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Author: Ms. Lâle Evrim Briese
DLR, German Aerospace Center, Germany, lale.briese@dlr.de

Mr. Björn Gäßler
DLR, German Aerospace Center, Germany, bjoern.gaessler@dlr.de

ADVANCED MODELING AND TRAJECTORY OPTIMIZATION OF THE IN-AIR-CAPTURING MANEUVER FOR WINGED RLVS

Abstract

Future reusable launch vehicle concepts and their key technologies have been investigated within the DLR research project AKIRA. In this context, several return options for reusable launch vehicles (RLV) were categorized by vertical (SpaceX, Blue Origin) or horizontal landing strategies (Space Shuttle), and then systematically evaluated based on their influence on overall design and technical feasibility. In general, system dynamics, guidance, and control aspects are of special importance within preliminary design studies, in particular when complex and difficult maneuvers like the DLR patented in-air-capturing method are considered. Utilizing the in-air-capturing maneuver, the unpowered winged RLV is captured during descent by an aircraft and its aerodynamically controlled capturing device which is connected by a cable, and then towed back to a feasible landing site.

In previous studies, the technical feasibility of the in-air-capturing maneuver was mainly assessed by simulations of a presumably passive aircraft and an aerodynamically controlled RLV. In contrast to this, we consider an optimal control approach to the problem of in-air-capturing, investigating both passive and active (cooperative) RLV operations. To study the risk of failure of the in-air-capturing maneuver both the initial capturing approach and a subsequent second attempt for re-capture after an initial miss are analyzed. For this purpose, a multi-disciplinary multibody modeling and simulation framework based on the object-oriented modeling language MODELICA is used for the consistent flight dynamics modeling of each vehicle including a rigid cable connecting the aircraft and its capturing device. The trajectory optimization results provide an overview of the flight dynamic behavior of the multibody system for several constraints and flight conditions. Additionally, the results show that for a successful in-air-capturing maneuver with minimum control efforts and multiple re-capturing attempts, an actively controlled tow-aircraft with drag-increasing subsystems and a cooperative launch vehicle maintaining a suitable flight path angle are recommended. The obtained reference trajectories can be used for future controllability studies and control system design considering a flexible cable and disturbances.