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DISCLOSE UNCERTAINTY PROPAGATION LAWS OF MARS ENTRY DYNAMICS

Abstract

For the development of next generation Mars entry, descent, and landing (EDL) technologies, uncertainty is a major technical challenge. The probabilistic quantification of being inside or outside the predefined safety margin is sought, and the uncertainty propagation is required to be quantified according to the uncertainties in initial conditions and system parameters. Available uncertainty propagation laws that expressed in an explicit statistics manner are required as a significant prerequisite of many research and design work, such as risk and reliability assessment, robust optimization design, and system verification. Unfortunately, to date, almost no public report that exposes the uncertainty propagation laws of Mars entry. This investigation is attempt to disclose the uncertainty propagation laws of Mars entry dynamics under the consideration of four factors, including guided or unguided entry, and uncertainties with uniform or normal distributions. More precisely, stochastic Mars entry dynamical system is modeled at first. Then, polynomial chaos based computational framework is established. Intrusive and non-intrusive polynomial chaos methodologies are employed to obtain the explicit expressions of the mean and variance of the uncertainties along the guided or unguided Mars entry trajectories. Third, the propagations of uncertainties due to initial conditions, ballistic coefficient, lift-to-drag ratio, and atmospheric density are respectively quantified based on their uniform or normal distribution types. Thus, the magnitudes or scopes of the parameters in the explicit expressions can be determined. Next, the explicit expressions derived by intrusive and non-intrusive polynomial chaos methods are summarized and transformed into a generalized form using Bayesian theory. Finally, comparative numerical simulations are implemented to verify the effectiveness and available scopes of the provided uncertainty propagation laws of Mars entry. Examples considering variety distribution types of uncertainties are also given to illustrate how the uncertainties evolve along Mars entry trajectory and impact upon the landing footprint dispersion.