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ON ESTIMATION OF ORBIT DETERMINATION ACCURACY DURING DESIGN AND SUPPORT OF ADVANCED LUNAR MISSIONS

Abstract

After a long period of calm, the beginning of the 21st century marked a renewal of interest in lunar exploration on the part of spacefaring nations. Both recent and near-future missions, designed for the benefit of solving strategic problems of fundamental lunar and space physics, selenodesy, lunar resources exploration, navigation, telecommunications and interplanetary exploration, are implemented in correspondingly diverse domains of near-circular and elliptical orbits of lunar artificial satellites with various geometries and orientations, as well as Earth-Moon system libration point orbits. In terms of specific mission objectives, one of the key parameters during the design of any space system is represented by the motion determination accuracy for the space objects that constitute this system. Consequently, the problem of studying orbit determination (OD) accuracy gains standalone significance. The features of OD process, depending on their nature, could be subdivided into two fundamental groups. First, one should mention the methodological aspects of the OD problem. A wide array of sub-problems pertains to this group. It includes the selection of a specific set of estimated parameters and of the estimation method, the mathematical aspects of solving the equation systems, the substantiation of weight and covariance matrices for measured parameters and uncertainties in the specification of model parameters, as well as the appropriate selection of mathematical models for motion and measurements. The methodological support problem is closely interwoven with the general problem of measurement process organization. Its components include the rational selection of measuring tools and measured parameters, the determination of measurement schedule (including specification of the conclusive interval for reliable accuracy estimation for various orbits and their subsequent comparison), as well as the problem of measuring basis optimization and integration, taking into account its desired configuration and the existing a priori technical constraints. The authors illustrate the emerging challenges and approaches to solving them at the stage of project analysis, basing on the instances of specific practically valuable classes of near-circular lunar trajectories and collinear libration point orbits. The results of preliminary analysis of attainable OD accuracy are presented for these classes. The problem's boundary conditions are investigated. We also analyze how some variants of integrated measurement systems utilizing Earth-, Moon- and space-based tools affect estimation accuracy, demonstrating potentially high OD accuracies together with the required degree of autonomy and adaptability. Proposals are offered for the formation of measuring systems for advanced lunar missions, based on high-precision laser measuring technologies.