Estimating Shock Spectra: Extensions Beyond the Goddard Environmental Verification Standard

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*Spacecraft are subject to severe high-frequency dynamic loads, such as those generated by pyrotechnic devices. Although the structural frame of the spacecraft can handle these events, the equipment mounted on the frame can be impaired by the high-*frequency vibrations. To qualify the equipment, shock response spectra (SRS) are used to quantify the vibration environment at each equipment mount location.

The SRS concept is simple. We begin with the acceleration at a mount location on the structural frame due to the dynamic load. Then we impose this acceleration at the base of a single-degree-of-freedom oscillator and compute the maximum acceleration response of the oscillator. We repeat this computation for a series of oscillators with natural frequencies that cover a wide range, typically up to 10 kHz. These maximum responses, as a function of natural frequency, are the SRS for a specific mount location and dynamic load. The difficulty here is in determining the acceleration at the equipment mount locations. The most accurate method for finding this acceleration is to experimentally test the full-scale structure. The problem is that such tests cannot be performed until the design and manufacture of the spacecraft is nearly complete. Hence, there is a need to estimate SRS much earlier in the design phase.

In the General Environmental Verification Standard (GEVS) for Goddard Space Flight Center Flight Programs and Projects, a simple method is given for approximating the SRS. This method is applicable for a wide variety of shock events, is empirically based, and requires fairly simple descriptions of the structural frame and connections. Although the method is based on research and experimental work performed in the 1970s, it still serves as a useful tool for preliminary equipment qualification.

We show how the GEVS SRS approach can be extended to include more detailed information about the spacecraft structure. We follow the general analyti-

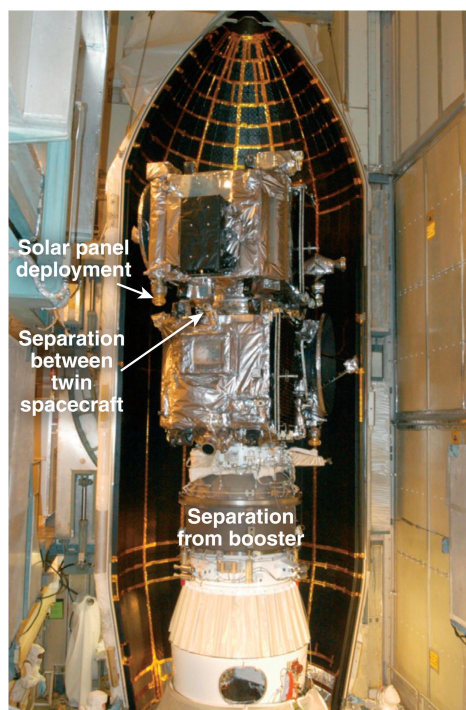

Figure 1. Major sources of shock in the STEREO spacecraft, shown here mounted on a Boeing booster.

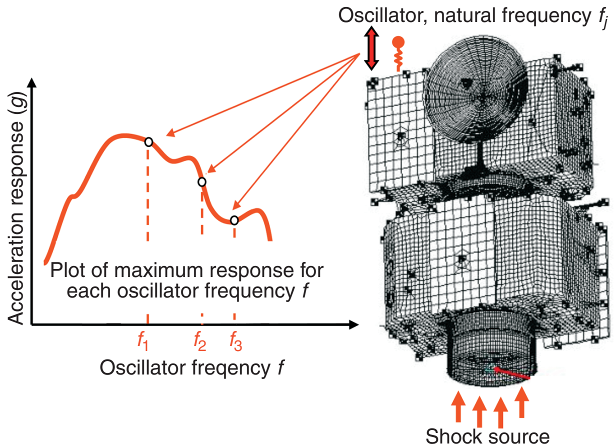

Figure 2. The SRS concept, illustrated for the case of the shock separation load on STEREO.

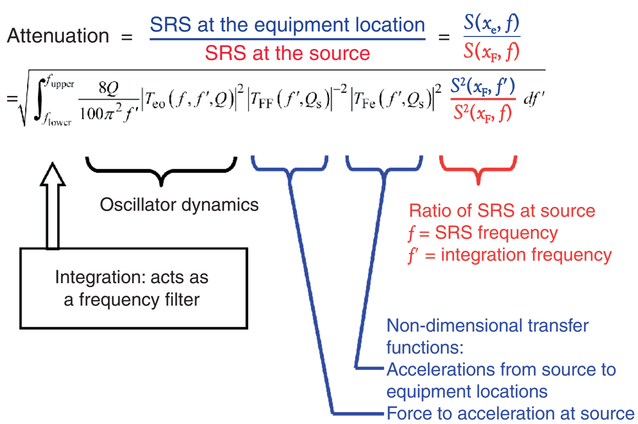

Figure 3. Analytical components of the attenuation factor used in the SRS computation.

cal framework of GEVS by starting with a base SRS close to the source of the dynamic load. This SRS is defined according to the type of pyrotechnic device. In GEVS, empirical attenuation relations are used to adjust the base SRS according to distance from the shock source, type of structural frame, and the properties of the structural joints between the source and equipment.

In our extended approach, we use information from finite-element models to analytically develop these attenuation relations. This extended approach can be useful for complex structures where the concept of distance and the assessment of structural joints can be difficult or ambiguous, and when there are multiple wave paths between the shock source and equipment mount location. In Figs. 1–5, we illustrate the extended GEVS approach by analyzing the shock response of the Solar TErrestrial RElations Observatory (STEREO).

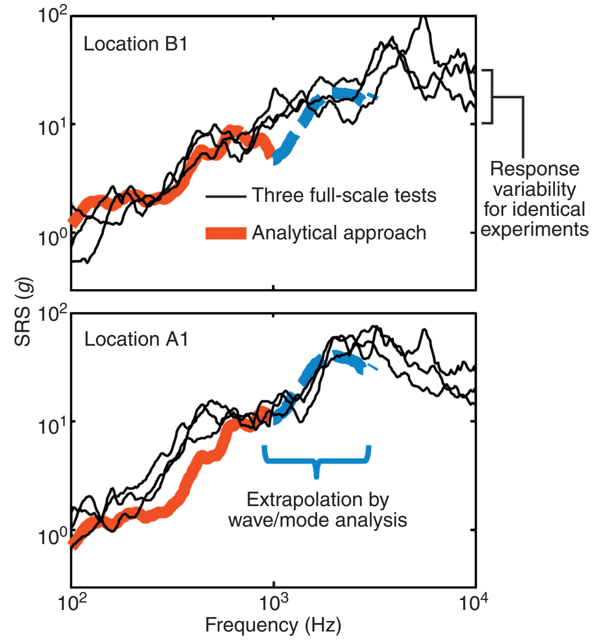

Figure 4. Comparison of SRS determined from the proposed extension of GEVS and from full-scale tests of STEREO.

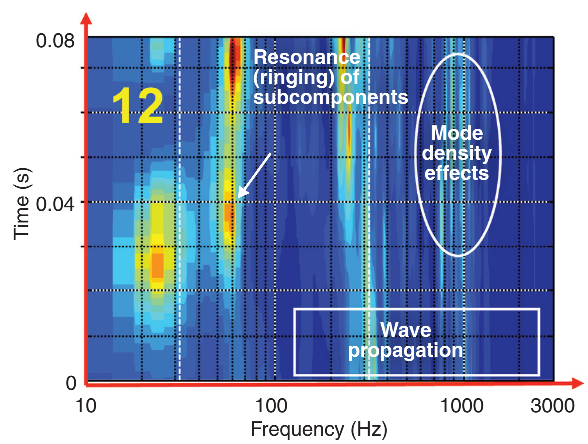

Figure 5. Time-varying Fourier spectra of the acceleration at an equipment mounting point in STEREO; the spectra illustrate the types of vibration characteristics that contribute to the shock response of the equipment.

For further information on the work reported here, see the references below or contact gordon.maahs@jhuapl.edu.

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