RSIM Lunar Surface Simulator

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RSIM Lunar Surface Simulator

- Built on top of Gazebo Classic and ROS 2
  - Originally developed for Resource Prospector Concept of Operations studies
    - General purpose, rapid prototyping
  - Extended and specialized to support VIPER software development and operations training
- Simulation of the Lunar Environment
  - Synthetically Enhanced Terrain
  - Simulated Lighting Environment
- Simulation of the Flight Vehicle
  - Simulation of cameras and other sensors
  - Physical simulation of vehicle dynamics

Synthetically Enhanced Terrain

- Terrain used for simulation must be able to represent rover-scale features
  - Minimum of 20x increase in resolution required over best available DEM (Digital Elevation Model) resolution of 1m
- Synthetic Enhancement
  - Fractal expansion upscaling
  - Enhance craters visible in orbital imagery
    - Compensate for smoothing due to low resolution
    - Shadow volumes used to estimate crater depth
  - Insert small synthetic craters below size threshold
  - Insert synthetic rocks

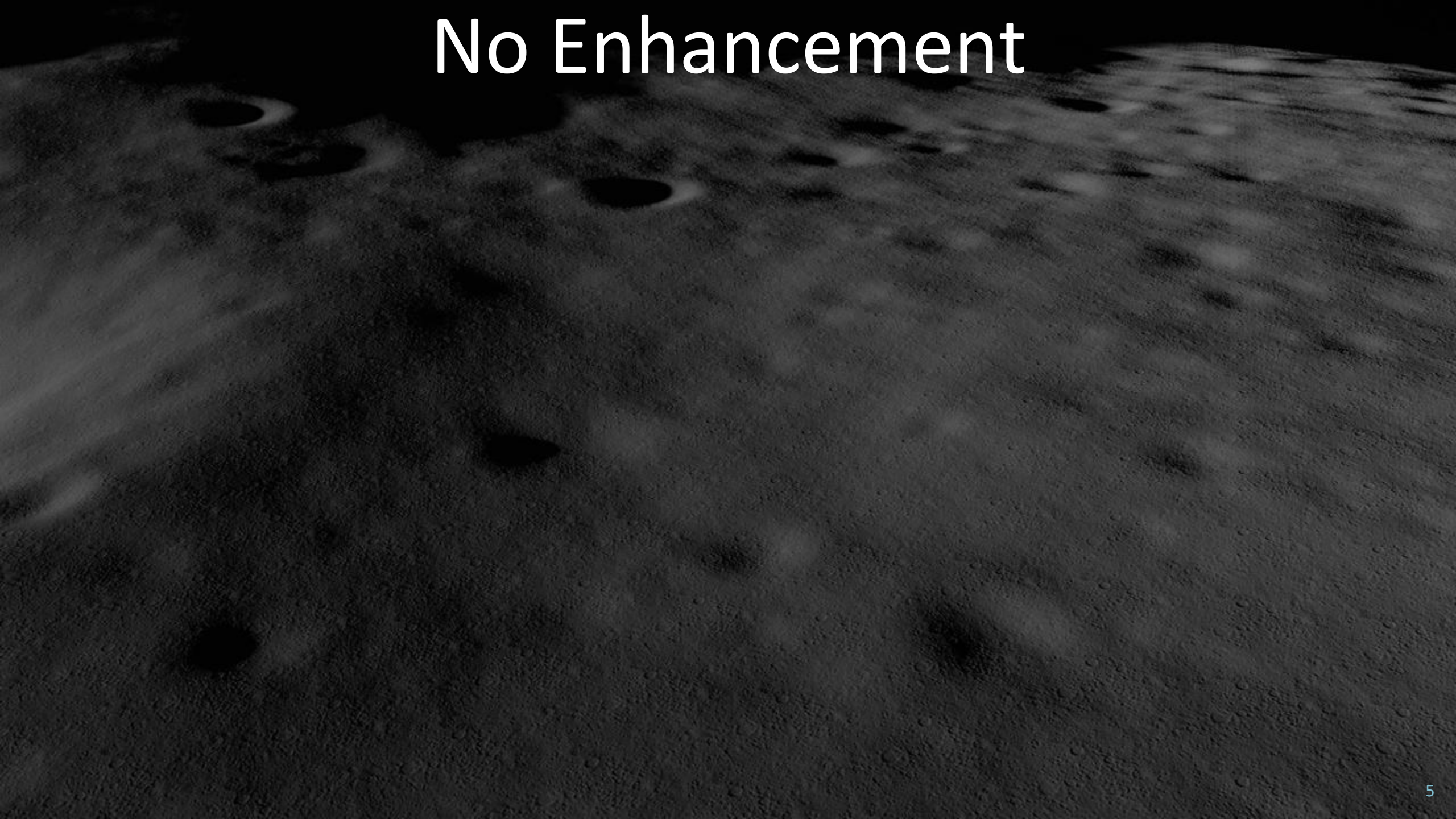
Synthetically Enhanced Terrain

- Generate synthetic orbital images to
  - Sanity check against available ground truth
  - Ensure simulated terrain matches traverse planning expectations

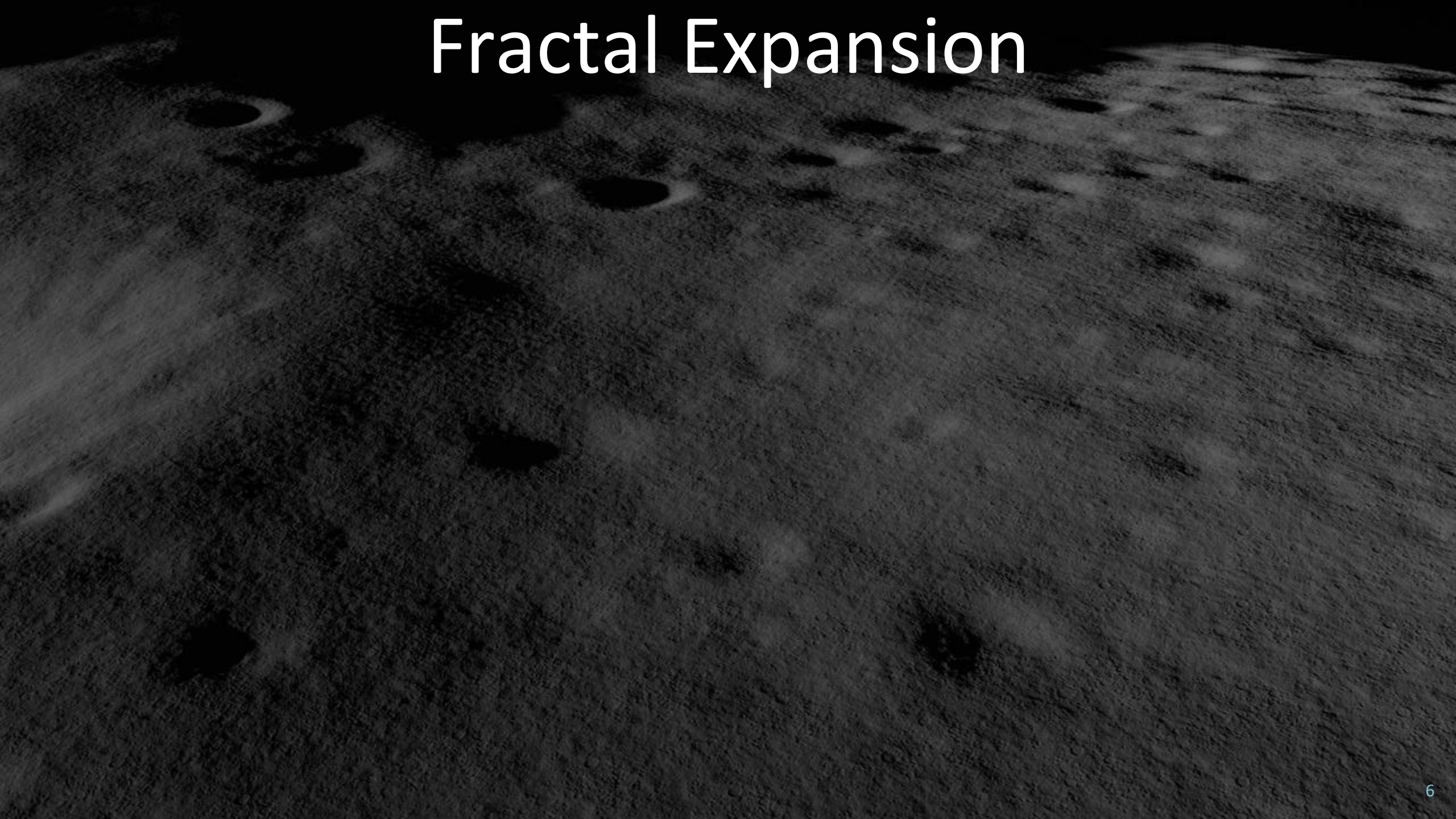
LRO NAC Image M1164797684LE

Simulated Orbital Image

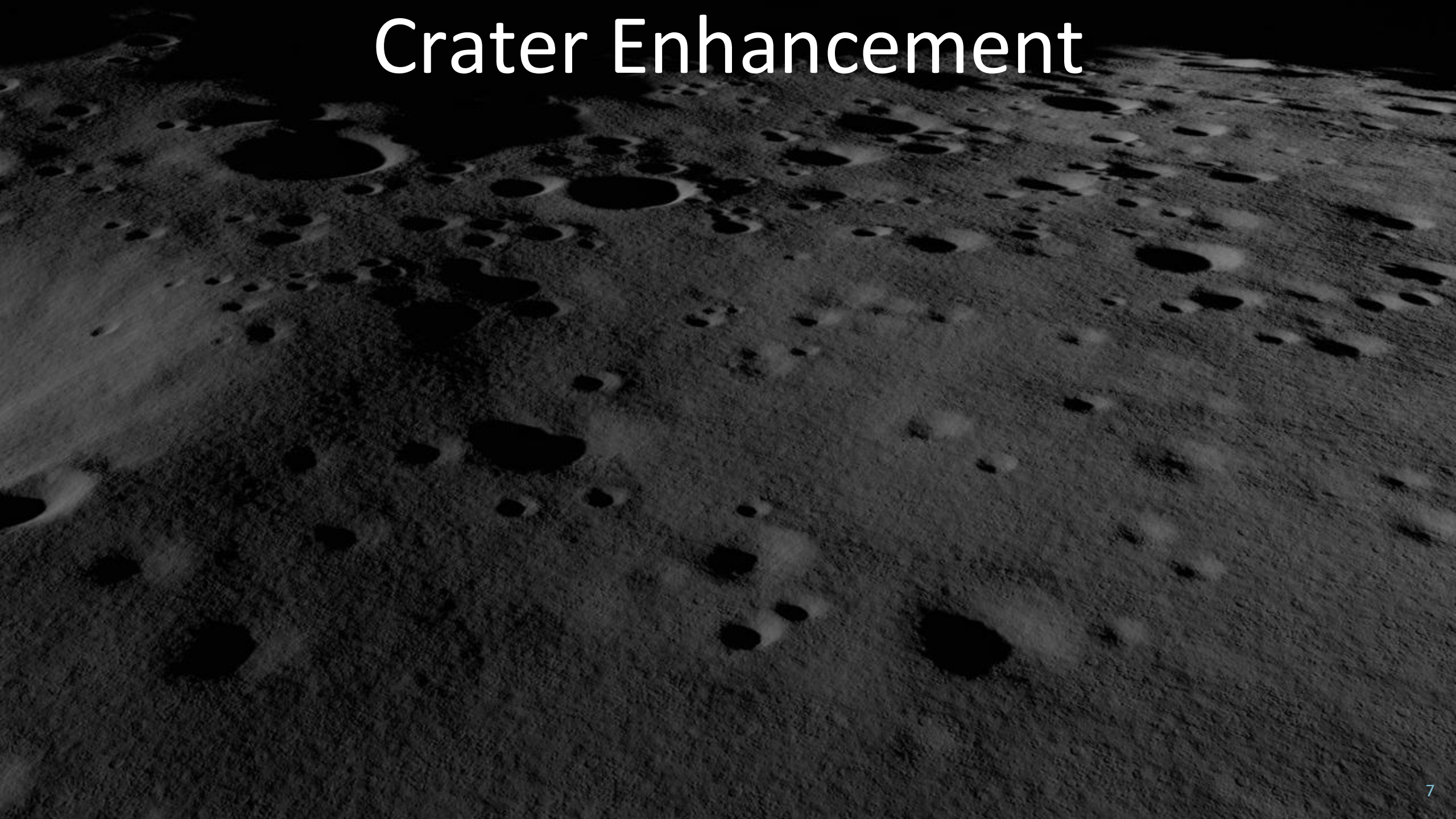
No Enhancement



Fractal Expansion

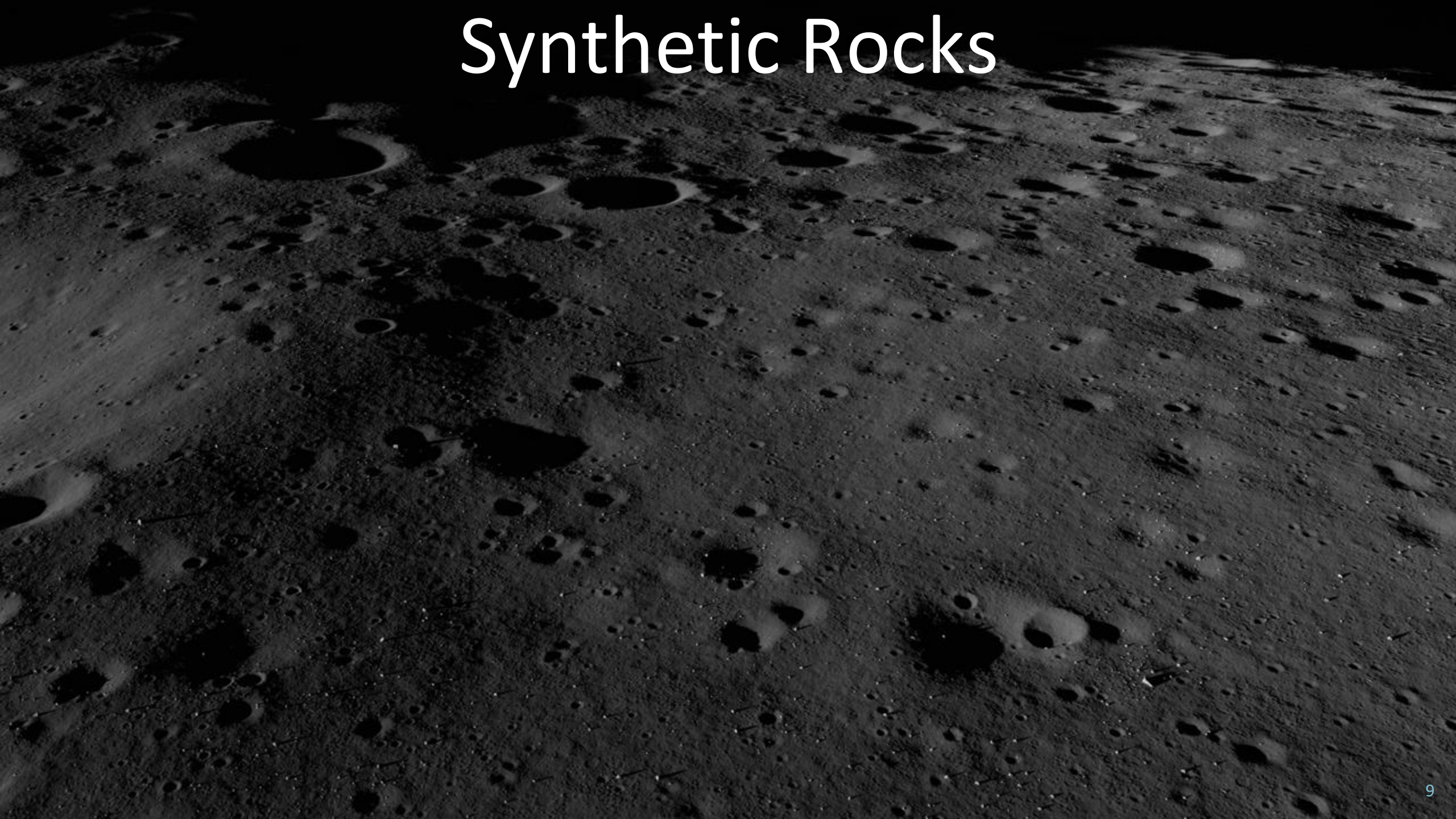


Crater Enhancement



Small Synthetic Craters

Synthetic Rocks



Camera Simulation

- Simulated sensor data must be representative of what we expect during flight from both **human operator** and **computer vision** perspectives

Simulated properties:

- Exposure
- Lens Distortion
- Focal Length
- Optical Center
- Depth of Field
- Aperture
- Vignetting
- Fixed Pattern Noise
- Read Noise
- Dark Current Noise
- Photon Shot Noise
- Modulation Transfer Function
- Pixel Defects
- Gain
- Bit Depth

Exposure

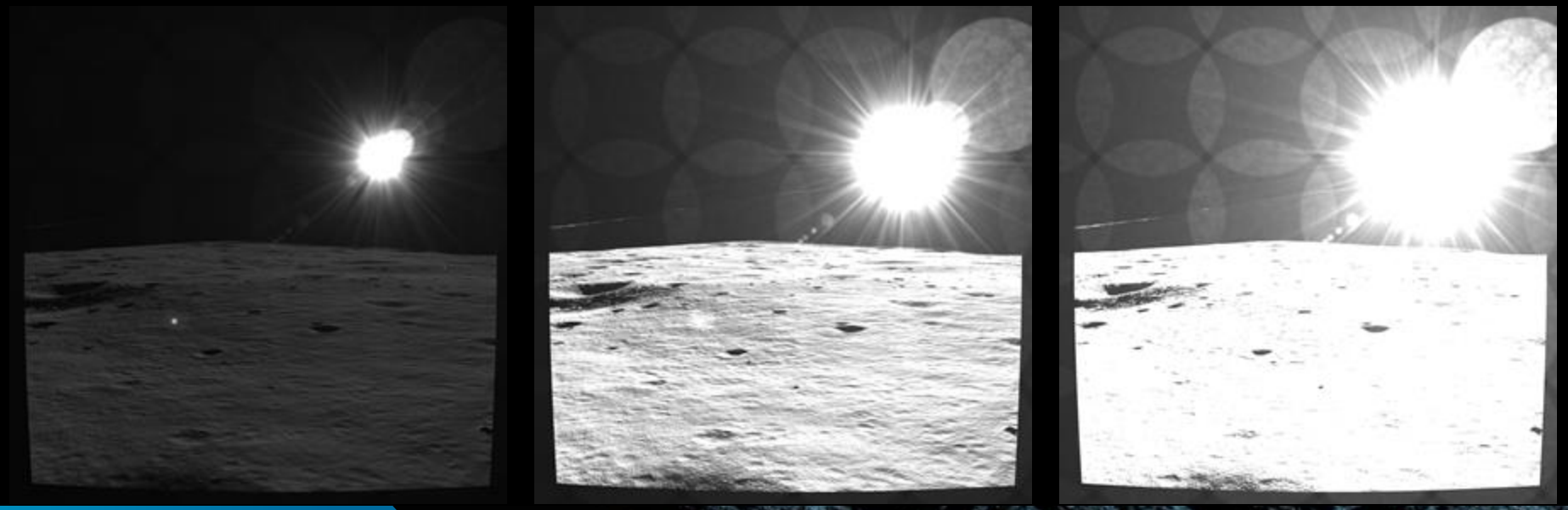
Real

RSIM

Lens Flare

Real

RSIM



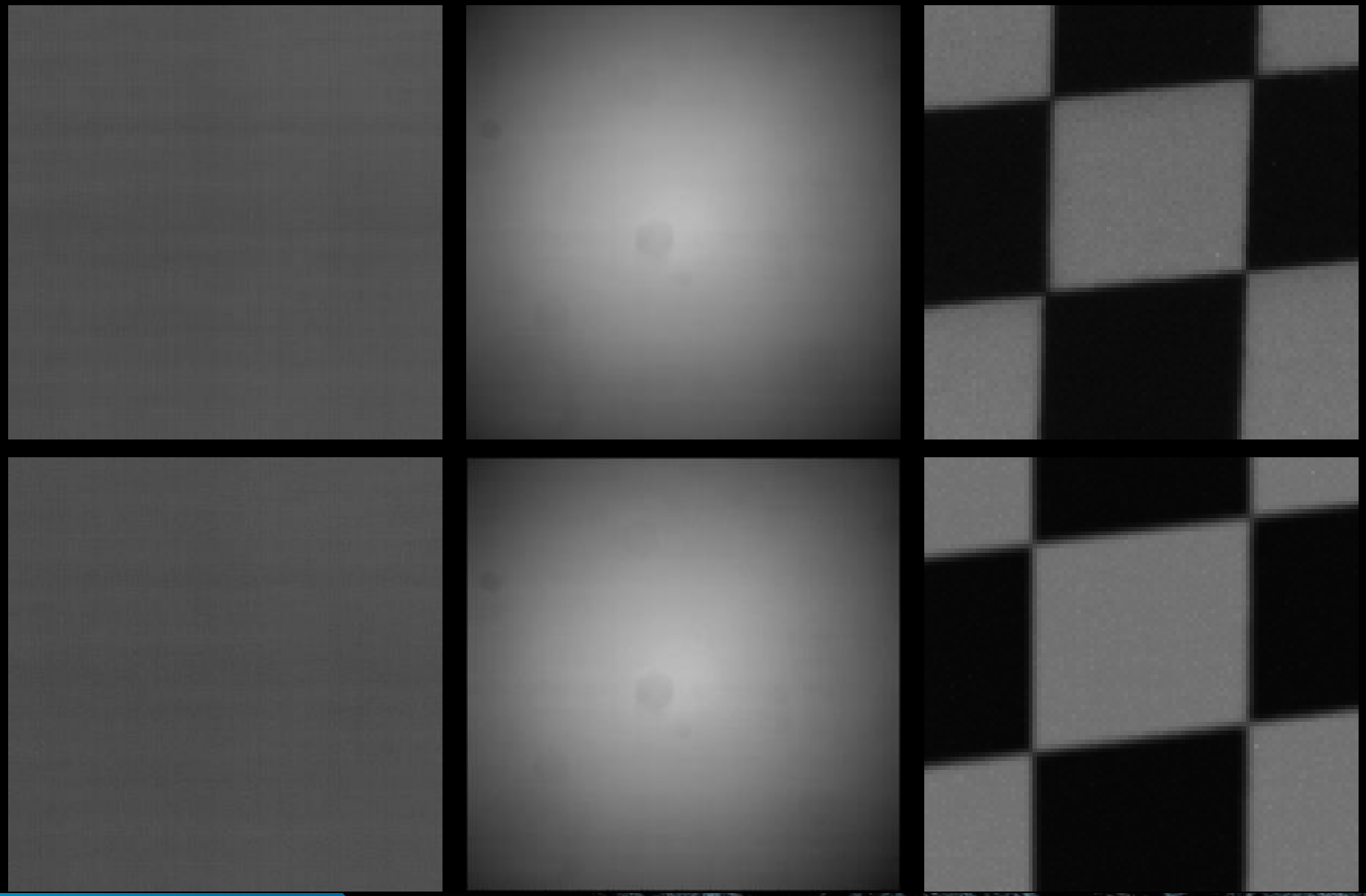
Fixed Pattern Noise

Flat Field Effects

DoF, Sensor Noise

Real

RSIM

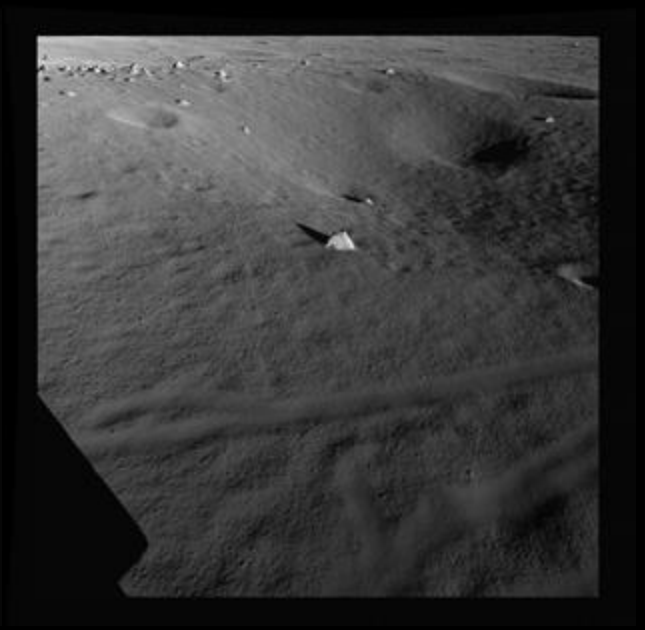


Camera Simulation

- VIPER NavHW team characterized flight cameras
- Lunar Lab imagery collected to test hazard detection, visual odometry
- Digital twin of Lunar Lab used to tune rendering and compare performance of simulated imagery vs real world

Lunar Lab

RSIM

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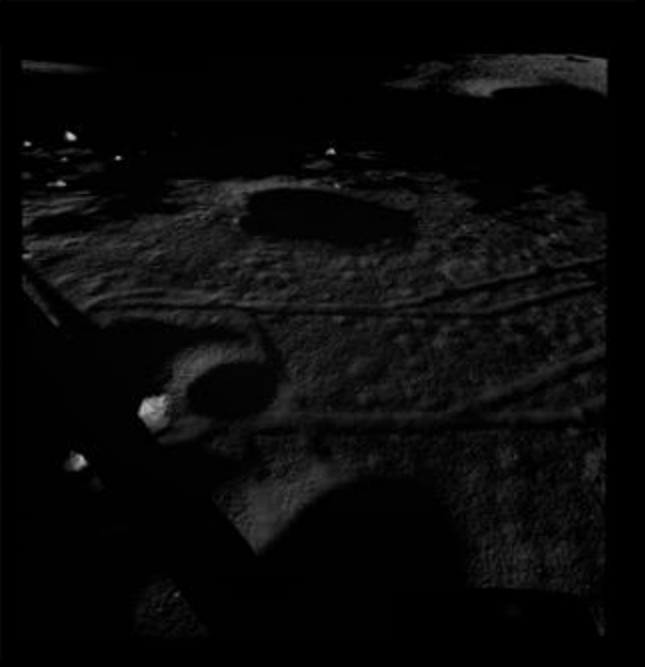
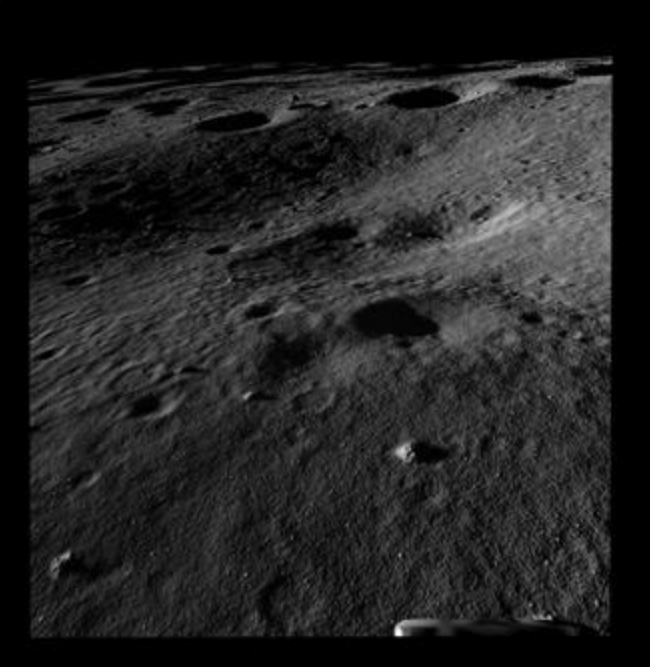
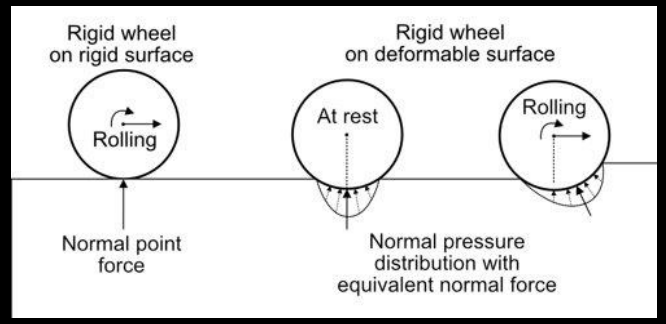




Mobility Simulation

- VIPER mobility system characterized at the NASA Glenn SLOPE facility
- Wheel slip modeled by
  - Modulating Force-Dependent Slip (FDS) based on slope
  - Modulating surface contact normal to simulate plowing effect
  - Slip compliance and friction are modulated by a ‘slip map’ on a per-wheel basis to account for soil compaction and rocks

Plowing Effect



SLOPE Lab

Mobility Simulation

- Wheel slip approximates terramechanics of driving on unconsolidated soil
- Tuned to match physical testbed results
- Negligible impact on runtime performance