RANDOM VIBRATION TESTING

Practice:

Define an appropriate random vibration test, and subject all assemblies and selected subsystems to the test for design qualification and workmanship flight acceptance.

Benefit:

This practice assists in identfying existing and potential failures in flight hardware so that they can be rectified before launch.

Programs Which Certified Usage:

Mariner series, Viking, Voyager, Magellan, Galileo

Center to Contact for Information:

Jet Propulsion Laboratory (JPL)

Implementation Method:

Apply broadband, shaped, random vibration to the test item through its service attachments. The frequency band should span from approximately 20Hz to 2000Hz. Apply vibration in each of three mutually perpendicular axes (preferably the principal axes of the test item). Closed loop, servo control the vibration specification at one or more of the test item-to-fixture interface points. Narrow band test item response limiting or force limiting may be warranted to avoid unrealistically severe resonant responses of the test item. Duration of the random vibration application in each axis should be not less than the flight duration for which the vibroacoustic environment is within 6dB of its maximum or 30 seconds; whichever is greater. The flight acceptance (FA) test level should be equal to or greater than the maximum predicted flight environment, but not less than a level which has been found to provide an adequate workmanship screen for the type of hardware being tested. Qualification and protoflight test levels should have margin above the FA level.

Random vibration testing has two principal objectives:

1. To verify the test item design's capability, with some margin, to withstand the launch vibroacoustic environment, and

2. To screen the workmanship integrity of the flight equipment.

Random vibration criteria should be developed by the process described in the following four steps:

RANDOM VIBRATION TESTING

1. Determine the Power Spectral Density (PSD) of the random vibration directly transmitted into the flight article through its mounts from the launch vehicle sources such as engine firing, turbopumps, etc (see Figure 1). These vibration conditions at the launch vehicle-to-payload interface are typically available from the launch vehicle builder.

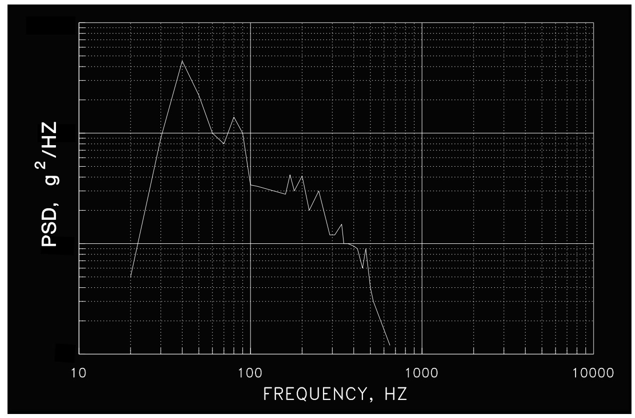

Figure 1. Vibration levels transmitted to flight article through mounts

2. Perform an analysis to predict the payload/flight article's vibration response to the launch vibroacoustic environment. Statistical energy analysis (SEA) methods such as the VAPEPS (VibroAcoustic Payload Environment Prediction System) program are effective predictors in the higher frequencies (see Figure 2). The VAPEPS program can also effectively extrapolate from a database using SEA techniques to provide predictions for a similar configuration. If random vibration predictions are needed for the lower frequencies, finite element analysis methods, such as NASTRAN, are commonly used. The vibration is induced into the test article both directly and indirectly (through its mounting).

3. Establish a minimum level of vibration which is necessary to ferret out workmanship defects--both existing and potential failures (see Figure 3). This is particularly applicable to electronic assemblies for which minimum effective workmanship levels have been established based on extensive test experience.

4. Envelope the curves from 1-3 to produce a composite random vibration specification for the test article as follows:

This resultant random vibration specification (curve 4), which is employed as the flight acceptance test level, covers the two primary sources of this vibration while also providing an effective process for uncovering workmanship defects, particularly for electronics. Qualification and Protoflight test levels are increased typically 3 to 6dB above flight acceptance to verify that the design is not marginal.

Conventional rigid fixture vibration tests can severely overtest the hardware at resonances. It is accepted practice to response limit, or notch the input, at resonances of fragile hardware where it can be technically justified with flight or system test data, or analysis. Recently developed techniques to alleviate the overtest at resonances by specifying force limiting criteria potentially provides a much more accurate simulation of the flight vibration environment, but have not yet been implemented NASA-wide.

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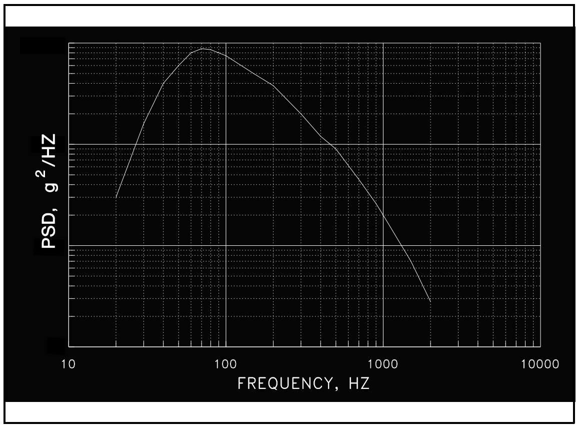

Figure 2. Payload/flight article response to vibroacoustic environment.

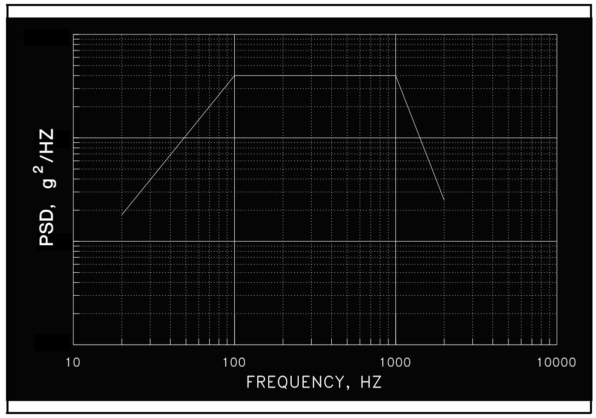

Figure 3. Minimum vibration levels for workmanship defect detection

Technical Rationale:

The launch vehicle acoustically excites the spacecraft. This excitation is impractical to simulate for electronic assemblies at the assembly level because of fixture complexity, etc. Therefore, random vibration is substituted to excite the hardware.

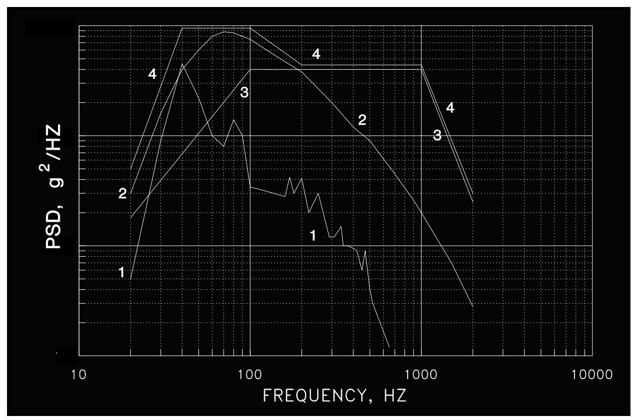

Figure 4. Composite random vibration envelope

Random vibration is currently the most widely adopted type of dynamics environmental testing for spaceflight hardware. It is generally perceived by users to be the most realistic environment to reproduce in the vibration test laboratory as well as an effective tool for uncovering workmanship defects-- especially in electronics assemblies.

Impact of Non-Practice:

Increased probability of in-flight failure due to design deficiencies or defective workmanship.