Glue-Infused Rotating Nanofibers Net (GRoNNet) for Capturing Space Debris - A Novel Debris Capturing System

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It is evident that space debris is a growing concern, particularly in the low altitude Earth orbits, and if not addressed in time, may have a drastic socio-economic impact on civilization. This paper describes the Glue-infused Rotating Nanofibers Net (GRoNNet), a novel debris capturing system for pico/nano/micro-satellites (PNNMs). GRoNNet is designed as a modular, cost-effective system with the capability to capture target debris in multiple attempts and expedite its re-entry by attaching a debris mitigation system. It may be best described by comparing it with a chameleon's tongue but several hundreds/thousands of them infused with a thick honey-like viscous adhesive in a rotary configuration, so as to adhere strongly with target debris even at the slightest contact.

INTRODUCTION AND NOVELTY

Space debris mitigation measures can be divided into three broad categories: (i) Temporary collision avoidance maneuvers using ground-based situational awareness facilities (ii) Permanent solutions to curtail potential future debris through post end-of-life procedures on space assets such as installation of onboard deorbit modules (iii) Targeted debris capturing in select orbits that are highly populated. The Glue-infused Rotating Nanofibers Net (GRoNNet), a novel debris capturing system for PNNMs, is envisioned in the context of a multiple space debris removal mission. The GRoNNet mission is scoped for targeting pico and nano class CubeSats in low Earth orbits (LEOs), which can pose a threat to a space asset and/or simply need to be deorbited passively. A CAD rendering of an autonomous GRoNNet module is shown in Figure 1. The main components of the GRoNNet include - (i) a tuft of braided nanofibers wound around a spool, (ii) a set of glue containers (resin and hardener) with electronic valves, (iii) a duct for facilitating the flow and infusing the nanofibers with glue, (iv) a microcontroller with a wireless communication link to the host satellite, (v) a power management system with battery, (vi) a LiDAR or a stereo camera for sensing the proximity of the target debris and (vii) a motor for rotating the glue-infused fibers. The novelty of GRoNNet lies in the use of sticky fibers to capture debris, thus narrowing the risk of collision with the debris. The trapping appendages (fibers) make no use of any corner masses to orient the fibers to maintain the final unfurled configuration, instead, we rely on the centrifugal force of the motor to keep the fibers separated and redistribute to cover an area that’s twice as large compared to a net of the same length, as shown in Figure 2, thus reducing the overall demand for precise debris altitude locking.

ABSTRACT

As mentioned earlier, the novelty of our design lies in the capturing method that uses sticky fibers. Numerous thin (20 m in diameter) activated carbon fibers (ACF) of long lengths (about 10m long) are individually attached to the holes of the perforated disc which allow some room around the fibers for the glue to flow over it. The ACFs used are manufactured to have an optimum balance between the number of pores and the pore size without compromising much on the mechanical strength of the precursor. The pores on the fibers are essential because they absorb the activating element for the glue, the alkaline gas, which helps create a conducive environment for the glue.

PROXIMITY OPERATIONS AND CAPTURE

The mission concept of operations (CONOPS) for capturing a target debris is shown in Figure 3. As shown in this figure, a host spacecraft carrying multiple GRoNNet modules is launched into a relevant orbit. A GRoNNet module is deployed using a tether system when the host satellite is in proximity with a target debris. The other end of the tether system connects to a passive deorbiting servicing module helps in optimization and better planning for capturing debris in one single mission.