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An active subspace approach to multidisciplinary robust design of small satellites

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Abstract

The design optimization of small satellites is a complicated task that includes multiple variables and engineering disciplines. Many attempts have been made to achieve the performance robustness and reliability; however, coupled multi-disciplines and cross propagation of multidimensional uncertainties hamper the efficiency and accuracy of uncertainty propagation. Aiming at cost-effective robust design of small satellites, this study presents an active subspace approach using a partial first-order second moment (p-FOSM) strategy and enable more uncertainties propagate among multi-disciplines. The main associated uncertain factors are characterized to determine their effects on the quantity of interest, consisting of total mass, payload precision, and total cost of the satellite. A dominant active subspace is identified with sufficient confidence intervals. The sample size required for uncertainty quantification is much smaller as compared to previous methods. The aforementioned approach is applied to an earth observation small satellite, in which a 23-dimensional uncertainty space is projected to one dimension with a linear combination. To tackle the highly nonlinear and closely coupled optimization, the efficient active subspace approximation is combined with the non-dominated sorting Genetic Algorithm-II (NSGA-II). The Pareto-optimal solutions are obtained and the effect degrees of all uncertainties are ranked, which provides a beneficial reference for reliable and robust performance control of small satellites in engineering.