Paper ID: 38462
student

SPACE SYSTEMS SYMPOSIUM (D1)
Space Systems Engineering - Methods, Processes and Tools (1) (4A)

Author: Mr. George Coulloupas
RMIT University (Royal Melbourne Institute of Technology), Australia, george.coulloupas@rmit.edu.au

Dr. Hideaki Ogawa
RMIT University (Royal Melbourne Institute of Technology), Australia, hideaki.ogawa@rmit.edu.au
Mr. Philipp Klink
RMIT University (Royal Melbourne Institute of Technology), Australia, s3379527@student.rmit.edu.au

MULTI-OBJECTIVE DESIGN OPTIMISATION & UNCERTAINTY QUANTIFICATION OF RBCC-BASED ORBITAL TSTO SPACE TRANSPORTATION SYSTEMS FOR MULTI-ASSET DEPLOYMENT

Abstract

The advent of completely reusable launch vehicles promises a disruptive approach to ground-to-space transport solutions by enabling economical and flexible space operations however not without a formidable multidisciplinary design challenge. Two-Stage to Orbit (TSTO) systems consisting of winged boosters and orbiter vehicles powered by a Rocket-Based Combined Cycle (RBCC) propulsion system comprising rockets and airbreathing components [1] , namely, ramjets and supersonic combustion ramjets (scramjets), removes oxidiser requirements on-board a Reusable Launch Vehicle (RLV), reducing total weight of the system and increase in payload mass owing to a higher effective specific impulse simultaneously achieving complete reusability. Various organisations have been conducting research for the development of RBCCs as a focus of attention for the practical design of next-generation launch systems in contrast to the modern classes of partially-reusable TSTO systems powered by rocket engines or assisted by air-launch regimes demonstrated by space agencies as well as private enterprise.

This paper conducts full trajectory optimisation and uncertainty quantification study for space system orbital deployment by means of RBCC-based TSTO systems towards enabling novel asset deployment strategies and mission benchmarks. Multi-objective Design Optimisation (MDO) is performed by employing 3-DOF equations of motion based on pseudo-spectral methods for the launch phase from the ground to LEO, coupled with high-fidelity numerical orbit propagation for on-orbit deployment and manoeuvring enabled by on-board chemical and electric propulsion. Specifically, a clustered launch regime for multi-asset orbital deployment and the identification of key design parameters is explored by employing a multi-layer strategy compromising of pseudo-spectral methods enabling efficient solution search for optimal control problems governed by differential equations suitable for launch trajectory optimisation and an efficient Runge-Kutta-Verner integration method leveraging geopotential, atmosphere, radiation and third-body models among others for precise orbit determination . Statistical techniques are employed directly to the simulation framework to identify the impacts of uncertainties associated with various factors such as flight conditions, vehicle control, engine operation, and staging, on the mission performance and feasibility. Additionally, evolutionary algorithms well-suited for the search of global optimal solutions to nonlinear problems in a multidisciplinary design space using population-based heuristic approaches are assisted by surrogate modelling. Variance-based global sensitivity analysis follows to quantify the impact of the decisions associated with the whole-trajectory design for the objectives of a feasible mission profile.

[1] Kanda et al., Conceptual Study of a Rocket-Ramjet Combined-Cycle Engine for an Aerospace Plane, Journal of Propulsion and Power, 23 (2007), 301-309.