CUBEROVERS FOR LUNAR EXPLORATION.

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Introduction: CubeRover exploration offers a new paradigm for robotic planetary missions in which small landers and small rovers operate as precursors to larger primary missions to explore a planetary body. Small rovers can potentially explore greater area more efficiently than large rovers, because several can operate in parallel, and they can be deployed widely from multiple landers. These rovers can act as scouts, identifying safe paths into regions that would otherwise be considered too risky. This enables follow-on missions to accomplish goals that would not otherwise have been attempted. Finally, CubeRover exploration offers the prospect for standardization, democratization, and broad applicability analogous to the transformation that CubeSats brought to the domain and economics of Low Earth Orbit.

For the specific context of this project, CubeRover is specialized to address a few of NASA's Strategic Knowledge Gaps (SKGs), in particular, In-situ Lunar Surface Trafficability (topic III-C-2) and Descent Engine Blast Ejecta Phenomena (topic III-D-4) [1].

Methods: Rover mechanical design will consider at minimum a four-wheel skid steer drive body averaging suspension and an invertible two-wheel differential drive tail dragger, shown in Figure 1. The four-wheel design has superior mobility, but the two-wheeled design has a higher chance of recovering from tip-over. In addition to mobility, mass and effects on 3D imaging capabilities will determine the final design.

Requirements for battery capacity and solar power generation will be investigated and a thermal analysis performed to choose between solar powered, lander-rover recharging, or strictly battery powered designs. This thermal analysis will be based on regolith temperature and incident solar radiation on the lunar surface at appropriate latitudes and times of the lunar day.

An avionics system will be developed similar to the single board computer in development by Carnegie Mellon University (CMU). A high-resolution camera will be included to facilitate simultaneous localization and mapping (SLAM) and ejecta characterization. A Wi-Fi radio will be integrated to provide communications with a lander, along with wheel encoders and an IMU. High bandwidth communication, high performance processing, and the use of COTS components will all be investigated for use on the CubeRover.

During the mission, after deployment from the landed spacecraft, the rover will perform a visual survey of the landing site while driving in a spiral pattern out to a radius of 20 meters. A 3D model of the terrain will be created using structure from motion (SfM), a method of deriving three-dimensional structure in the world from camera images up to scale. This method is robust to changes in camera parameters, does not need explicit calibration, and can be performed using a single monocular camera. Open source SfM algorithms that may be employed include the OpenMVG Algorithm [2] and the Multi-View Environment (MVE) [3].

Field testing will occur at the LaFarge Duquesne Slag Heap just outside of Pittsburgh, PA where lunar analog terrain will be constructed. Early tests will evaluate a monocular camera on one of CMU's preexisting rovers, which will aid in the modification of software and parameters that may impact later design decisions. Other tests will evaluate slip detection, maximum travel distance, obstacle surmounting height, climbable slope angle, and rollover angles. The software will be evaluated based on its ability to produce a 3D model that provides meaningful information regarding terrain trafficability for small rovers and for characterizing lander descent blast ejecta.

Figure 1. Early concept two-wheeled rover design.

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