Spacecrafts are subjected to severe mechanical loads, especially during the ascent phase of the launcher. Among several vibrational environments, shock loads, which are caused mainly by the activation of pyrotechnic devices used for the separation of the payloads and the different stages of the launcher, are transmitted throughout the entire structure and reach the scientific instruments of the spacecraft. Therefore, it is important to verify if the space instruments can withstand this environment, considering the nature of the shock, which generally consists in an intensive and short load. In recent years, numerical analyses are being demanded to predict the responses of the structures against shocks and for this reason, it is necessary to establish adequate numerical methods, taking into account the complex mathematical treatment and the uncertainty in the load characterization. The purpose of this study is to present the application of different methods to calculate the required structural results for a space instrument subjected to a shock environment using a finite element model (FEM). The procedures for each method, type of results that can be calculated and the comparison of results are described below. The objective is to select the most suitable analysis method for shock loads based on the precision of the results and the capability of obtaining all the variety of data for a complete evaluation of the structure.

**METHODOLOGY**

The Supra Thermal Electrons and Protons (STEP) instrument constitutes together with other instruments the Energetic Particle Detector (EPD) payload for the European Solar Orbiter spacecraft, which is scheduled to be launched in 2019. The main purpose of the Solar Orbiter project is to better understand the behaviour of the heliosphere.

The recommended method for structural calculation in European space projects is the Finite Element Analysis (FEA), and for the European project of Solar Orbiter, the use of Nastran code for the FEM structural analyses is a requirement.

**Shock Analysis Methods**

This is the summary of different FEM analysis options to simulate shock loads. All proposed methods are compatible with Nastran code and linear analysis, meeting with the requirements for shock modelling and analysis in space projects:

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transient Analysis</td>
<td>Transient analysis is the most general way to compute the behaviour of a structure subjected to a time-varying load or forced acceleration.</td>
<td>Accurate, time consuming</td>
<td>Big amount of output data</td>
</tr>
<tr>
<td>Response Spectrum Analysis</td>
<td>The Response Spectrum Analysis (RSA) method calculates directly the approximation of the peak responses of any type of result using a normal modes computation of the structure (Sol 103) and by defining as input the SRS specification applied to the base. The summation options in Nastran are ABS, SRSS, NBL, and CQC.</td>
<td>Small amount of output data, only peak values of response, results depend on the selected summation option</td>
<td></td>
</tr>
<tr>
<td>Sine Transmissibility Method</td>
<td>An alternative method to calculate SRS curves of response acceleration for selected nodes is in multiplying the input SRS by the shock transmissibility between the base and the nodes of interest. The sine transmissibility obtained from sine sweep test or by Frequency Response Analysis is used to estimate the shock transmissibility.</td>
<td>Only SRS curves calculation</td>
<td></td>
</tr>
<tr>
<td>Equivalent Quasi-Static Load Method</td>
<td>The calculation of the equivalent quasi-static (EQS) inertial acceleration that approximately gives the same total interface force than the shock load.</td>
<td>Quick evaluation, only peak values for IF forces</td>
<td></td>
</tr>
</tbody>
</table>

**SHOCK TEST**

The shock tests of the instrument were performed on the Airbus Defence & Space Test Laboratories in Portsmouth, England. The shock load is generated by a pendulum that hit to the horizontal table where the instrument is attached. To measure the input acceleration, two reference triaxial accelerometers are located on the interface table near to two diagonally opposite interface bolts.

**RESULTS**

The results (accelerations, forces and stresses) obtained to evaluate the STEP instrument subjected to shock loads considering the proposed analysis methods are compared in different formats (peak values, time functions and SRS curves) to estimate their differences.

**CONCLUSIONS**

This study has exposed a variety of numerical analyses that can be employed to evaluate the shock environment using the finite element model of a space instrument. Transient analysis have the best precision and is the only capable of providing all the required types of results as time functions, peak values and SRS curves. The inconvenience is the high computational costs in terms of analysis time and amount of output data. The rest of analysis methods presents high differences of results, which are quite dependant on the selected option.

**REFERENCES**


