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INNOVATIVE SYSTEM DESIGN SYNTHESIS AND OPTIMIZATION OF RE-ENTRY VEHICLES CONCEPTUAL DESIGN

Abstract

Designing a space transportation vehicle traditionally happens in a sequential manner, that is, one step at a time, passing the design from one disciplinary team to another. In this manner, the design goes through several iterations until the requirements from all disciplines are satisfied. The conceptual design phase is generally completed in a few weeks or months, where the main objective of the design concept is the definition of the mission-technology-configuration options that satisfy the customer's requirements. This is achieved by evaluating multiple system design concepts and, eventually, defining the system baseline with subsystem technology, and programmatic and cost assessment. The level of detail increases enormously with the increase in the level of the design phase. Depending on the complexity of the system and the available resources, the detailed design phases may take months to years to fully design the system. From the literature study it is also observed that, although there are significant advancements in the propulsion system, landing mechanism, avionics, and interior of the spacecraft, the aerodynamic shape or vehicle configuration is still scaled or modified with respect to the heritage designs (benchmark designs: Apollo and Space Shuttle). Thus, if a poor configuration is chosen during the conceptual design phase, this will lead to a worse and expensive system at the end of the process.

Hence, there is a need for an approach which allows us to explore the complete set of possible configurations rather than directly selecting the benchmark design as a starting point. This paper discusses an innovative approach for the conceptual design of re-entry vehicles. Before considering a fixed benchmark configuration of a re-entry vehicle, a design synthesis approach allows the user to explore the complete set of feasible vehicle configurations for the given mission and system requirements. Furthermore, a parametric solution-space exploration is performed to refine the set of considered configurations. This allows the user to derive the best possible solution set to start the optimization process. In this paper, simultaneous optimization of the configuration and trajectory is performed. The performance of the vehicle is computed using first-order analysis methods for mass budget, aerothermodynamics, thermal protection system, and trajectory design. Thus, this approach allows the user to investigate the best possible configuration for the mission scenario as well as derive the optimized configuration and its respective optimized trajectory to re-enter safely.