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# New Transient Finite Energy Shock Prediction Methodology

Shock prediction is one of the top loads and dynamics discipline technical challenges identified within NASA and industry programs and projects. The physics-based Transient Finite Energy (TFE) shock prediction methodology has been developed and compared favorably against test results. TFE can provide another approach to develop predictions of shock response spectra (SRS) for use in the analysis of structural margins.

## Need for Improved Shock Prediction

Traditionally, SRS prediction has been extremely challenging. It has been consistently considered a top challenge by the NESC's Loads and Dynamics Technical Discipline Team, most NASA Centers, and industry. Despite being required by many aerospace projects, NASA and industry recognize that the accuracy of current shock predictions can be analyst-dependent and in need of improved reliability. It is typical, but not desired, to have programmatic and technical risks related to shock prediction and margins still open late in the design cycle. Therefore, government and industry will benefit from improved shock prediction, not only for design, but also for risk mitigation.

## TFE Methodology

Physically, a shock source behaves as an impulsive force applied to a structure in a brief time, or a sudden release of strain energy within a structure and therefore has finite energy. The basic shape of the shock source force impulse is best modeled by a half sine. The physical phenomenon can be explained as a sudden expansion and contraction of the system, due to the half sine impulse. TFE is formulated by decoupling the impulsive shock input from propagation through the structure. It is considered physics based because it solves for an actual physical input forcing function called the TFE forcing function (TFE FF).

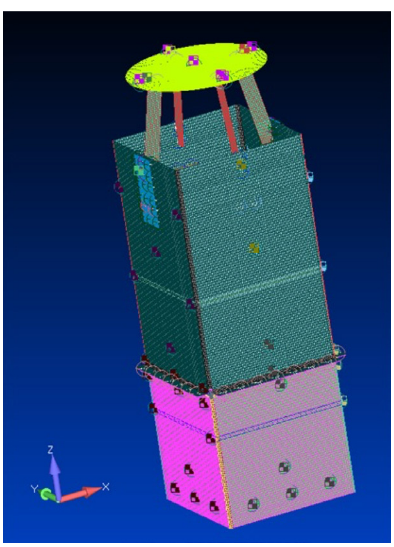
The TFE FF is calculated by connecting three domains: SRS, Fourier spectra, and time. A shock synthesis is performed over the input SRS. The resulting time history is transformed to the frequency domain via a Fourier transform and multiplied by the driving point apparent mass of the structure at the shock source location. An inverse Fourier transform is performed on the resulting force spectrum to obtain the TFE FF time history. A Monte Carlo simulation is then performed applying the TFE FFs and calculating the mean SRS response. A dynamic uncertainty factor (DUF) is then added.

There are two TFE calculation modes: TFE finite element model (FEM) analysis and TFE test. TFE FEM analysis uses a finite element analysis (FEA) transient analysis solution or steady-state transfer accelerations for prediction, compared to the TFE test-based mode, which uses transfer accelerations produced by a hammer tap. The FEM-based TFE has been validated and envelopes SRS measurements with reasonable DUFs (1.4 and 2.0 for 3 and 6 dB, respectively).

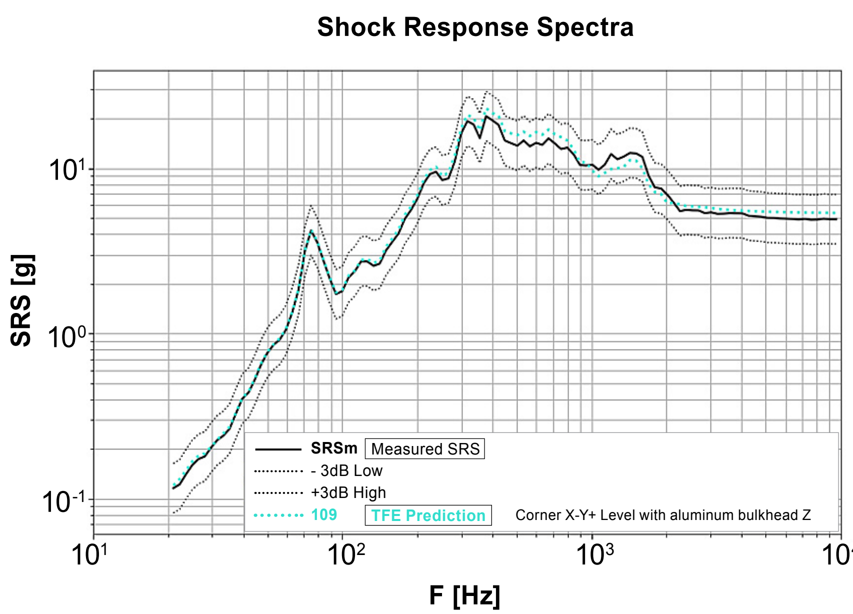
In summary, the TFE methodology uses existing industry standards and a projects baseline FEA and consist of analysis and test procedures that are easily used by structural analysts.

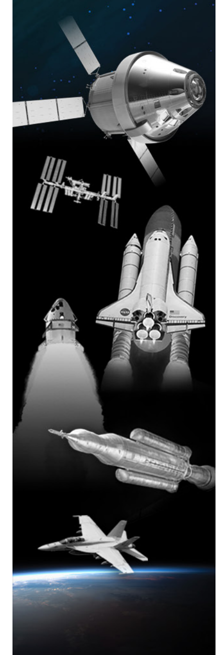
## References

1. Applications of Finite Energy Methods to Transient, Random, and Shock Predictions: D. Kaufman, A. Majed, A. Kolaini, J. Sills, and E. Henkel, SCLV, 2022. ntrs.nasa.gov/citations/20220008193




Finite element model of notional satellite (above) and its SRS using this TFE shock prediction methodology (right)



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