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SIMULATED IMPACT OF TRANSIENT AEROSHELL DEPLOYMENT ON COUPLED AERO-ATTITUDE DYNAMICS OF A NANOSATELLITE FOR FAST PASSIVE DISPOSAL IN LEO

Abstract

Flexible aeroshells are lightweight structures which can be deployed from small satellites in low Earth orbit (LEO) to hasten their return to Earth at end-of-life. Aeroshells may be hard or flexible, but only flexible type is considered here. Like other drag enhancing devices such as deployable sails, aeroshells provide higher rates of orbital decay when satellite frontal area is maximised in the direction of travel, giving a lower ballistic coefficient. In this flow-pointing attitude, high aerodynamic drag reduces time in orbit which generally decreases the risk of collision with other orbiting space debris. Disposal of space debris usually results in burn-up in the atmosphere. However, upstream-mounted aeroshells with a stable flow-pointing attitude may in addition provide thermal protection during re-entry and enable recovery of in-space assets.

Assuming a worst-case scenario where the defunct satellite is without active attitude control, environmental torques determine attitude dynamics after aeroshell deployment. Aerodynamics dominate below around 400km altitude. Aerostabilisation of satellite attitude about the flow direction can be achieved passively with a suitably large static margin, but feasibility depends on initial attitude and spin conditions at deployment. The finite duration of aeroshell deployment introduces an additional aerodynamic and inertial disturbance on attitude/orbit due to temporary geometric skewness. To the authors' knowledge there has been no prior research on the effect of this disturbance, which is expected to depend on: (i) length of the transient partially deployed phase, and (ii) aeroshell asymmetry during the deployment sequence.

In this study, the effect of transient aeroshell deployment on aerostabilised attitude-orbital dynamics of a 3U nanosatellite is investigated by coupled simulation. Aeroshell design is from the 2017 EGG mission, which demonstrated first in-space release of an inflatable structure from a CubeSat. The in-house simulation platform, called SCRAMBL, contains a free-molecular aerodynamics model accelerated by a database approach, and accounts for gravity gradient torques and satellite residual magnetic moments (RMM). Transient aeroshell deployment is modelled by 2-stage interpolation for satellite aerodynamic and inertial properties between fully-stowed, half-deployed, and fully-deployed states. A new methodology is introduced to transform the attitude disturbance caused by aeroshell deployment into a more convenient equivalent initial satellite spin rate.

The results show that aeroshell deployment duration should be below 10-100s for the 3U satellite to achieve aerostabilised flow pointing. This implies that fast gas-based or bi-stable tape deployment mechanisms are more suitable than slower alternatives such as shape-memory alloy (SMA) ribs, deployed by passive environmental heating.