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On use of electrodynamic tethers for Saturn missions II

Juan R. Sanmartín (1), Jesús Peláez (1), Henry B. Garrett (2) and Ignacio Carrera (1)
(1) Universidad Politécnica de Madrid, (2) JPL/California Institute of Technology,
(juanr.sanmartin@upm.es)

Abstract

Recent NASA news on chemicals favouring life being detected in geyser plumes ejected from moon *Enceladus* has brought back interest for exploration of the moons of *Saturn*. The case for using *electrodynamic tethers* for Saturn missions presents, however, a basic issue in its quite weak magnetic self-field $\mathbf{B}$ as compared with Jupiter, where tether use does appear readily possible [1, 2]. The planetary-surface B value for Saturn is about 5% of the corresponding Jovian value, while tether efficiency of spacecraft capture (S/C-to-tether mass ratio) goes down as B^2 for low enough field. This is compounded for Saturn by its comparatively low mean-density and fast rotation among the four *Giant Outer* planets, resulting in a relatively short *reach* of Lorentz-drag on a tether, as indicated by the low ratio of radius at the stationary circular orbit, a_s, to the planet radius R, ambient values B_s and plasma density N_s characterizing the capture operation.

In this work we show that, nonetheless, tether drag (a thermodynamic effect [3], like its capability to generate power), can effect capture of a spacecraft incoming from a *Hohmann Earth* transfer, with S/C-to-tether mass ratio about 3, as already found possible for Jupiter too [2]. The capture *perijove* radius would be about R_S, just hundreds of kilometres above the planet, and the tether-tape chosen long enough to ensure that its length-averaged current is close to the short-circuit, upper-bound value; this raises no issues as in the Jovian case [2], —where current is well below the corresponding short-circuit value— because of the very low Saturn field B itself. In this respect, a rough Chamberlain model [4] of the ambient plasma density is developed from measurements carried out at the Cassini mission.

Further, there is a gain in capture efficiency by a factor just about 2, arising again from the low B itself and the ensuing weak Lorentz drag, requiring no tether spin to keep it from bowing, as opposite the Jovian case. Finally, a similar increase in efficiency involves moving the capture orbit from pro-grade to retrograde, which eliminates drag-reach considerations, the positive effect on capture being sensible for a low prograde-reach case such as the Saturn one.

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