



National Aeronautics and Space Administration



Digital Lunar Exploration Sites (DLES)

Presenter: Cory Foreman

Authors:

Sam Lawrence, Ph.D., Edwin Z. {Zack} Crues, Ph.D., Andrew Britton, Paul Bielski, Jonathan Schlueter, Amy Jagge, Chris Raymond, Nick Davis, Cory Foreman

10 March 2022

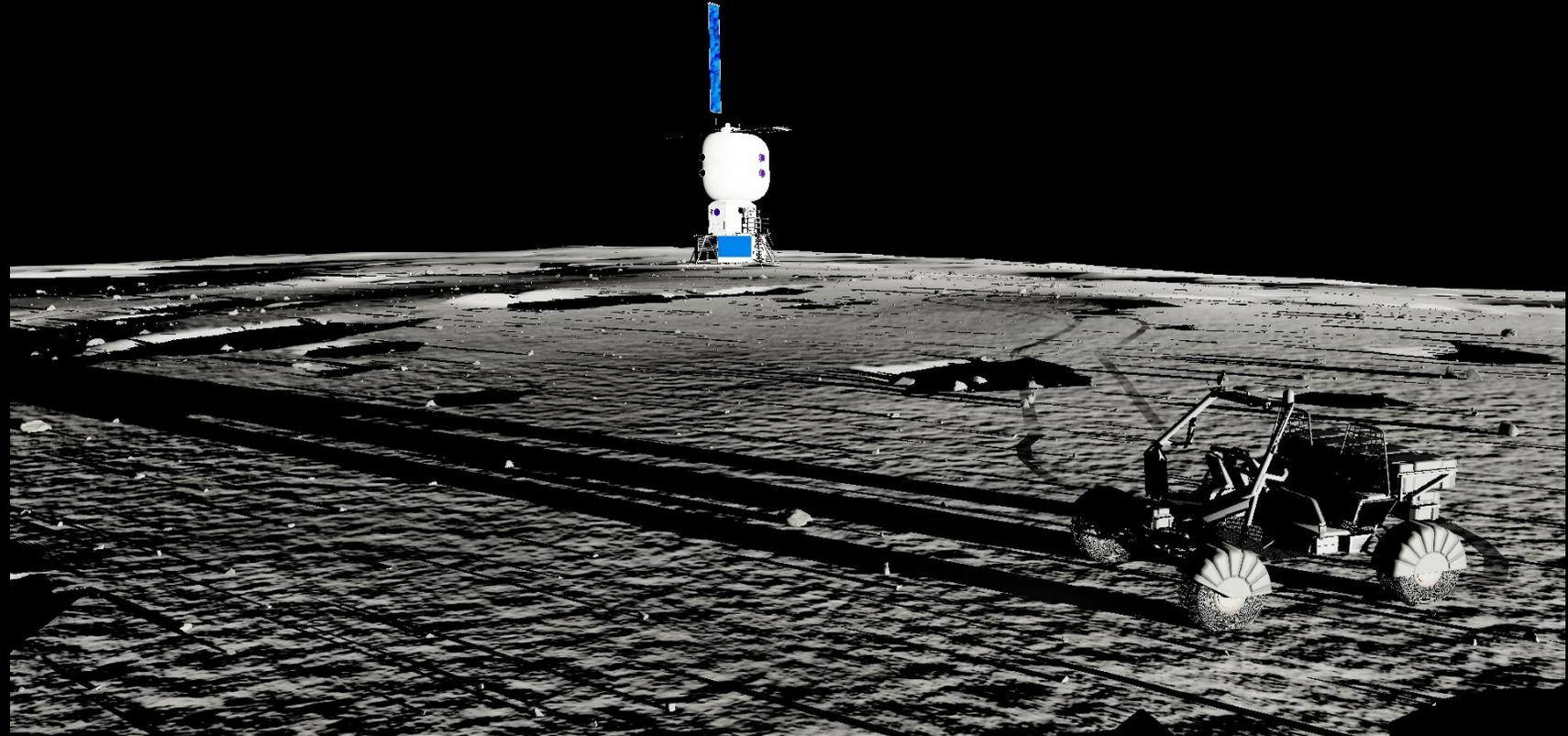
Presentation to the IEEE Conference, Big Sky, MT 2022



Overview



- Introduction
- The Need for DLES
- Building DLES
- DLES Products
- DLES In Use
- Future Work
- Conclusions
- Questions





Introduction



- Apollo 17:
 - Last time humans set foot on the moon
 - December 1972 – almost 50 years ago!
 - Made significant use of modeling and simulation
 - Provided a wealth of data about the lunar surface
 - <https://apolloinrealtime.org>
- Artemis:
 - Return Date: mid-2020s
 - Will rely heavily on simulation
 - Better data describing lunar surface
 - Developing Digital Lunar Exploration Sites (DLES) products

AS17-140-21391.jpg





The Need For DLES



- The Artemis program is currently focusing on exploration sites at the Lunar South Pole (LSP).
 - Rugged, mountainous, and cratered terrain.
 - Low Sun and Earth angles.
 - Lighting conditions will be challenging.
- Limited information at the LSP
 - No system has soft-landed at the LSP.
 - Apollo missions focused on equatorial regions
 - We do have significant imagery, terrain elevation, and resource information from remote observations.



Building DLES



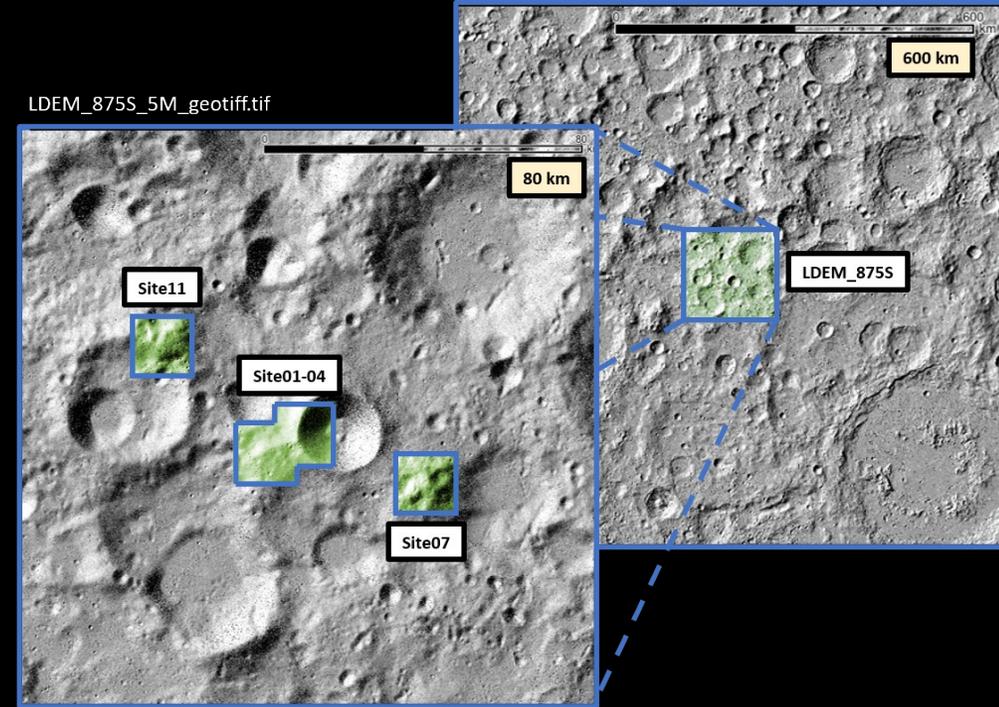
- NASA collaboration between planetary science and space systems simulation
 - Astromaterials Research and Exploration Sciences (ARES) Team (JSC)
 - NASA Exploration Systems Simulations (NExSyS) Team (JSC)
 - Engineering Simulation and Graphics Lab (ESGL) (JSC)
 - NASA Planetary Geology, Geophysics and Geochemistry Laboratory (GSFC)
- Data sources
- Data processing
- Data generation
- Infrastructure

NASA Building DLES: Data Sources



LRO_LOLA_DEM_SPole75_30m.tif

- Lunar Reconnaissance Orbiter (LRO)
 - Launch Date: June 18, 2009
 - Lunar Orbiter Laser Altimeter (LOLA)
 - Able to generate 5 meter per pixel (mpp) Digital Elevation Models (DEM)
 - 2x LRO Camera Narrow Angle Cameras (NAC)
 - Able to generate 1-4mpp surface imagery
 - Depends upon altitude
 - Stereo images can be processed to generate higher resolution DEM



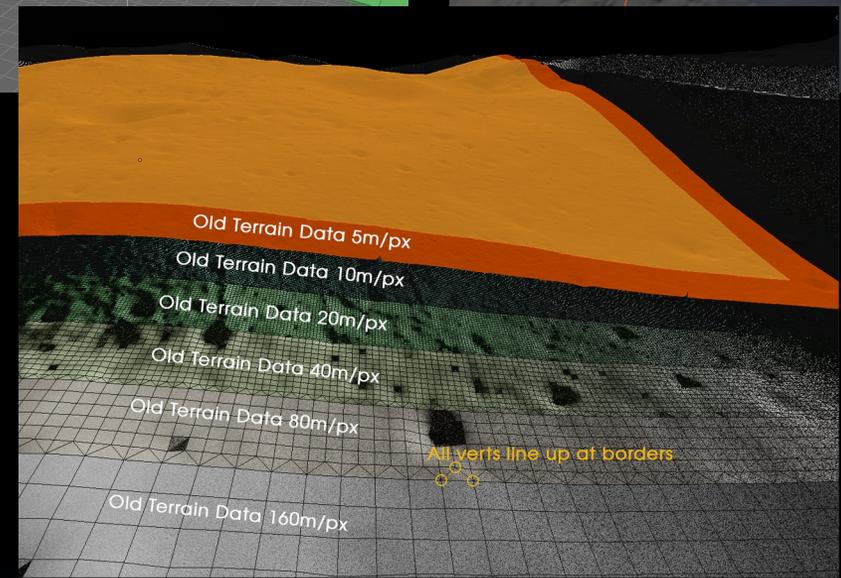
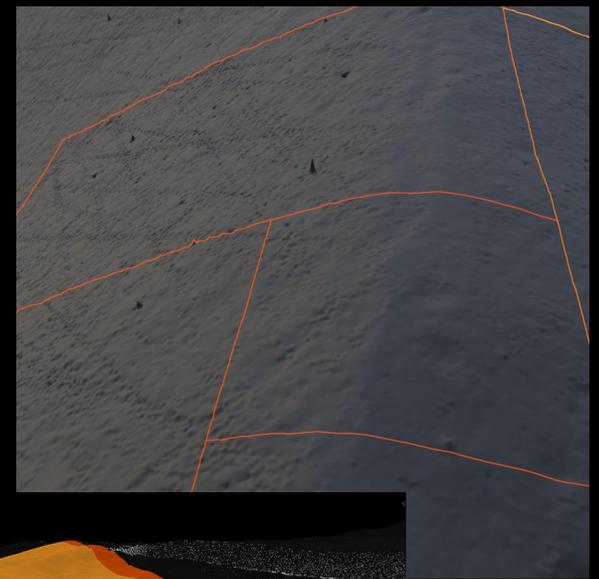
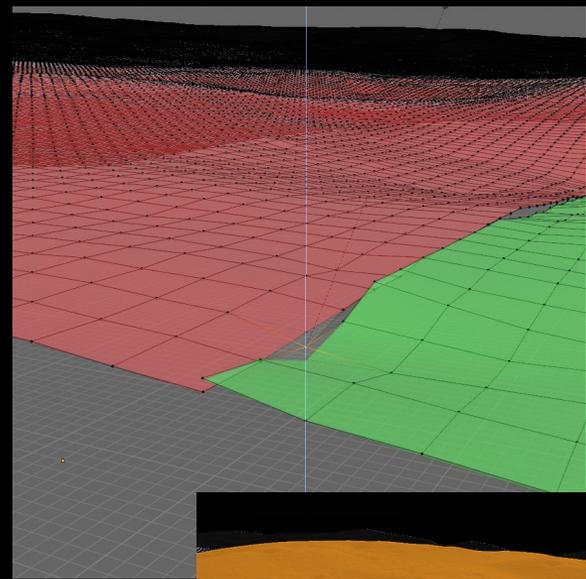
Filename	Resolution	Description
Site01-Site04_merge-fillseam-crop.tif	5 mpp	Blended and mosaicked DEM defining an area of roughly 25km x 25km around Connecting Ridge and Shackleton Rim
Site07_final_adj_5mpp_surf-reproj_scaled.tif	5 mpp	DEM defining an area of 16km x 16km around Site 007. Reprojected pixel units to m from km
Site11_final_adj_5mpp_surf-reproj_scaled.tif	5 mpp	DEM defining an area of 16km x 16km around Site 011. Reprojected pixel units to m from km
LDEM_875S_5M_geotiff.tif	5 mpp	Regional LOLA DEM extending from -90° to -87.5° latitude
LRO_LOLA_DEM_SPole75_30m.tif	30 mpp	Regional LOLA DEM extending for -90° to -75° latitude
NAC DTMs	2 mpp	DTMs
SFS	1 mpp	NASA Ames product from Beyer et al.



Building DLES: Data Processing



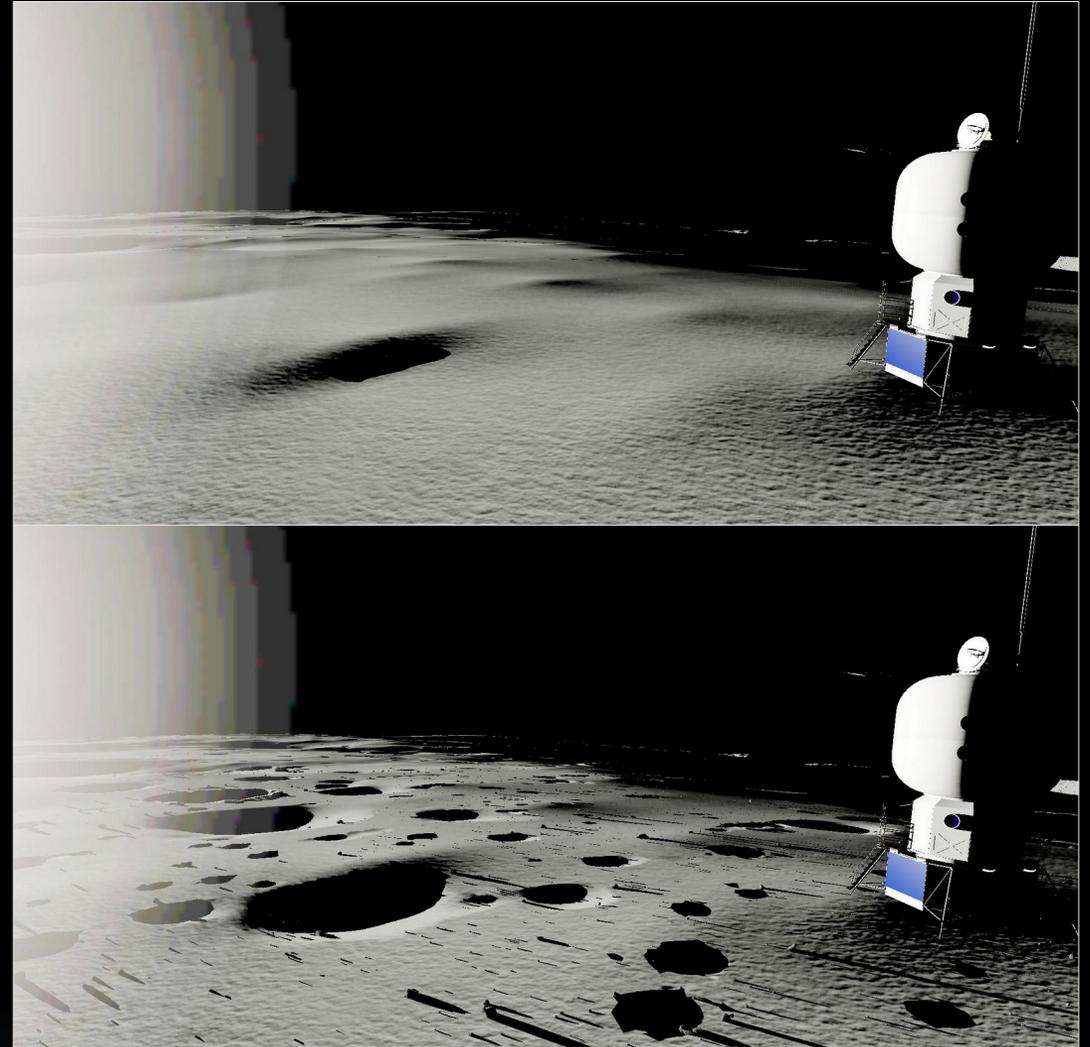
- Artifacts
 - Orbital errors
 - Spurious noise points
 - DEM data can be processed, reducing artifacts around regions of interest
- Gaps
 - Occur at seams between or overlapping DEM data
 - Must be properly stitched together
- Resolution Changes



NASA Building DLES: Data Generation



- Truth data provides good base
- Not able to capture smaller surface details
- Artificial Features:
 - Rocks and Craters are used to enhance surface level detail
 - Built on top of 5mpp truth data
 - Populations are believed to be statistically representative
 - Information is stored in the Persistent Object Database (PODB)





Building DLES: Infrastructure



- Persistent Object Database (PODB)
 - Tracks information of persistent objects on the surface of the MOON
 - Position, Orientation, and Metadata
 - Web interface and API
 - Rocks:
 - Currently tracks: 1,483,507 rocks
 - Data is stored such that retrieval of items in a region is very fast
 - This feature is heavily used in simulations when scattering rocks
 - Functions like a level of detail (LOD) system
 - Only the rocks near the viewpoint are displayed in the rendering engine



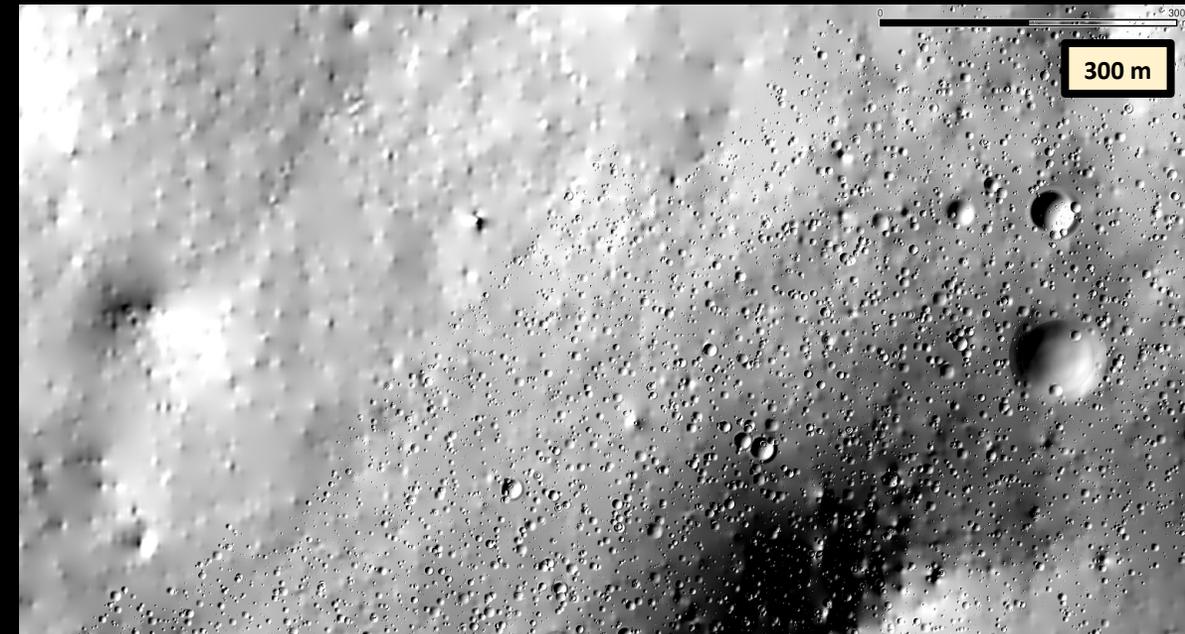


Building DLES: Infrastructure



- Persistent Object Database (PODB)
 - Craters:
 - Currently Tracks: 128,559 craters
 - Offline process, unlike rocks
 - 5mpp DEMs are upscaled to 20cmpp
 - Craters are then inserted into the DEM
 - Upscaled DEM can then be used like any other DEM

Upscaled 20cmpp DEM Hill-shade Image





DLES Products



- Truth Data DEMs:
 - 5mpp - 1mpp
- Upscaled DEMs:
 - 20cm per pixel with craters inserted
- FBX models:
 - Generated from DEMs of region
- Sub-resolution features via PODB:
 - Craters
 - Rocks

Unity FBX Rendering

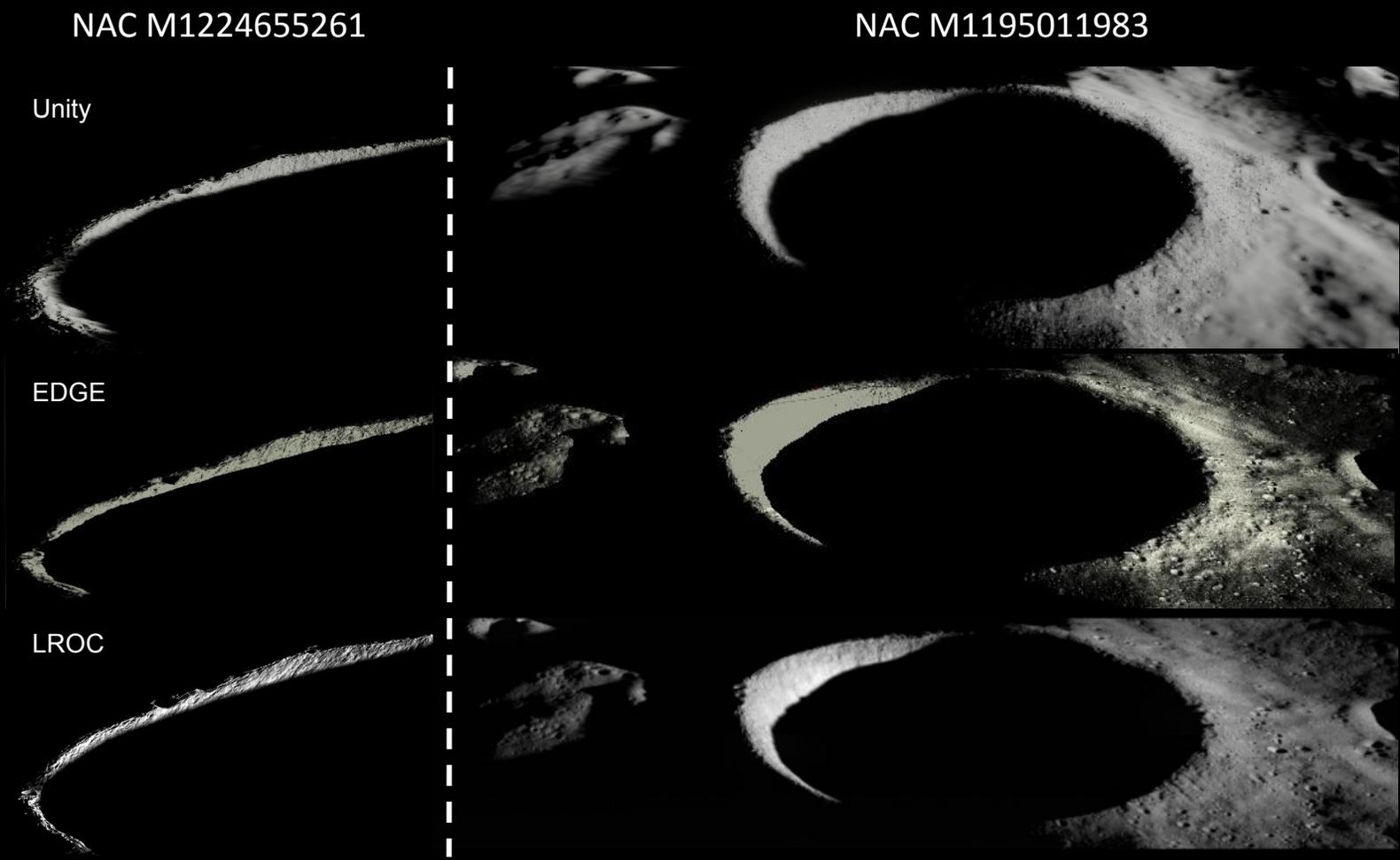




DLES Products: Validation



- Validation Efforts:
 - LRO imagery is replicated
 - Side by side comparisons
- Images:
 - NAC M1224655261
 - Date: 08-01-2016 1:46:34
 - NAC M1195011983
 - Date: 8-23-2015 23:31:55

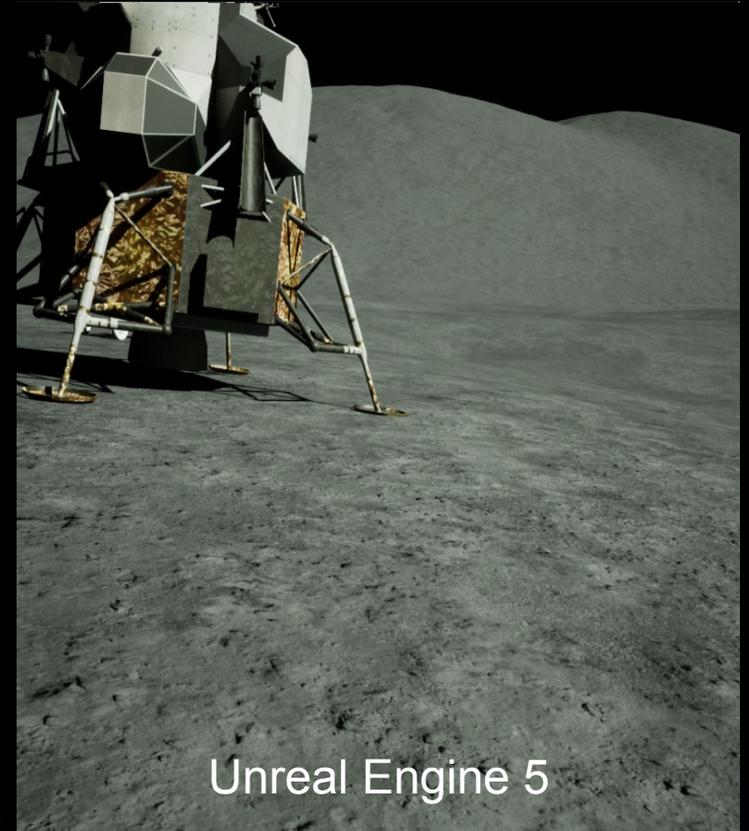
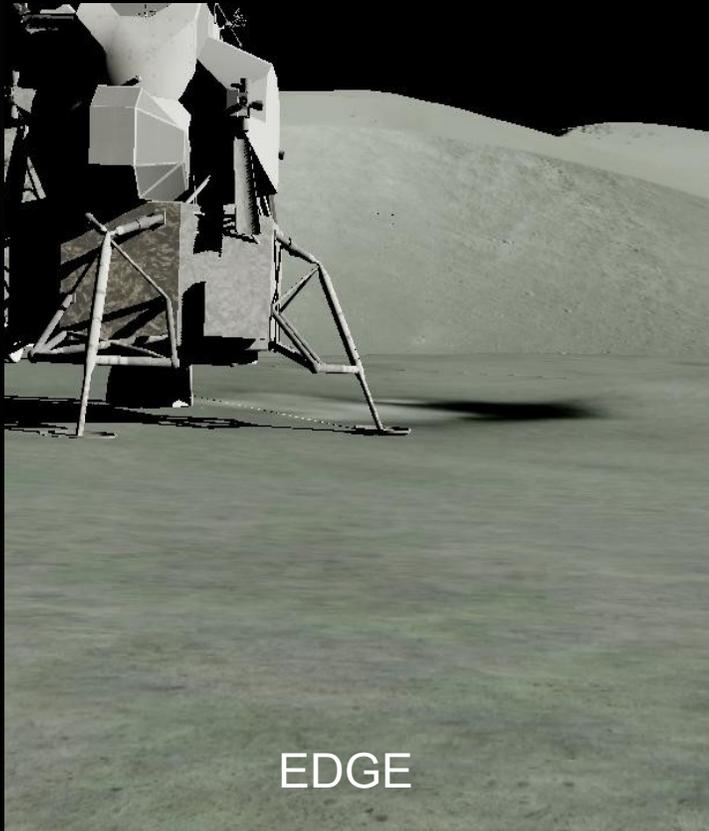
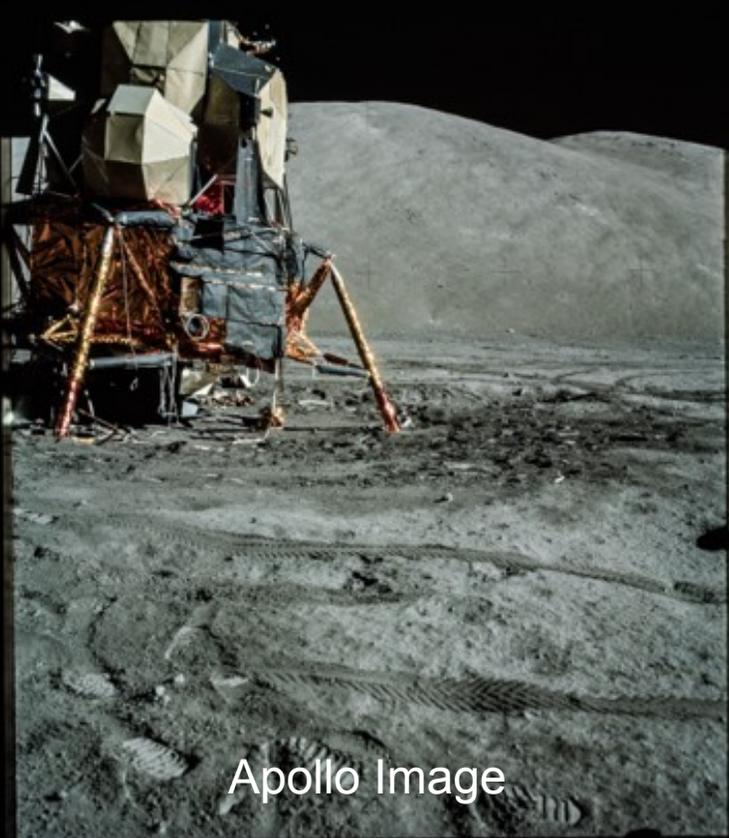




DLES Products: Validation



- Surface image comparisons
 - Apollo 17: AS17-137-20874, Capture Date: Dec. 12th, 1972, 8:31:52 PM

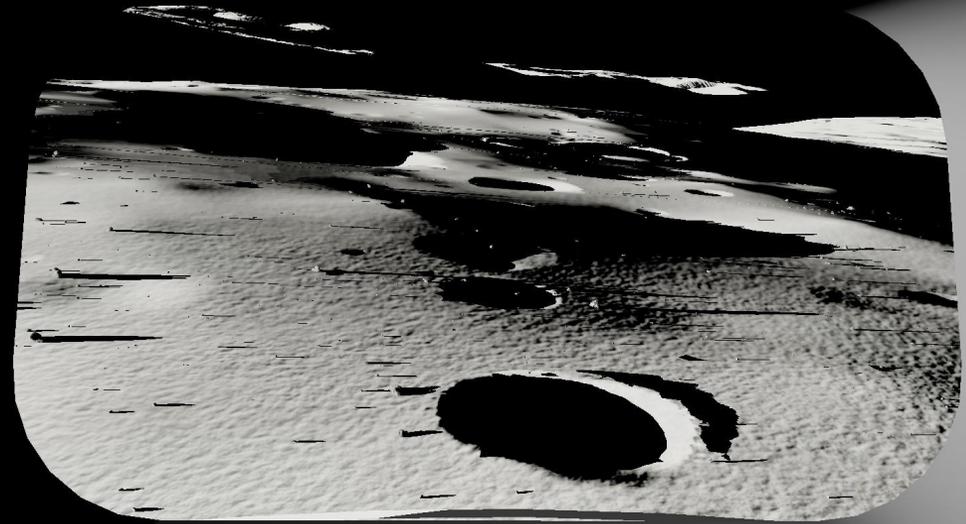
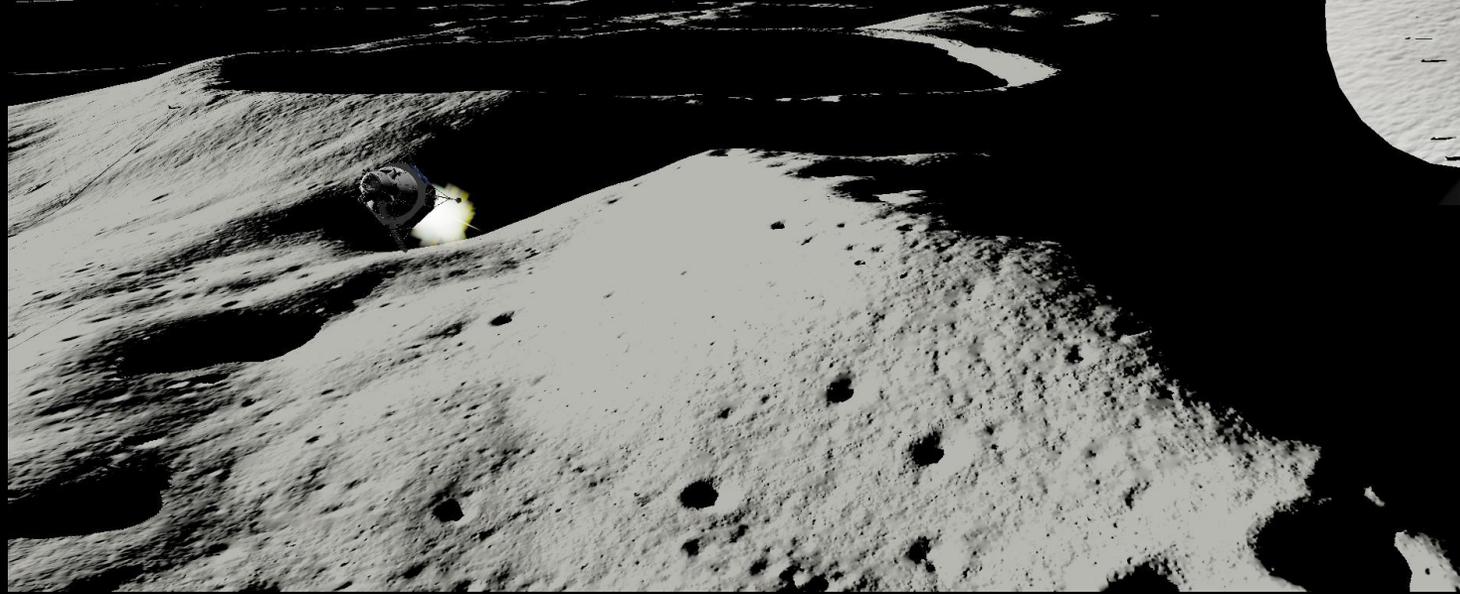




DLES In Use: Lunar Landing



- Realtime Lander Simulations
 - NASA Artemis Program:
 - Human Landing Systems (HLS)





DLES In Use: Lunar Surface Exploration

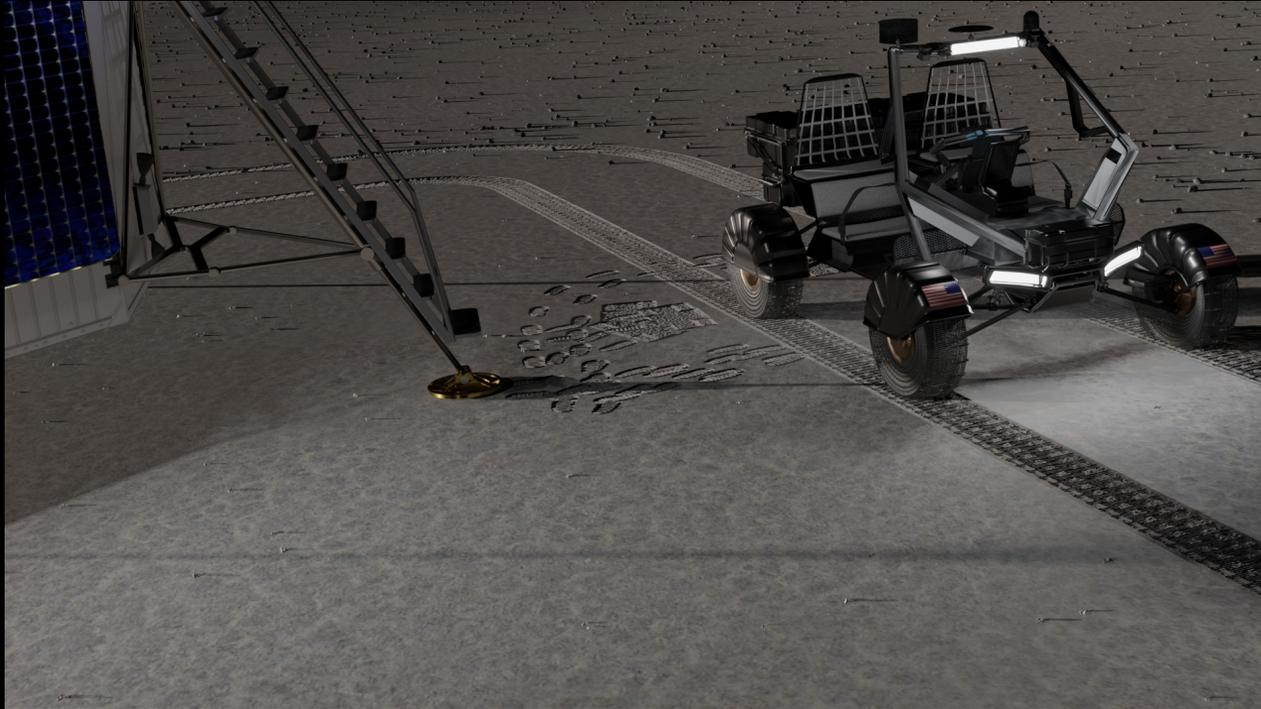


- Realtime Rover Simulations
 - NASA Artemis Program:
 - EVA and Human Surface Mobility (EVAHSM)





Future Work



- Rover tracks
- Footprints
- Tools
- Working with ARES
 - 1mpp & 2mpp DEMs
- PO DB Development
 - Migrate to PostgreSQL / PostGIS
 - Push for public release



Future Work



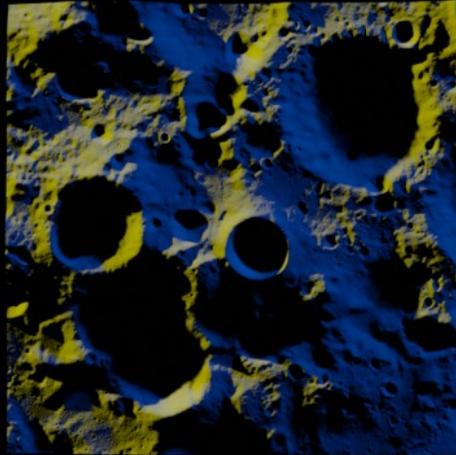
Earth Illumination



Sun Illumination



Combined



Combined-Colored

- Earthshine
 - Roughly 50x more powerful than a full Moon on Earth

- DLES Visualization Tool (DVT)
 - 3D site exploration tool
 - Unity3D based tool
 - Available on Windows, Mac, and Linux
 - Date and planetary data based on JPL Spice package





Conclusions



- DLES provides a functional digital model of the Lunar South Pole region
 - Elevation data
 - Environmental lighting
- Derived from the best available lunar data sources
- Supports the 'addition' of higher resolution site detail
 - Rock distributions
 - Smaller craters
- Supports the addition and management of ancillary data that needs to persist across simulation runs and analysis (PODB)
 - Footprints
 - Rover tracks
 - Exploration artifacts
- Upgradeable as new and improved data sets become available



Questions?





DEM

