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MISSION CONCEPT FOR ENTRY PROBES TO THE FOUR OUTER PLANETS BASED ON E-SAIL PROPULSION

The Electric Solar Wind Sail (E-sail) is a new propulsion method that uses long, thin, positively charged tethers to convert solar wind momentum flux into thrust. The E-sail concept was invented in 2006 (http://www.electric-sailing.fi/) and its development is partly funded by the European Union's Seventh Framework Programme for Research and Technological Development, EU FP7. According to current estimates, the E-sail can be 2-3 orders of magnitude more efficient than traditional propulsion methods (chemical rockets and ion engines) in terms of produced lifetime-integrated impulse per propulsion system mass. In an E-Sail, the "screen" that reflects the solar wind protons is made by a network of the electrostatic sheaths forming around each of the highly positively charged tethers. Despite the fact that the solar wind dynamic pressure is smaller than the radiation pressure of solar photons, the E-Sail can be more efficient than the photonic Solar Sail as the electrostatic screen that reflects the solar wind protons can be orders of magnitude larger -when using long, highly-charged tethers-, than that of a solar sail. Although the solar wind flux and the solar radiation flux both vary with the squared distance to the sun, the thrust produced by an E-Sail is inversely proportional to the distance from the sun (F α 1/r) as the sheath size around each tether increases when the solar wind density decreases, while the thrust produced by a photonic solar sail is directly proportional to the solar radiation flux (F α 1/r2). This makes the E-Sail a propellantless method very attractive for outer solar system missions.

The science case for entry probes in the four outer planets has been made by several authors (e.g. Owen T. C., Atmospheric Probes: Needs and Prospects, in *International Workshop on Planetary Probes, ESA SP-544*, 2004; Atreya et al., Multiprobe exploration of the giant planets- shallow probes, *Proceedings, International Planetary Probe Workshop, IPPW-3, ESA SP-WPP263, 2006*). In this paper, we describe the concept of a multi-probe mission to each of the four outer planets that is based on a common concept of a carrier-entry probe composite propelled by an E-Sail to each destination for a direct entry into the atmosphere of the planets. The E-sail technology would allow significantly reduced travel times and reduced launch costs compared to traditional propulsion techniques. The concept of a standard 1-N E-Sail has been recently studied in detail (Janhunen et al., Electric solar wind sail: Towards test missions (Invited article), Rev. Sci. Instrum., 81, 111301, 2010, doi:10.1063/1.3514548). It requires hundred 20 km long tethers charged to several 10's of kV. It would allow to propel a 500 kg spacecraft (carrier-probe composite, but excluding the E-Sail propulsion stage) to Jupiter in a mere 1 year, to Saturn in 1.7 year, to Uranus in 3 years and to Neptune in 4.6 years. The four probes could either be launched independently by a small launcher or together by more powerful launcher on a trajectory that would place them in the solar wind. The constraints of a planetary launch window would not apply, thus providing increased launch flexibility compared to a classical planetary mission launch window. The arrival velocity of the probes would be relatively large, but it would not significantly affect the entry speed as this key parameter would essentially be governed by acceleration due to planet gravity (the same would not be true at Titan). This makes the E-sail concept a very appealing propellant-less method to conduct a multi-probe mission to the four outer planets at an affordable cost, especially if a similar entry probe design would be used for all four planets. The scientific return that would be allowed by identical probes to each of the four outer planets would need to be evaluated carefully to confirm the attractiveness of the proposed approach. Alternatively, for a higher cost, each probe could be tailored for optimizing the science return at each of the four planets.