Geomorphometric Assessment of Marius Hills Pit for LunarLeaper

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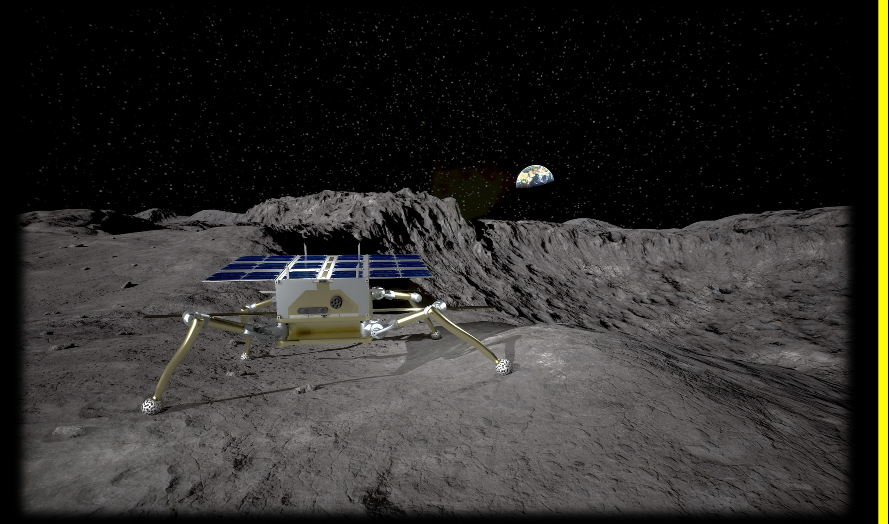
LunarLeaper

A small <15 kg robotic mission aiming to confirm the presence of subsurface lava tubes and to assess their value for future human habitation. Uniquely suited to provide valuable insights to past volcanic eruptions and regolith.

The mission will land on a lunar pit, a hypothesized collapsed lava tube ceiling, here we focus on the Marius Hills pit (MHP). Along its traverse, the robot will take geo-physical measurements and will take images. The latter is the subject of this study.



Objectives and Take-Home Messages

1. **Is the LunarLeaper's camera able to image the lava tube from the edge of the pit?**
   Yes. Even without including a camera mast and remaining at low-risk slopes, the camera could capture the upper layers of the funnel.

2. **What is the effect of including a mast to elevate the camera height?**
   Elevating the point of view with a mast will enable the camera to capture deeper volcanic layers down to the entrance of the proposed lava tube. Including a mast would also help to avoid obstacles and boulders to ensure capturing the lava tube.

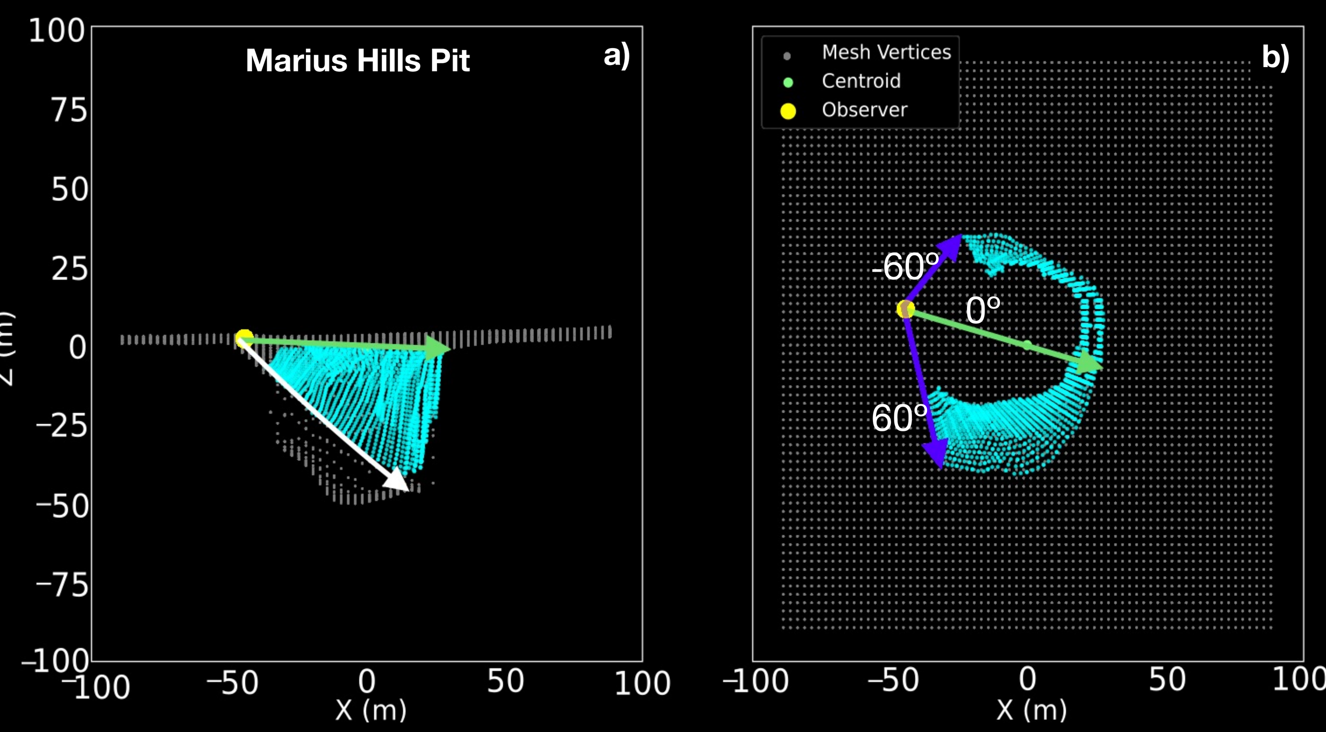
3. **How do trade-offs (slope / camera height) determine the optimal placement of the robot on the rim for image capture?**
   The trade-offs inform of the optimal locations around the pit rim. These insights are crucial for developing various mission planning strategies, including the optimization of the robot's path, and accurately determine the best positions for image capture.

Methodology

1. Perform ray-casting from a point on the LRO mesh. This location represents an observer, i.e., the camera position, and determines the FoV.

Figure:
a) Lateral view of the MHP. **Blue points**: observable points along the pit wall [1]. **Green arrows**: central crossing view.
b) Top view of the MHP. **Purple arrows**: maximum horizontal FoV. **White arrow**: maximum observation depth.

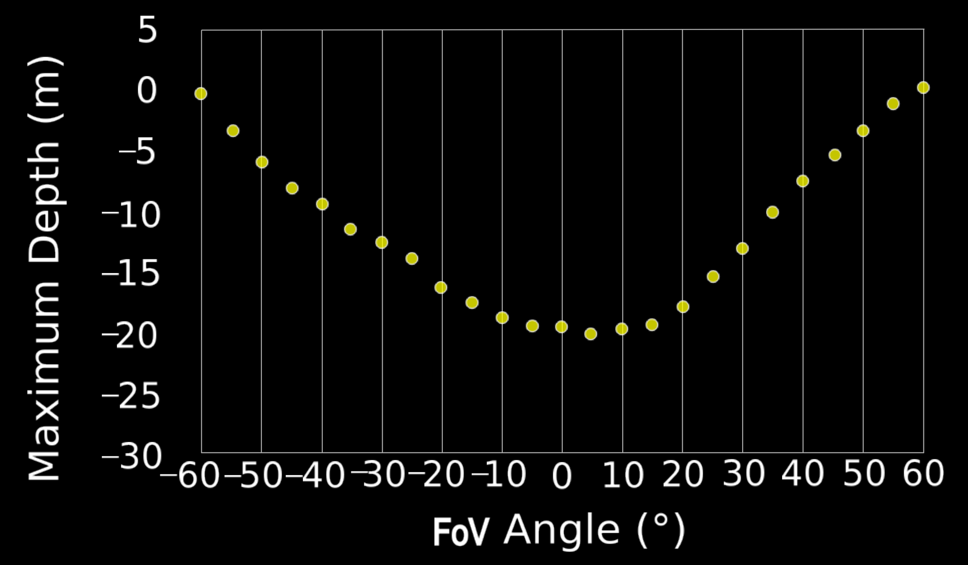
Summary:
Observers act as a ray-source. Rays are directed towards the funnel with a defined field of view (FoV) (-60°, 60°).



2. For every observer, the FoV is divided into 5º slices. The maximum observation depth is used to create the cross-sections.

Figure:
Cross-section example from an observer point using a camera height of 1m. **Yellow dots** represent the maximum visible depth per slice.

Summary:
We investigate the cross-section of the maximum visibility for every observer. This allows to identify the optimal locations and configurations to capture images of the pit.



3. Loop over all observers for different slopes and camera heights. This covers different geological scenarios and camera mast configurations.

Results

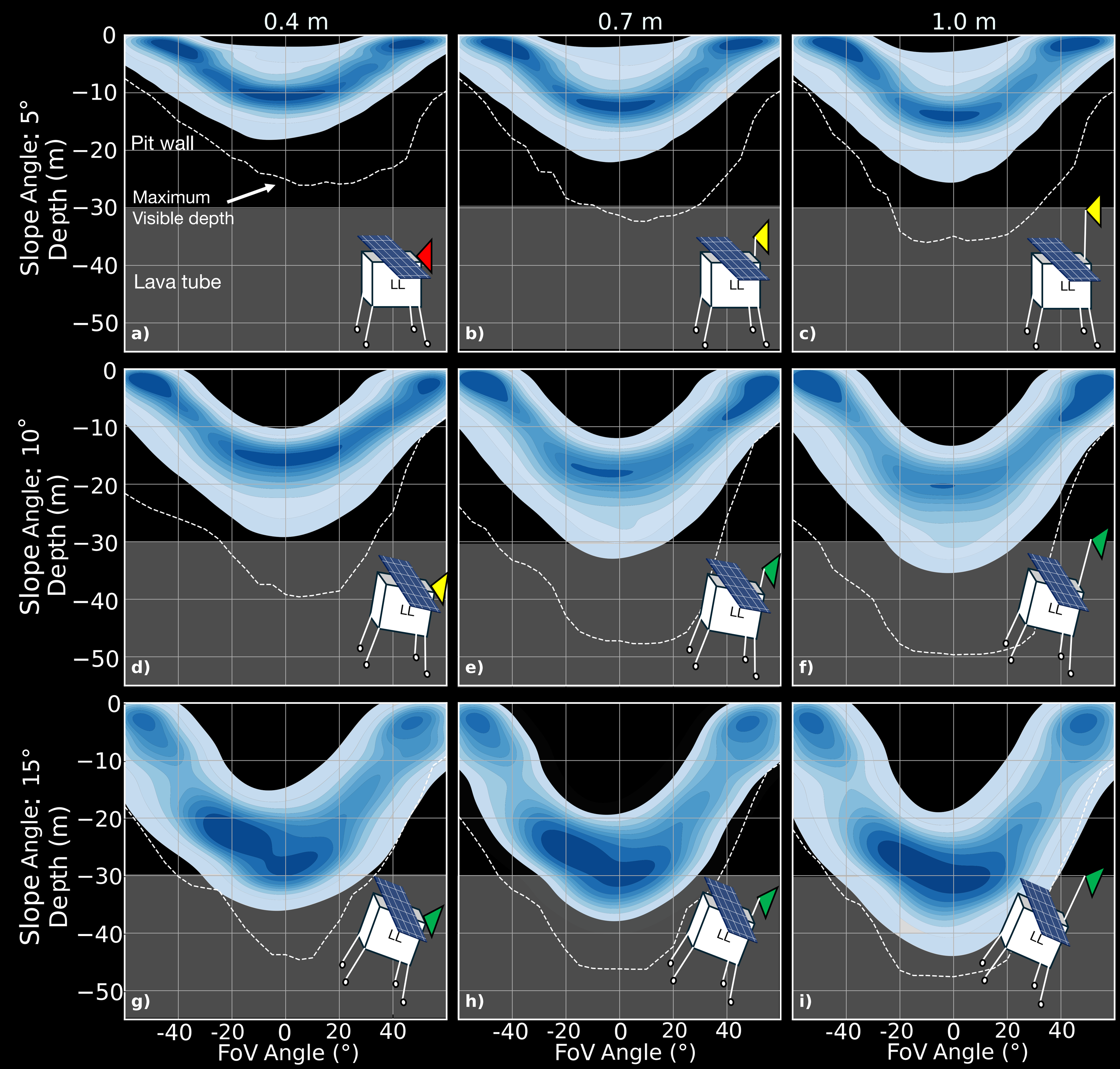


Figure:
Density plots of the combined contributions from all observers at different slopes and camera mast configurations. **Grey area:** depth at which the subsurface cave has been proposed [1]. **Red** color indicates that the camera cannot capture the lava tube. **Yellow** indicates that very few observers reach the lava tube. **Green** indicates that the lunar subsurface network is mostly visible.

Summary:
At a 5º slope, a camera at 0.4 m (no mast) captures only the shallow (10 m) upper layers. Raising it to 0.7 m reveals deeper wall layers.
At 15º, even without a mast, visibility increases (up to 30 m) and may include the lava tube entrance.
Adding a mast enables full mapping of the underground network, the lower layers and the entrance of the lava tube. This configuration not only optimizes the observations but also helps map and avoid obstacles along the traverse.

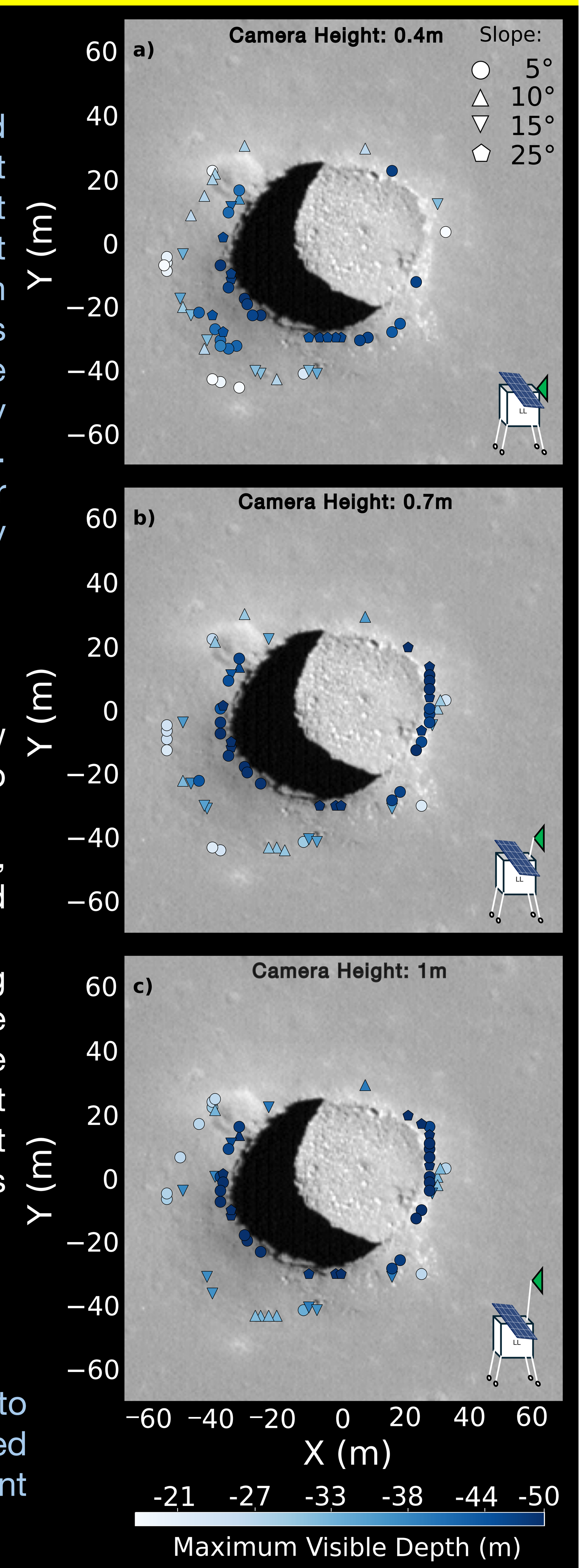


Figure:
Optimal positions around the rim to capture images of the pit. Evaluated for different slope values and different camera height configurations.

Summary:
Looping over all observation points for different slopes and mast configurations, we can identify the optimal locations to capture images. With a low camera mast, locations on the south-west of the rim may provide a better view. A robot with a camera positioned at 1m above the ground can optimally target positions on the east rim. This information holds great importance for mission planning strategies.

Reference: [1] Wagner, R. V., & Robinson, M. S. "Lunar Pit morphology: Implications for Exploration". JGR: Planets. doi: 10.1029/2022je007328.