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ORBITAL DEBRIS RISK ASSESSMENT OF HARNESSING: COMPARING ALUMINUM PLATE BALLISTIC LIMIT EQUATION PREDICTIONS TO TEST DATA

Abstract

On robotic spacecraft, harnessing routed outside the spacecraft structure is generally considered to be at relatively high risk of micrometeoroid and orbital debris (MMOD) impact-induced failure. It is therefore desirable to quantify that risk. However, there are no ballistic limit equations (BLEs) that describe the response of harness geometries to hypervelocity impacts. A typical workaround consists of calculating an equivalent aluminum shield for the critical conductors of a harness based on the areal density of insulation and shielding surrounding those conductors. Once an equivalent aluminum shield is established, the harness is modelled as a flat aluminum plate, and techniques using well-established BLEs can be used to assess risk. However, there are several reasons to expect that modelling a harness as an equivalent aluminum plate is a bad approximation. First, the harness is made of many different materials, none of which is typically aluminum. Second, the components of a harness geometry are loosely held together compared to the homogenous metallic plate assumed in the BLEs. Third, compared to the parallel and relatively large flat plates assumed in typical double-wall BLEs, a harness is a small, rounded target behind the bumper wall, likely receiving a glancing blow from only a portion of the debris cloud. For these reasons, predictions made by aluminum plate BLEs of harness response to hypervelocity impact are suspect. In this paper, the authors compare the results of a set of harness hypervelocity impact tests to predictions of the harnesses' performance using the equivalent aluminum plate method described above. The tests identify two failure modes for the harnesses: signal distortion resulting from partial severing of a conductor, and short circuit resulting from contact between a braid and conductor. Therefore, for harnesses with braids, the modelled equivalent aluminum shield thickness accounted for all material up to the first core conductor, simulating contact between the braid and conductor. For harnesses without braids, the equivalent aluminum thickness also included half of the conductor itself, simulating partial severing of that conductor. In the single wall case, the Cour-Palais equation was used with the semi-infinite plate failure criterion. In the double wall case, the Reimerdes modification was applied to the Christiansen NNO BLE for marginal bumpers. Used in this manner, the BLEs do a reasonably accurate job predicting the ballistic limit found in the tests. This gives the authors more confidence in their estimations of harness risk using an equivalent aluminum plate method.