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SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Future Space Transportation Systems (4)

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OPTIMISATION OF 6DOF ASCENT AND DESCENT TRAJECTORIES FOR LIFTING BODY SPACE ACCESS VEHICLES

Abstract

This paper will examine trajectory modelling and optimisation to solve for the control of a reusable lifting body space access vehicle for a payload delivery mission to LEO. Previous work in the field has focused mainly on 3DOF control or developing guidance laws for attitude based on a nominal 3DOF trajectory for the re-entry. The novelty of this work lies in solving an optimal control problem for a full 6 DOF model examining both the ascent and descent paths for a specific orbit requiring a non-planar trajectory.

One popular option for space access has been, and still is a reusable single stage lifting body vehicle capable of horizontal take-off and landing. Significant process has been made recently on overcoming the technological barriers to entry for hypersonic vehicles, such as novel propulsion and thermal protection systems. Capitalising on advances in computing power, work is being done in the area of multi-disciplinary design optimisation to model the vehicle and environment to optimise the vehicle design based on performance and operational objectives during the preliminary design stage to better assess design choices.

The analysis focuses on the powered ascent phase after take-off and the gliding re-entry phase up to the terminal matching approach for equatorial plane and sun-synchronous orbits. Computationally fast models for the propulsion and aerothermodynamics of the vehicle are used, with a 6 DOF dynamic model for a rigid body and the US76 standard atmospheric model. The aerothermodynamic solver uses reduced order models for transatmospheric flight at super- and hypersonic velocities.

The control law, determined through solving the designed optimal control problem, will govern the magnitude of the net thrust (as a percentage of the maximum available thrust at that point in time) and the vehicle attitude through the deflection of the aerodynamic surfaces. The trajectory and control optimisation will maximise the payload mass that can be delivered into orbit for a fixed dry mass of the vehicle, and minimise the peak heat flux and heat load. Constraints are imposed on the dynamic pressure and acceleration components. The optimisation process will be performed by a two level approach: an initial global search will be performed using a novel evolutionary-based algorithm for constrained multi-objective. The results will then be locally refined by a gradient based solver, which will consider hard constraints.