SPACE PROPULSION SYMPOSIUM (C4)
Hypersonic Air-breathing and Combined Cycle Propulsion (9)

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PERFORMANCE ANALYSIS OF RBCC-BASED TSTO SPACE TRANSPORTATION SYSTEMS VIA MULTI-OBJECTIVE DESIGN OPTIMISATION

Abstract

Efficient and flexible launch and deployment technologies are fundamental to the future of space systems from scientific, commercial, as well as strategic perspectives. The rocket-based combined cycle (RBCC) system is a reusable launch propulsion concept comprising air breathing engines to enable access to space via two-stage to orbit (TSTO); more specifically, the phases consist of winged boosters and orbiter vehicles powered by a hydrocarbon-fuelled ramjet, scramjet and rocket engine, utilising atmospheric oxygen to orbit, thus minimising the mass associated to the supplementary oxidant and increasing the specific impulse [1]. However, highly nonlinear aerodynamic and propulsion characteristics associated with multi-mode engine operations and multi-stage trajectory inherently pose a considerable challenge for the design and control of the vehicle, as well as the integration of RBCC propulsion into the airframe [2].

This paper examines the feasibility and capability of the RBCC engine to provide sufficient access to space carrying a small payload for satellite constellation, simulating its full trajectory, the path and direction of all phases from launch to orbit by means of multi-disciplinary design optimisation. A high-fidelity trajectory simulation and optimisation capability based on numerical orbit propagation integration and pseudo-spectral methods, is combined with a specifically constructed framework using advanced vehicle aerodynamic characteristics and multi-mode propulsion characteristics and coupled with a precise orbit propagation algorithm, for advanced mission analysis [3]. This optimisation is performed by employing 3-DOF equations of motion for the launch phase from ground to LEO, with respect to the following three design criteria: maximising the velocity, altitude and mass at the end of the systems trajectory, decisively realising the aim of validating the design optimisation framework, evaluating the feasibility of the transportation system and providing useful insights into the technological requirements necessary to reach orbit. The analyses are expected to reveal the expediency of RBCC-based access to space, thus defining the outlook of RBCC-powered transportation systems in future.

[1] Tomioki et al., "System Analysis of a Hydrocarbon-fueled RBCC-engine applied to a TSTO Launch Vehicle," ISTS-2013-a-36, 29th International Symposium on Space Technology and Science, Nagoya, Japan, Jun2013.

[2] Ogawa et al., "Multi-Phase Trajectory Optimization for Access-to-Space with RBCC-Powered TSTO via Surrogated-Assisted Hybrid Evolutionary Algorithms Incorporating Pseudo-Spectral Methods", AIAA Paper 2014-2360, 19th AIAA International Space Planes and Hypersonic Systems and Technologies Conference, Atlanta, GA, Jun2014.

[3] Coulloupas et al., “A Systems Engineering Approach to Miniaturised Satellite Constellation Design Optimization”, In proceedings of: 16th Australian Space Research Conference, Melbourne, Australia, Sep2016