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LANDING SITE SELECTION AND LANDING DISPERSION ANALYSIS FOR THE HAYABUSA2 MISSION

Abstract

The Hayabusa2 spacecraft successfully landed on the asteroid Ryugu on February 21st, 2019 UTC, within a 3-m-radius target area. The engineering landing site selection (LSS) and landing dispersion analysis (LDA) for the Hayabusa2 mission, which were indispensable for the successful touchdown, involved several difficulties that were not necessarily present in past missions. First, due to limited capabilities and opportunities of ground-based surveys, information for Ryugu had lacked sufficient detail before the arrival even on fundamental characteristics, such as its shape, rotation axis, gravitational constant, and surface features; therefore, the Hayabusa2 LSS had to be conducted after the arrival based on proximity observations. In addition, the LSS process for this mission is subject to severe time constraints, because multiple touchdown operations and rover release operations are scheduled during a 1.5-year stay at the asteroid. Moreover, numerous boulders are distributed across the entire surface of Ryugu, resulting in the absence of wide and flat landing sites. For this reason, dedicated LSS and LDA are required to guarantee the touchdown safety.

To identify a promising landing site and design an optimal landing trajectory even under these constraints, a systematic and stepwise analysis strategy was developed. The LSS and LDA were conducted by the following three steps relying on proximity observations. First, candidate sites with 100-m width were pre-selected based on a global shape model by computing geometrical parameters that are associated with engineering requirements, such as slope angle, solar incident angle, and surface roughness. Then, landing sites with less boulders were down-selected based on boulder distribution maps generated from optical images. Finally, candidate landing areas were narrowed down by using local digital elevation maps. In this step, LDAs based on a high-fidelity gravity model were performed to minimize a collision probability, considering guidance and control errors. As a result, orbit and attitude profiles suitable for touchdown were obtained. Although beyond the scope of this paper, scientific values of each candidate site were also discussed through the process.

Following the proposed strategy, a circular area with a radius of 3 m had been selected as a safe landing site, where Hayabusa2 successfully performed the touchdown. This paper presents primary results of the LSS and LDA for the Hayabusa2 touchdown operation. Then, the analysis data are compared with actual operation results, which demonstrates the validity of the described methodology. Consequently, this article provides the basic framework for designing secure landing operations for small-body missions.