UNIVERSITY OF TRENTO | PhD SST Space Science and Technology | Università degli Studi di Padova

Research activity for debris deorbiting using Electrodynamic Tether technology - 276

G. Polato*, A. Valmorbida, M. Urbinati, G. Anese, A. Brunello, S. Salmistraro, S. Chiodini, G. Colombatti, E.C. Lorenzini

Space debris

Space debris, also known as space junk, consist of defunct human-made objects in space, that are orbiting primarily around Earth without the possibility to control them. These include spent rocket stages, non-functional satellites, fragments from collisions or disintegration, and debris from satellite explosions. Space debris are a growing concern due to their potential impact on operational satellites, space missions, and the International Space Station (ISS).

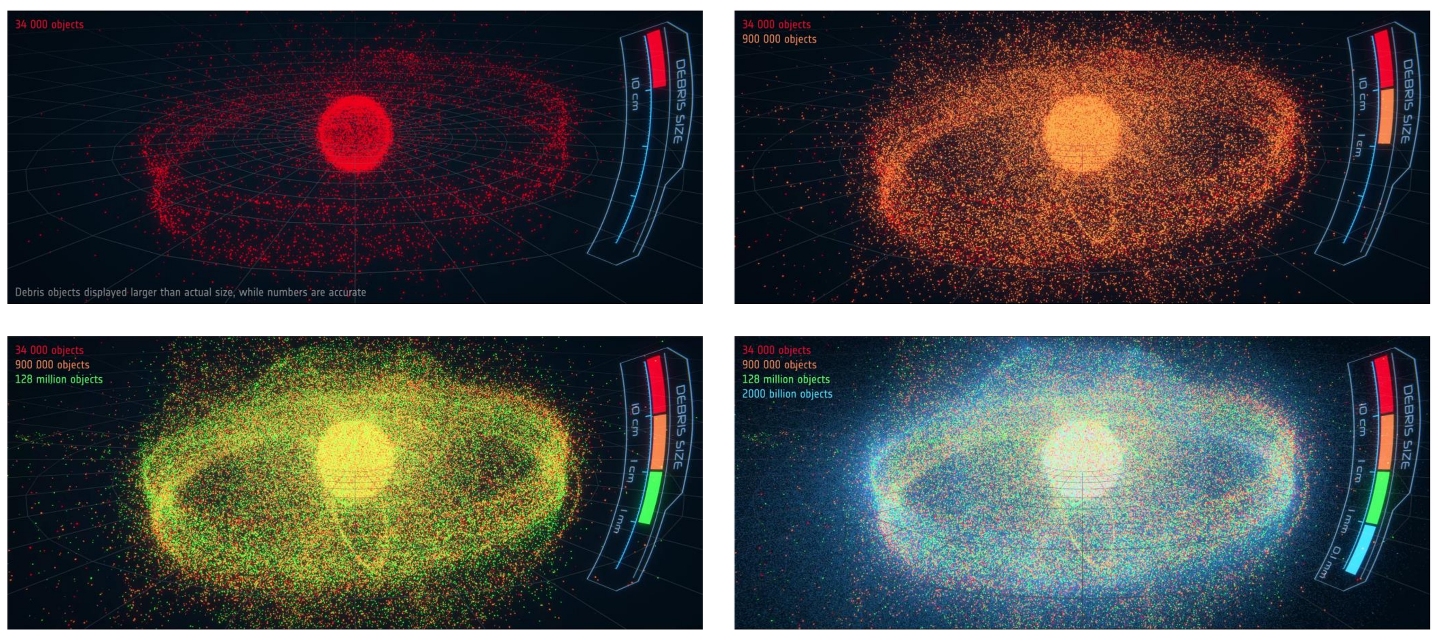


Figure 1. Space debris (not in scale) colored by size (courtesy of ESA, 2020)

E.T.PACK-F project

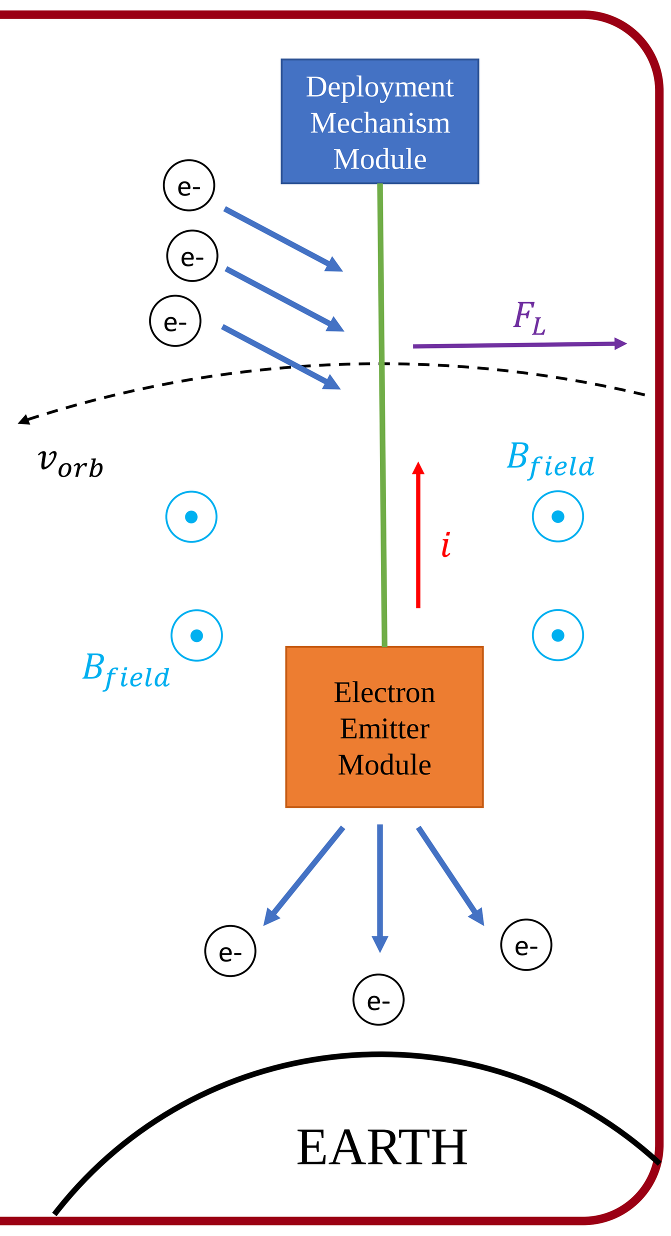
The E.T.PACK-F project is, funded by the European Innovation Council (EIC), aims to develop a TRL 8 product prototype, known as Deorbit Kit, leveraging EDT technology to safely deorbit end-of-life satellites.
The team of the project includes Universidad Carlos III de Madrid (UC3M, Coordinator), the University of Padova, the Technical University of Dresden (TU Dresden), the Spanish company SENER Aeroespacial and the German start-up Rocket Factory Augsburg (RFA).

Figure 2. the Deorbit Kit concept (courtesy of E.T.PACK-F, www.etpack.eu)

Figure 3. E.T.PACK-F team at the University of Padova for a project meeting (courtesy of E.T.PACK-F, www.etpack.eu)

Electrodynamic Tether (EDT)

The main idea is to deploy a bare and conductive tether in orbit, using the Deploy Mechanism Module. The relative motion of the tether through the geomagnetic field induces an electromotive force (EMF) along the tether.
By interacting with the ionosphere, an electric current is induced within the tether thanks to the ionospheric electrons that are collected on the positively-charged portion of the tether. In order to close the electrical circuit, the electrons are re-emitted into the ionosphere by an electron emitter positioned at the lower end of the tether (the Electro Emitter Module), as shown in the figure.
The interaction between the induced current i and the geomagnetic field B_field, generates a Lorenz drag force F_L that decelerates the satellite.
Conversely, by using a power supply to overcome the motional electrical field (EMF), hence biasing the entire tether positively with respect to the surrounding plasma, and inverting the positions of the two modules the system generates a thrust and works as a propulsion system.



SPARTANS facility

The SPARTANS facility at the University of Padova comprises a 3 m x 2 m testing table on which two floating platforms can move with almost no friction thanks to an air-cushion system. The facility employs a motion capture system consisting of six infrared cameras and spherical markers attached to each platform to accurately reconstruct the position and orientation of the platforms.
This facility offers an advanced testing environment for developing and validating on-ground algorithms, sensors and mechanisms related to satellite proximity operations, including Vision-based Navigation, Identification of Motion of a non-cooperative spacecraft and Rendezvous and Docking. Furthermore, each floating platform can accommodate specialized payloads, like docking mechanisms and/or relative navigation sensors.

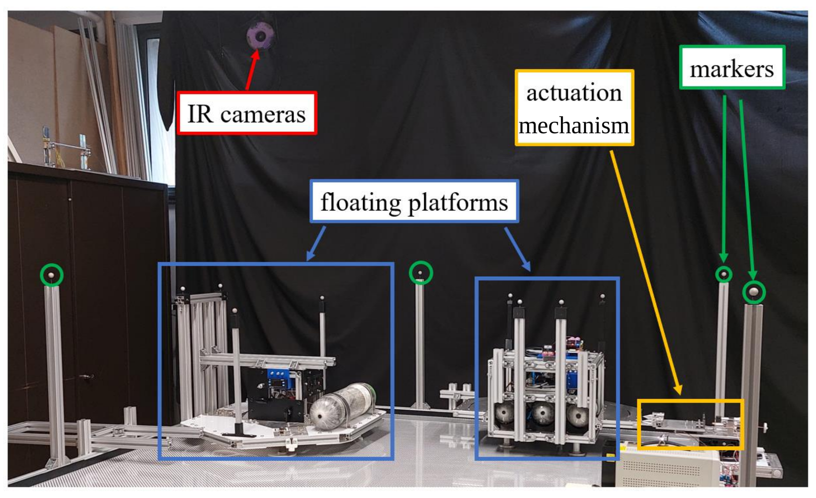


Figure 4. SPARTANS facility with the complete experimental setup

Testing the In-Line Damper

The In-Line Damper (ILD) is a patented mechanical device developed at the University of Padova and it is utilized in the E.T.PACK project. Its purpose is to dissipate the oscillation induced by the Lorentz forces on the tether (libration) during the deorbiting phase.
In general, the ILD acts like a mass-spring-damper system, making the characterization of its dynamic response critical for the successful deployment of the tether and the deorbiting of the modules.

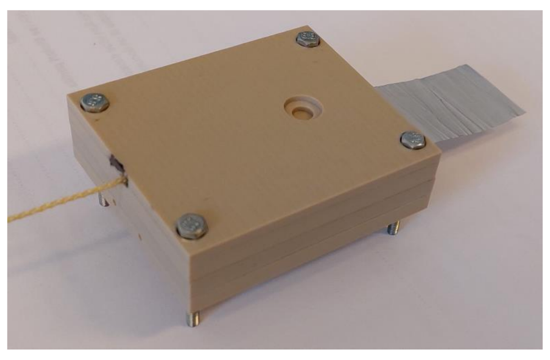


Figure 5. photo of the ILD

For this reason, our research group implemented a dedicated experimental setup employing the SPARTANS facility (Figure 6). The ILD was attached to one floating platform through four cables, representing the EEM. Four thrusters were used to push the platform along the axial direction, and the motion capture was employed to detect position and orientation of the platform, enabling to reconstruct the total elongation of the ILD.
The experimental results were then correlated with a 2D mathematical model through an optimization process.
This process also determined key parameters of the system, including the initial conditions of the module, the total thrust force, and the stiffness of the cables.

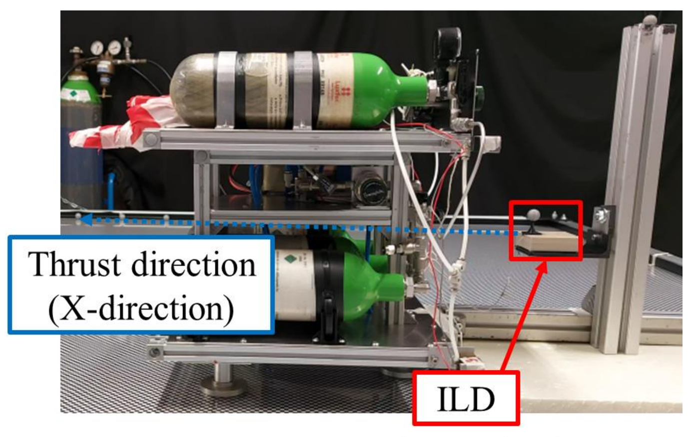


Figure 6. experimental setup for the ILD characterization tests

The optimization results revealed that during elongation, most of the energy dissipation is due to ILD internal friction. By modifying the model to better describe the dynamics of the ILD, we obtained results that are shown in Figure 7, where it can be seen the similarities between the experimental and the optimization data, highlighting the effectiveness of the updated model.

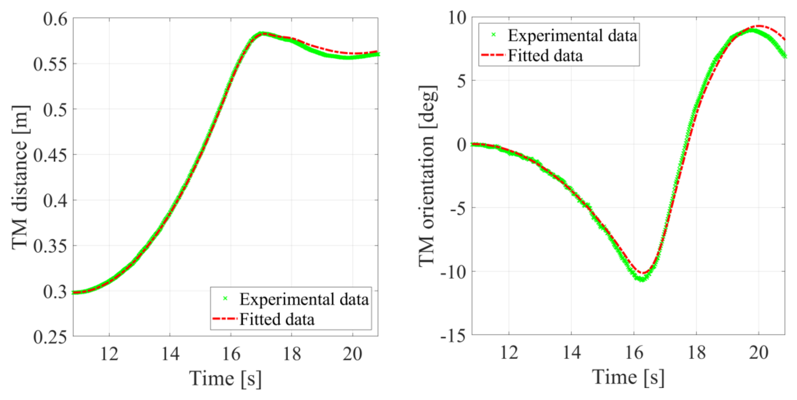


Figure 7. comparison between experimental and fitted data

POC1 activity: testing a standard docking interface

Satellite proximity navigation plays an important role in space debris removal. In fact, the debris must first be approached by a hypothetical chaser, hence the relative motion between the satellites needs to be studied. The SPARTANS facility is well-suited for this purpose and our research group is collaborating with OHB Italia within the ESA program "Preliminary Design of In-Space Transportation Proof of Concept-1 (Poc-1): In-Orbit Rendezvous and Docking - Phase B1 Studies".
OHB Italia has supplied the docking mechanisms breadboards for testing in our air-bearing facility. Meanwhile, our research group has co-designed the actuation mechanism (shown in Figure 4) capable of imparting initial conditions of position (linear and angular) and relative velocity (linear and angular) to one platform with respect to the other. In addition, we have enhanced the motion capture data acquisition system with custom-developed MATLAB routines, in order to track the relative motion between the two platforms in real time.

*giulio.polato@unitn.it

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