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REGION-ADAPTIVE TRADE-OFF ANALYSIS OF ROVER MOBILITY SYSTEMS FOR LUNAR SOUTH POLE REGION TRAVERSAL

Abstract

The nine shortlisted Artemis III landing regions within the Artemis Exploration Zone (AEZ) align with specific launch windows and contain areas identified for scouting, exploration, and In-Situ Resource Utilization (ISRU). These regions exhibit highly variable surface properties, including slopes exceeding 15°, temperatures ranging from 20K to 327K, and uneven distributions of permanently shadowed and boulder-cluttered areas. Such extreme conditions pose significant mobility challenges for rovers, which will play a critical role in future surface missions. Existing rover mobility systems i.e. wheeled, legged, and hybrid, each have distinct advantages and limitations and have been deployed or proposed for lunar exploration. However, given the highly irregular terrain of the lunar south pole, a single mobility system may not be suitable for all regions.

This paper presents a generalized trade-off analysis of rover mobility systems optimized for exploration and ISRU activities in targeted Lunar South Pole (LSP) regions, based on user-specified environmental characteristics. The environmental conditions of the nine landing regions are used to define a set of locomotion performance parameters based on accessibility, traversability (e.g., slope climbing, obstacle traversal), solar power consumption, and mechanical complexity. Based on these parameters, the trade-off model determines the most suitable mobility system for a given region.

The model employs a relative grading approach to assess the performance of the mobility systems. The user provides key surface characteristics of a chosen LSP location, such as slope range, solar irradiance, and whether the region is permanently shadowed. The model translates these inputs into performance parameters and assigns relative scores (on a scale of 1 to 5) to each parameter for every candidate mobility system. To account for mission objectives, design constraints, and cost considerations, the user specifies relative importance (weights) of each parameter. The trade-off algorithm then computes a total score using the Weighted Sum Model (WSM), a widely used multi-criteria decision analysis technique. The WSM systematically integrates multiple performance parameters, enabling comprehensive evaluation of rover mobility options. The system with the highest total score is identified as most suitable for the selected LSP region.

We evaluate rover mobility in two AEZ landing regions: de Gerlache Rim 2, within 1° of LSP, and Mons Mouton, within 6°. These topographically distinct sites test the trade-off model across contrasting LSP terrains, validating its effectiveness in generating region-specific mobility solutions. The findings will inform future development of single, hybrid, and multi-rover systems for exploration and ISRU in specific LSP regions.