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SPACE SYSTEMS SYMPOSIUM (D1)
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SPACE SYSTEM RELIABILITY ANALYSIS AND OPTIMIZATION BASED ON SYSTEM CHARACTERISTIC SPACE

Abstract

Satellites are stepping into the era of "smaller, faster, and cheaper", stimulated by the emerging concepts and technologies, e.g., modular design, commercial off-the-shelf (COTS) products, and fractionated spacecraft. This lowers the market entry threshold and increases the opportunities, yet simultaneously incurs some side effects, particularly the loss of system reliability. On the other hand, instead of promoting the conceptual and technical progress, the traditional design methods, which are typically customized and labour-intensive processes, prevent the current space systems from delivering the non-traditional values, such as flexibility and responsiveness. Therefore, efforts should be made not only to improve the capability and the performance of the existing technologies, but also to develop the appropriate design methodologies. This paper addresses this need by presenting a value-centric design architecture and enabling the reliability analysis and optimization for space systems based on the system characteristic space.

In accordance with the philosophy of value-centric design, the overall architecture of reliability analysis and optimization for space systems is proposed. As the mathematical fundamental, the system characteristic space, consisting of duplication, fractionation, and derivation, is concretized to build the bridge between configuration characteristics and system reliability. The quantitative analysis and assessment of system configurations is subsequently achieved by the value models of system reliability, enabling the optimization of system configurations associated with appropriate optimization algorithms. Such an optimization problem can be concluded as the mixed integer nonlinear programming (MINLP) problems in the literature, while the genetic algorithm (GA) associated with Laplace crossover, Power mutation, and special truncation procedure, is recently considered to increase the possibility of obtaining the global optimum. The results of case studies reveal that the proposed architecture can effectively and efficiently reach the optimal solution with less than 5% of the feasible domain searched, beneficial for the improvement of system reliability when applying the innovative concepts and technologies into the design process.