SPACE EXPLORATION SYMPOSIUM (A3)
Poster Session (P)

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THE GEODESY AND ORBITOGRAPHY OF MERCURY FROM KA-BAND RADIO TRACKING AND PRECISE ACCELEROMETRY OF ESA'S BEPICOLOMBO PLANETARY ORBITER

Abstract

Although Mercury is an extraordinarily interesting object for planetary sciences, its exploration is difficult because of the harsh thermal environment and the need for large delta-V. NASA has reached the planet twice, with Mariner 10 in 1974 and Messenger in 2011. ESA has also undertaken a complex and challenging mission to Mercury, named BepiColombo after Giuseppe (Bepi) Colombo, the scientist who explained the planet's 3:2 spin-orbit resonance. Its launch is planned for 2015, with insertion in planetary orbit in 2022. BepiColombo is a twin-spacecraft mission made up by a planetary orbiter (MPO), optimized for remote sensing observations, and a co-planar magnetospheric orbiter (MMO, provided by JAXA). The MPO is endowed with a unique suite of instruments for the investigation of the surface, the topography and the interior of the planet, taking advantage of a low eccentricity, low altitude, polar orbit. The proximity of Mercury to the sun will be exploited for improved tests of relativistic gravity.

The precise determination of the Hermean gravity field and the spacecraft orbit is essential to the achievement of the mission's scientific goals in geodesy, geophysics and relativity. These goals are attained from a unique combination of spacecraft tracking at multiple frequencies and measurements of the non-gravitational accelerations by means of a tri-axial, high performance accelerometer. The key elements of the onboard radio system are a Ka-band uplink, Ka-band downlink radio science transponder (an element of the Mercury Orbiter Radioscience Experiment, MORE) and the TTC transponder (X-uplink, X/Ka-downlink). The radio system supports a multi-frequency radio link, already experimented with the Cassini mission, and a 24 Mcps, pseudo-noise ranging channel, providing range and range rate measurements of unprecedented accuracy (respectively 20 cm and 3 micron/s at 1000 s integration times). The removal of the non-gravitational accelerations in the orbit determination process (to a level of 10^{-8} m/s^2 at time scales of 10-10000 s) is made possible by the ISA (Italian Spring Accelerometer) instrument. The determination of Mercury's gravity field and orbit will be carried out jointly by the MORE and ISA teams, international consortia of scientists and engineers from Italy, Belgium, France, Germany and the United States, selected by ESA in 2004. Since its initial design, the geodesy, geophysics and relativity investigations underwent significant changes and improvements. This work presents the current implementation of the instruments and the experiments, together with an up-to-date assessment of the attainable measurement accuracies and science goals.