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PRELIMINARY DESIGN AND MISSION ANALYSIS FOR THE ASCENT PHASE OF A SINGLE-STAGE-TO-ORBIT VEHICLE

Abstract

The increasingly larger request for access to space, driven by the constant growth of the space economy, leads to the request for new tools capable of performing fast and reliable mission designs. In this context, the development of a software tool capable of supporting the conceptual design of access-to-space missions with reusable vehicles has been advocated. In particular, this tool will be able to guide researchers and engineers throughout the earliest design phases, enabling quick but reliable analysis of alternative mission concepts. Given the complexity of the subject, this work focuses on the conceptual design of the ascent phase of reusable Single Stage to Orbit (SSTO) launchers, and particularly on horizontal take-off and landing (HTOL) vehicles. After a general identification of high-level requirements for the ascent phase of a reusable SSTO vehicle, the aerodynamic and propulsive characterisation of the vehicle is addressed. From the aerodynamic perspective, the most suitable analytical aerodynamic models for the ascent phase have been selected among those already available in literature in order to enable the aerodynamic characterisation of the vehicle in case numerical or experimental databases are not available. Starting from the vehicle preliminary configuration, these analytical models provide the aerodynamic coefficients as a function of flight conditions, ranging from subsonic to hypersonic regimes. From the propulsive perspective, the methodology supports the preliminary analytical estimation of propulsive performance for all possible propulsive systems combinations and combined cycle engines that might support future reusable launcher, adopting an energy balance approach. Analogously to the aerodynamic characterisation, the analytical propulsive modelling can be substituted with a corresponding numerical or experimental database if available. Subsequently, in an effort to extend the applicability of the Matching Chart beyond the aeronautical sector, the Multiple Matching Chart tool approach has been upgraded by adding a new requirement representing the minimum thrust-weight ratio as a function of wing loading necessary to reach the desired orbit. Eventually, knowing the geometrical and aero-propulsion characterisation of the vehicle, nominal and out of nominal mission analysis are performed thanks to the commercial software ASTOS. The methodology described has been applied to the SKYLON vehicle, a reusable SSTO spaceplane developed by Reaction Engines Limited (REL) which exploits the Synergetic Air-Breathing Rocket Engine (SABRE) technology, a combined-cycle engine able to cover the entire mission profile of the vehicle using liquid hydrogen as propellant.