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Title
Atmospheric Test Campaign of a Hydrogen Peroxide Propulsion System for CubeSats

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Abstract
The CubeSats market is continuously growing in recent years, pushing the need to provide this class of satellites with propulsion systems for orbit maneuverability. The requirements imposed by these small satellites are very restrictive, especially in terms of mass, envelope, and power consumption. Today few nearly off-the-shelf European propulsion solutions can satisfy these requirements. In this context, the European Space Agency launched a call to identify the most promising European Propulsion Systems for CubeSats. The University of Pisa participated in this ESA call with the CHIPS project (CubeSat HTP Innovative Propulsion System) focused on designing, manufacturing, and testing an affordable chemical monopropellant propulsion system for CubeSats which uses hydrogen peroxide as the propellant. The hydrogen peroxide represents a green alternative to the carcinogenic hydrazine used in most monopropellant thrusters. In the frame of the CHIPS project, two test campaigns took place, one in atmospheric conditions and another in vacuum conditions. Both test campaigns aimed to verify if the designed propulsion system meets the imposed requirements and if its performance can compete with the one given by Off-the-Shell hydrazine thrusters. This paper shows the results obtained during the propulsion system's tests in atmospheric conditions at the University of Pisa facility. The basic idea under this test campaign was not to test the thruster alone, but the entire propulsion system mounted on a 3U CubeSat. For this reason, an innovative thrust balance capable of holding a whole 3U CubeSat was developed and calibrated for the low level of thrust required. A flight-proven CubeSat structure [2] contained the engineering model of the propulsion system formed by Off-the-Shelf tank, valves, sensors, and a newly designed thruster. This engineering model comprised additional sensors inserted to obtain a full characterization of the propulsive performance. The setup of the monopropellant thruster for the atmospheric test campaign included the use of 98% wt. Hydrogen Peroxide as the propellant, and alpha Platinum Alumina pellets as the catalyst. A specific test matrix agreed upon with the European Space Agency indicated the steps to follow during the test to verify as many requirements as possible. In particular, the propulsion systems fired in continuous and pulse mode, reducing the time of opening of the valves down to 25 ms and starting with the thruster in cold and hot conditions. The results obtained during this test campaign showed how the propulsion system verified most of the imposed requirements: it generated a thrust lower than 0.5 N with a rise time of about 50 ms, reaching a minimum impulse bit lower than 0.025 Nms; it was able to fire in both pulse and continuative mode with a high level of thrust roughness and repeatability. The temperature of all components was inside the operative limits for the whole test duration, thanks to the effective reduction of the heat soak-back and the heating of critical components. These promising results allowed the tested configuration to reach TRL 3 and constitute a solid ground on which to base future developments of this propulsion system.

References
[1] Pasini, Angelo, et al. "Design of an Affordable Hydrogen Peroxide Propulsion System for CubeSats." *AIAA Propulsion and Energy 2021 Forum*. 2021.
[2] https://www.endurosat.com/cubesat-store/cubesat-structures/3u-cubesat-structure/ (visited: 30/01/2023)