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MISSION DESIGN AND SENSITIVITY ANALYSIS FOR IN-AIR CAPTURING OF A WINGED REUSABLE LAUNCH VEHICLE

Abstract

The cost of access to space has always been a major obstacle for space exploration. With the growing commercial success of Reusable Launch Vehicles (RLVs) however, low cost and more frequent launches become achievable. While most RLVs currently in service rely on vertical landing, the German Aerospace Center (DLR) has proposed a unique RLV recovery approach that can facilitate further cost reduction. The 'In-Air Capturing (IAC)' mode involves capturing of a winged launcher stage mid-air using an aircraft and towing it back to the launch site. By using the aircraft for propulsion, the RLV stage no longer requires its own propulsion system for descent. This reduces the overall launch mass and cost compared to the RLVs with vertical landing systems, which require additional descent propellant. A typical recovery profile of IAC starts when the winged first stage separates from the launch vehicle. Subsequently, it re-enters the atmosphere and slows down to subsonic velocity using aerodynamic deceleration. Between 8 km and 2 km altitude, an awaiting aircraft attempts to capture the RLV by maintaining a parallel formation and following a similar flight path during descent. Next, a capturing device released from the towing aircraft autonomously connects the two vehicles via rope. Finally, the RLV is towed back to the launch site where it lands horizontally using its own landing gear. Within the Horizon 2020 project FALCon, full-scale simulations and sub-scale flight testing were carried out for development of the technology.

A major success factor for IAC is the interaction between the two vehicles involved. The RLV and the towing aircraft must come into proximity of each other at around 10 km altitude to attempt an unpowered formation flight. However, uncertainties can lead to non-ideal conditions for the capturing attempt. The RLV could deviate from its reference trajectory due to variations in separation conditions, or other factors like technical failures and wind. The towing aircraft can correct for some errors in the trajectory and improve chances of capture. But non-ideal conditions at the beginning of the formation flight can make it challenging to maintain longer formation, reducing the probability of successful capture. Thus, the paper will evaluate different parameters affecting the success rate of IAC. A capture zone will be defined based on the dispersion of RLV trajectories and manoeuvrability of the aircraft. The re-entry trajectory will be optimized to improve the chances of capture. Finally, the mission design will be re-iterated.