IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (2) (4)

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THE DEVELOPMENT AND VERIFICATION METHOD OF SLIM LUNAR LANDING NAVIGATION ALGORITHMS

Abstract

SLIM (Smart Lander for Investigating Moon) is Japanese first successful lunar lander, which landed near the Sea of Nectar in January 2024. This lander aimed to improve the accuracy of landing on the moon and achieved the world's first successful landing with an error of less than 100 meters. As the system manufacturer for this lander, MELCO was responsible for the development of the entire system, including GNC. The landing sequence of SLIM is divided into a powered descent phase, which the lander decelerates from the lunar orbit and moves to above the target point, and a vertical descent phase, which moves from above the target point toward the target point. For navigation during the descent phase, the navigation system that uses optical navigation, which calculate lander's position and velocity by extracting craters from images, RAV (landing radar), LRF (laser range finder) and inertial sensors was built. The navigation filter was adopted based on the navigation coordinate system and used the system equation of state simply incorporating RAV and LRF observation values. Additionally, in case of the failure of optical navigation with onboard software, the backup navigation system by ground support was prepared. To evaluate these algorithms, verification using Monte Carlo simulation was conducted, and it contributed to improve the probability of landing success. Software verification with a ground testing system which was built by engineering model hardware and image simulators was also conducted. On orbit, a last-minute evaluation by actual lunar images taken by onboard cameras was also conducted in the checkout phase. In this paper, summarization of the design, verification, and operation phase of this project, as well as the evaluation methods and lessons and learned obtained in this project would be described. First, the overview of the navigation system during the descent phase, including the optical navigation would be shown. Next, the verification which includes the Monte Carlo simulation method and its results, and also the test configuration, procedure, and results of the engineering model test is explained. Consideration about the results of evaluating the validity and effectiveness of the simulation by comparing with on-orbit results would be described.