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DEVELOPMENT OF A 3D-PRINTED COLD GAS PROPULSION SYSTEM FOR CUBESATS

Abstract

The Philippine Space Agency (PhilSA) has extensively employed Cubesat platforms, mainly for educational purposes, and more recently, for technology demonstrations to bolster its transition towards undertaking operational missions. To enhance the capabilities of these small satellites, this study focuses on developing PhilSA's first integrated Cubesat cold-gas propulsion system using additive manufacturing. The integration of propulsion systems capable of rotational/attitude control, orbit change, and de-orbiting significantly increases the autonomy and control of these small satellites. Additive manufacturing emerges as a compelling solution due to its versatility in creating complex, composite, and hybrid structures. By consolidating propulsion hardware into a monolithic structure, the study aims to reduce costs, mitigate risks associated with assembly, and maximize the use of limited volume and mass allowance of Cubesat buses.

The methodology involved deriving system requirements from a reference PhilSA 3U Cubesat mission. Delta-V and attitude and orbit control system (AOCS) scenario verification and performance analyses were performed to size the propulsion system and to the optimal propellant. Numerical analysis using flow relations and computational fluid dynamics were used to calculate the expected performance, and finite element analysis was performed to verify the design. A dedicated propulsion controller unit was designed to manage hardware, perform housekeeping, and interface with the main satellite onboard data handling and AOCS boards. A thrust test-stand was constructed to validate the theoretical performance. As part of design for manufacturing, the study also explored print parameters and methods suited for printing sealed containers while maintaining dimensional accuracy.

The initial design utilizes R-236fa as the propellant, selected using Digital Logic Method. A five-nozzle configuration allows for orbital and three-axis rotational control for orbital maneuvers including orbit change, de-orbiting, and conjunction avoidance, and attitude maneuvers including nadir-pointing,

target pointing, and detumbling. The 3D-printed body, inclusive of tanks, hardware interfaces, conduits, and nozzles, is optimized for volume capacity and ease of assembly. Preliminary design results indicate performance of 24-mN thrust, 49-s specific impulse, and a 599-cc main tank and 187-cc plenum capacity. Initial mass-strength optimization of the body based on preliminary stress analysis results show an increased complexity in the resulting structure, further highlighting the advantages of additive manufacturing.

The study contributes to the field by showcasing the potential of integrated additive manufacturing for cost-effective, efficient, and bespoke Cubesat propulsion systems. Further discussions during the conference can delve into specific challenges encountered, insights gained from testing, and potential applications for future missions.