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ORBIT PERTURBATIONS AND ECCENTRICITY VECTOR CONTROL IN LOW-ALTITUDE MOON ORBITS

Abstract

The German Space agency, DLR, was planning a lunar mission in order to provide high resolution maps of the Moon surface in a large variety of spectral bands and with an unprecedented accuracy. In order to do so, the Lunar Exploration Orbiter (LEO) spacecraft, along with his two sub-satellites, was expected to probe the Moon in a quasi polar and circular orbit and at a low altitude.

The main mission requirement of the LEO spacecraft concerning its orbit was to obtain small altitude variations during the mission lifetime, assuming a minimum propellant consumption. Added to that, the sub-satellite's orbits were to be long-term stable since no orbit maintenance maneuvers were planned.

In order to cope with these requirements, EADS Astrium in Friedrichshafen made an in-depth orbit analysis, looking in detail on how varying orbital parameters impacts the lifetime of low lunar orbits. It was shown that perturbations caused by the non-spherical gravity field of the Moon and third-body attraction (Earth and Sun) induce to an increase of the eccentricity which would ultimately lead to large altitude variations.

Under these perturbations, an analytical analysis of orbit perturbations has been carried on where the long-term evolution of the eccentricity vector was described. This study has shown that the characteristics of long-term stable orbits (eccentricity and argument of pericenter) strongly depend on the mission inclination. For a specific mission nominal altitude, a thorough selection of the inclination and eccentricity vector enables to place the spacecraft into a quasi-frozen orbit that can achieve the expected lifetime of several years. Moreover the influence of the lunar gravity field accuracy was taken into account. Also, high fidelity numerical simulations and Monte-Carlo analysis were performed so as to validate the analytical results.

For the cases where orbit maintenance is necessary, different methods of eccentricity vector control were presented. An orbit keeping strategy for which the altitude variation and ground coverage requirements are fulfilled with a minimum propellant consumption is proposed. It is shown that, when long-term stable orbit are selected, controlling the inclination allows reducing the propellant consumption. Numerical simulation results of the different orbit keeping strategies are presented.