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ANALYSIS OF DATA COLLECTION CAPABILITY AND AERODYNAMIC STABILITY DURING UNCONTROLLED ATMOSPHERIC RE-ENTRY

Abstract

STRATHcube is a student-led CubeSat mission at the University of Strathclyde, designed to contribute to space debris mitigation by collecting data on the aerothermodynamic and mechanical forces which lead to solar array fragmentation during atmospheric re-entry. The mission relies upon an aerodynamically stable re-entry that will allow for transmission of critical data, such as heat flux, temperature and acceleration. Successful transmission of this data would contribute to validating re-entry modelling tools such as TITAN (TransatmospherIc flighT simulAtioN), developed at the University of Strathclyde, and would provide the space community with unique insights into the conditions experienced by objects during uncontrolled re-entry.

The experiment requires balancing competing design constraints, including optimising sensor selection within strict volume limitations, trading off aerodynamic stability against restriction of antenna gain pattern for data transmission, and thermally protecting critical components such as the onboard computer without distorting heat flux measurements. These interdependencies necessitate an iterative design approach, integrating aerothermal analysis, mechanical constraints, and communications requirements to facilitate reliable data acquisition and transmission. This paper discusses advancements in the design of the CubeSat, and in the Re-entry Stability Analysis Framework (RSAF) that has been developed to assess passive aerodynamic stability during re-entry.

To address these constraints, a feasibility analysis of the secondary payload refined specific data collection goals, considering both experimental limitations and mission objectives. Key aerothermodynamic parameters were identified, leading to the creation of a new framework for measuring aerothermodynamic

and mechanical loads during re-entry. This includes selecting the most suitable sensors and strategically placing them across the CubeSat. As a result, the CubeSat's novel solar array locking hinge mechanism was redesigned to provide passive locking during re-entry. The RSAF has been updated to improve STRATHcube's geometrical representation in GMSH, and to introduce new methods for evaluating the CubeSat's centre of pressure during re-entry. Additionally, improvements were made to the aerodynamic instability metric, and a high-dimensional model representation was applied to enhance the efficiency of sensitivity analysis.

These efforts, along with continued improvements to the RSAF, will strengthen the mission's ability to gather valuable data during re-entry, further contributing to space debris mitigation and advancing efforts in Space Situational Awareness and Design for Demise processes.