Paper ID: 2098
student

SPACE SYSTEMS SYMPOSIUM (D1)
System Engineering Tools, Processes & Training (3)

Author: Mr. Nicolas Croisard
University of Glasgow, United Kingdom, n.croisard@aero.gla.ac.uk

Dr. Massimiliano Vasile
University of Strathclyde, United Kingdom, massimiliano.vasile@strah.ac.uk
Mr. Stephen Kemble
Airbus Defence and Space Ltd, United Kingdom, stephen.kemble@airbus.com
Prof. Gianmarco Radice
University of Glasgow, United Kingdom, Gianmarco.Radice@glasgow.ac.uk

PRELIMINARY SPACE MISSION DESIGN UNDER UNCERTAINTY

Abstract

In the early phase of the design of a space mission, it is generally desirable to investigate as many feasible alternative solutions as possible. At this particular stage, an insufficient consideration for uncertainty would lead to a wrong decision on the feasibility of the mission. Traditionally, a system margin approach is used in order to take into account the inherent uncertainties related to the computation of the system budgets. The reliability of the mission is then independently computed in parallel. An iterative, though integrated, process between the solution design and the reliability assessment should finally converge to an acceptable solution. This paper proposes a way to model uncertainties and to introduce them explicitly in the design process. The overall system design is then optimised, minimising the impact of uncertainties on the optimal value of the design criteria (e.g. minimum system mass, minimum system power, etc.). Using Evidence Theory, also know as Dempster-Shafer's theory, both aleatory and epistemic uncertainties, coming from a poor or incomplete knowledge of the design parameters, can be effectively modelled. The values of uncertain or vague design parameters are expressed by means of intervals with associated probability. Each expert participating in the design assigns an interval and a probability according to their experience. Ultimately, all the pieces of information associated to each interval are fused together to yield two cumulative values, Belief and Plausibility, that express the confidence range in the optimal design point. In particular the value of Belief expresses the lower probability that the selected design point remains optimal (and feasible) even under uncertainties. In this paper, Evidence Theory is applied to the optimal design of the mission BepiColombo. The main spacecraft subsystems are modelled using Evidence Theory to deal with uncertain parameters. The design process is then formulated as an Optimisation Under Uncertainties (OUU) problem and the Belief is optimised (maximised) together with all the other criteria that define the optimality of the design point. Three techniques are proposed to solve the OUU problem: (a) a gradient-based technique consisting of maximising the belief for different levels of performance using a local optimiser, (b) a clustering method that identifies, in the space of design and uncertain parameters, the set of points for which the design criteria assume values below a given threshold, and (c) an evolutionary multi-objective approach aiming at minimising the effect of uncertainties on both constraints and objective functions, while optimising the mission goals. The results in the paper show the difference between the margin approach and the Evidence Theory approach. Moreover, we assess the effectiveness of the three proposed techniques at solving efficiently the OUU problem.