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A COMPONENT-RESOURCE MODEL FOR EVOLUTIONARY SPACECRAFT DESIGN

Abstract

Space missions, particularly robotic science missions, have grown increasingly competitive over recent years. More and more missions are proposed to a relatively constant number of competed mission calls, and the concurrent design resources to prepare these proposals have remained fixed. There is a growing need to efficiently evaluate mission proposals, giving decision makers the necessary information to maximize the productivity of each mission conducted. Concurrent design teams have adopted increasing levels of automation in the design of some individual spacecraft subsystems. However, no previous automated tool exists to evaluate and optimize the entire design from a multidisciplinary standpoint. This paper presents an automated framework for modeling spacecraft at a pre-phase A conceptual design phase. The framework performs multi-objective optimization of an entire spacecraft, allowing upfront assessment and decision analysis among mission stakeholders prior to a concurrent design study. It then acts as a systems engineer's tool during a concurrent design study, determining how changes to a specific design aspect alter the performance of the entire system. The insight provided by the framework allows for the selection of a globally optimal or Pareto-optimal initial design to be refined and locally optimized to a proposal level through a concurrent design campaign. The framework models spacecraft as a collection of independent components and the resources that flow between them. It can evaluate a wide range of missions without significant modification, allowing it to be packaged as an end-user conceptual spacecraft design tool. New missions can be considered and capabilities added by simply adding components and resources. Constraints can be imposed on a component basis or system-wide based on the flow of the resources within the system. Design optimization is performed by a genetic algorithm (GA) utilizing a variable length genome (VLG). The VLG naturally allows the GA to represent the variable number of components that could be present in a system design. This ability to model an entire spacecraft down to a component level with a variable number of components allows for a more open-ended design capability than previous frameworks of this nature. Systems are evaluated through a user-defined simulation, and results can be presented in any trade space of interest based on the designs' performance in the simulation. We apply the framework to the design of a generic Earth orbiting, data gathering mission, as well as to the design of low Earth orbit active debris removal spacecraft constellations.