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HARVESTING SOLAR ENERGY FOR PROPULSION: A BREAKTHROUGH IN GREEN MOBILITY FOR SPACE APPLICATIONS

Abstract

The increasing congestion of Low Earth Orbits (LEOs) due to growing satellite constellations and space debris has raised the urgency for sustainable propulsion technologies that eliminate the reliance on traditional chemical and electric thrusters. The E.T.COMPACT project, an Horizon Europe Pathfinder project funded by the European Innovation Council (EIC) in 2024, pioneers a game-changing, fully propellantless thruster system, combining Electro-Dynamic Tether (EDT) technology with in-space solar energy harvesting. Unlike conventional chemical or electric propulsion, which requires onboard fuel and complex power processing units, E.T.COMPACT's Green-propulsion Mobility Module (GMM) features a Bare-Photovoltaic Tether (BPT), an electrodynamic tether embedded with thin-film solar cells. This unique integration allows for simultaneous thrust generation, Lorentz-drag-based deorbiting, and energy harvesting, offering a self-sustained mobility solution for small satellites.

The 3U-class GMM module incorporates a few hundred meters of deployable tape-shaped tether, an advanced Field Emission Cathode (FEC) for electron emission, and an innovative Deployment Mechanism (DM) enabling both reel-out and reel-in capabilities. This bidirectional system supports autonomous orbital maneuvering, including deorbiting, station-keeping, and orbit raising, making it a highly versatile solution for space debris mitigation, Active Debris Removal (ADR), satellite re-boosting, and In-Orbit Servicing (IOS). The thin-film tandem perovskite-CIGS solar cells integrated into the BPT significantly enhance energy efficiency, providing power for both onboard subsystems and electrodynamic propulsion, reducing dependence on large solar arrays.

Building upon the success of E.T.PACK and E.T.PACK-F, two previous European initiatives funded by EIC that developed a 12U autonomous deorbit device, E.T.COMPACT shifts the focus to miniaturization with increased functionality. By integrating drag and thrust capabilities within a compact, scalable system, this project introduces a low-cost, high-efficiency alternative to conventional low-thrust propulsion, perfectly aligned with the needs of modern small satellite constellations.

The project is currently advancing towards Technology Readiness Level (TRL) 4, with ground-based validation of tether deployment mechanisms, high-current FEC performance, and in-space power harvesting efficiency. Future In-Orbit Demonstration (IOD) missions will further validate the system's viability in real operational scenarios. When being commercialized by the E.T.COMPACT partner "PERSEI Space", E.T.COMPACT will establish a new paradigm in self-sustained, low-maintenance space mobility, revolutionizing satellite operations, debris mitigation strategies, and future deep-space exploration. This paper presents the system architecture, performance simulations, and a roadmap for future commercialization, outlining the disruptive potential of propellant-free solar-electrodynamic propulsion in modern space applications.