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Hypersonic Air-breathing and Combined Cycle Propulsion, and Hypersonic Vehicle (7)

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COMBINED AIR-BREATHING AND ROCKET PROPULSION SYSTEM TRAJECTORY ANALYSIS FOR DELIVERING PAYLOAD TO SPACE

Abstract

The goal for Space Engine Systems is to become the lowest cost trucking company capable of delivering customer payloads to space and lunar mission. This will be realized through leveraging air-breathing propulsion during early stages of flight. In doing so, the spaceplane will have horizontal take-off capability from any airport and more practical stowed space. In order to be successful with this mission and quantify payload mass, the Dymos optimal control of dynamic multidisciplinary systems library built onto the OpenMDAO high-performance computing platform will be utilized to simulate flight trajectories. Air-breathing engine performance values will be obtained from the thermodynamic cycle modeling library pyCycle. This engine cycle factors in losses associated with compressing supersonic inlet air and a turbojet precooler and identifies optimal equivalence ratios that ensure surface temperatures do not exceed structural limits. The engine-mode strategy is aligned with optimizing specific impulse whereby a turbojet is employed up to Mach 3, ramjet takeover accelerates the spacecraft to Mach 5 and roughly 30 km where there is no longer sufficient air, and then a rocket is fired to propel the vehicle into space.

To gain confidence in the proposed trajectory methodology, the authors performed an optimization study on a single expansion ramp nozzle geometry for a ramjet mission from flight Mach 3 and 20 km altitude to Mach 7 and 31 km altitude. The flight trajectory analysis made use of lift- and drag-coefficients estimated using computational fluid dynamics and results found a geometry and flight path that reduced mission time by 10% relative to their baseline solution [1]. Results to-date for a turbo-ramjet propulsion demonstrator vehicle that utilizes hydrogen fuel whose mission profile is from horizontal take-off to Mach 5 and 30 km have quantified fuel requirements and identified opportunities to improve the vehicle aerodynamics. The purpose of this paper is to add a rocket mode to the demonstrator vehicle flight trajectory in order to quantify maximum payload capacity.

References [1] Cerantola, DJ, Gagnon, J, Handford, D, and Dass, P. "Design Methodology for Selecting a Single Expansion Ramp Nozzle Geometry that can Complete a Mission between Machs 3 and 7." In 25th AIAA International Space Planes and Hypersonic Systems and Technologies Conference, p. 3052. 2023.