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Launch Vehicle Atmospheric Flight Loads

THE papers presented in this special section represent significant advances in the area of launch vehicle atmospheric flight loads analysis. The work was accomplished over a two-year period and involved experts from the fields of structural dynamics, atmospheric sciences, time series data analysis, numerical analysis, and statistics. As a result, the papers represent a unique multidisciplinary body of work.

The first paper, "Identifying Slowly Varying and Turbulent Wind Features for Flight Loads Analyses," describes the methodology developed to identify the spectral boundary between the slowly varying wavelengths of atmospheric winds and the more rapidly changing, turbulent components. Measured wind profiles were analyzed for two launch sites in the United States, and a function was developed to describe the spectral boundary. Identification of this boundary allows for a consistent development of turbulence/gust forcing functions and the exclusion of these components from the winds measured just prior to launch for load analysis on the day of launch.

The second paper, "Derivation of Atmospheric Gust-Forcing Functions for Launch-Vehicle Loads Analysis," describes two related studies. The first is a comprehensive review of the capabilities of the Jimsphere wind measurement system and the establishment of the shortest wavelengths at which valid turbulence data can be extracted from the measured wind profiles. The second part presents the methodology developed to extract the turbulent components from measured wind profiles and to provide forcing functions that can be used in Monte Carlo gust load analyses.

The third paper, "Statistical Analysis of Atmospheric Flight Gust Loads Analysis Data," presents the tolerance bound (statistical enclosure) procedures used to establish the launch vehicle gust loads presented in the fourth paper, "Atmospheric Flight Gust Loads Analysis." Two procedures are described. The first procedure assumes a gamma distribution for the calculated loads and is most suitable for small sample sizes. The second approach makes no assumptions about the distribution but requires relatively large sample sizes. The paper presents examples to support the conclusion that launch vehicle gust loads have a gamma distribution.

The fourth paper presents a new Monte Carlo gust load analysis approach for launch vehicles. The loads-analysis results presented in the paper were developed using more than 1000 forcing functions in each analysis. Gust loads were calculated as a function of altitude and time between when a wind is measured and when the launch vehicle actually flies through the wind. Results are presented for a heavy-lift launch vehicle and a medium-lift launch vehicle. Of particular significance are the findings that turbulence loads for the Western Range of the United States are higher than for the Eastern Range and are considerably higher during the winter than during the summer.

The last paper, "Refined Day-of-Launch Atmospheric Flight Loads Analysis Approach," proposes a new methodology for day-of-launch load placard analysis. The methodology is based on the recognition that, once loads that result from turbulence have been properly accounted for statistically, the turbulent wind components do not need to be included in the other loads analyses that are performed with winds measured just before launch. Critical aspects of the proposed approach were implemented on a heavy-lift launch vehicle simulation, and the results are compared with those obtained during the actual launch processing of the vehicle.

The work presented in these papers allows for a consistent and more accurate prediction of loads that launch vehicles can experience during atmospheric flight. Various aspects of the proposed procedures have been implemented on several launch vehicle simulations, and in each instance reductions in loads and increase in launch availability were achieved.

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