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MANAGING HIGH THERMAL LOADS IN SMALL SATELLITES - ANALYSIS, DESIGN, AND VERIFICATION OF A 3D-PRINTED RADIATOR

Abstract

The revolution of small spacecraft is currently propelling space access, allowing for technological as well as scientific advances by drastically reducing the overall development times and mission costs. Single or constellations of small satellites are getting increasingly attractive for an ever-growing host of civil and military applications, including climate studies, surveillance, and space-based internet. Beyond Earth-based missions, small spacecraft also begin to be considered for interplanetary or even interstellar missions. One of the main challenges in expanding the functionality of small satellites is the handling of high thermal loads from energy-demanding payloads generating large amounts of heat. The situation intensifies by the substantially reduced radiating area of small satellites and necessitates highly optimized surfaces to dissipate excess heat. Here, we demonstrate a highly flexible thermal analysis tool in conjunction with additive manufacturing to develop, optimize, and experimentally test a 3D structured radiator. Specifically, we balance the generated heat from a cryocooled payload of the German 12U nanosatellite ERNST (Experimental Spacecraft based on NanoSatellite Technology) to be launched in 2020.

In a first step, we determine the heat generation of the payload in different operational regimes to define the approximate size and location of the radiator within the satellite. Next, we investigate the influence of the payload and radiator on the overall thermal load when coupled to the satellite. In particular, we make use of a newly developed, GPU-accelerated lumped capacitance network approach developed for CubeSats. This results in a substantial reduction in computationally intensive view factor calculations and helps to drastically decrease the necessary computation time for thermal analysis. Opposed to the traditionally employed finite volume approach, our methodology is surface based with a focus on the most relevant areas. This allows considering heat conduction only at well-defined cross-sections of surface elements. The methodology adapts well to the more flexible design approach of small satellites and allows to continuously examine the influence of design decisions on the thermal balance of the system.

Following the design recommendations from the thermal analysis, we accordingly modify the radiator design, e.g., by enhancing the effectively available radiating area for heat dissipation. We investigate different 3D structures and materials and their effect on the thermal balance of the payload. Lastly,

we employ additive design solutions to manufacture the radiator geometry and subsequently verify our simulations in thermal-vacuum tests.