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STAGED DEPLOYMENT PLAN OF LUNAR NAVIGATION SATELLITE CONSTELLATION CONSIDERING DEMAND UNCERTAINTY

Abstract

In recent years, the global movement for lunar surface development has intensified, driven by the current goal to secure water resources in the lunar polar region to expand human activity beyond Earth and utilize planetary resources. As a key infrastructure facilitating lunar positioning and communication, the Lunar Navigation Satellite System (LNSS) is highlighted among countries. However, there are significant challenges to effective design assessment caused by numerous uncertainties regarding the demand of the users, including the evolution of demand for navigation performance, targeted regions of activity, and the timing of developmental onset. This study proposes a novel framework for multi-stage design optimization methodologies, integrating the dynamic nature of regional and temporal demand into a stochastic mathematical model. This framework was applied to a design for the LunaCube mission, a domestic joint industry-academia research project supported by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT). The study revealed that the optimal system configuration varies significantly based on the probability distribution of demand development scenarios, affirming the efficacy of the proposed method in quantitative evaluation. These findings promise substantial contributions to Japan's strategic leadership in lunar activities within the broader international context.