SPACE DEBRIS SYMPOSIUM (A6)
Modelling and Risk Analysis (2)

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MODELING OF LEO ORBITAL DEBRIS POPULATIONS IN CENTIMETER AND MILLIMETER SIZE REGIMES

Abstract

The building of the NASA Orbital Debris Engineering Model, whether ORDEM2000 or its recently updated version ORDEM2010, uses as its foundation a number of model debris populations, each truncated at a minimum object-size ranging from 10 μm to 1 m. This paper discusses the development of the ORDEM2010 model debris populations in LEO (low Earth orbit), focusing on centimeter (smaller than 10 cm) and millimeter size regimes. Primary data sets used in the statistical derivation of the cm- and mm-size model populations are from the Haystack radar operated in a staring mode. Unlike cataloged objects of sizes greater than 10 cm, ground-based radars monitor smaller-size debris only in a statistical manner instead of tracking every piece. The mono-static Haystack radar can detect debris as small as 5 mm at moderate LEO altitudes. Estimation of millimeter debris populations (for objects smaller than 6 mm) rests largely on Goldstone radar measurements. The bi-static Goldstone radar can detect 2- to 3-mm objects. The modeling of the cm- and mm-debris populations follows the general approach to developing other ORDEM2010-required model populations for various components and types of debris. It relies on appropriate reference populations to provide necessary prior information on the orbital structures and other important characteristics of the debris objects. NASA's LEO-to-GEO Environment Debris (LEGEND) model is capable of furnishing such reference populations in the desired size range. A Bayesian statistical inference process, commonly adopted in ORDEM2010 model-population derivations, changes a priori distribution into a posteriori distribution and thus refines the reference populations in terms of data. This paper describes key elements and major steps in the statistical derivations of the cm- and mm-size debris populations and presents results. Due to lack of data for near 1-mm sizes, the model populations of 1- to 3.16-mm objects are an empirical extension from larger debris. The extension takes into account the results of micro-debris (from 10 m to 1 mm) population modeling that is based

on shuttle impact data, in the hope of making a smooth transition between micron and millimeter size regimes. This paper also includes a brief discussion on issues and potential future work concerning the analysis and interpretation of Goldstone radar data.