Using Statistical Risk Assessment to Optimize the Design of Inflatable Membrane Structures in Low Earth Orbit

A. Chandra (ASU), A. Babuscia (JPL), J. Thangavelautham (ASU)

The increasing need for space structures with large surface area for applications such as parabolic antenna, solar sails and large reflectors has focussed an interest in inflatable membranes as a viable solution. Inflatable membrane structures provide an effective solution due to their low mass, low cost and very low storage volume compared to conventional solutions. The principal design challenges are maintenance of shape accuracy upon deployment, ensuring structural reliability and ensuring a robust deployment sequence. This paper focuses on methods to quantify structural reliability of inflatable membranes. Using these results we seek to optimize membranes structures to better withstand orbital environments. The study identifies two possible alternatives. The first is a membrane structure with multiple layers within a single bladder and the second is a multi-cellular inflatable structure designed to attain specific shapes upon inflation. Both the above designs lead to increased amount of structural redundancy in the inflatable. The present work quantifies the relative risk of failure due to micro-meteoroid impact in the low earth orbit for the proposed designs. Probabilistic failure models have been developed as limit state equations and risk has been quantified using first order reliability methods (FORM). Monte – Carlo simulations are used to test the accuracy of the obtained results. The analysis leads to a sensitivity study to identify the most critical structural parameters and the relative effects of each on the system as a whole. Our analysis forms the basis of feasibility studies for each of the proposed inflatable membrane designs. These studies are focussed on factors such as stowage volume, packing efficiency and total weight of the membrane. The findings of the present work provides insight into the design of structurally reliable inflatable membranes.

Keywords: inflatable membrane, structural reliability, sensitivity, multi cellular inflatable