# Extrapolation of Spacecraft Vibration Test Data

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Vibration tests of flight spacecraft are difficult to justify because they are: 1) expensive, 2) time consuming, 3) risky, 4) too late to impact the design, and 5) of little use to future programs. It is therefore understandable that the trend in the aerospace industry is to rely more on finite element analyses (FEA) and less on testing to simulate dynamics environments. However, comparisons of test data with even very sophisticated FEA predictions of the dynamic behavior of complex structures often show very disturbing discrepancies. A great deal of effort has been devoted to the development of experimental methods for accurately measuring the vibration characteristics of spacecraft, and other complex structures, and to the problem of reconciling FEA models with the test data. However, very little effort has been devoted to the problem of extrapolating the knowledge learned in spacecraft vibration tests to benefit future designs, and that is the subject of this paper. The development of vibration test extrapolation techniques, which are compatible with FEA, is the subject of current R & D at JPL. This paper discusses the problem and several approaches being pursued, with the hope of motivating others to identify relevant literature, generate ideas, and join this quest.

Assume one has 1) a database of one or more previously tested spacecraft, for which both vibration test data and an FEA are available, and 2) a new "similar" design for which only an FEA test simulation is available. Vibration tests of interest may include random, sine sweep, sine burst, base-drive modal, etc. (The provision of such a database, with both FEA and test data, and the definition of similarity are important first steps in the extrapolation process.) One extrapolation approach being investigated involves projection of modal parameters determined from the base-drive apparent mass frequency response function (FRF). Another approach is an adaptation of the modal mass acceleration curve (MMAC) used at JPL to characterize the dynamic excitation of spacecraft by different launch vehicles. (The MMAC is a plot of the maximum modal acceleration versus modal effective mass.) Simple model calculations and vibration test data from the 1995 Mars Pathfinder and 2003 Mars Exploration Rover spacecraft vibration tests are used to explore these and other extrapolation techniques.

The afore mentioned data base would also be useful for tracking typically, unexpected vibration test phenomena such as: 1) test failures, 2) structural interface problems, 3) low amplification going from the base up through various subsystems, 4) non-linearity, and 5) examples of coupled modes and other test complications. Test data from the Cassini, HESSI, GRACE, and GALEX spacecraft vibration tests illustrate these cases.