Lunar Robotics Update

NESS Steering Committee Meeting

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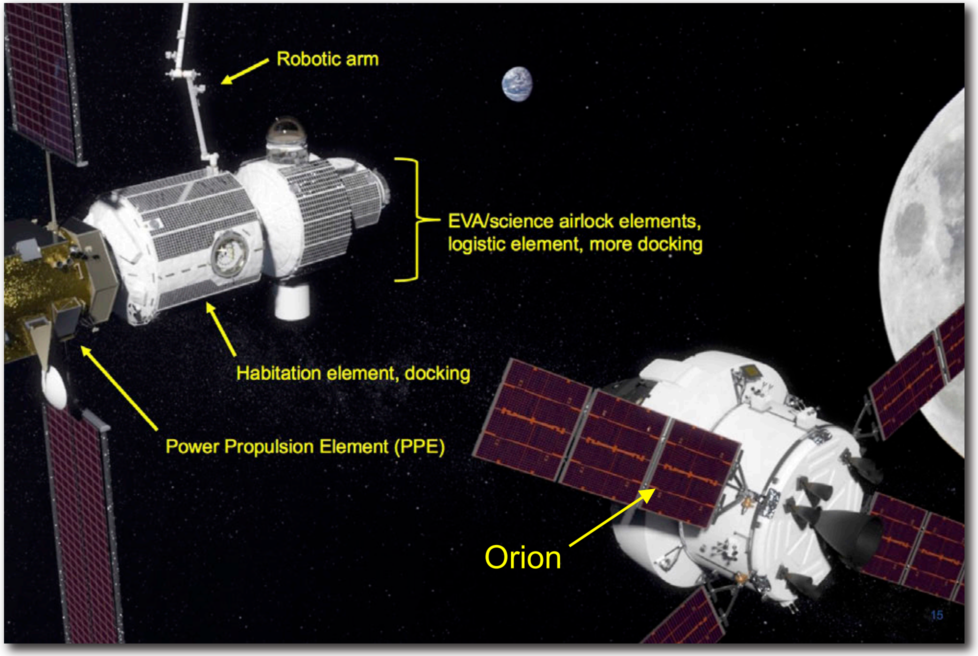
Topics

1. **Gateway technology utilization RFI**
   (issued 5/10/2018 by HEOMD, responses due 6/11/2018)
2. **Lunar surface imaging studies**
   (Matt Deans, Larry Edwards, Ara Nefian, Uland Wong)
3. **Synthetic lunar terrain model**
   (Mark Allan)
4. **Lunar surface simulator**
   (Mark Allan, Terry Welsh, Uland Wong, OSRF)

1. Gateway Technology Utilization RFI

Focus

- Ideas and concepts for technology demonstrations
- Evolve Gateway capabilities
- Enable new capabilities for human exploration
- Responses will inform NASA planning and acquisition strategy



High-priority areas

- Cloud computing on the Gateway to support payloads and lunar missions
- Novel instruments / sensors for space or lunar science
- Technologies for robotic and telerobotic science

http://tinyurl.com/gateway-rfi

- Open to all sources (academia, government, industry)
- Responses are due no later than **6/11/2018** at **4p EDT**

2. Lunar Surface Imaging Studies

Performance

- What are the limits and failure modes of stereo vision for navigation?
- How well will hazard detection and localization based on stereo vision work in polar regions?

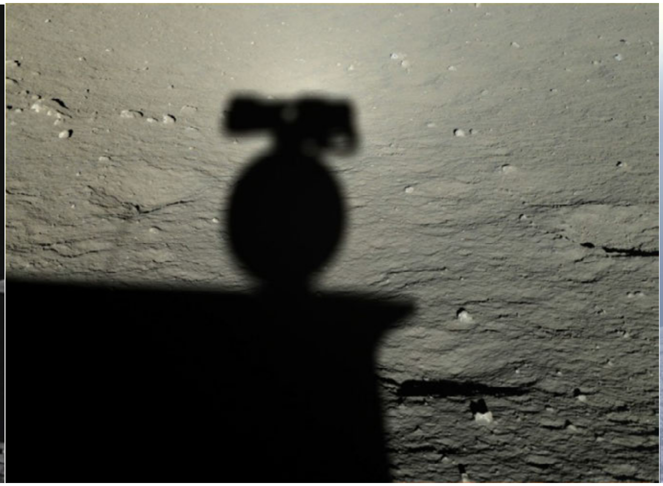
Use of High Dynamic Range (HDR)

- Can hardware or software HDR improve navigation performance?
- Under what situations is HDR required (not just for improvement)?

Use of image compression

- How much image compression is tolerable?
- What compression methods are appropriate?

Imaging Challenges at the Lunar Poles



Strong shadows, bright light, high contrast

Oblique lighting ⇒ shadows are long

- Sun +6° ⇒ shadows ~10x object height
- Sun +3° ⇒ shadows ~20x object height

Opposition surge ⇒ washes out texture

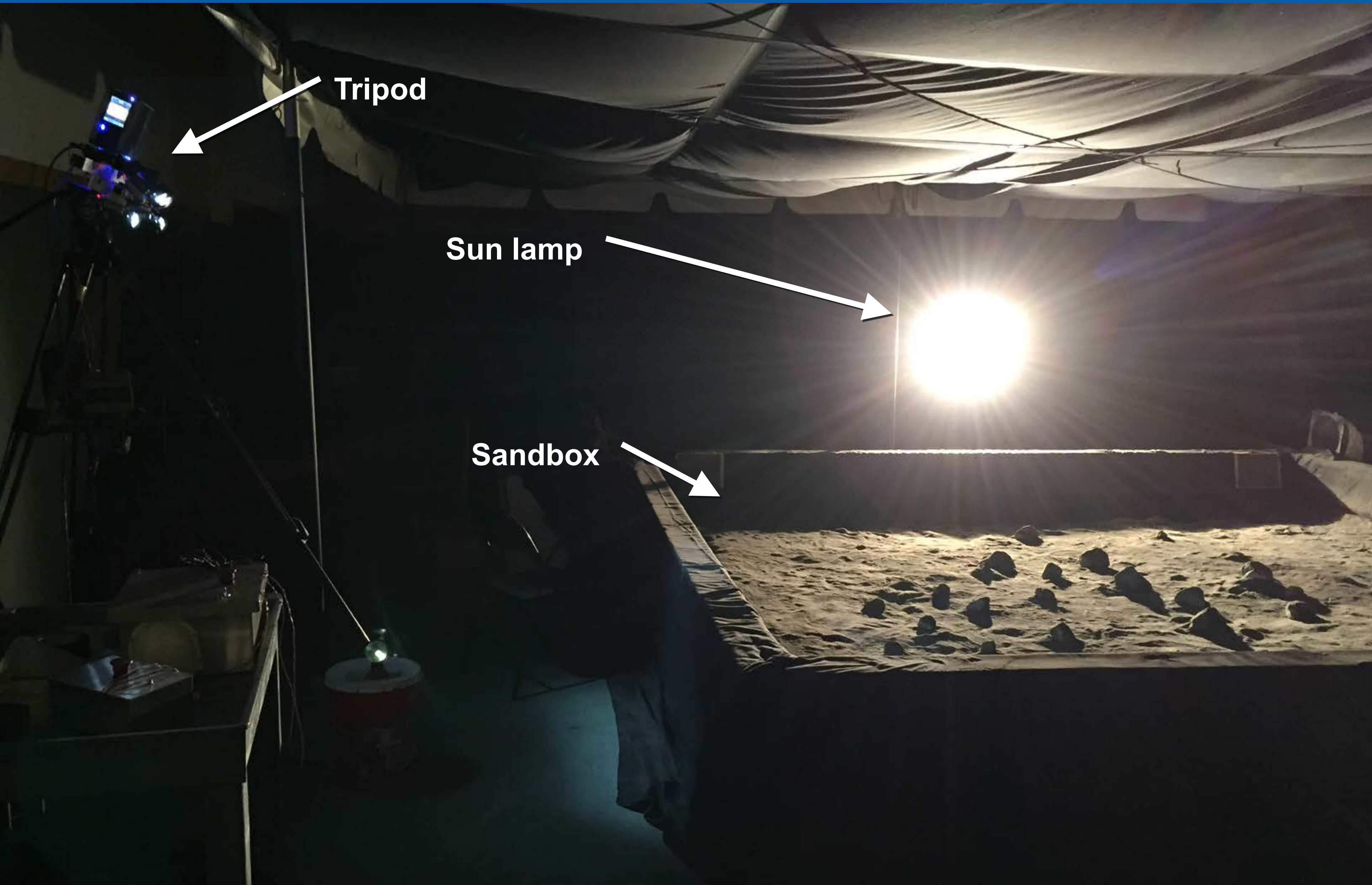
Low sun ⇒ sun in view, sun on optics

- Exposure issues, lens flare, etc.

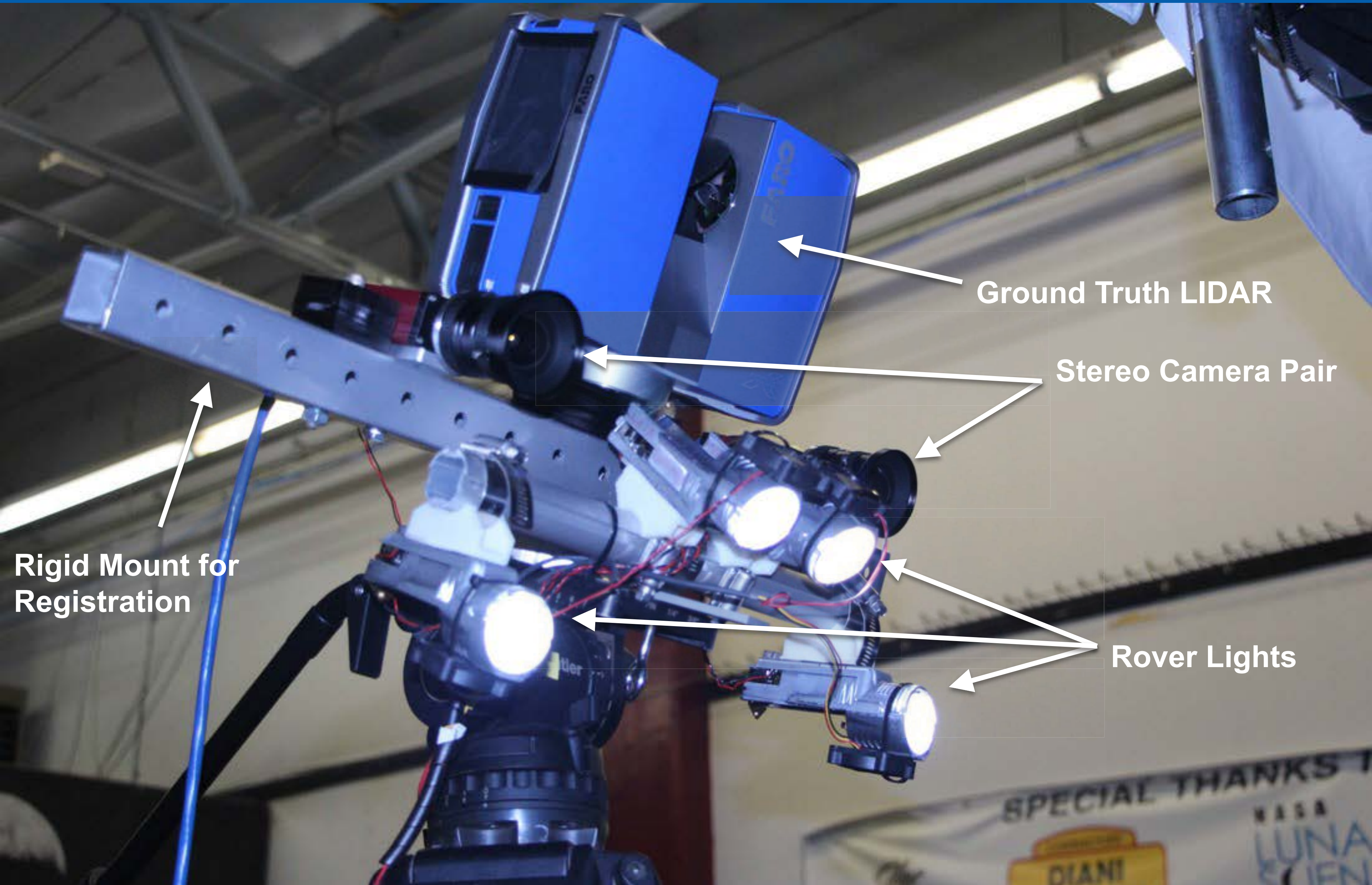
NASA Ames Lunar Lab

4 x 4 x 0.75m sandbox with 8 tons of JSC-1A regolith simulant
Dark room with copious amounts of light blocking material

Simulating Lunar Surface Conditions

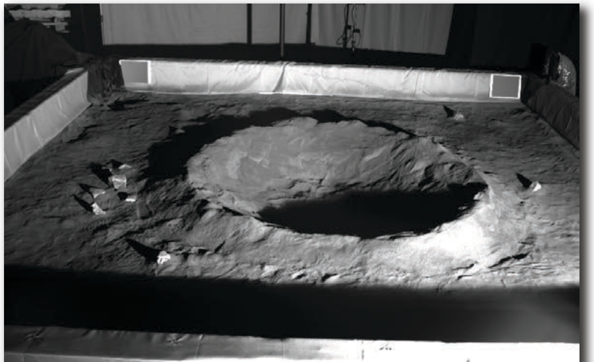


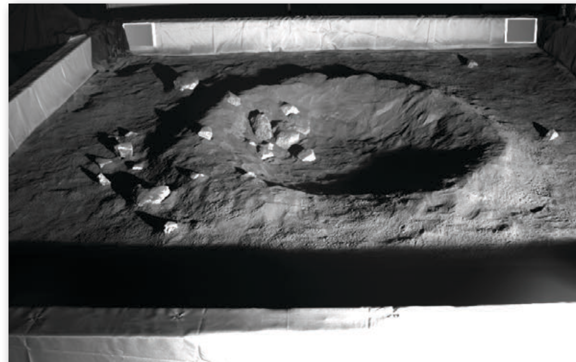
Imaging Setup



Test Cases

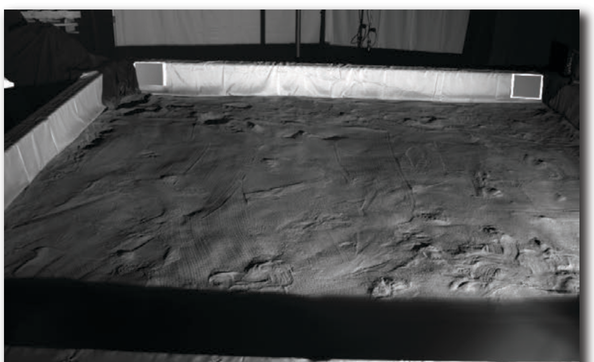
Negative Obstacle

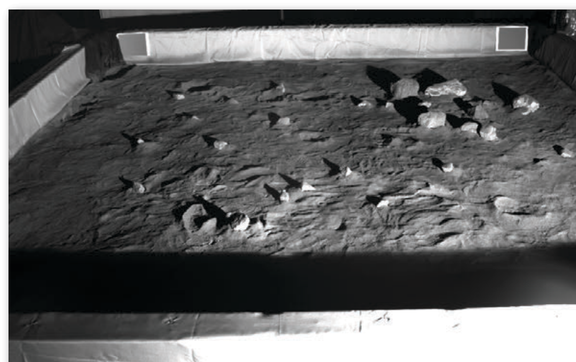




Defined Rim → **Eroded**

Positive Obstacle



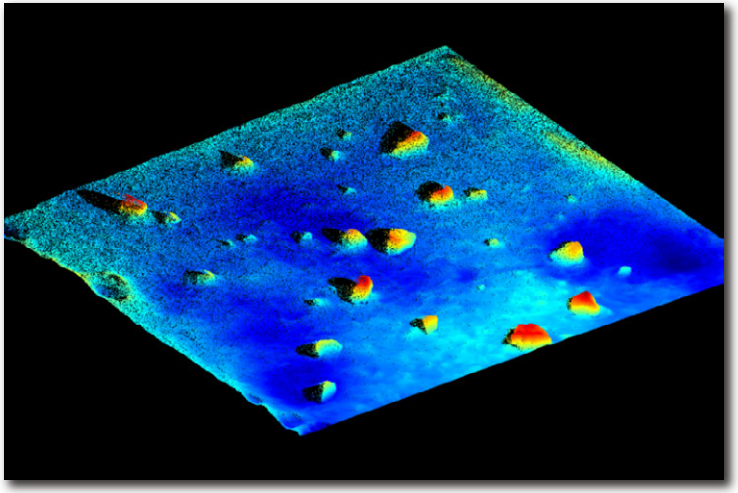


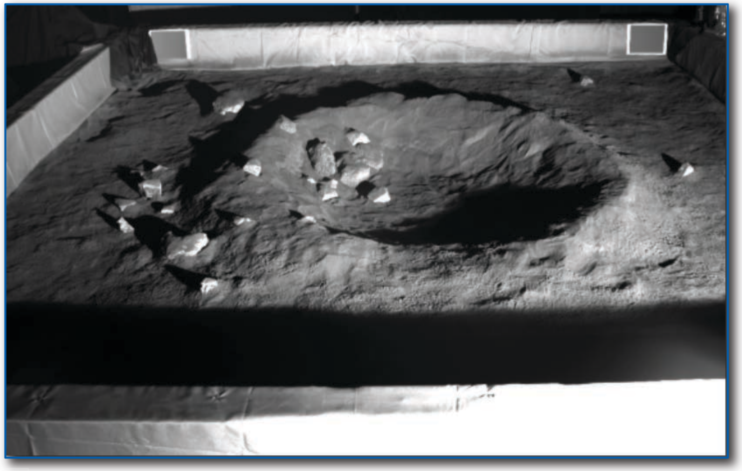
Smooth → **Rough/Rocky**

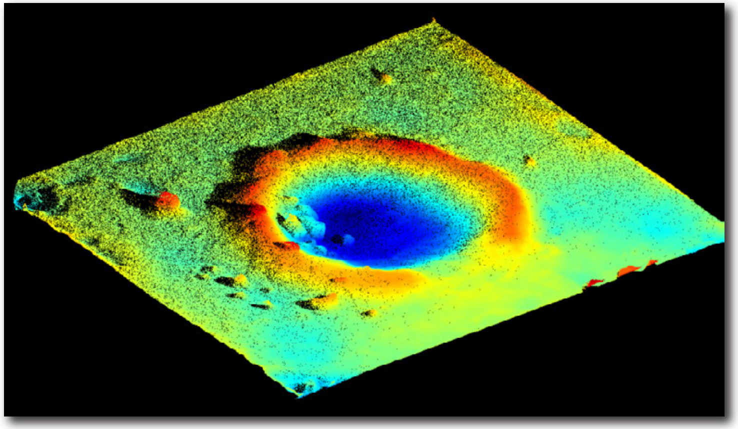
Data Sets

Stereo (Left Image)

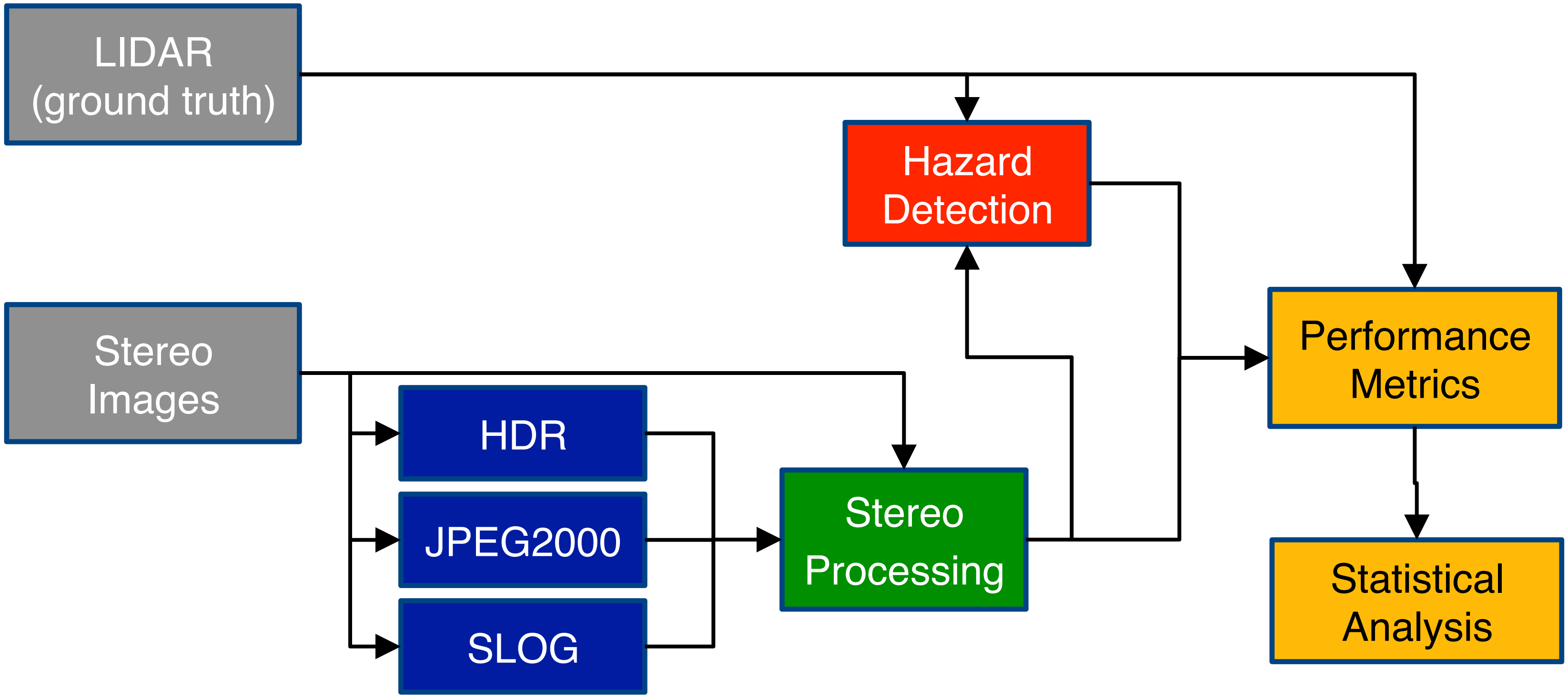
Ground Truth 3D







Data Processing



24 test conditions, plus:

- High Dynamic Range (HDR)
- JPEG compression at multiple ratios
- SLOG compression at multiple kernel widths

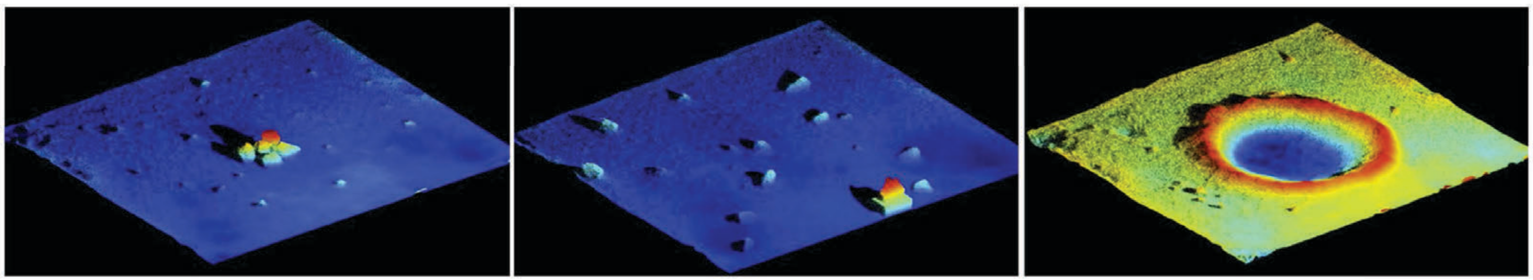
POLAR public dataset release

NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

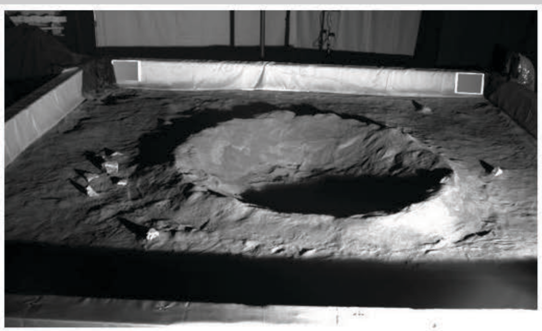
Ames Research Center

POLAR Stereo Dataset

[Polar Optical Lunar Analog Reconstruction]



Terrain 11



Description: This scene features a large negative obstacle which is meant represent a smooth "fresh" crater. There are some medium-sized rocks along the rim and periphery. The relief of the crater is exaggerated (particularly the rim) in order to also test detection of steep slopes at the particular angle of view. The shape of the crater produces interesting interior shadows and inter-reflected light. The smooth slopes and terrain provide a correlation challenge case. There are 9 rocks in this distribution and one crater.

Download: 903 MB [.zip]

https://ti.arc.nasa.gov/dataset/IRG_PolarDB

Lunar Surface Imaging Studies

Stereo vision will work for lunar polar rover missions

- Hazard detection (20 cm positive obstacles)
- Localization (within 35m even with only 4m DEM and 8m max range)

HDR helps

- HDR does better than the best LDR

Compression is acceptable

- JPEG compression up to 6x has little affect on range and density
- SLOG compression up to 25x has little affect on range and density

3. Synthetic Lunar Terrain Model

Need

- High-resolution DEMs (10 cm/post) are needed for conops studies, development of rover navigation systems, mission simulations, etc.
- Best-available lunar DEMs are 1-10 m/postand typically noisy

Polar crater model

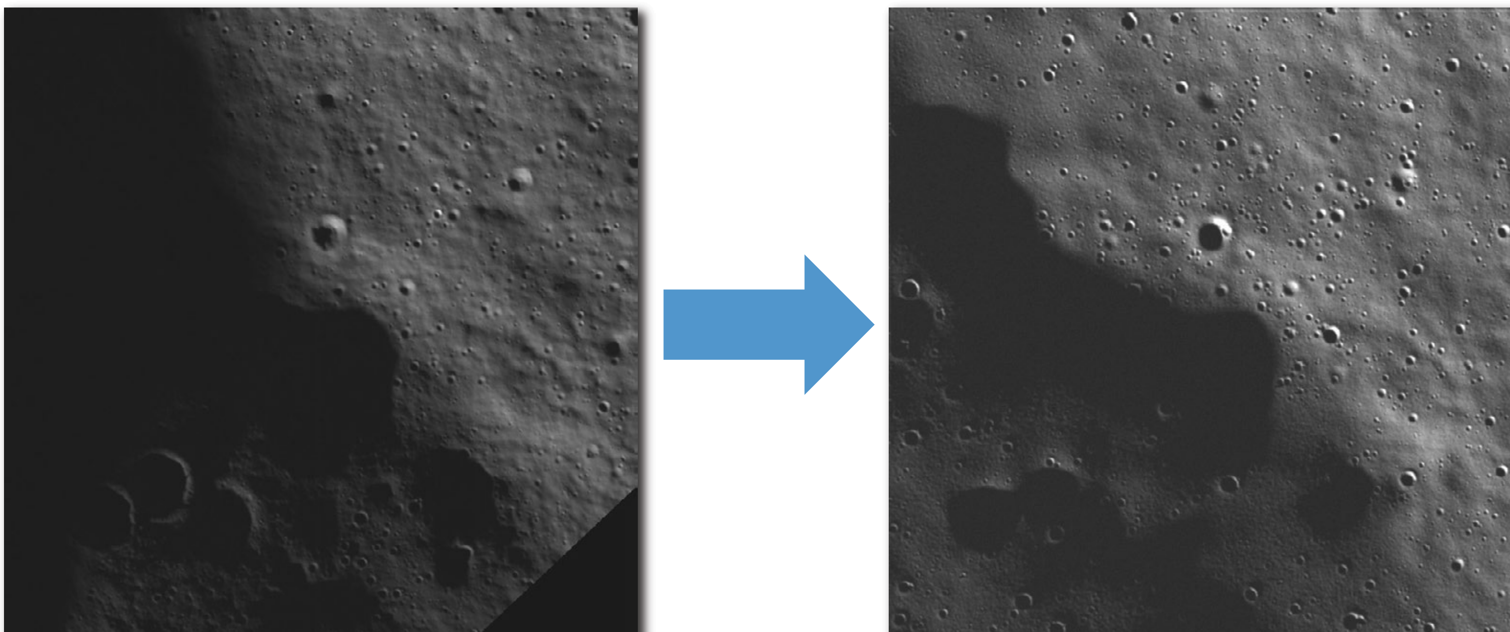
- 1 km x 1 km area near the Hermite A crater (86.17°N, 93.32°W)
- 4 cm / post

Disclaimer

- NOT an accurate measurement of the actual lunar terrain near Hermite A
- NOT appropriate for lunar mission planning or operations
- Suitable for education use, outreach activities, research, or simulation

Synthetic DEM Generation Process

1. LROC-NA Images and LOLA laser altimetry of the Hermite A region
2. Create initial DEM with 1 m/post using photoclinometry
3. Synthetically enhance DEM via fractal synthesis to create high-resolution surface detail that is consistent with lunar morphology
4. Add synthetic craters and rocks using a parametric shape model with size-frequency distributions to control density

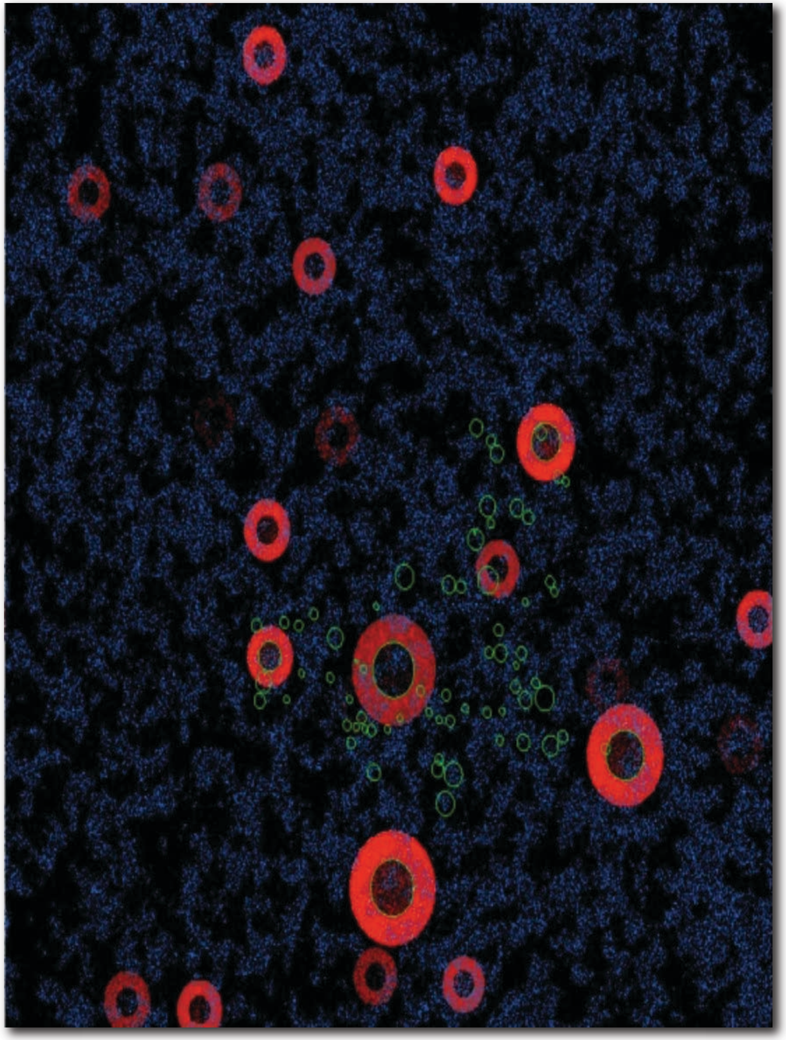


Crater Placement

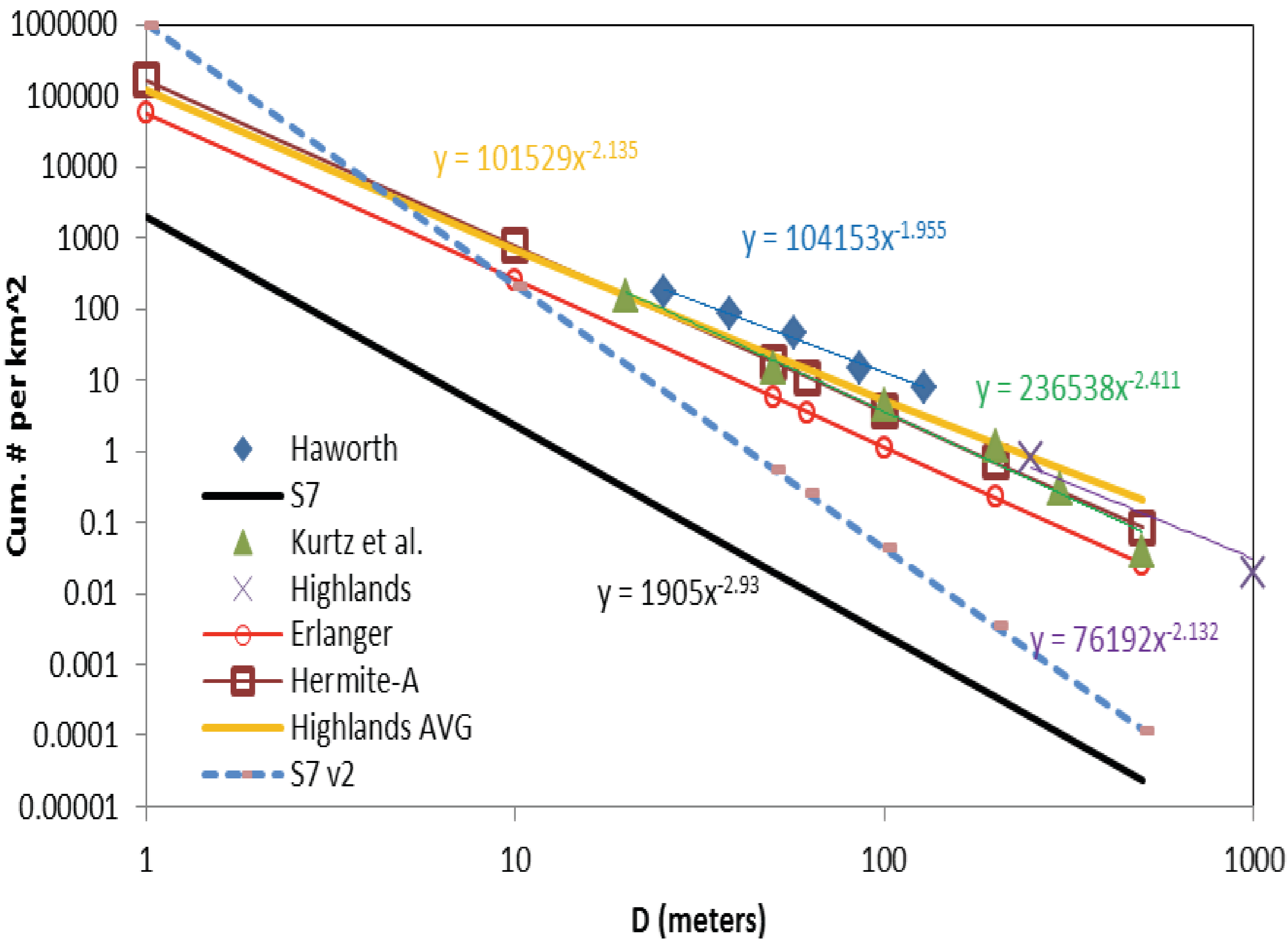
Approach

- Spatially uniform, random locations
- Older craters are slowly “overwritten” by newer (fresher) craters
- Larger new craters “overwrite” smaller old ones
- Smaller new craters excavate into larger old ones

Craters can also be manually placed to match orbital imagery



Crater Size-Frequency Distribution



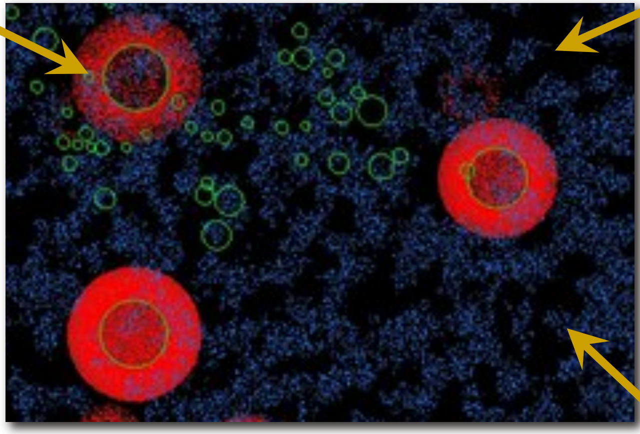
Rock Placement

Approach

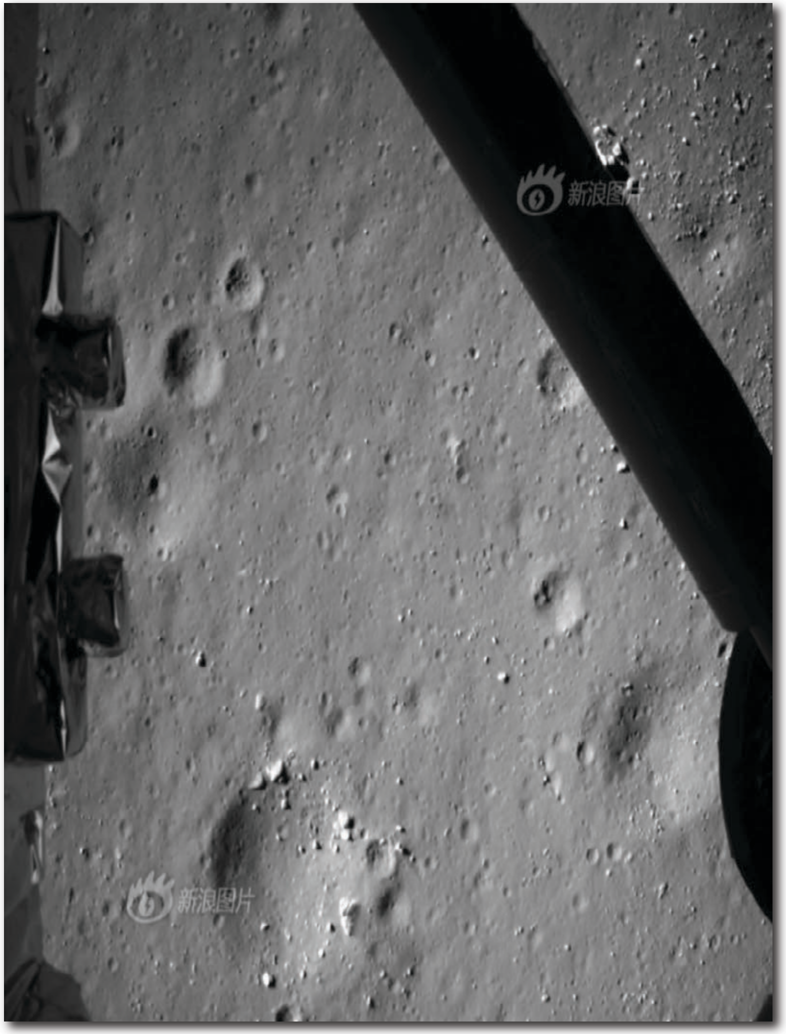
- High density near fresh crater rims
- Low density between craters
- Random “clumping” parameter applied to control spatial uniformity
- No attempt to model ejecta rays

Crater Ejecta

No rocks

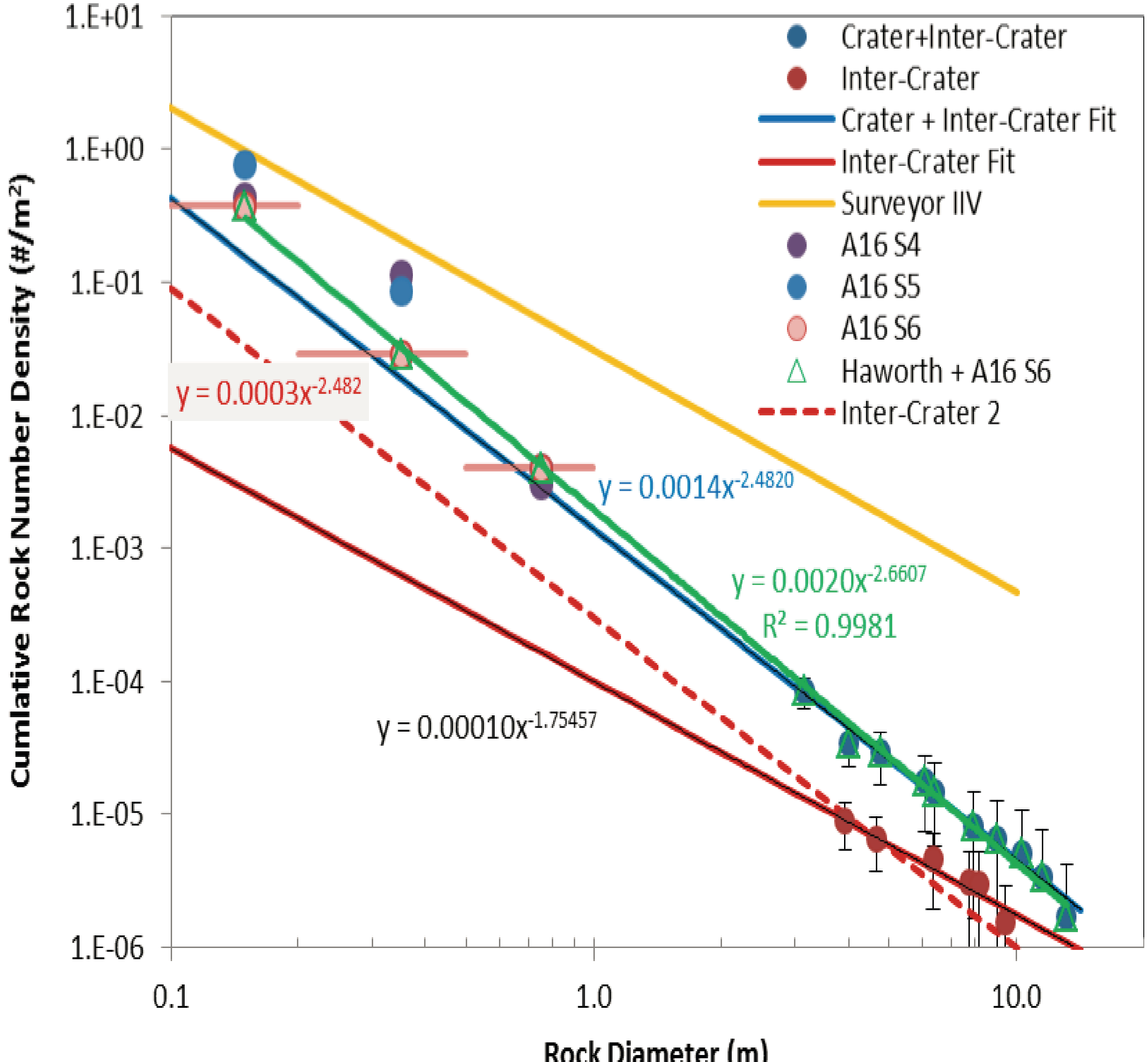


Inter-crater rocks



Chang-e descent image

Rock Size-Frequency Distributions



Synthetic Terrain Results

Synthetic Terrain Results

Synthetic Terrain Results

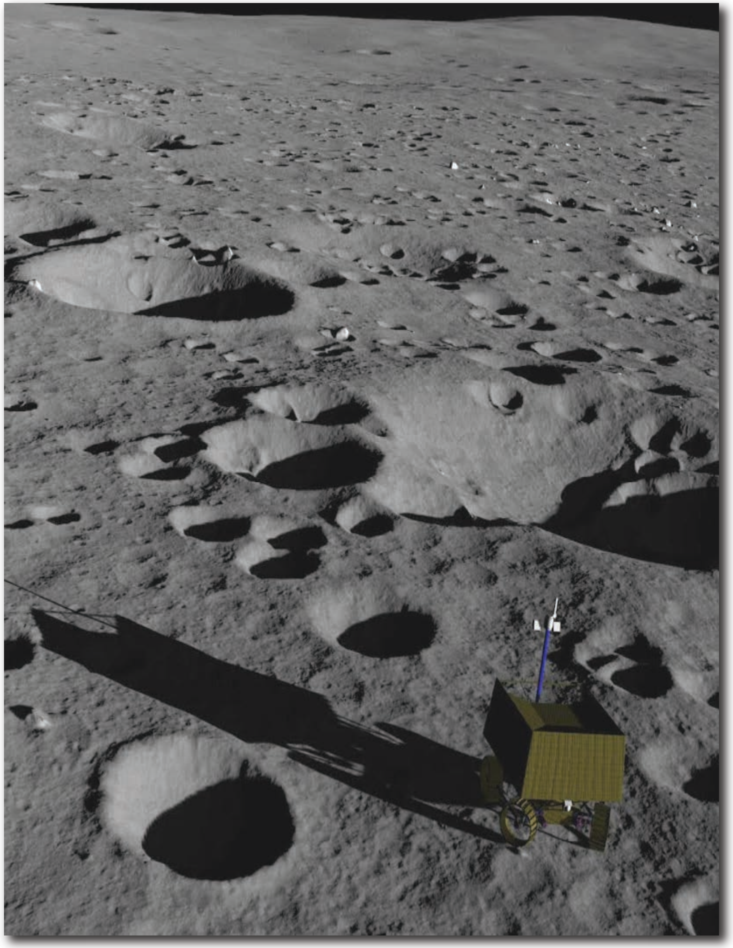
4. Lunar Surface Simulator

Need

- Real-time simulation for conops studies and engineering ("plausible fidelity")
- Provide high-quality 2D/3D data to operator interfaces, rover software modules, science displays, etc.

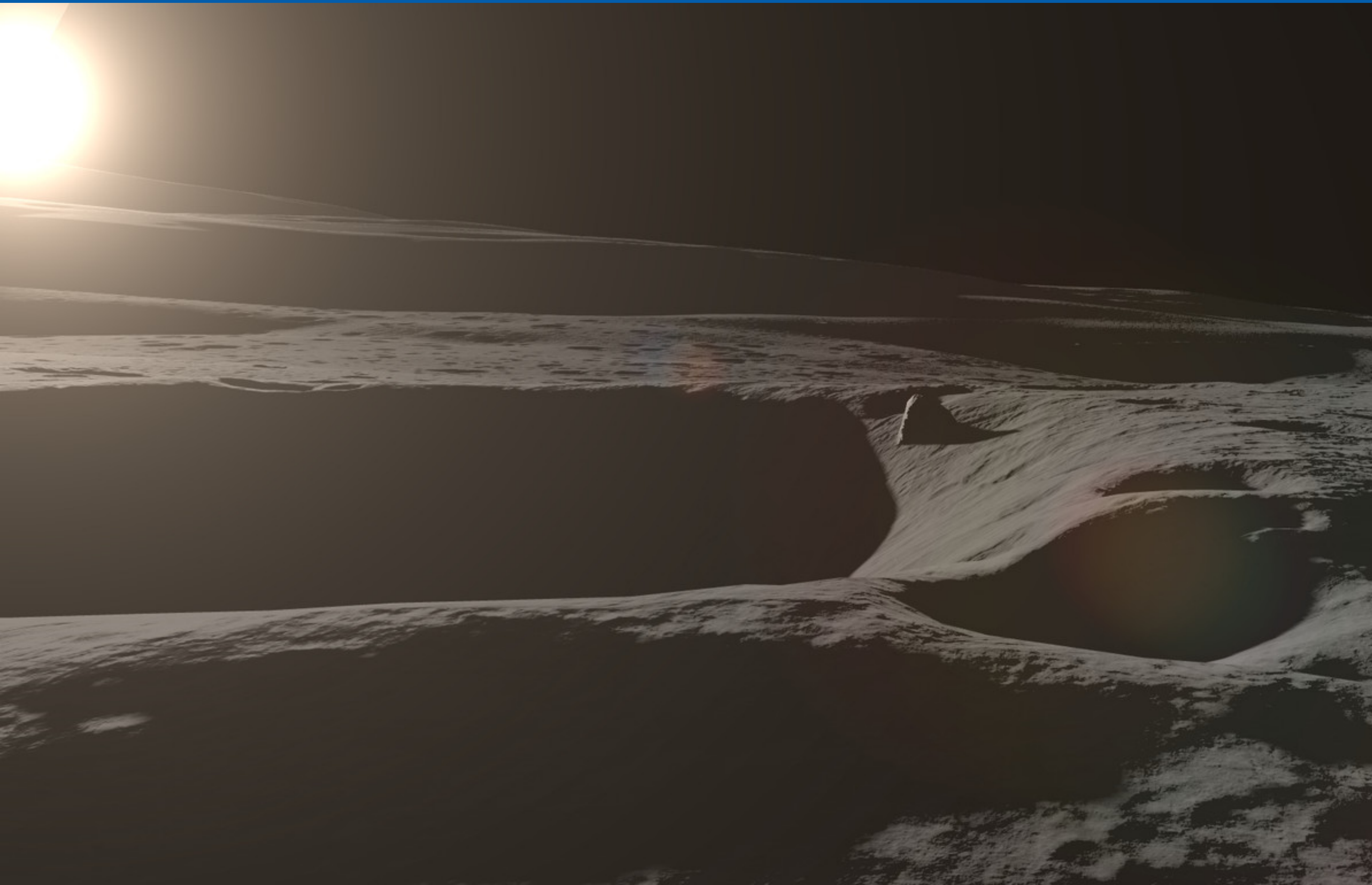
Features

- High dynamic range rendering
- Real-time shadows
- Support for high resolution terrains
- Support for custom terrain appearance
- Rover wheel tracks and slip modeling
- Rover lights with custom beam pattern
- Simulated lens flare and camera noise
- Lunar regolith reflectance model (Hapke)
- Accurate Sun & Earth location (SPICE)

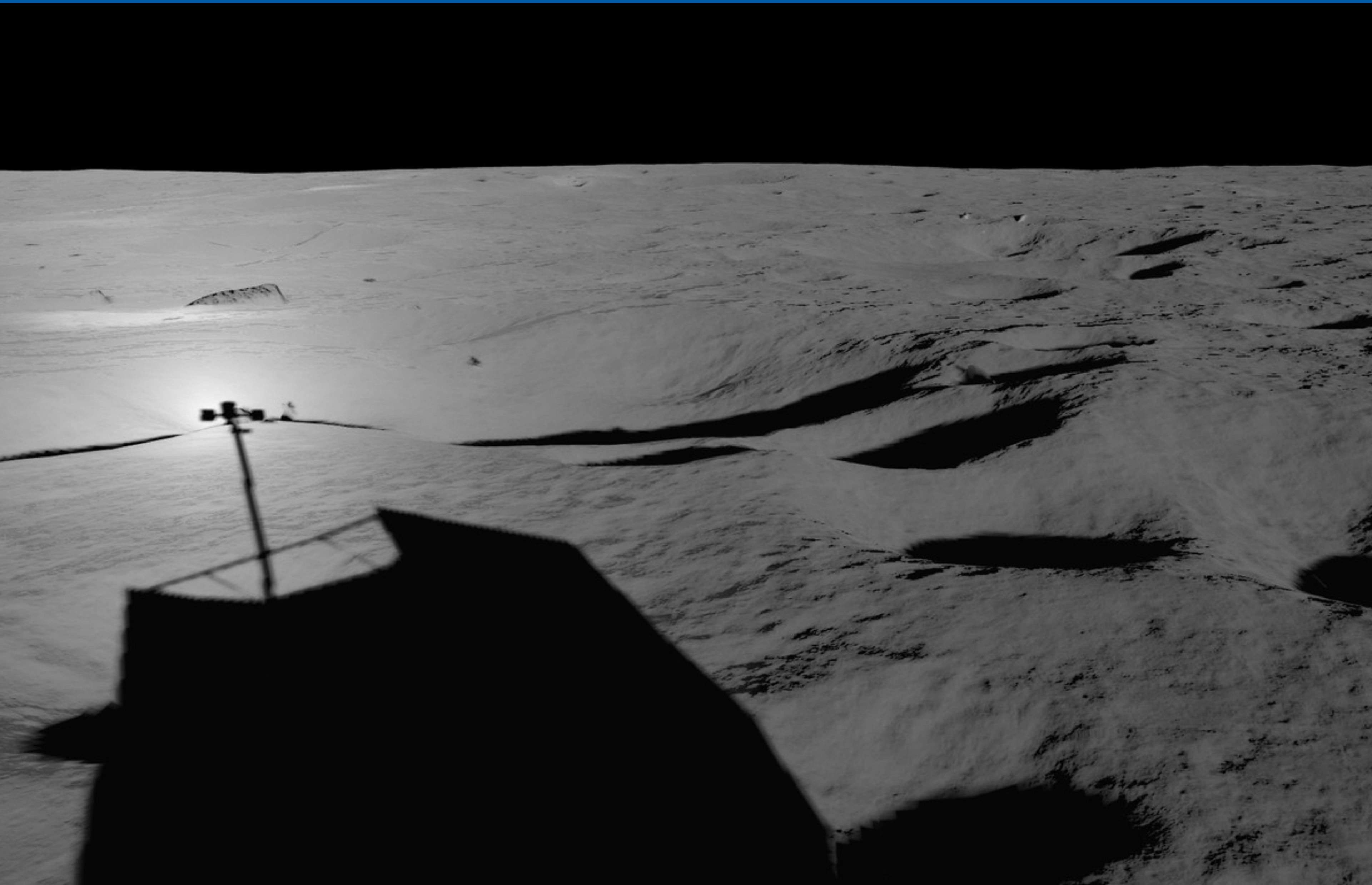


Lunar surface simulator based on "Gazebo" robot simulator (Open Source Robotics Foundation)

Lens Flare



Opposition Surge



Long Cast Shadows

Questions?

Intelligent Robotics Group

Intelligent Systems Division

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