

Lunar Pits

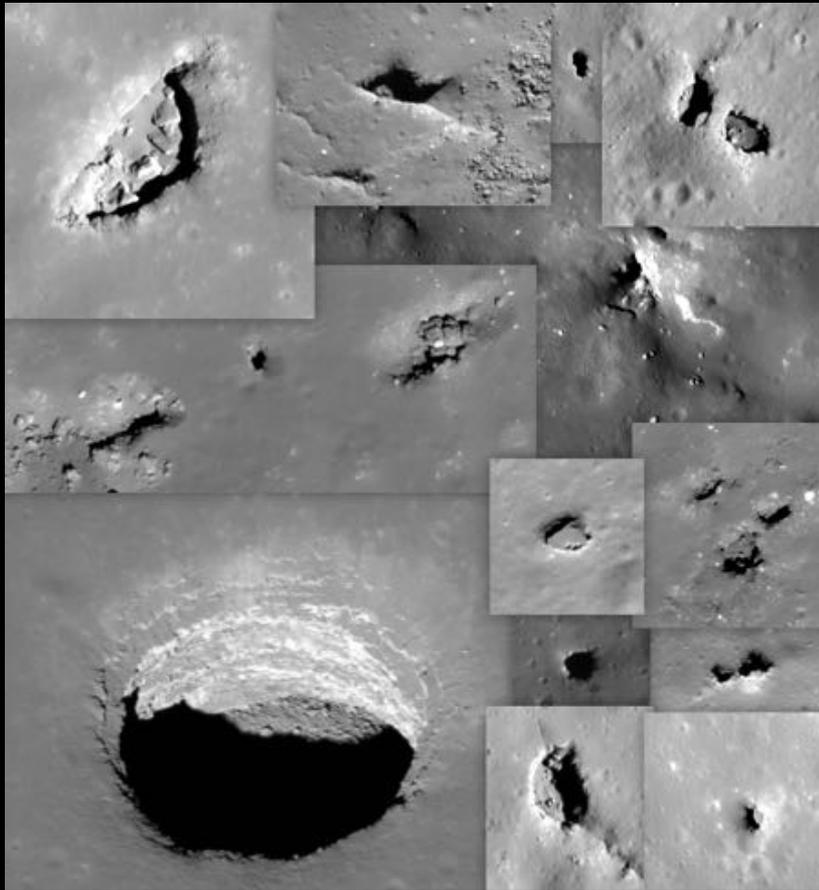
Gateway to the Subsurface

Mark Robinson and Robert Wagner

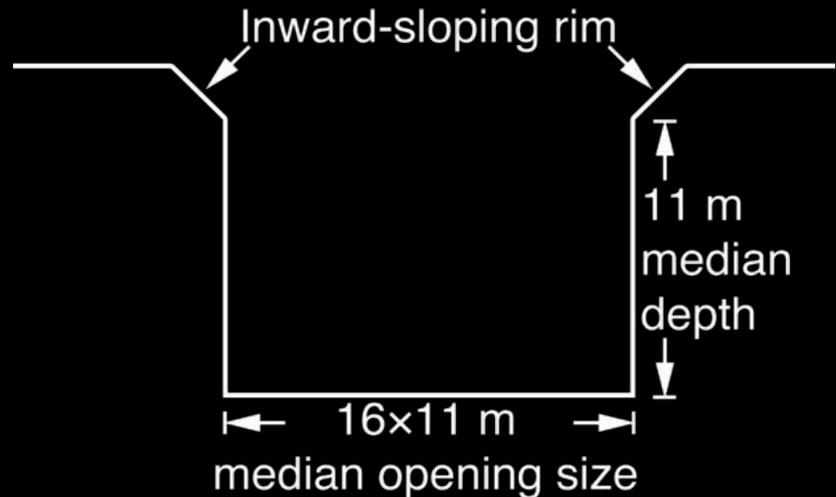
Outline

- Overview of pits
- Good destinations
- Arne mission

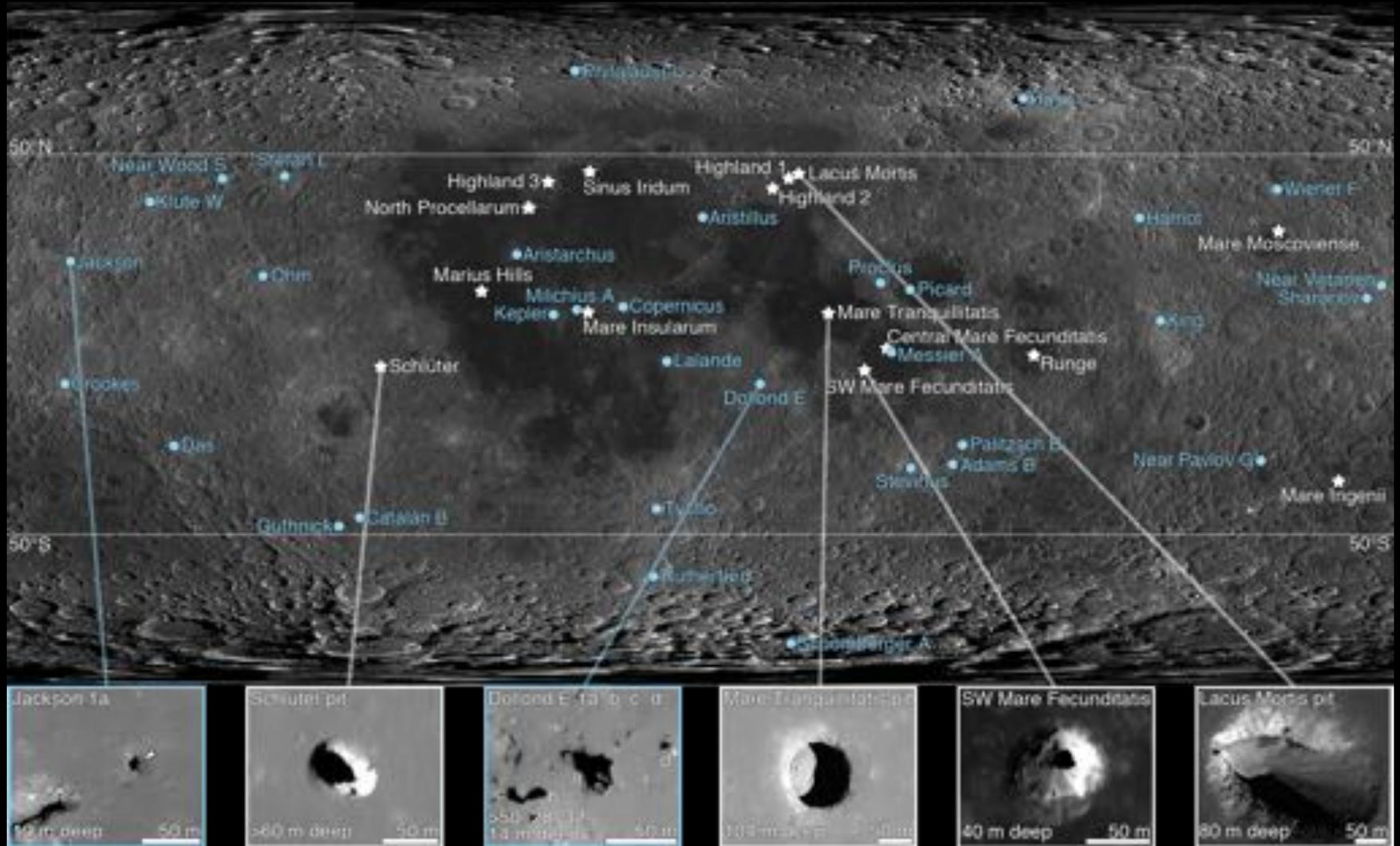
Pits: What are they?



- Small, steep-walled collapse features
- Of >300 known, all but 16 in impact melts



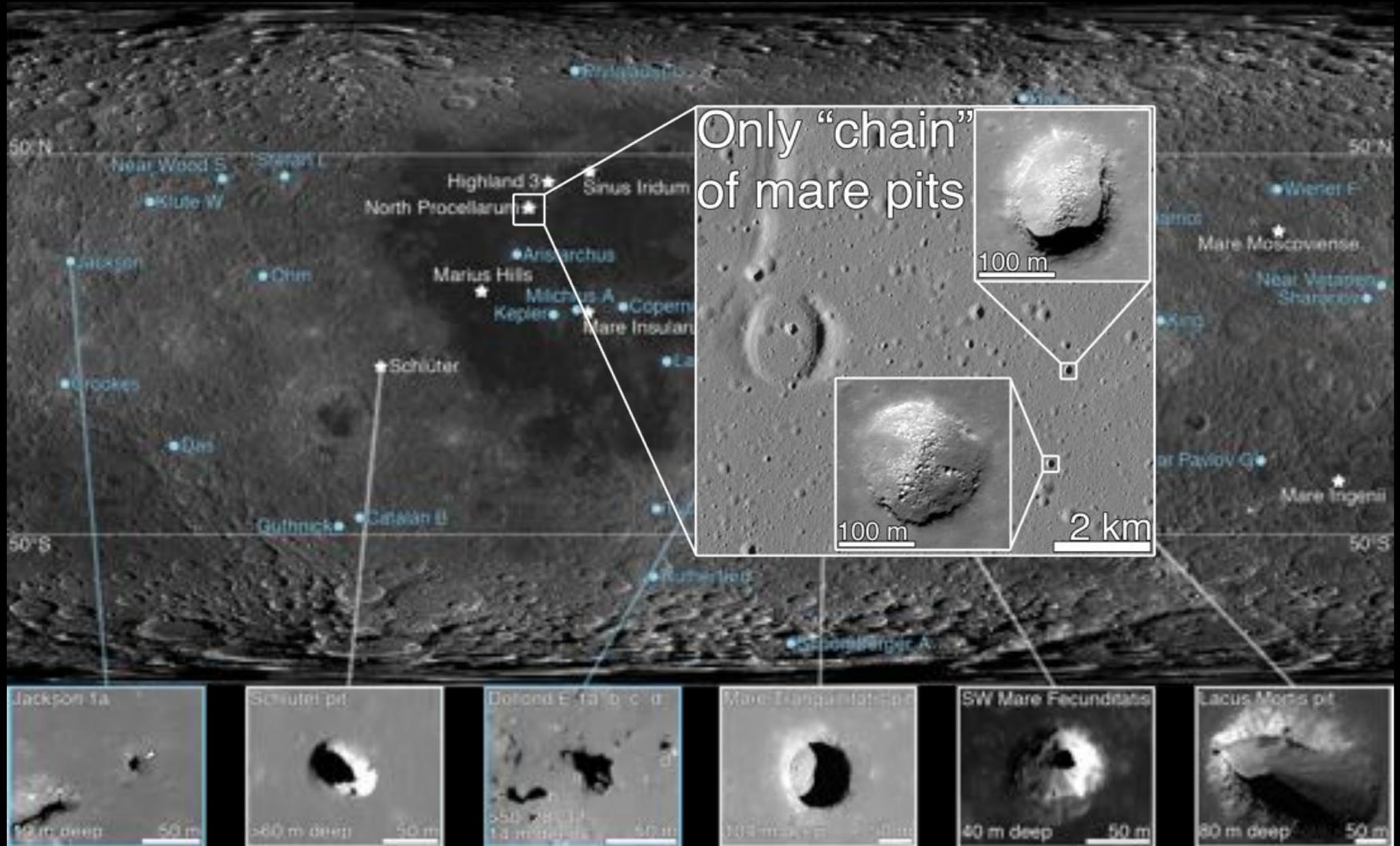
Pits are widespread on the Moon



White: Mare and highland pits

Blue: Impact melt pits

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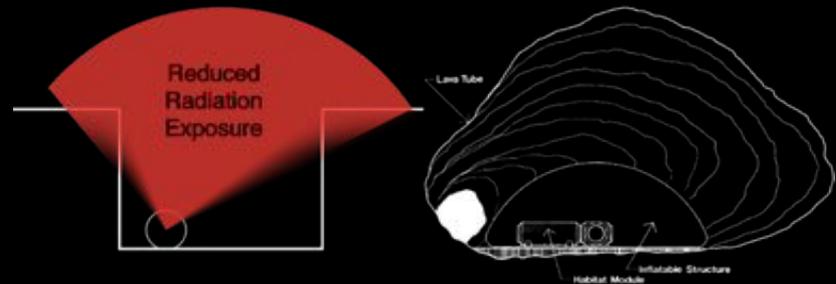
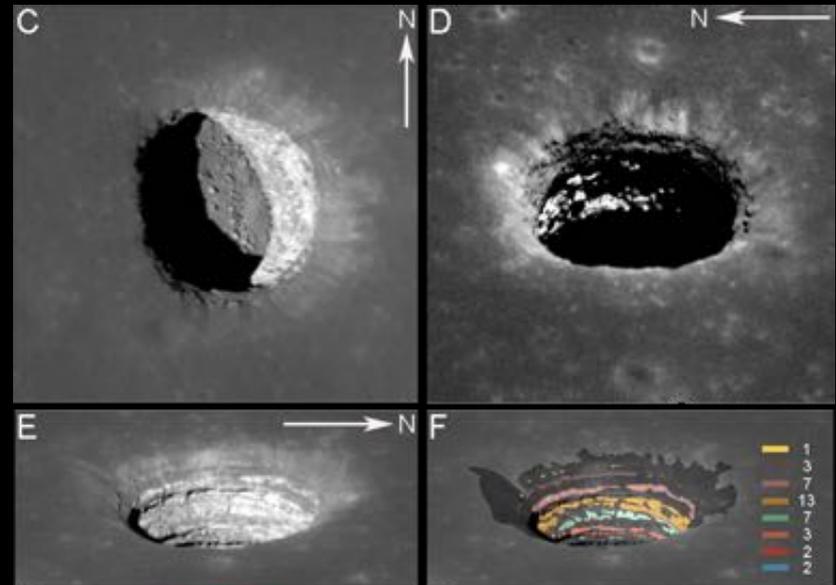


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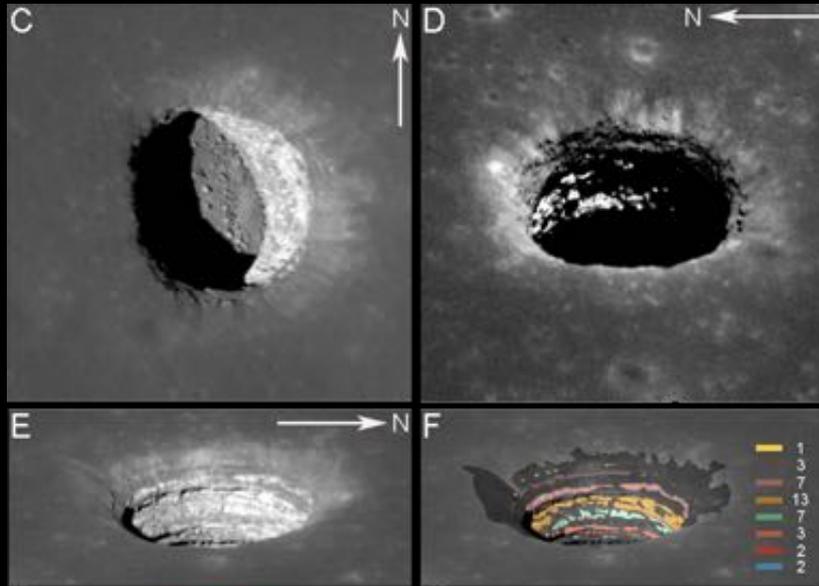
Pits are interesting for exploration

- Exposed layer profiles
- Benign environment
 - Radiation, meteorites, temperature variation
- Potential cave access
- Access to un[space]weathered minerals

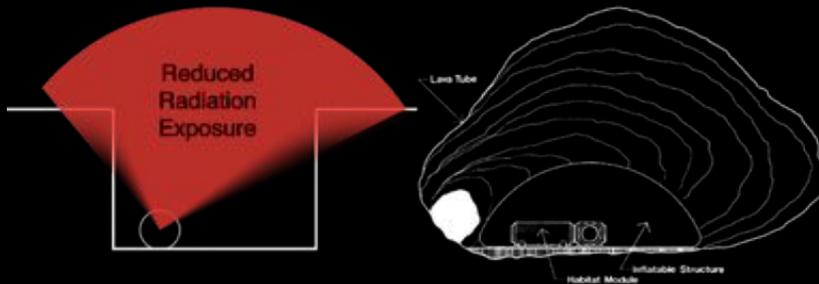


Top panels from Robinson et al. 2012
Bottom-right from Daga and Daga 1992

Desired data from initial visit



- cm-scale wall and floor morphology/albedo
 - Stretch goal:
Composition of layers
- Thermal and radiation environment
- Presence and extent of any caves
- Traversability



Top panels from Robinson et al. 2012

Bottom-right from Daga and Daga 1992

Pit Exploration Challenges

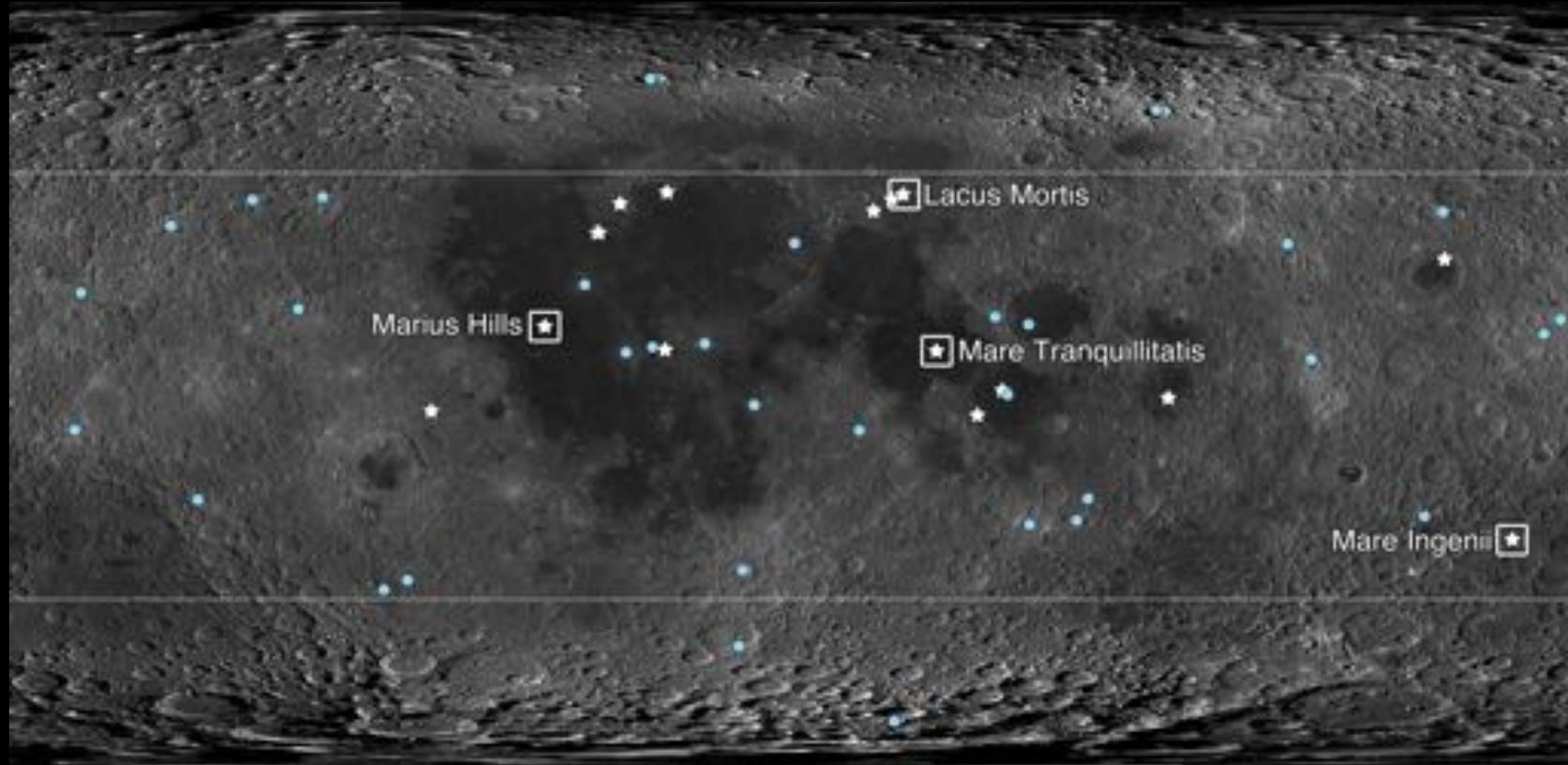
- Probably can't just "drive up to the rim" and see the floor
 - Surrounding "funnels" are likely unstable
 - Need a tether or flight
- Limited lighting within
- Difficult to communicate out



Top: Devil's Throat in Hawai'i

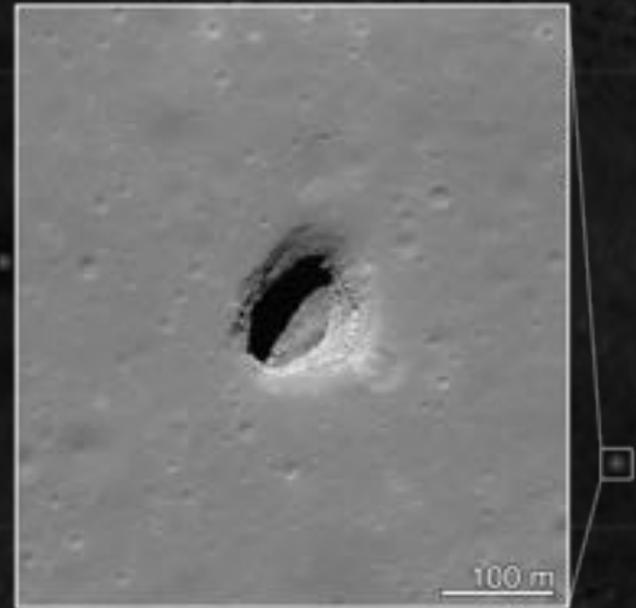
Bottom: Oblique view of Mare Ingenii pit

Good targets for exploration



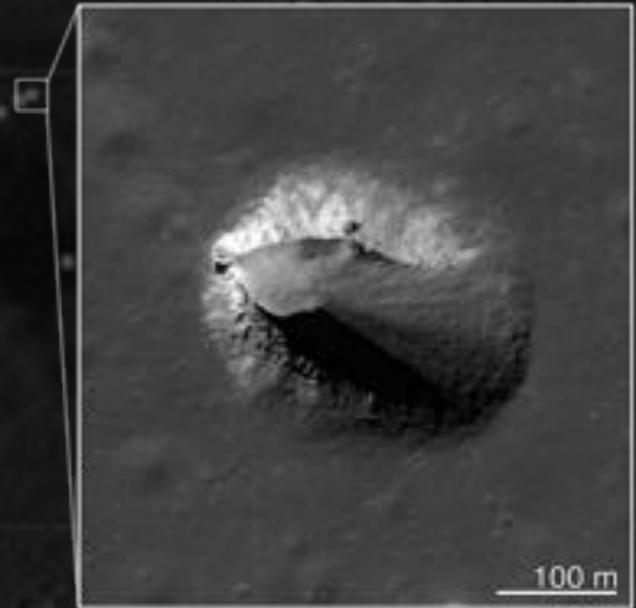
Good targets for exploration

- Mare Ingenii
 - 100 x 68 x 65 m
 - Large overhung region on west side (>20 m)
 - On lunar far side



Good targets for exploration

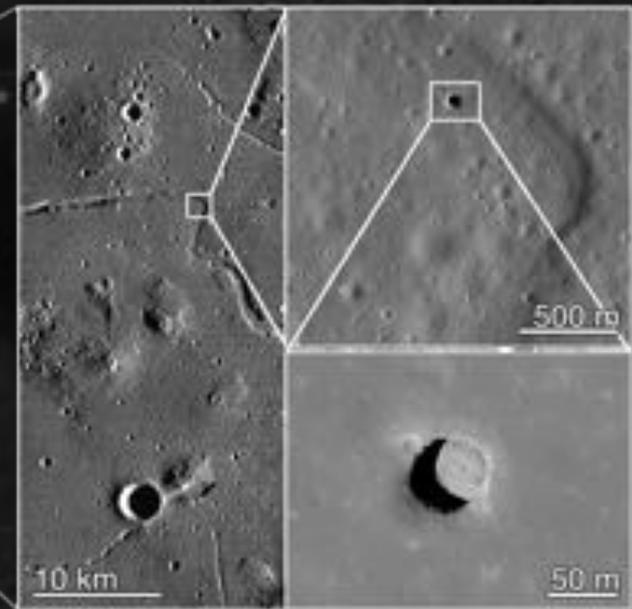
- Lacus Mortis
 - >150 x 110 x 80 m
 - 23° entrance slope,
 - Almost certainly no caves



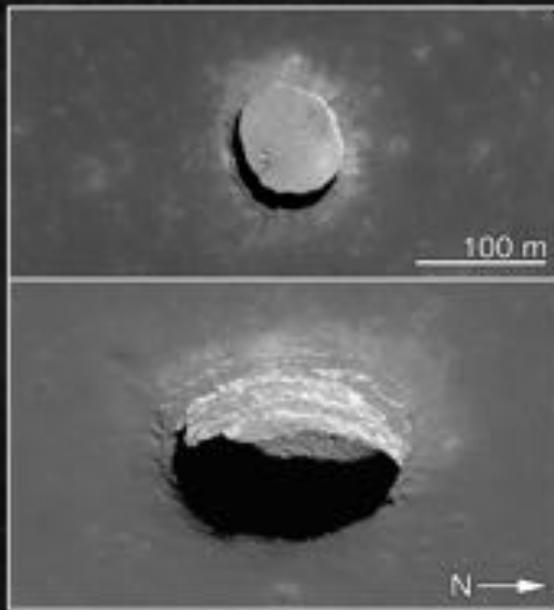
Good targets for exploration

- Marius Hills

- 58 x 49 x 40 m
- Very strong evidence for large lava tube
- No obvious connection between tube and pit
 - Yet...

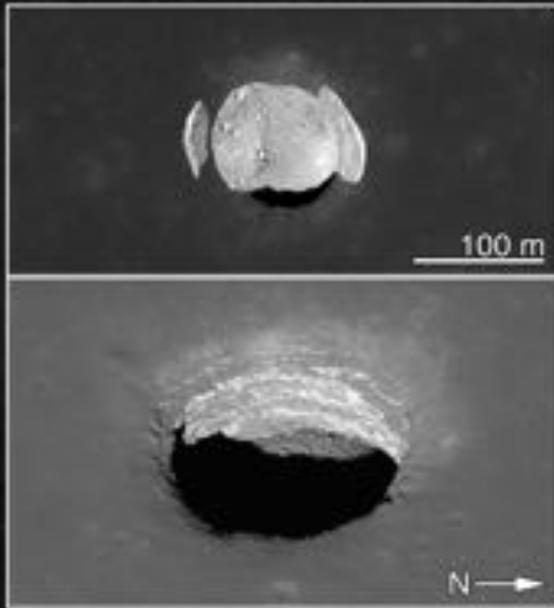


Good targets for exploration



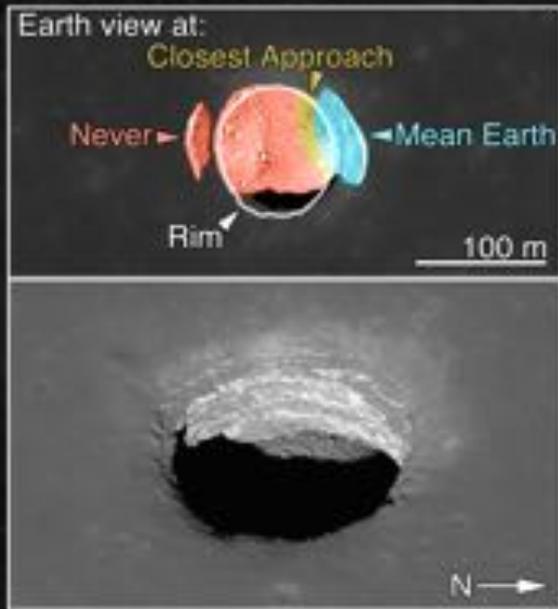
- Mare Tranquillitatis
 - 100 x 88 x 104 m
 - Excellent LROC imagery
 - ≥ 20 m overhangs to east and west
 - Earth view from floor

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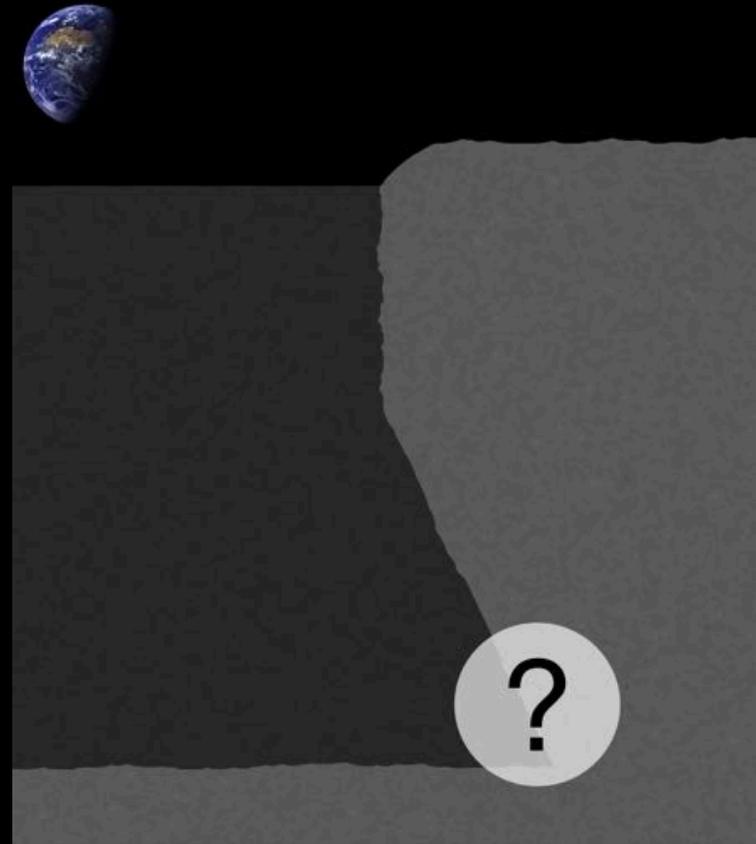
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Arne: Initial foray into a lunar pit

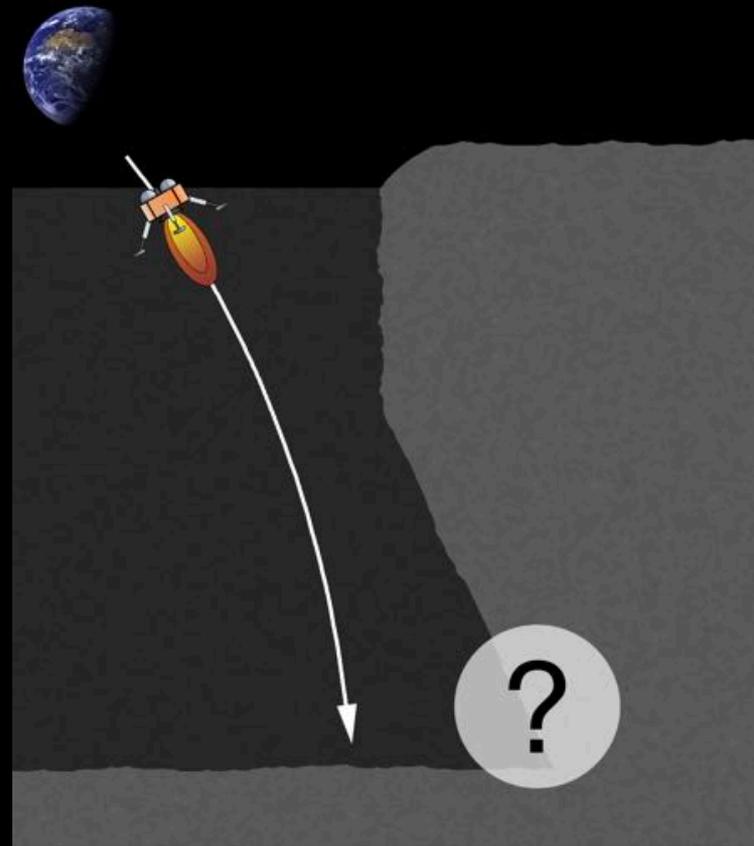
- Goal: To find answers that can't be found from orbit
 - How far *do* the overhangs go back?
 - What do the wall layers look like?
 - What will it take to traverse the floor?
- Destination: Mare Tranquillitatis pit



East wall of Mare Tranquillitatis pit, based on current observations

Arne ConOps

- Land inside pit
- Observe walls, relay directly to Earth
- Launch “pit-bots”
 - Basketball-sized flying drones
 - Will explore overhangs and any caves
 - Multiple pit-bots will explore deeper into any cave, or multiple walls



Lander not to scale

Arne ConOps

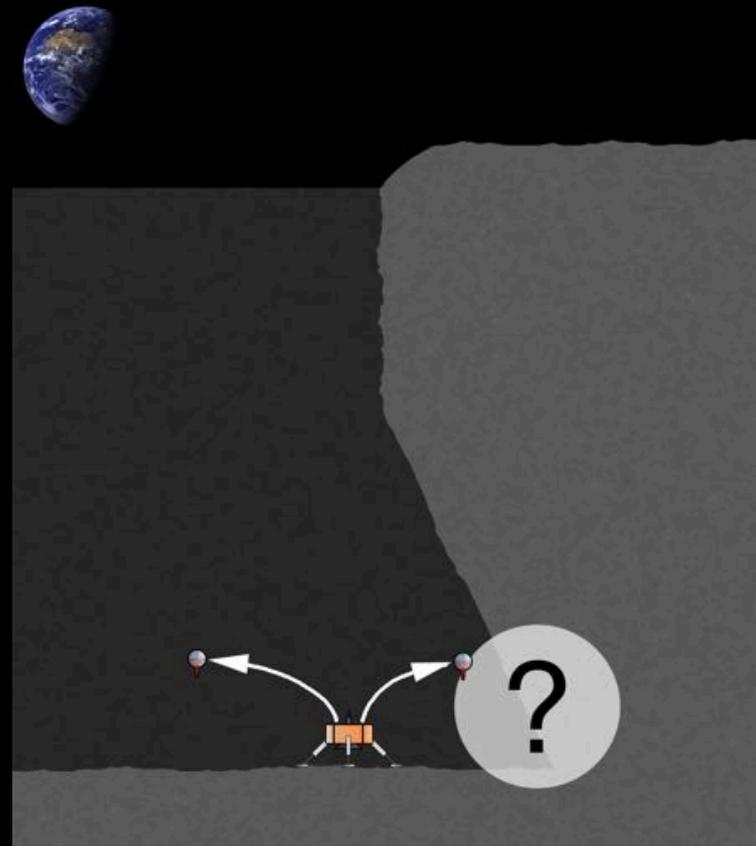
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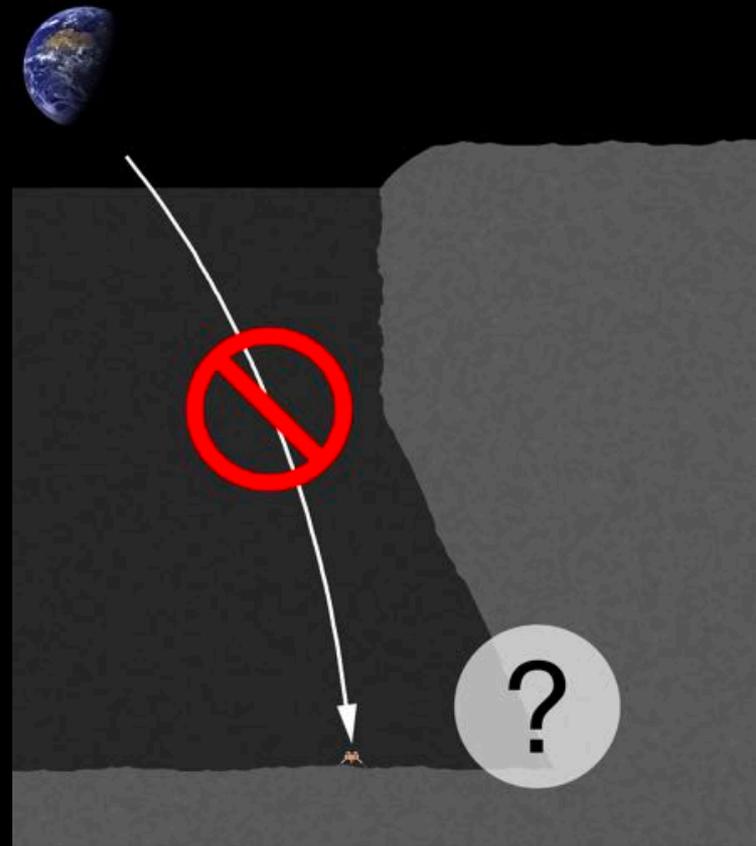
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Arne Variations

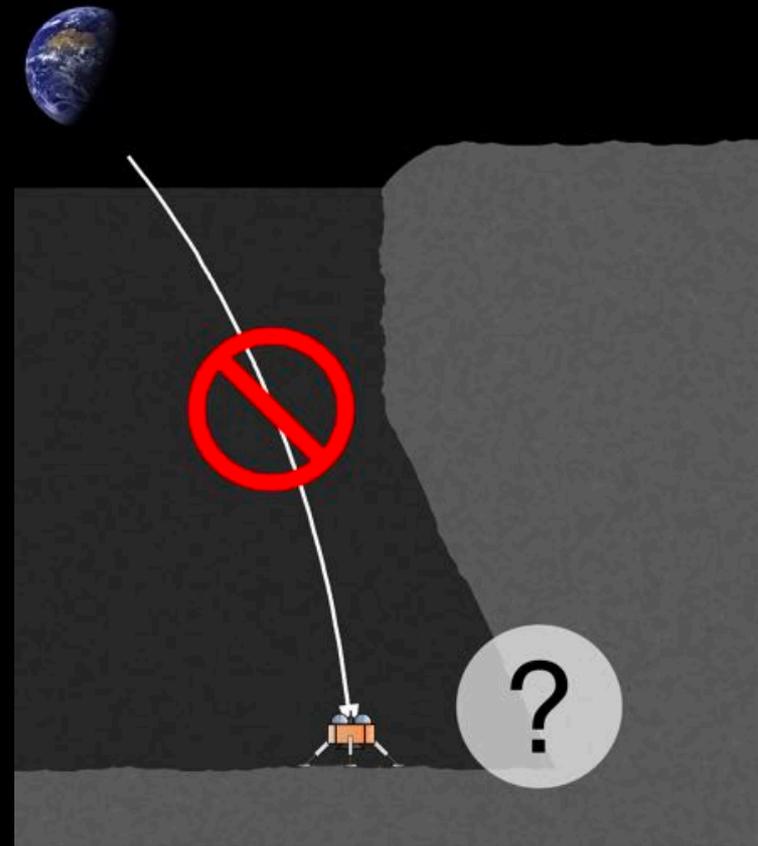
- Land outside, fly in
- Land outside, send tethered descender in
- Descender and fliers



To scale, assuming a 3 m tall lander

Arne Variations

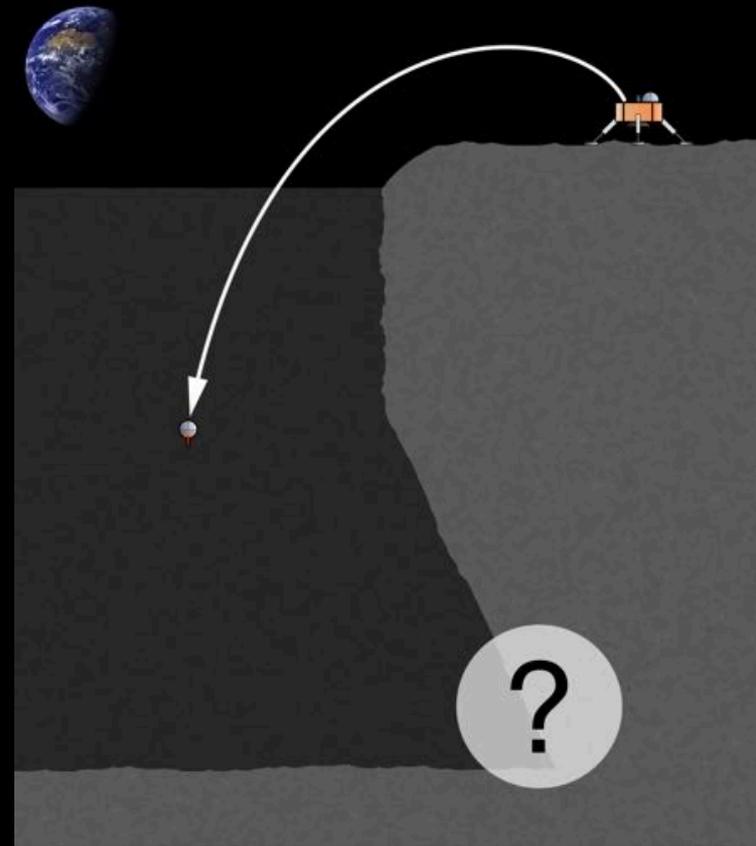
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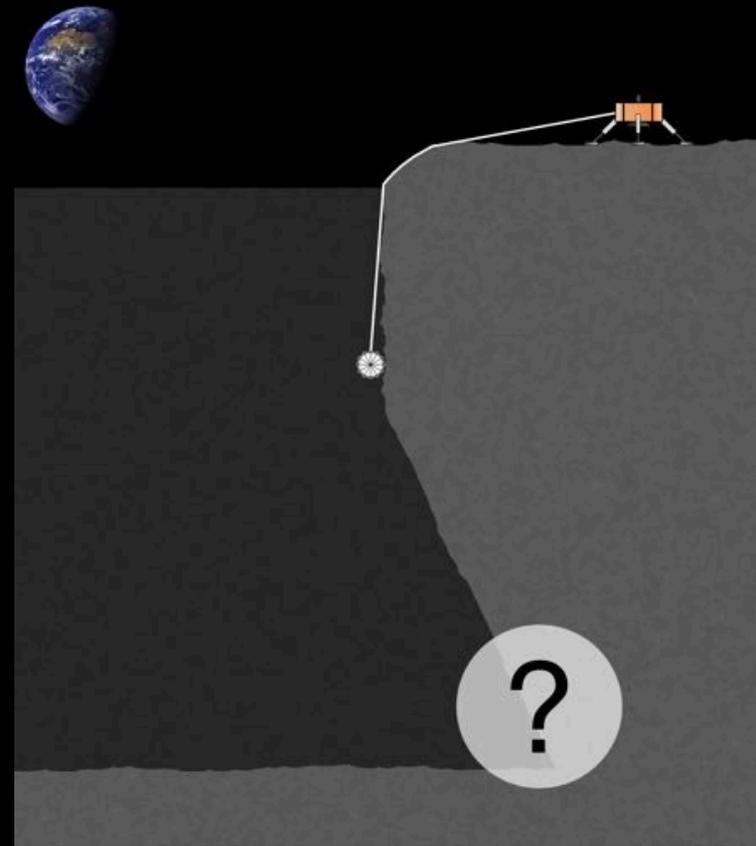
- Land outside, fly in
 - Strong limits on in-pit instrumentation
 - More complicated communications
- Land outside, send tethered descender in
- Descender and fliers



Lander not to scale

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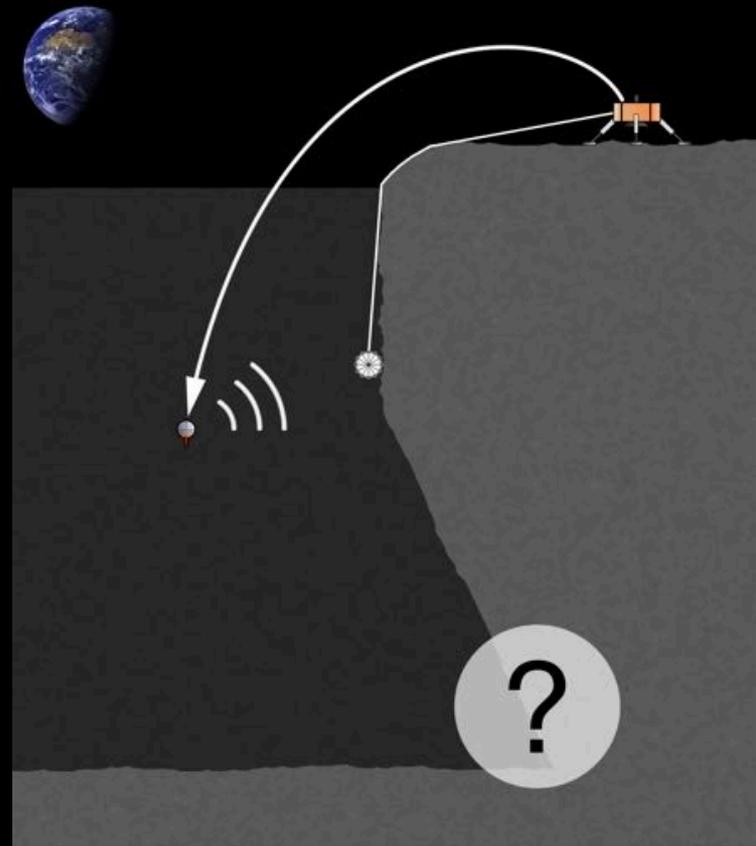
- Land outside, fly in
- Land outside, send tethered descender in
 - Would only get partial high-res wall coverage
 - Little caving ability
 - Wall composition*
 - Longer-term monitoring?
- Descender and fliers



Lander not to scale

Arne Variations

- Land outside, fly in
- Land outside, send tethered descender in
- Descender and fliers
 - Best of both worlds?



Lander not to scale