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The determination of gravity and topography from a planetary flyby mission

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Abstract

Planetary science missions are often best accomplished by spacecraft in orbit about the planet or moon since an orbital mission usually provides the best coverage and highest observational resolution. However, in some circumstances a mission composed of a number of close flybys is the most effective way of obtaining the desired scientific data. However, the more globally balanced datasets often required by geodetic or geophysical investigations are usually more difficult to accomplish on a multi-flyby mission than an orbital mission. We have simulated a flyby mission of the Europa moon of Jupiter with the intention of assessing the ability to acquire a useful geophysical dataset of primarily gravity and topography from the tracking of a spacecraft for the gravity and the altimetry from an altimeter. The importance of these 2 data sets, both individually and together, is their ability to provide data about the crust and interior of the body, including the dynamics that are associated with tidal effects, the strength and thickness of the crust, and the rotation of the body.

The simulation

In our full simulation of a Europa multi-flyby mission we consider as many aspects of the spacecraft operation as is possible including the limitations of observation from Earth for downlink, including the effects of radio wavelengths, and acquiring tracking data. We simulate 45 individual flybys of Europa for a spacecraft that is in Jupiter orbit, apply the observational schedule for tracking and for the operation of an altimeter. The altimeter is generic but with a ranging capability of 5000km to the surface of Europa and accounting for signal strength return, effective spot size of the measurement and the spatial variability of the reflectance of the surface.

The simulated tracking data are generated for about 4 hours around the time of closest approach to Europa using a nominal model for the gravity of Europa and of the spacecraft attitude and properties. The simulated data for each flyby are processed as real data starting from a perturbed orbital state and the trajectory estimated and compared with the nominal orbit. The altimeter data acquired below an altitude of 5000 km through closest approach are processed in a similar manner and provide a topographic profile of Europa on each flyby using the orbital information obtained from the simulated tracking data. The ultimate combination of the tracking data and the altimetry data in a joint solution provide estimates for the recovery of the shape of Europa, its low degree gravity field, the mass of Europa, the amplitudes of the gravity and body tides, the rotation of the of Europa and the associated errors and correlations which can be compared with the a priori values and constraints.

The simulation used the mission design for proposed NASA Europa Clipper mission where possible to assess its potential for geophysical observations of Europa.