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Titan gravity investigation from a SmallSat Satellite-to-Satellite Tracking Mission

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During its tour of the Saturn system, Cassini has revealed that the icy satellites of Saturn are among the most intriguing and complex bodies in the Solar System. In particular Titan, the Saturn's largest moon, possesses a global sub-surface water ocean. This may interact with an organically rich and dynamic atmosphere and surface, with implications also for Titan's potential habitability. However, many questions are still to be addressed, so that several future missions to Titan and other icy satellites were proposed in the latest years, in the context of both NASA and ESA calls for proposals.
Radio science measurements are powerful tools to determine the static and dynamic gravity field of a body, posing constraints on its radial interior structure and assessing mass anomalies. In particular, gravity investigations at Titan could provide information on the internal dynamics and evolution, ocean properties, crustal thickness and state.
Traditionally, the observable quantities used by interplanetary gravity science experiments are obtained by means of spacecraft tracking at microwave frequencies from a ground antenna. The generation of these observable quantities requires the spacecraft antenna to point in the direction of the Earth and have an onboard coherent radio transponder. Using both of these simultaneously impacts spacecraft resources including mass, power, and attitude control. Moreover, the geometry and the operations of the entire mission must be carefully designed to meet all science requirements, including the ones posed by the gravity experiment, through a complex and expensive trade-off process.
In recent years it was proposed to use smallsat companion missions, dedicated only to specific investigations, to complement the science observations of a traditional larger exploration spacecraft. This represents a promising option since smallsats provide relatively low-cost and versatile platforms for scientific observations.
Here we propose a mission consisting of two smallsats to be released in orbit around Titan and capable of globally characterize its gravity field through Satellite-to-Satellite Tracking (SST). This mission proposal is intended to complement a traditional larger mission to Titan or Enceladus. The observables are generated and decimated on-board the smallsats and transmitted back to Earth for data analysis and gravity field reconstruction, using the main mission as a relay spacecraft.
We present the expected accuracy in the estimation of Titan's static and dynamic gravity field, obtained through numerical simulations of the orbit determination of two smallsats in similar orbits around the moon. The main observable quantities used in the analysis are two-way Doppler data obtained from the frequency shift of a stable microwave carrier transmitted between the two spacecraft. White Gaussian noise was added to the simulated data, with a conservative standard deviation obtained from a preliminary noise budget. A covariance analysis was carried out using a multi-arc approach, comparing different orbital, observational, and modeling strategies.