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SYSTEMS DESIGN OF MARIO: A STAND-ALONE 16U CUBESAT TO MARS

Abstract

CubeSats have been extensively used for Low-Earth Orbit Missions with unquestionable success. Interplanetary CubeSats are the future of low-cost high-return solar system exploration missions, especially to Mars. These are achieved either through in-situ deployment from a larger satellite or through stand-alone CubeSats launched into high-energy orbit and pursuing a deep-space cruise. To this extent, a stand-alone CubeSat mission, the Mars Atmospheric Radiation Imaging Orbiter (MARIO), is envisaged.

MARIO shall demonstrate the capabilities of CubeSats to escape Earth, perform autonomous deep-space cruise, achieve ballistic capture, and be emplaced on an areosynchronous orbit at Mars. The MARIO mission shall conduct radiation imaging to characterise the thermal environment in the Mars upper atmosphere. The mission shall serve as a pioneer for Interplanetary CubeSat missions with high launch flexibility and cost efficiency.

The current work focuses on the systems design of MARIO. Crucial system specifications, requirements, trade-off, mission design and subsequent systems design are presented. Several innovations and improvements over conventional CubeSat design are implemented. These include dual chemical—electric propulsion systems for hybrid high-thrust—low-thrust Earth—Mars transfer concomitant with ballistic capture and circularisation. Chemical propulsion system comprises FLP-106 based green monopropellant thruster and the electric propulsion utilises Iodine-fuelled inductively-coupled RF Ion thruster. A novel autonomous navigation strategy is proposed which includes full-disk optical navigation near target bodies and celestial triangulation during deep-space cruise for accurate state estimation. Reflectarrays along with high-gain antennas are utilised to establish long-distance low-bandwidth X-band communication link with the Earth. Steady power production is ensured using a Solar Array Drive Assembly for continuous Sun pointing of the solar arrays. Flexible electrical power system architecture is defined for enhanced power management. Semi-active thermal control system is designed to preserve the payload, propellants, and other subsystems within their operational temperature limits at Earth, Mars and interplanetary environments.

The spacecraft is a 16U form factor CubeSat with a mass of 30 kg. The design includes a majority use of COTS equipment with variations, especially in the propulsion system. The mission lifetime is 6 years, which includes interplanetary transfer and science operations. The final design yields feasible budgets on mass, configuration, communications and power.