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Covariance Analysis of Hera Radio Science Experiment including LIDAR Altimetric Crossovers

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Hera is a European Space Agency (ESA) space mission, part of the Asteroid Impact and Deflection Assessment (AIDA) international collaboration with NASA, with a targeted launch to the Didymos system next October 2024. Following last 26 September 2022 extremely successful NASA's DART impact on Dimorphos, the secondary body of the Didymos binary system, all the attention is now focused on the Hera mission. The main goals of Hera are the detailed study and characterization of DART's crater, analysis of the impact in terms of momentum transfer efficiency, and accurate estimation of the physical properties of Didymos and Dimorphos, in order to validate and demonstrate the kinetic impactor technique to deflect potentially hazardous asteroids in the future.

In this context, one of the main goals is to accurately estimate the mass and mass distribution of Didymos and Dimorphos, by means of radio science investigations. In particular, one of the very few direct measurements of the internal mass distribution of planetary bodies is the determination of their gravity field. The gravity of Didymos and Dimorphos will be estimated by precisely reconstructing the trajectory of Hera and the two companion CubeSats (Juventas and Milani) during a selected number of close encounters, by performing an orbit determination process. In particular, Hera will make use of an Inter-Satellite Link system (ISL) to track Juventas and Milani, measurements which will further improve Didymos' system extended gravity field estimation.

Furthermore, the Hera spacecraft is equipped with a Light Detection and Ranging instrument (LIDAR), a time-of-flight Planetary ALTimeter (PALT) that will measure the distances from the Hera spacecraft to the target body surfaces. The PALT altimetric measurements can be combined with Earth-based radiometric, ISL radiometric, and Hera optical observables to enhance the gravity science scientific parameters.

This work discusses a covariance study of the Hera radio science experiment including *crossovers* estimation to the PALT LIDAR altimetry data. The trajectory constraints obtained from the radiometric tracking and optical data can be supplemented by altimetric *crossovers*, to further improve the reconstruction of the spacecraft trajectory with respect to the case without *crossovers* (i.e. PALT LIDAR altimetry data considered as single measurements, without estimating the surface landmarks probed multiple times by the LIDAR swaths). As a consequence of a better knowledge of Hera's trajectory, the formal uncertainties of the scientific parameters of interest decrease, too. In particular, there is a potential further improvement of Dimorphos' relative orbit estimation, as well as Didymos and Dimorphos gravity field, and their rotational state, with respect to the case without altimetric *crossovers*.

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