GLOBAL MOON COVERAGE VIA HYPERBOLIC FLYBYS

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ABSTRACT

Traditionally the problem of global coverage of a moon such as Jupiter's Europa or Saturn's Titan has led to the design of orbiter missions. Such orbiter missions are very expensive as a result of the large amount of propellant needed to insert into orbit around such small bodies, and are often plagued by orbit stability complexities.

As part of the Cassini Equinox Mission design effort, a new method for the placement of the groundtrack of a hyperbolic orbit over desired latitudes and longitudes was developed [1]. This method has been expanded such that a number of flybys can be used to systematically cover a specific hemisphere of a moon. This technique is referred to as a crank-over-the-top (COT) sequence, and entails starting from an equatorial orbit, cranking the inclination up to the maximum (i_{max}) and then returning it to the equatorial plane via a set of resonant transfers. When starting from an inbound flyby, the COT sequence changes the flybys to outbound (transition occurs after i_{max} is reached, hence the term "over the top"), and vice versa when starting with outbound flybys. COT sequences starting from inbound flybys render coverage of the sub-planet facing hemisphere (assuming the moon is tidally locked); COT sequences starting from outbound flybys cover the anti-planet facing hemisphere. The number of flybys—hence the density of groundtracks—for a given COT sequence is a function of spacecraft orbit period and its V_∞ relative to the gravity-assist body. Specifically,

- For a given period: The number of flybys increases/decreases as V_∞ increases/decreases.
- For a given V_∞: The number of flybys increases/decreases as the spacecraft period decreases/increases.

Lastly, if the same period resonant transfers are used throughout a COT sequence (i.e., only cranking, no pumping), all closest approaches will lie very near the prime or 180º meridians (i.e., longitudinally 90º away from gravity-assist body's velocity vector). If different period resonant transfers are used during a COT sequence (i.e., cranking and pumping), the closest approach can be placed away from the prime or 180º meridians.

This method can be extremely useful in the design of missions with global coverage of the moons of: Jupiter (Europa, Ganymede, and Callisto), Saturn (Titan and Enceladus), and Neptune (Triton). This paper will describe the theory behind this design technique, and give one or more example showing how with proper selection of an instrument suite, a multiple flyby mission can provide science return similar (and in some cases greater) to that of an orbiter mission. Specifically, this paper will highlight how the COT technique enabled the design of a flyby-only

Europa mission (Fig. 1) that successfully fulfilled a set of pre-defined scientific objectives including ice penetrating radar, topographic imaging, and short wavelength infrared observations, and ion neutral mass spectrometry *in-situ* measurements, and is currently the preferred path (given fiscal constraints and the quality and quantity of science return) by the scientific community and JPL management to exploring Europa in the near future.

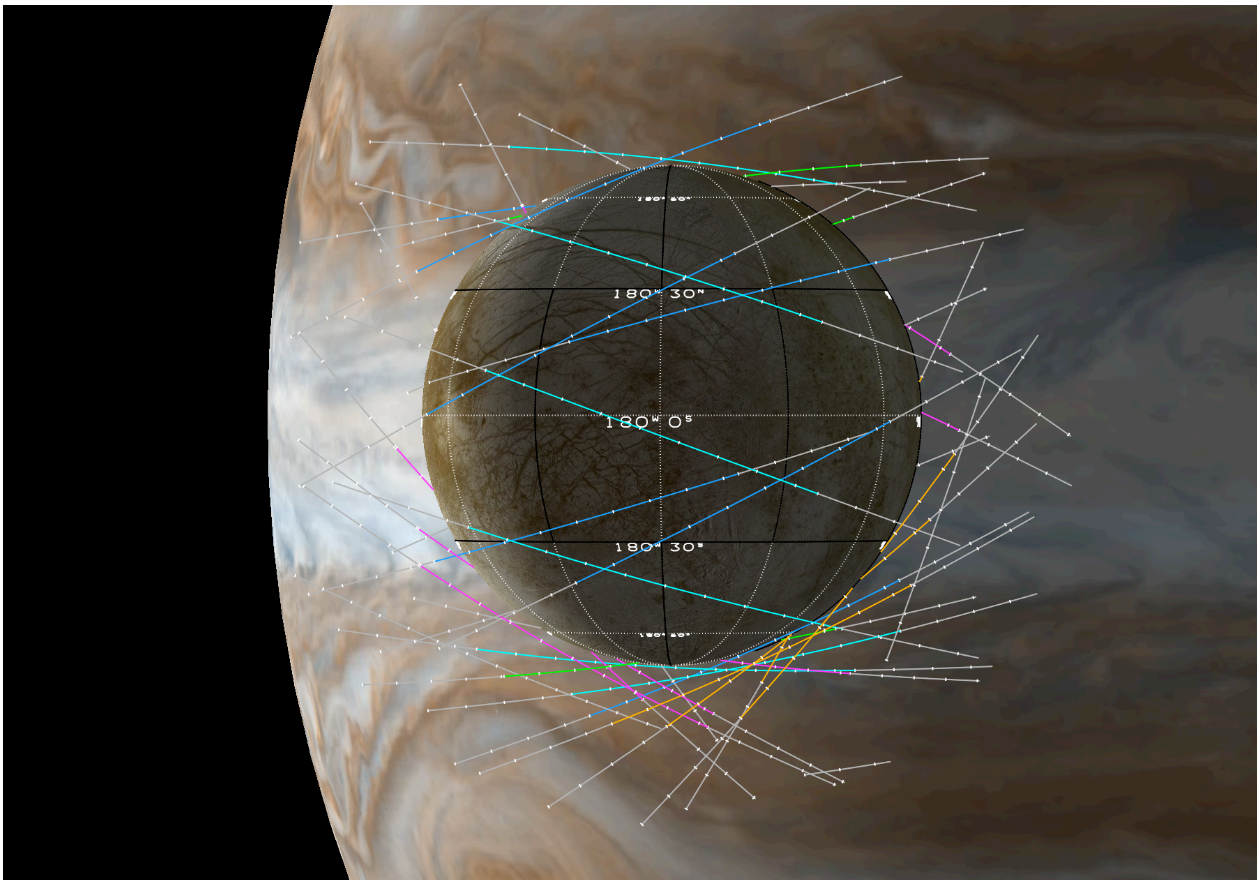

Figure 1. Global coverage with only flybys. *An example trajectory which covers 13 of the 14 "sectors" defined by the Europa Science Definition Team (SDT) to assess global coverage with Ice Penetrating Radar (IPR).*

References:

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