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DESIGN & EXPERIMENTAL DEMONSTRATION OF A RIGID SUSPENSION SYSTEM FOR LUNAR MICRO-ROVING

Abstract

Traditional planetary rovers exhibit high degree-of-freedom (DOF) mobility systems, such as explicitly steered wheels, rocker-bogie suspension, and body-averaging mechanisms; these enable large vehicles to turn, surmount obstacles, and traverse with confidence. However, the high actuator count, substantial mass, and requisite stowage constraints for these systems cannot be afforded on micro-rover missions. This paper demonstrates the merits of a "suspensionless" mobility system where the rover's wheels are rigidly located relative to the chassis and the system relies on skid-steer turning. While rigid skid-steered platforms are common in field robotics, application of such a system to a lunar micro-rover is novel. This design is exhibited on MoonRanger, a micro-rover that will fly to the lunar south pole in late 2023 as part of NASA's Lunar Surface Instruments and Technologies Payload (LSITP) program. Necessity for a rigid suspension system arises from MoonRanger flying as part of a ride-share style program, where stringent budget and mass limitations preclude dedicated stowage structures and deployment mechanisms, such as suspension locking devices and ramps. Given the shift towards commercial payload development on a shorter timeline and smaller budget relative to traditional missions, this design constraint will be relevant for future lunar exploration robots. The rationale and design details for MoonRanger's wheel modules are presented to help inform future micro-rover programs with lessons learned.

The structural design of MoonRanger's wheel modules is presented and analyzed in the context of mobility requirements and launch loads. Results of subsystem and system-level vibration tests demonstrate the qualification of the wheel modules for flight. The development, methodology, and results of MoonRanger's mobility testing are articulated, emphasizing performance in straight level driving, slope climbing, point turning, side-slope traversing, and obstacle surmounting in regolith simulant. Current draw from actuators during these tests show that MoonRanger's low ground pressure, long grousers, and wide wheels enable excellent traction with exceptionally low power consumption. Use of fillite and sand as lunar regolith simulants is discussed. While foregoing a high-DOF system is an inherent hindrance to mobility, MoonRanger's test results show that a rigid suspension system is not only adequate for micro-rover mobility, but advantageous when accounting for reduced part count, design simplification, and cost savings.