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Tether-mission design for multiple flybys of moon Europa

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Abstract

A tether mission to carry out multiple flybys of Jovian moon Europa is here presented. There is general agreement on elliptic-orbit flybys of *Europa* resulting in cost to attain given scientific goals lower than if actually orbiting the moon, tethers being naturally fit to fly-by rather than orbit moons[1]. The present mission is similar in this respect to the *Clipper* mission considered by NASA, the basic difference lying in location of periapsis, due to different emphasis on mission-challenge metrics. Clipper minimizes damaging radiation-dose by avoiding the Jupiter neighborhood and its very harsh environment; periapsis would be at Europa, apoapsis as far as moon Callisto. As in all past outer-planet missions, Clipper faces, however, critical power and propulsion needs.

On the other hand, tethers can provide both propulsion and power, but must reach near the planet to find high plasma density and magnetic field values, leading to high induced tether current, and Lorentz drag and power. The bottom line is a strong radiation dose under the very intense Radiation Belts of Jupiter. Mission design focuses on limiting dose. Perijove would be near Jupiter, at about 1.2-1.3 Jovian radius, apojove about moon *Ganymede*, corresponding to 1:1 resonance with Europa, so as to keep dose down: setting apojove at Europa, for convenient parallel flybys, would require two perijove passes per flyby (the *Ganymede* apojove, resulting in high eccentricity, about 0.86, is also less requiring on tether operations).

Mission is designed to attain reductions in eccentricity per perijove pass as high as $\Delta e \approx -0.04$. Due the low gravity-gradient, tether spinning is necessary to keep it straight, plasma contactors placed at both ends taking active turns at being cathodic. Efficiency of capture of the incoming S/C by the tether is gauged by the ratio of S/C mass to tether mass; efficiency is higher for higher tape-tether length and lower thickness and perijove. Low tether bowing due to the Lorentz force requires opposite conditions. Low heating requires not too low perijove and not too long length. In addition, too long a tape will result in attracted electrons hitting the anodic end with somewhat relativistic energy, and penetration depth larger than thickness[4]. Tape width is not involved in the above design criteria, just scaling with S/C mass.

A no-tilt, no-offset dipole model of the magnetic field and the plasma density in the equatorial plane as given by the classical Divine-Garrett model, are used in calculations; Δe proves near-independent of the e-value before each perijove pass[1-3]. Capture from the direct (no-gravity assists) hyperbolic, Hohmann–like, transfer orbit, corresponds to an incoming velocity of about 6.4 km/s, and eccentricity $e_h \approx 1.02$, requiring a net Δe decrement around 0.16 to reach Ganymede.

Dose per orbit for eccentricity above 0.5, say, proves also nearly independent of perijove at 1.2-1.5 Jovian radius, the number of perijove passes thus being a metric for total dose. The dose per orbit is about 0.1 Mrad for 200 *mils* of Aluminum shielding (or 13.5 kg for 1 m^2 surface). Dose is also near independent of longitude, proving accurate the simple dipole model in the inner magnetosphere. The GIRE radiation model was used throughout calculations[2-3].

A typical sequence of eccentricity decrements Δe = - 0.04, would allow reaching $e = 0.86$ in about 4 perijove passes, though the last decrement previous to a first resonant orbit must be reached in two convenient steps, by switching current off appropriately over part of the drag arc, to allow for a first flyby of Europa; switching off the current afterward over the entire resonance orbit would allow for repeated flybys.

Over 20 flybys would then make a total of 25 perijove passes, leading to 25 $\times$ 0.1 Mrad, or 2.5 Mrad cumulative dose under 200 mils shielding (to be compared with 2.9 Mrad for 100 mils shielding of the *Jupiter Europa Orbiter* in the originally planned *EJSM* mission. As with *Clipper*, individual payload electronics could have their own shielding and use existing components currently qualified. Also, some nesting radiation protection could be used. The suggested flyby tour is quite rapid. The apojove lowering steps to reach Ganymede would add to over three months, whereas the 20 flybys, each taking the Europa period of 3.5 days, amount to 70 days. The total duration of the mission would add to about 6 months.

In addition to Europa flyby measurements, perijove passes could allow high resolution determination of gravity and magnetic fields, and bulk abundance of water. Also, the orbiting tether itself could be an active instrument. During each flyby, with hollow cathodes off, the tether will be electrically floating; ions will be attracted over most of the tether, resulting in a continuous beam of energetic secondary-emission electrons, energy and flux increasing with distance from tether top. This will allow for artificial auroral effects to probe the Jovian ionosphere.

References

1 J.R.Sanmartin, M.Charro, E.C.Lorenzini, H.B.Garrett, C.Bombardelli, C.Bramanti, *Electrodynamic Tether at Jupiter- I: Capture Operation and Constraints*, IEEE Transactions on Plasma Science **36,** 2450-58 (2008)

2 J.R.Sanmartin, M.Charro, E.C.Lorenzini, H.B.Garrett, C.Bombardelli, C.Bramanti, *Electrodynamic Tether at Jupiter- II: Fast Moon Tour after Capture*, IEEE Transactions on Plasma Science **37**, 620-626 (2009).

3 M.Charro, J.R.Sanmartin, C.Bombardelli, A. Sanchez-Torres, E.C.Lorenzini, H.B.Garrett, R.W.Evans, *A Proposed Two-stage Two-tether Scientific Mission at Jupiter*, IEEE Transactions on Plasma Science **40**, 274-281 (2012).

4 G.Sanchez-Arriaga, J.R.Sanmartin, *Relativistic current collection by a cylindrical Langmuir probe*, Physics of Plasmas **19**, p063506 8pp (2012)