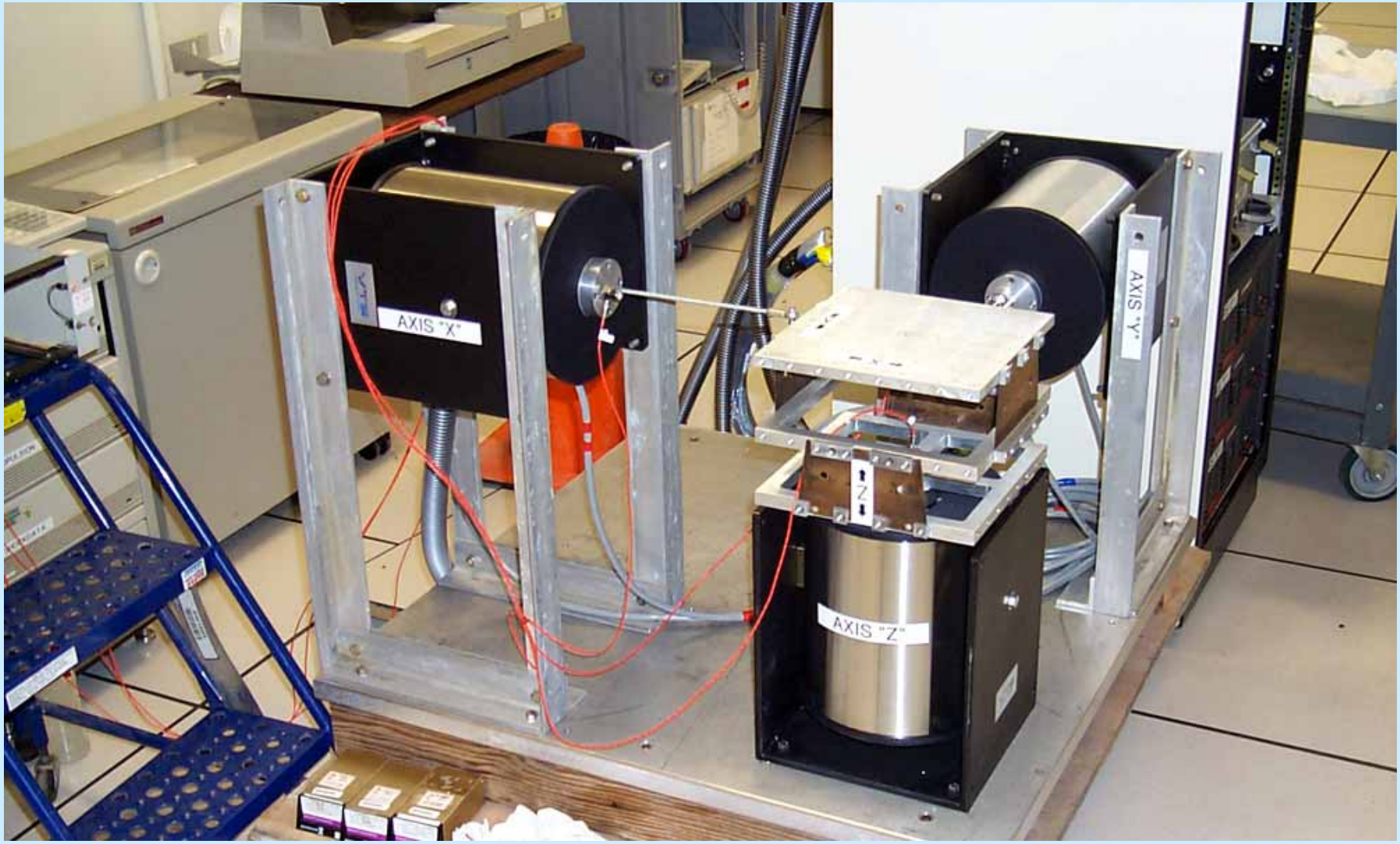


A weakness of Willoughby: in 1979 everyone was satisfied with one-axis-at-a-time shaking, a holdover from the mechanical shakers of the ‘thirties and ‘forties. Willoughby knew about combining ED shakers with thermal chambers,

Figure 15-27 Combined Environment Testing

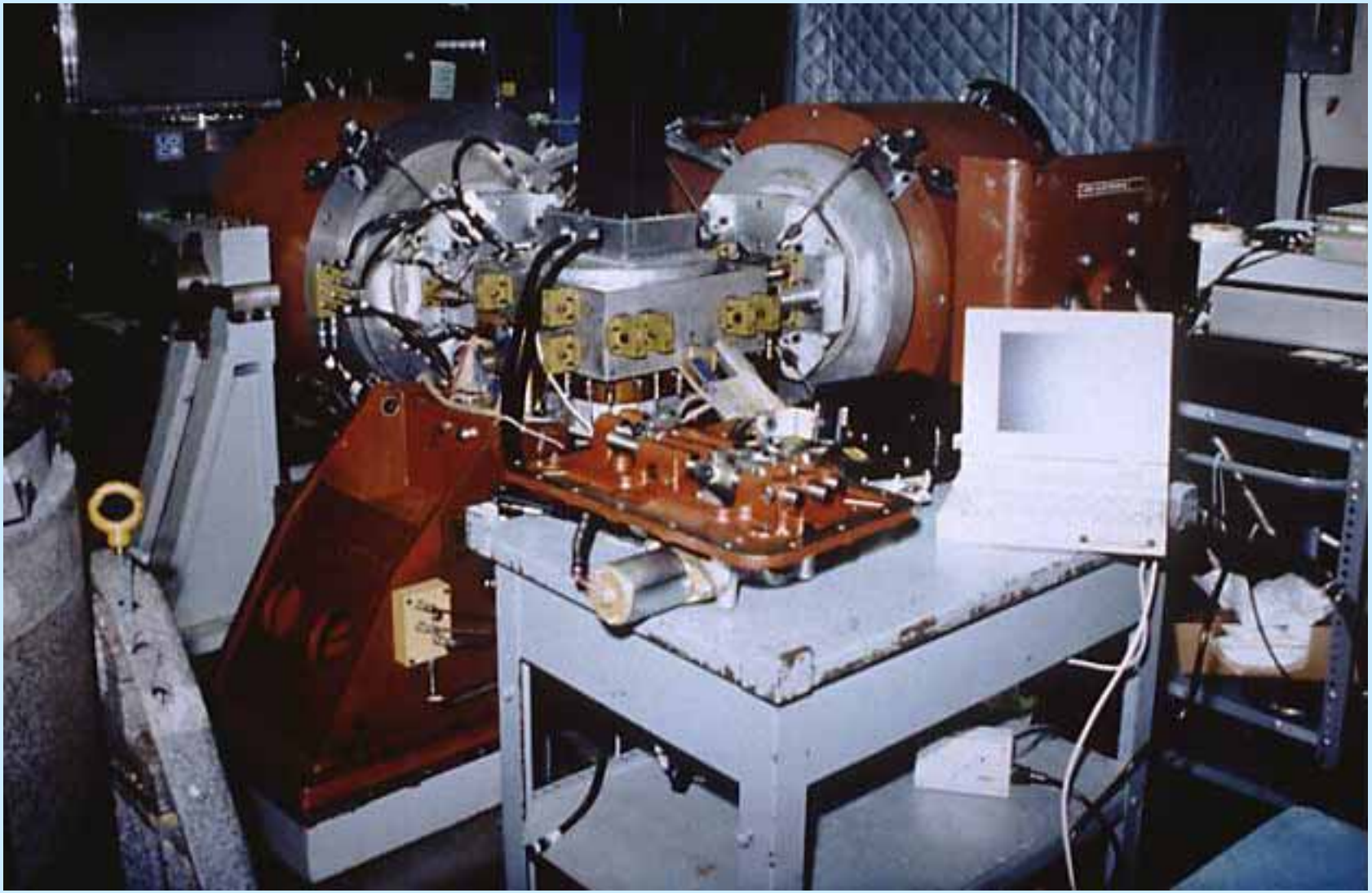
But he didn’t know about need for multi-axis shaking, that some field failure modes could not be duplicated with single axis shaking.

Figure 16-9 Three-shaker 3DoF concept



courtesy NUWC Keyport

Figure 16-8 Three-shaker 3DoF realization

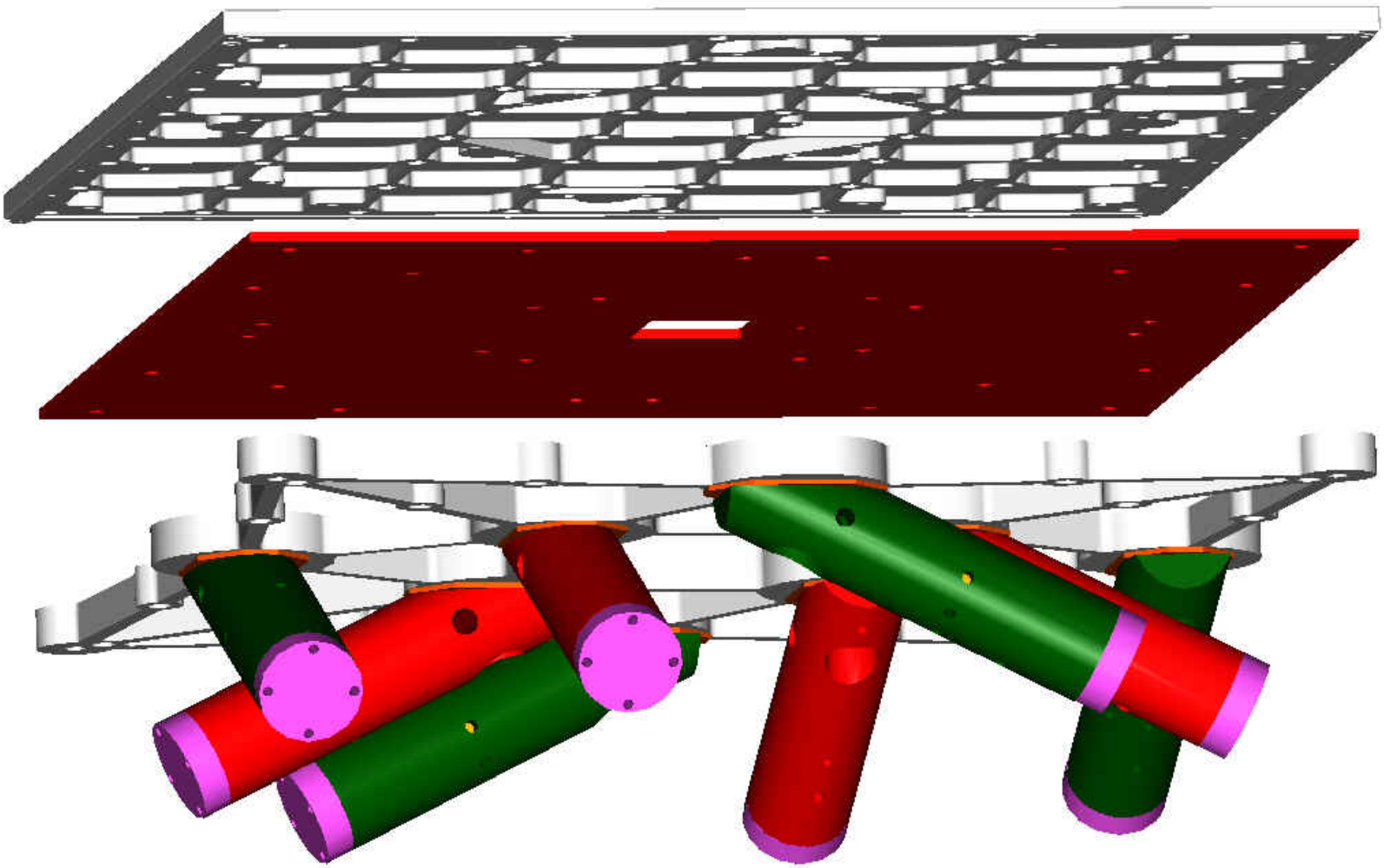


courtesy Army Research Lab, Adelphi, MD

Very expensive. 3 or more ED shakers, 3 or more power amplifiers, 3 or more channels of control.

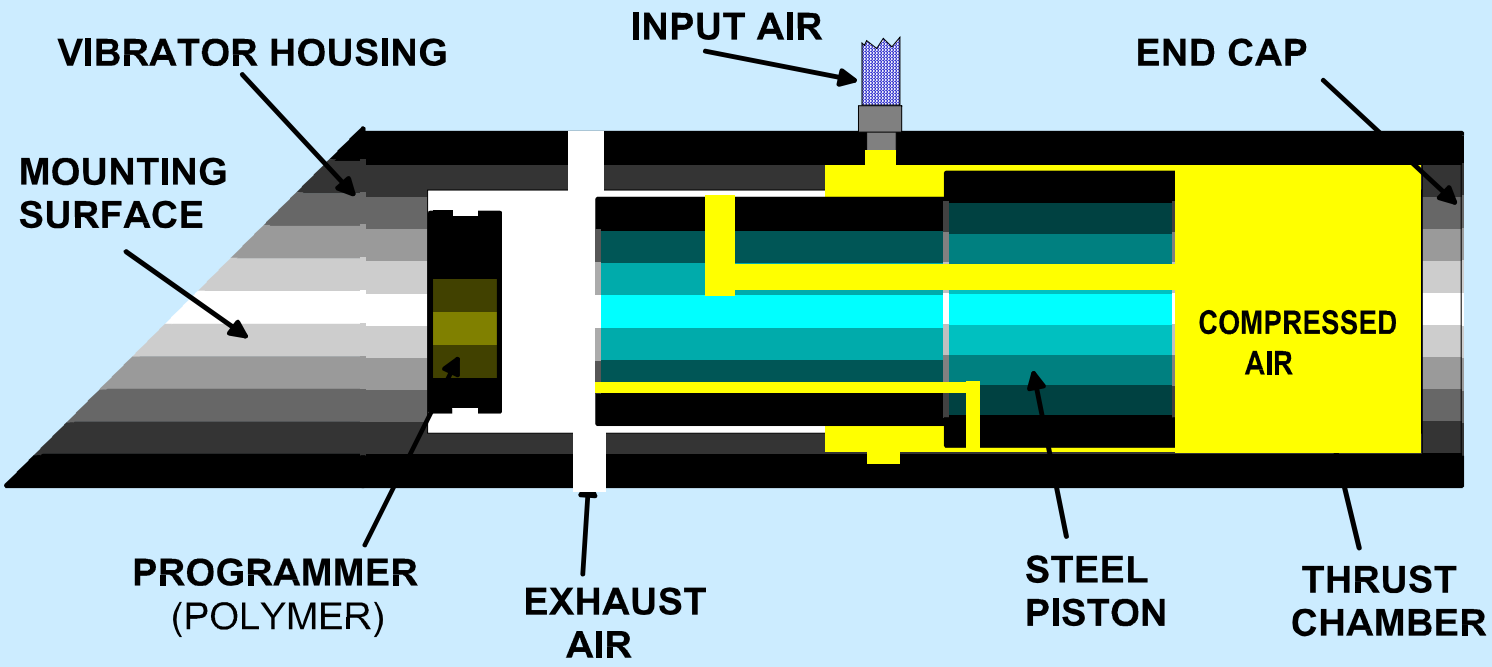
If we want to do multi-axis HALT (highly accelerated life testing) and HASS (highly accelerated stress screening), how to do it more cheaply? Let's use 12 or 16 pneumatic vibrators or RS (repetitive pulse) hammers …

Figure 25-35 Pneumatic Vibrators on “Rigid” Table



courtesy QualMark

Figure 25-40 Pneumatic Vibrator



courtesy C. Felkins

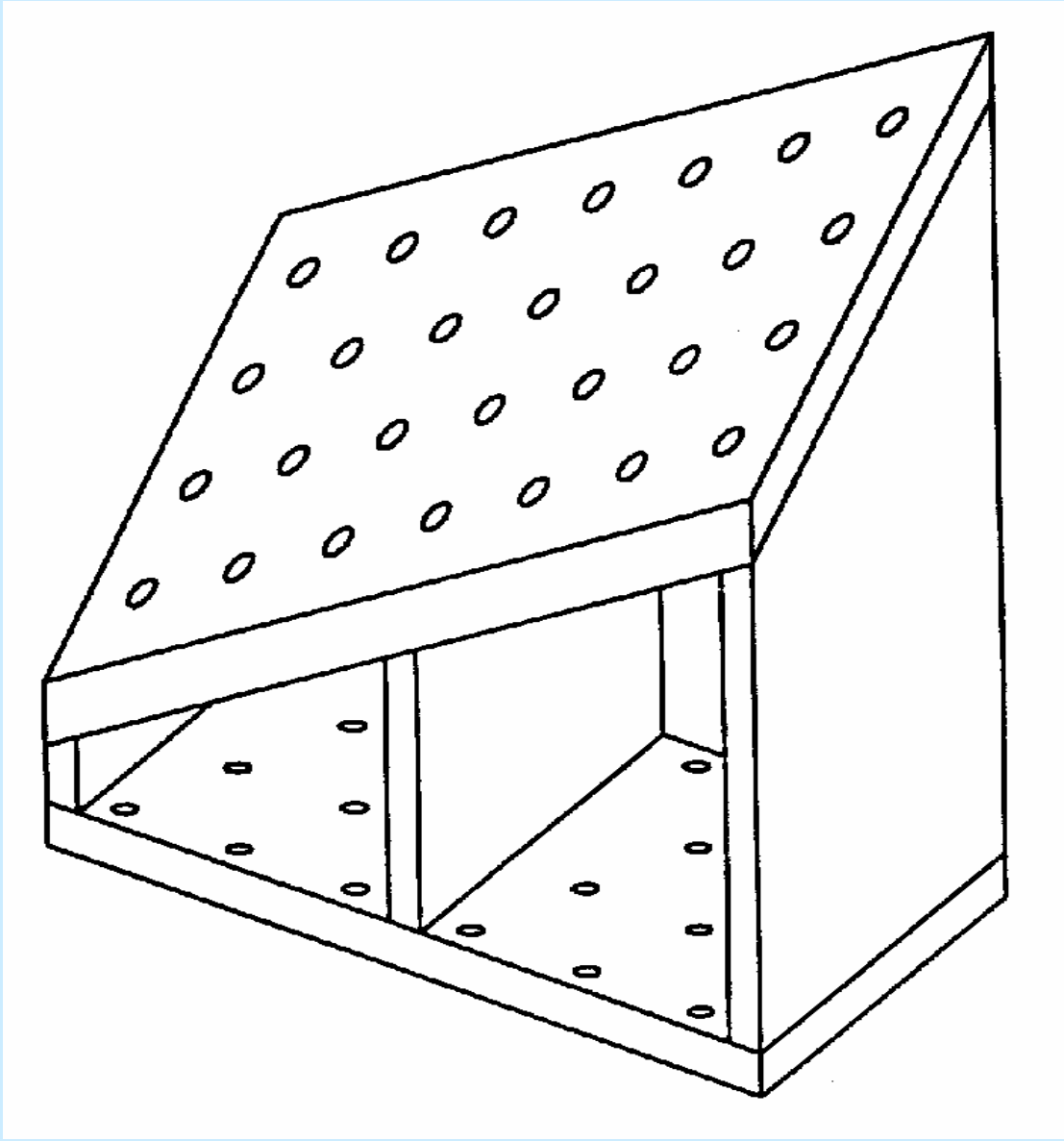
on the bottom of a softly-sprung platform that’s the bottom of a thermal chamber, with high-velocity air (now hot, now cold) streaming through electronic assemblies.

Figure 25-45 Flexible Air Ducting

courtesy GHI

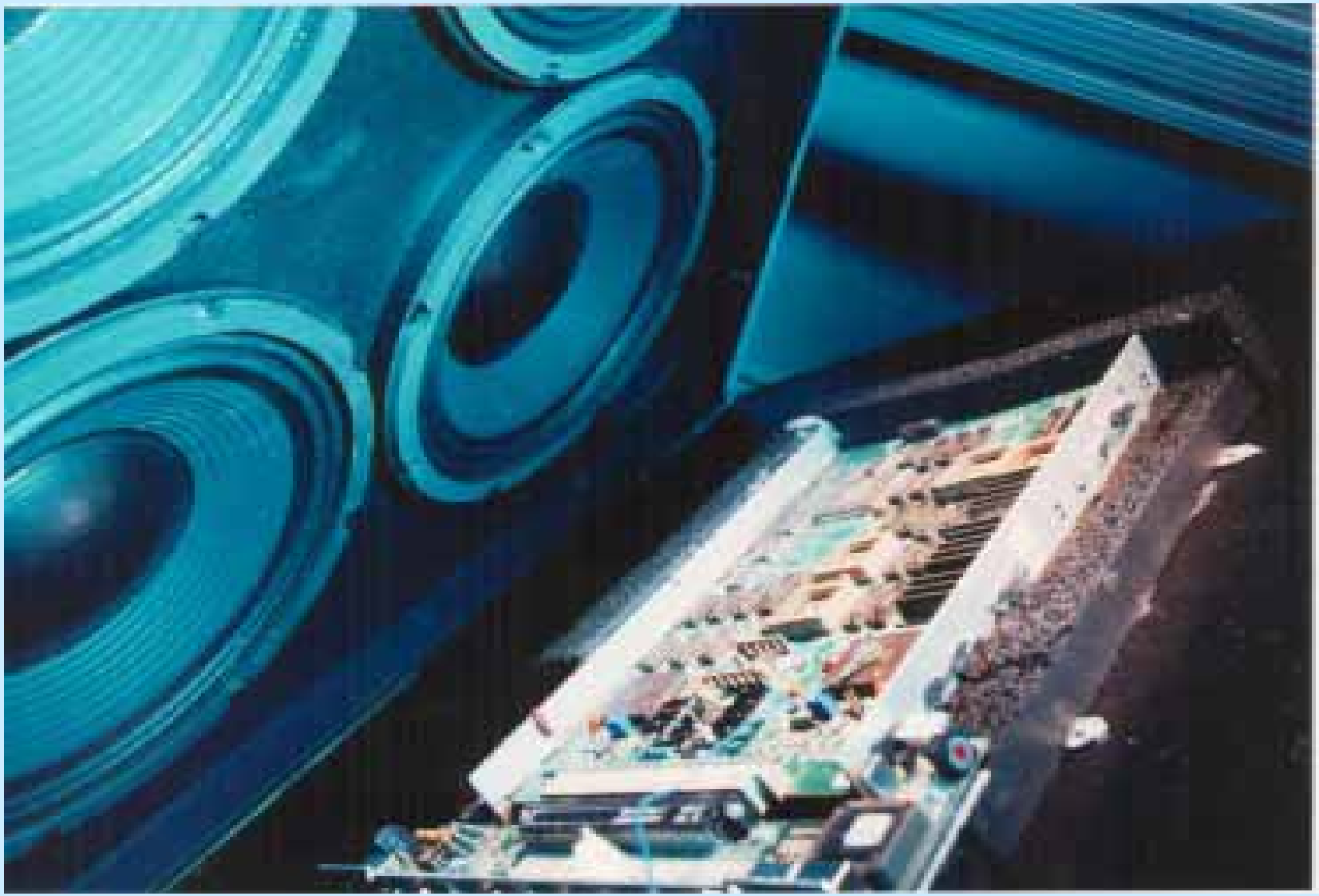
Don’t be fooled by the tilted skewed single ED shaker fixture seen here. Product excitation is only single axis.

Figure 16-14 “Tilted” Fixture does not Multi-axis Test



One other multiaxis random approach, imported from Montreal, uses intense sound to excite card vibrations.

Figure 25-42 Acoustic Excitation for Screening



OK, I think I’m finished. Perhaps your fathers had the left-hand 1984 book. The ink is hardly dry on the right-hand version, in which today’s slides and video clips appear.


RANDOM VIBRATION IN PERSPECTIVE
Wayne Tustin and Robert Mercado
TUSTIN INSTITUTE OF TECHNOLOGY
A Minimal-Mathematics Introduction to the Fundamentals of
Random Vibration & Shock Testing
HALT, ESS & HASS
also Measurements, Analysis & Calibration
Wayne Tustin

Thanks for listening to me talk about Multiaxis Random Vibration for HALT and HASS

Wayne Tustin
Equipment Reliability Institute
Santa Barbara, California

Aerospace Testing Expo 2005 NORTH AMERICA (Long Beach)

November 8, 2005