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INVESTIGATION OF SYSTEM PROPERTIES FOR PERFORMING IN-ORBIT ADDITIVE MANUFACTURING OF ULTEM 9085 WITH A CUBESAT

Abstract

Additive Manufacturing (AM), also called 3D printing, is a manufacturing technique where successive layers of material are deposited one on top of the other to form an object. AM will be an integral part of in-space manufacturing, manufacturing performed in orbit and in the space environment. There are several projects investigating how to print and assemble large metal structures in space, but these plans are still many years away from implementation and their Technology Readiness level (TRL) is still very low, partly due to the difficulty in printing metals. Although not as robust as metal parts, polymer 3D printing is easier, requires less power, and polymer parts can be used in applications where mechanical strength is not critical.

The focus of this paper is therefore on the considerations that must be made in designing a CubeSat that can 3D print ULTEM 9085 in low Earth orbit, a thermoplastic that has already been flown in space. The 3D printing technology used would be Fused Deposition Modelling (FDM), like that employed on the International Space Station. The main assumption is that the spacecraft could be launched in a couple of years and, being a CubeSat, it should be relatively cheap and simple.

Several system properties make the design of this spacecraft challenging. ULTEM has a high printing temperature so enough power must be provided during the printing process, making the tolerance for the solar panel pointing very small. There are other properties that must be considered are changing angular momentum due to the moving printhead, the spacecraft's centre of mass shifting as the material is transferred from storage to the part, ensuring printing quality, and the space environment itself. It is clear therefore that there is a large coupling between AM fabrication challenges and guidance and control (G&C), which is also addressed.

This paper presents the challenges for in-orbit AM fabrication of polymer parts and a novel optimization-based attitude and orbit control framework that explicitly considers the manufacturing, dynamic, and physical constraints present in the system. The proposed design is validated via simulations that are formulated with inputs from on-ground and International Space Station based AM experimental results. It is concluded that designing and launching a 3D printing CubeSat with the proposed novel framework would increase the TRL of AM and bring the world one step closer to the dream of in-orbit manufacturing.