29th IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS (B4)
Small Satellite Missions Global Technical Session (9-GTS.5)

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QARMAN RE-ENTRY CUBESAT: FROM DESIGN AND PRE-FLIGHT TESTING TO POST-FLIGHT LESSONS LEARNED

Abstract

QARMAN, the "QubeSat for Aerothermodynamic Research and Measurements on AblatioN," finally bursts through the Earth's atmosphere on February 5, 2022, closing a 9-year project endeavor which has seen the von Karman Institute of Fluid Dynamics (Belgium) developing, testing, and flying the world's first CubeSat designed to survive atmospheric re-entry. The aim of this ESA-funded project was to demonstrate the usability of a CubeSat platform as an atmospheric entry vehicle. Moreover, QARMAN was designed to collect scientific data during re-entry through Earth atmosphere.

The overall design of QARMAN was the one of a 3U CubeSat. However, the re-entry phase calls for a very specific thermal design, which is based on a front cork-based ablative thermal protection system, and on internal heavily insulated survival units protecting "key equipment", which included the subsystems required for re-entry and final data transmission: data acquisition systems, on-board computer, batteries and related regulators, and Iridium transceiver. The subsystems related to the orbital phase of the mission were hosted out of these survival units, in a custom-designed chassis. QARMAN also featured deployable solar panels as a payload (so-called AeroSDS). These panels were kept stowed and released only after deployment of the satellite from the ISS to be finally locked in deployed position within a defined angle by a unique custom-made mechanism, providing a passive mean for stabilization and accelerated deorbiting through drag increase.

Due to its specific mission and design, QARMAN and its thermal protection system underwent extensive pre-flight ground testing during development, culminating with an unprecedent full-scale plasma wind tunnel testing in the Scirocco arc jet (CIRA, Italy). QARMAN was deployed in orbit from the ISS on 19 February 2020. It was operated for 5 months, demonstrating proper functioning of the main subsystems. The AeroSDS payload (solar panel deployment) was successfully demonstrated in Space, thus reaching TRL 9. QARMAN unexpectedly stopped transmitting on 14 July 2020. Analysis identified UHF transceiver malfunction and battery thermal failure as potential failure root causes. Potential signals were still monitored until QARMAN reentry.

The proposed contribution will first introduce QARMAN objectives and mission before detailing its

design, focusing on the technical challenges to be tackled. Ground testing for the aerothermodynamic database generation in plasma wind tunnels will be highlighted with their relevance to the reentry flight situation. Mission data will be analyzed, with specific focus on the failure analysis. Finally, the contribution will conclude with notable achievements and lessons learned.