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APPLICATIONS OF MULTI-BODY DYNAMICAL ENVIRONMENTS: THE ARTEMIS TRANSFER TRAJECTORY DESIGN

Abstract

The application of multi-body dynamical environments in order to permit the transfer of spacecraft from Earth to Sun-Earth weak stability regions and then return to the Earth-moon libration (L1 and L2) orbits has been successfully accomplished. This demonstrated transfer is a positive step in the realization of a design process that can be used to transfer spacecraft with minimal Delta-V expenditure. Initialized using gravity assist to overcome fuel constraints, the ARTEMIS mission design has successfully placed two spacecraft into Earth-moon libration orbits by means of this application.

Various design methods relying on multi-body dynamics were applied to achieve our transfers. Generation of manifolds from dynamical information, optimization of forward numerically integrated states, and the selection of various trajectory conditions along these manifolds were combined to ensure the design was successful given inherent modeling, navigation, and maneuver execution errors. The ARTEMIS design has two distinct transfers, one for each spacecraft, which shows the variability in the application. The spacecraft used a lunar gravity assist (one of which used a double gravity assist with a 13 day interval between lunar encounters), to archive the correct energy and orbital orientation to place it on the appropriate transfer manifold. Having placed the spacecraft onto a manifold to attain the final Earth-moon orbital conditions, operational support then focused on remaining on this manifold or a nearby manifold given navigation errors and mismodeled perturbations as the manifold changed from dynamically stable to unstable modes. This dynamical change was performed multiple times.

Along this transfer trajectory several maneuvers were executed, each adjusting the trajectory slightly onto an associated manifold, all converging to the chosen target location at the desired epoch. As shown in the figures, these designs are very sensitive to mismodeled perturbations and to the maneuver errors. The paper addresses lunar gravity assist, manifold generation, optimization techniques and numerical solutions, sensitivity of the transfer, and operational navigation solutions and trajectory design achieved. The achieved transfer trajectories, one via the sun-Earth L1 and the other via the sun-Earth L2, into Earth-moon libration orbits at L1 and L2 are demonstrated. Earth-moon rotating coordinates for both spacecraft and sample manifolds for the transfer trajectory are available.