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IAF SPACE PROPULSION SYMPOSIUM (C4)
New Missions Enabled by New Propulsion Technology and Systems (6)

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CHEMICAL PROPULSION SYSTEM DESIGN FOR A 16U INTERPLANETARY CUBESAT

Abstract

Interplanetary CubeSats are the future of low-cost high-return solar system exploration missions, especially Mars. CubeSat missions to Mars are achieved through in-situ deployment from a larger satellite or through stand-alone CubeSats launched into high-energy geocentric orbit and pursuing a deep-space cruise. One of the key enabling technologies for stand-alone CubeSats is the primary propulsion system that shall enable orbital manoeuvring and trajectory control, which are indispensable for interplanetary missions.

Dual Chemical-Electric Propulsion Systems enabling a Hybrid High-Thrust / Low-Thrust Transfer from Earth to Mars are the key tools used in achieving this mission. The high-thrust chemical propulsion system is used to achieve Earth escape while the low-thrust electric propulsion system enables deep-space cruise and ballistic capture. This shall demonstrate the ability of Interplanetary CubeSats to escape Earth, perform autonomous deep-space cruise, achieve ballistic capture, and enter an Areostationary orbit to conduct science observations on Mars.

This work focuses on the sizing, design, and characterisation of the chemical propulsion stage that is utilised in performing orbit raising and Earth escape. With the overall spacecraft mass being 30 kg, the propulsion system requirements, especially on ΔV ($\sim$450 m/s for Earth escape), mass, tumbling rate etc., are established and the thrust, specific impulse and burn times are characterised while considering the minimisation of Van Allen belts crossing time to reduce radiation damage. Limitations are set for maximum thrust and burn times to restrict undesired destabilisation and gravity losses.

Design characterisation of the chemical propulsion system is performed and critical design parameters such as sizes, operating pressures, material and geometric characteristics regarding propellant tanks, feed system, thrust chamber, and nozzle are calculated, along with their design limits. A trade-off analysis on thruster performance using different propellants is done. Performance analysis yields thrust-time profiles, total impulse, impulse bit, flow rate, and temperatures of thrust chamber and nozzle. The overall size of the system is $<$8 U and has a mass $\sim$25% of the overall system mass. Heat transfer analysis is performed and thermal control strategies to mitigate excessive heating and propellant freezing are expounded.