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Author: Mr. Xingzhi Hu
National University of Defense Technology, China, huxingzhi@nudt.edu.cn

QUANTIFYING MULTIDISCIPLINARY UNCERTAINTY IN SATELLITE SYSTEM DESIGN WITH ACTIVE SUBSPACES

Abstract

More recently, uncertainty quantification has been receiving much attention from aerospace engineering community. With ever-increasing requirements for robustness and reliability, it is crucial to quantify multidisciplinary uncertainty in satellite system design which dominates overall design direction and cost. However, coupled multi-disciplines and cross propagation of high-dimensional uncertainties hamper the efficiency and accuracy of uncertainty analysis. In this study, an uncertainty quantification methodology based on active subspaces is systematically established for satellite system design. The active subspace effectively reduces the dimension and measures the contribution degrees of input uncertainties. A comprehensive characterization of associated uncertain factors is made and all subsystem models are built for uncertainty propagation. By integrating a system decoupling strategy, the high-dimensional uncertainty effect is efficiently represented by a one-dimensional active subspace for each design of a certain satellite system, e.g. earth observation satellite and 3U CubeSat. The identified active subspace is checked by bootstrap resampling for confidence intervals and verified by Monte Carlo propagation for the accuracy. In order to show the performance of active subspaces, 18 uncertainty parameters of an earth observation small satellite are exemplified and then another 5 design uncertainties are incorporated. Robust results rank the uncertainties that contribute the most to satellite mass and total cost, and confirm the efficacy of quantifying high-dimensional uncertainty through a relatively small number of random samples. The quantification approach with considerably less cost exhibits high accuracy and strong adaptability for conceptual design of the small satellite, which provides a potential template to tackle multidisciplinary uncertainty in other satellites and aerospace vehicles.