# Glue-infused Rotating Nanofibers Net (GRoNNet) A Novel Space Debris Capturing System (SSC20-P2-18)

Sneha M. Raibagi, Prithvi S. J. Monteiro, Rashmi K. Pallam, Amogh Anantha Murthy, Amit G Gadag - PES University, Bengaluru, Karnataka 560085 India

Advisors: Sharanabasaweshwara Asundi, Oleksandr Kravchenko - Old Dominion University, Norfolk, VA 23529 USA

## ABSTRACT

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 (PNMSats). 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 PNMSats, 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

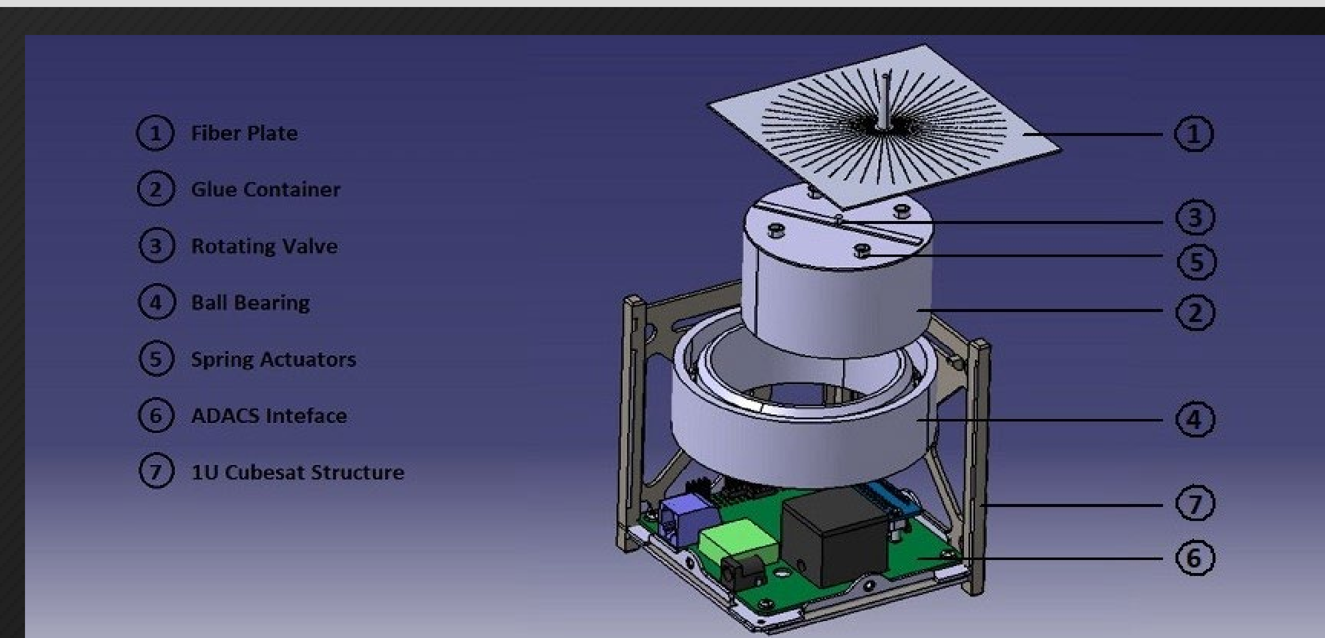


Figure 1. A CAD rendition of the GRoNNet module

nanofibers with glue, (iv) a microcontroller with a wireless communication link to the hostsatellite, (v) a power management system with battery, (vi) a LiDAR or a stereo camera for sensing the proximity of the target debris and (vi) 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.

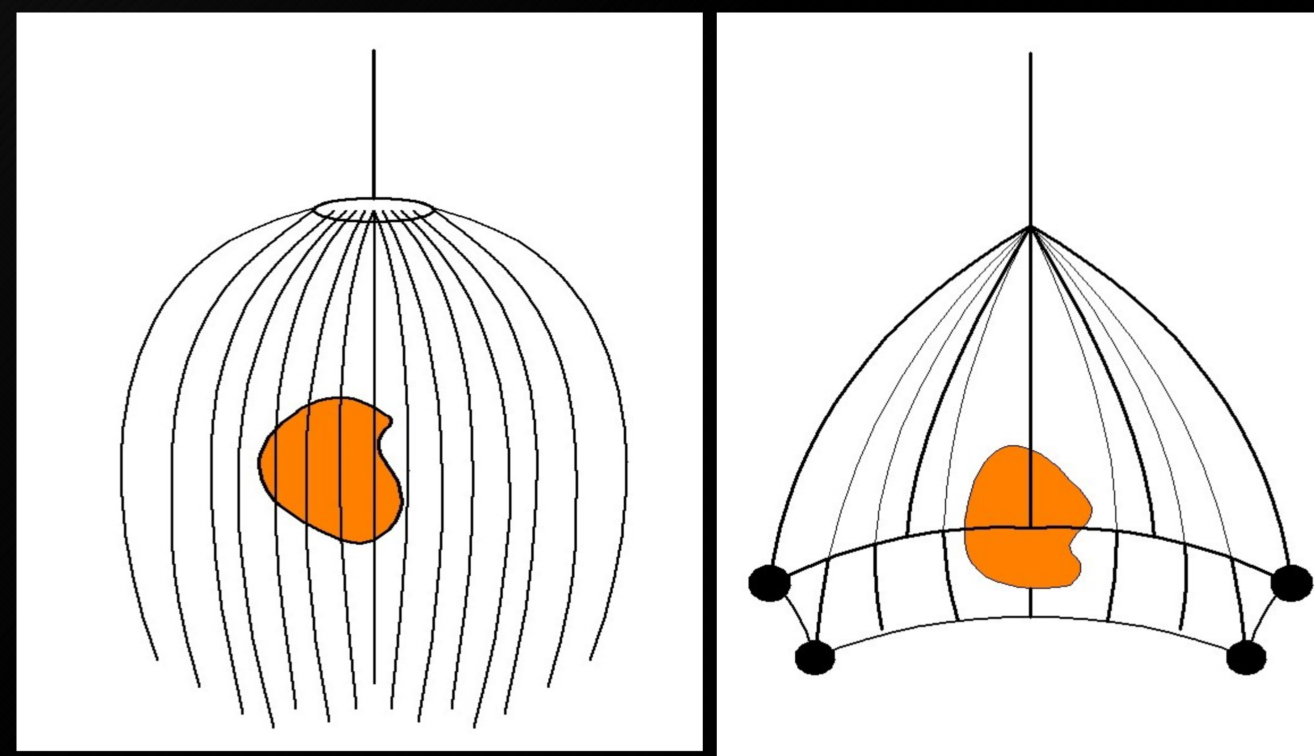

Figure 2. Comparing the Effective Area Covered by a Conventional Net vs the GRoNNet of the Same Length

## FIBERS AND STICKY GLUE

As mentioned earlier, the novelty of our design lies in the capturing method that uses sticky fibers. Numerous thin (20m 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 module through a mechanical umbilical. The GRoNNet module when commanded by the host satellite using the wireless link, activates the deployment of the braided activated carbon nanofibers, which are set in rotary motion by the onboard motor. Almost concurrently, the nanofibers are infused with a peptide-based space glue, which works particularly well when devoid of moisture. A successful capturing of the target debris is sensed by the host satellite through a load cell connected to the umbilical. Upon successful capture, the tether system along with a passive de-orbiting module (UWDES, mDEMS) is launched out of the host satellite to expedite the re-entry of the target debris. Detailed simulation of the rendezvous and proximity operations are presented in the paper.

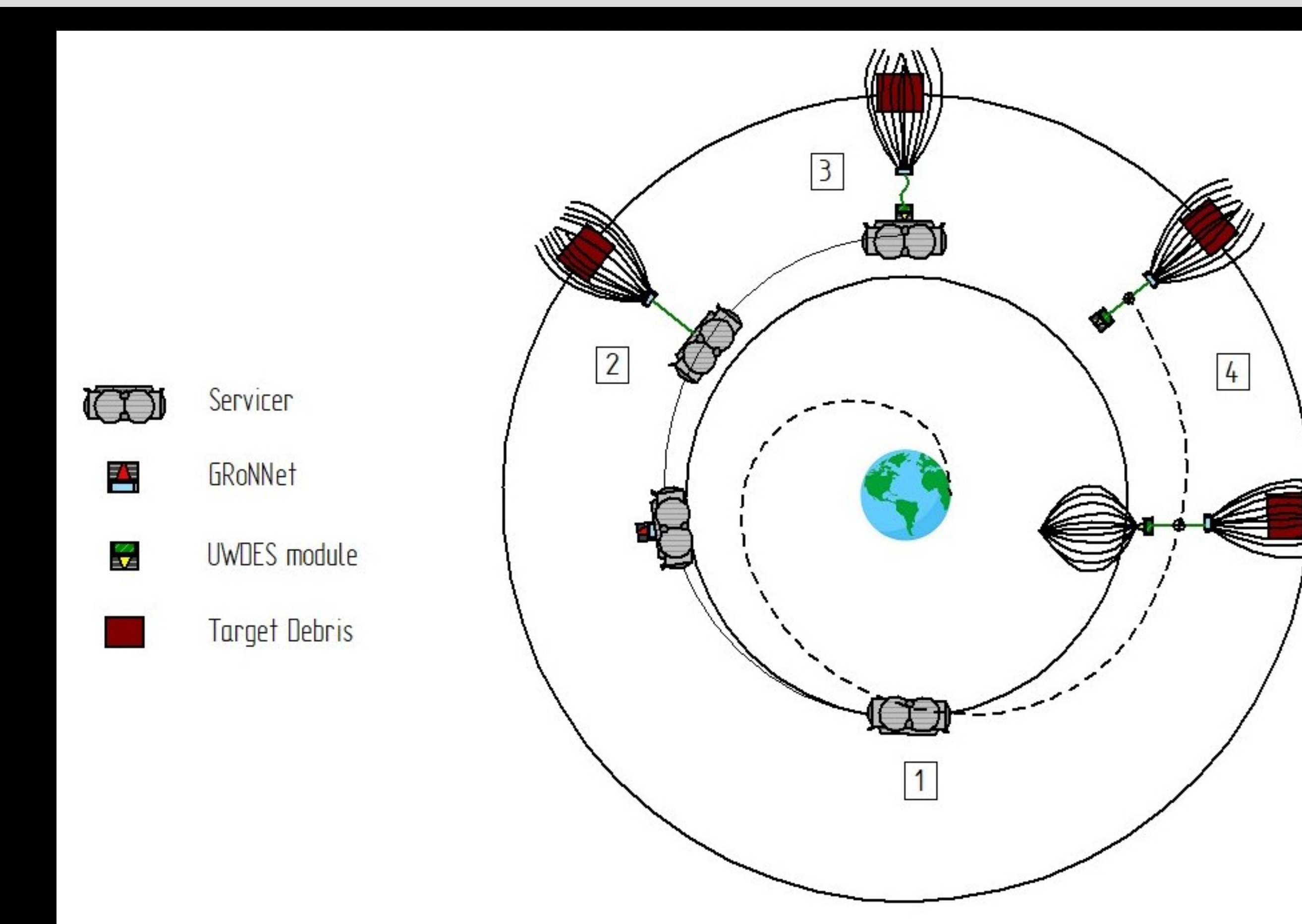


Figure 3. Mission CONOPS – (1) Host S/C Orbit Insertion, (2) GRoNNet Module Deployed, (3) GRoNNet Captures Target Debris, (4) UWDES or mDEMS is Deployed for Expedited Re-entry of Target Debris

## CONCLUSION AND ONGOING WORK

This paper proposes a new capturing method that favors multi space-debris capturing missions. The GRoNNet , owing to its flexible features, makes it suitable for use even in scenarios where the debris is non-supportive and uncontrollable. The concept of safe detachable GRoNNet structures along with the deorbiting servicing modules helps in optimization and better planning for capturing more debris in one single mission

## REFERENCES

1.The Kessler Syndrome: Implications to Future Space operations, AAS 10-016, Donald J. Kessler , Nicholas L. Johnson , J.-C. Liou , and Mark Matn UK

2.Kessler,D.,"CollisionalCascading:TheLimitsofPopulationGrowthin Low Earth Orbit," Advances in Space Research, Vol. 11, No. 12, 1991, pp. 63–66. doi:10.1016/0273-1177(91)90543-S

3.Drag sails for space debris mitigationLourens Visagie a,n, Vaios Lappas a, Sven Erb ba Surrey Space Centre, University of Surrey, Guildford, Surrey GU2 7XH, UK

4.Mikkel Jorgensen, Inna Sharf, "Optimal Drift Orbit Planning for a Multiple Space Debris Removal Mission using High-Accuracy Low-Thrust Transfers," Acta Astronautica, July 2020

5.B. W. Barbee and et al., "Guidance and Navigation for Rendezvous and Proximity Operations with a Non-Cooperative Spacecraft at Geosynchronous Orbit," in George H. Born Symposium, Boulder, Colorado, 2010.

6.*Y.Li and M.Zhang*: Mechanical properties of Activated Carbon Fibers,2017.

7.John Tomich and Takeo Iwamoto: PH Dependent Adhesive Peptides

8.Aishwarya Manjunath, Vinod Ravi, Sharan Asundi, "Drag enhancement for spacecraft using numerous ultra-thin wires arranged into drag-wire webs of various configurations,"

9.Asundi, Sharan & Bhagatji, Jimesh & Tailor, Piyushkumar. (2017). Genesis of a multi-function drag measurement system to facilitate atmosphere modeling and space debris mitigation. 10.2514/6.2017-5251.