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Titan gravity investigation with the Oceanus mission

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Oceanus is a proposed mission for NASA's New Frontiers 4 Announcement of Opportunity to study Saturn's largest moon Titan. One of the main goals of Oceanus is to examine crustal properties and determine the potential interaction of organics with the subsurface ocean, with implications for potential habitability of Titan. To this end, Oceanus could potentially characterize the thickness of the external icy shell and determine the extent of convection in the shell. The product (average ice rigidity) x (ice shell thickness) can be retrieved from the Love numbers k2 and h2, which describe Titan's gravity and shape response to Saturn's tidal field during its orbital motion around the planet, using a combined analysis of gravity and topography but also measuring Titan's physical librations from gravity data and the on-board camera surface landmarks.

The gravity science experiment is crucial to accomplish the mission goals, because precise orbit determination of the spacecraft provides a direct measure of Titan's static gravitational field, the real and imaginary parts of the Love number k2, and its rotational state (obliquity and amplitude of physical librations in longitude). Moreover, a precise spacecraft orbit reconstruction throughout the entire mission is necessary to process radar altimetry data and accurately measure Titan's h2 through crossover analysis.

We present the expected accuracy in the estimation of the scientific parameters of interest, obtained through numerical simulations of the orbit determination of the Oceanus spacecraft during its 2-year mission around Titan. The main observable quantities used in the analysis are two-way Doppler data obtained from the frequency shift of a highly stable microwave carrier between the spacecraft and the stations of NASA's Deep Space Network. White Gaussian noise was added to the simulated data, with a realistic standard deviation obtained from an accurate noise budget derived from the experience with Cassini Ka-band Doppler data. A covariance analysis was carried out using a multi-arc approach, comparing different observational and modeling strategies, in particular for the non-gravitational perturbations. Our results show that Oceanus will allow estimating the real and imaginary parts of Titan's k2 to an accuracy of 0.0001, the gravity field to at least degree 12 with SNR of 10, and also provide spacecraft orbit reconstruction with a radial uncertainty better than 0.5 meter during the mission.