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EMBEDDED OPTIMIZATION FOR SPACE RIDER REENTRY MODULE PARAFOIL GNC

Abstract

Space Rider (SR) is Europe's first reusable space transportation system, developed by Thales Alenia Space Italy for ESA, with SENER Aerospace and Defense as GNC Design Authority. The Space Rider Re-entry Module reusability concept makes use of a guided parafoil during the descent and landing phase. The Space Rider landing shall comply with stringent requirements for what concerns landing accuracy and vertical and lateral velocity at impact. This paper addresses the use of onboard optimization techniques for the Parafoil GNC (PGNC) phase. Such techniques are investigated for the Terminal Guidance flight, in which the GNC steers the vehicle from the parafoil opening location to the landing site, and for the final touchdown, in which the GNC executes a flare manoeuvre to minimize the vertical velocity at impact. For what concerns the Terminal Guidance, the SR baseline algorithm is based on a pseudo-optimal trajectory generation in closed loop, in which the guidance TPBVP is solved assuming a specific parametric shape for the trajectory. The baseline landing flare, on the other hand, is executed as an open loop manoeuvre based on lookup tables. In this paper, an alternative onboard optimization scheme is used to solve the TPBVP for the terminal guidance. In addition, the use of onboard optimization allows major improvements in the landing performance with respect to baseline by making use of Model Predictive Control (MPC) schemes to actively control the parafoil to minimize the impact velocity. Emphasis has been put on practicality with real-world SR use in mind hence the main drivers for the development of this optimization algorithm are the computational load and simplicity of the problem formulation. A Gauss-Newton method is applied for the terminal guidance solution, while an interior point solver tailored for the case is used for the impact velocity minimization, formulated directly as a convex problem. Preliminary results under realistic wind conditions and system uncertainties show a major improvement with respect to the baseline. Such is the case, that the predictive landing flare control has been accepted for inclusion in Scale Down Flight Tests (SDFT), in view of inclusion in the GNC baseline. The MPC has been fully developed using autocodable in-house optimization toolbox (SOTOB) with a significant focus on reducing the computational footprint to comply with hardware restrictions. The developed algorithms are supported by theoretical convergence guarantees and extensively tested on representative hardware empirically demonstrating their real-time reliability.