New Challenges and Opportunities of Passive Deorbiting Systems: Emulation of Micro-Gravity for the ESA-Dragliner

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***Abstract*— The ESA-Dragliner project, led by the Finnish Meteorological Institute in partnership with Aurora Propulsion Technologies, GRADEL, and the University of Luxembourg, seeks to develop, produce, assemble, and test a prototype of a tether-based system for deorbiting Low Earth Orbit (LEO) telecommunication satellites. The Dragliner project has chosen the PB (Plasma Brake) microtether, a novel propellant-free technology designed to efficiently deorbit LEO satellites. This system, which utilizes Coulomb drag, is lightweight, compact, requires minimal power, and operates independently without using resources from the host satellite during deorbiting. The project's goal is to preliminarily design this tether-based deorbiting system for LEO satellites, and to produce, assemble and test a Breadboard Model demonstrating the most critical functions. Additionally, the project aims to analyze and optimize a deorbiting strategy using this technology to successfully deorbit a LEO spacecraft weighing up to 250 kg, reducing its altitude to a maximum of 400 km within 2 years from an initial altitude of 850 km, or within 100 days from an initial altitude of 550 km. This paper outlines the planned deployment tests of the Dragliner project at the Zero-G Lab of SnT-University of Luxembourg.**

I. Introduction

The project aims to advance the Technology Readiness Level (TRL) of the satcom PB to level 4. This requires choosing a deployment strategy, selecting the tether material, finalizing the tether design, performing simulations for deorbiting performance and tether dynamics, testing the tether material in zero-friction lab conditions, and creating the initial breadboard model of the essential components of the Dragliner, including the main tether reels, the main tether itself, and the supporting tape tether and its housing.

When a high-voltage charged tether is introduced into a streaming space plasma, its electric field disrupts the plasma ion flow, extracting momentum from it. This effect, known as electrostatic Coulomb drag, has several applications. One such application is the electric solar wind sail, which uses the solar wind for interplanetary propulsion. Another application is the Plasma Brake (PB), which uses the ionospheric ram flow to generate Coulomb drag, gradually deorbiting the satellite [1]–[3]. Both positive and negative tether polarities can be utilized, as they both result in momentum transfer, though the underlying plasma physics differ. However, positive polarity is preferred for the solar wind, while negative polarity is more suitable for the ionospheric PB.

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Fig. 1. The high-level block diagram

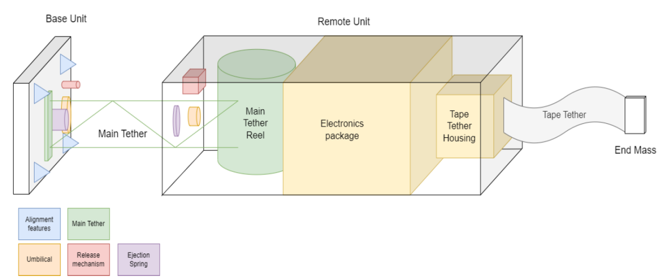

Fig. 2. Physical architecture of Dragliner

The schematic overview of the tether deployment process is illustrated in Fig. 1. Initially, the Main Tether, spanning approximately 5 km, will be deployed, followed by the deployment of the Tape Tether, which extends to tens of meters. Fig. 2 provides a depiction of the physical layout of the Main Tether and its connections to the Platform, although the drawing is not drawn to scale. During the deployment tests conducted in the Zero-G Lab, only the deployment of the Main Tether will be conducted. The Base Unit, serving as the end mass, will be positioned atop floating platforms, simulating a free-floating scenario in space during deployment. Due to space constraints within the Zero-G Lab, the Main Tether will not be fully extended to its maximum length.

The module releases a tether around 5 km long, consisting of four conductive wires with diameters varying between 25 and 50 micrometers. In addition to the aluminum wires used in previous Cubesat projects, we've explored the potential of employing more advanced carbon fiber composite wires. To ensure redundancy and mitigate the risk of tether breakage due to micrometeoroid damage, a multi-wire tether structure is adopted. The tether is deployed from a storage reel and is maintained at a voltage of -1 kV by an onboard high-voltage source. A metal-coated tape tether, approximately tens of meters long, is utilized as an electron-collecting surface to complete the current loop. The power consumption of the

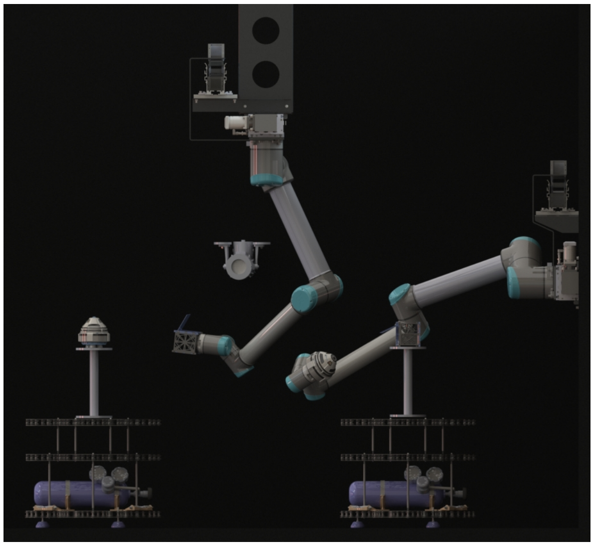

Fig. 3. the Zero-G Lab

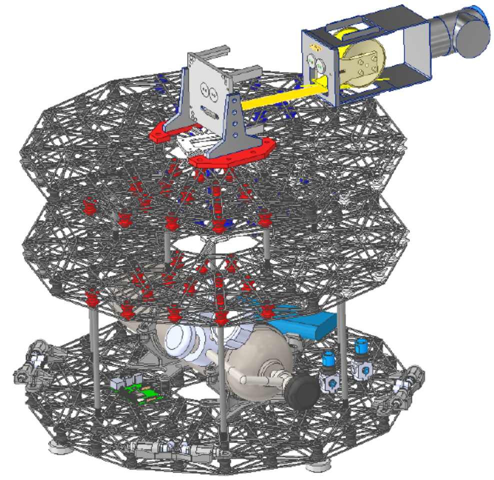

Fig. 4. The floating platform integrated with the tether mechanism

system is estimated to be around 2.2W.

The system consists of two primary components: the Base Unit and the Remote Unit. The Base Unit, affixed to the host satellite, incorporates the Release Mechanism, along with the Satellite's Mechanical and Electrical Interfaces. The Remote Unit encompasses the Tape Tether Assembly, the Main Tether Assembly, the Electrical Power System, and Control Electronics including Deployment Sensors.

During the project, the most crucial functions to be showcased with the Breadboard Model will be identified, but they will encompass at least the following:

- A vital task to be shown with the Breadboard Model involves assessing the force needed to deploy the Main Tether from its reel and confirming that it is lesser than the gravity gradient force produced by the designated End Mass and the chosen length of the Tape Tether. 6 meters of Main Tether is used on the Reels in the Breadboard Model.
- Another essential function to be exhibited with the Breadboard Model is showcasing the deployment of the Main Tether and confirming its suitability with the selected ejection mechanism.

II. Expected Outcome

The Zero-G Lab at the University of Luxembourg [4], [5], depicted in Fig. 3, is equipped with an advanced mechatronic system called a floating platform [6]. This platform is indispensable for carrying out research on satellite operations in space. As depicted in Fig. 4, the Base Unit is linked to the floating platform, whereas the Remote Unit is linked to a stationary UR10 robotic manipulator. Throughout deployment, the Base Unit and the floating platform will move away from the manipulator, facilitating the simultaneous deployment of the Main Tether connected to the Base Unit. The anticipated results of the dynamic deployment test for the Main Tether are outlined as follows:

- The deployment of the Remote Unit from the Base Unit has been completed successfully.
- Make sure that a minimum of 2 meters of the Main Tether is smoothly deployed from the Reel without encountering any problems.
- Ensure that the release velocity of 0.15 m/s with a tolerance of ±0.05 is attained.
- Verify the successful activation of the Reel brake and confirm the tether's integrity after the test, ensuring it remains securely attached at both ends.

III. Conclusions

The proposed system will employ a Coulomb Drag microtether, also referred to as a Plasma Brake, which leverages momentum from ionospheric plasma ram flow through electrostatic interaction. This paper has outlined the test strategies for the Dragliner project in the Zero-G Lab, with the test outcomes set to be disclosed upon the project's completion.

Acknowledgment

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