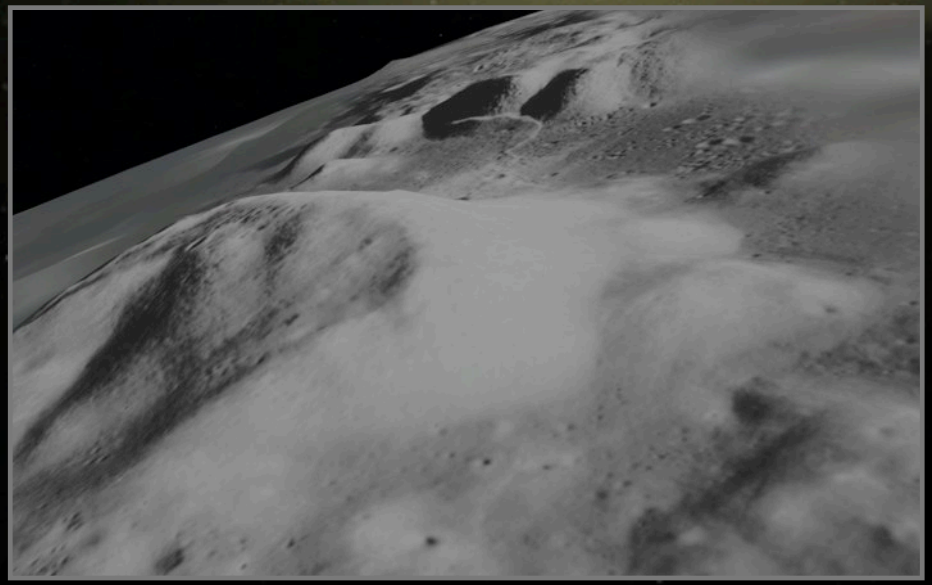
Digital Techniques for Imaging & the Development of Lunar DEMs



Michael Broxton
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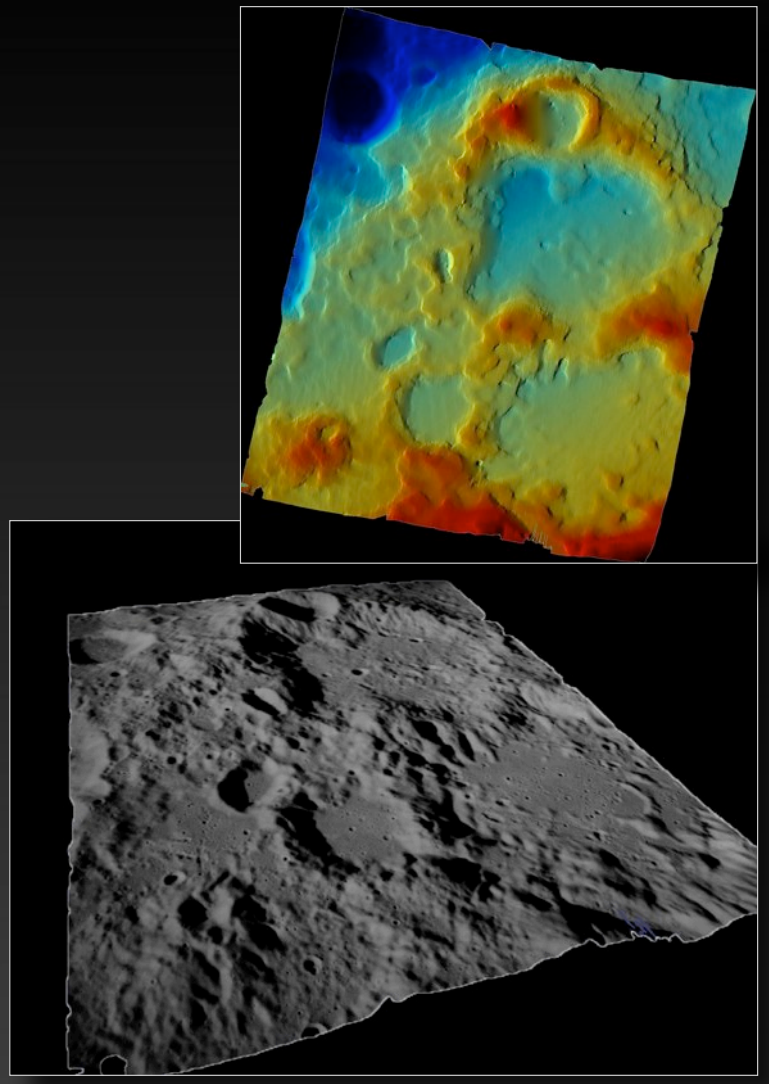
NASA Ames Research Center

Go for Lunar Landing:
From Terminal Descent to Touchdown.

March 3, 2008

Outline

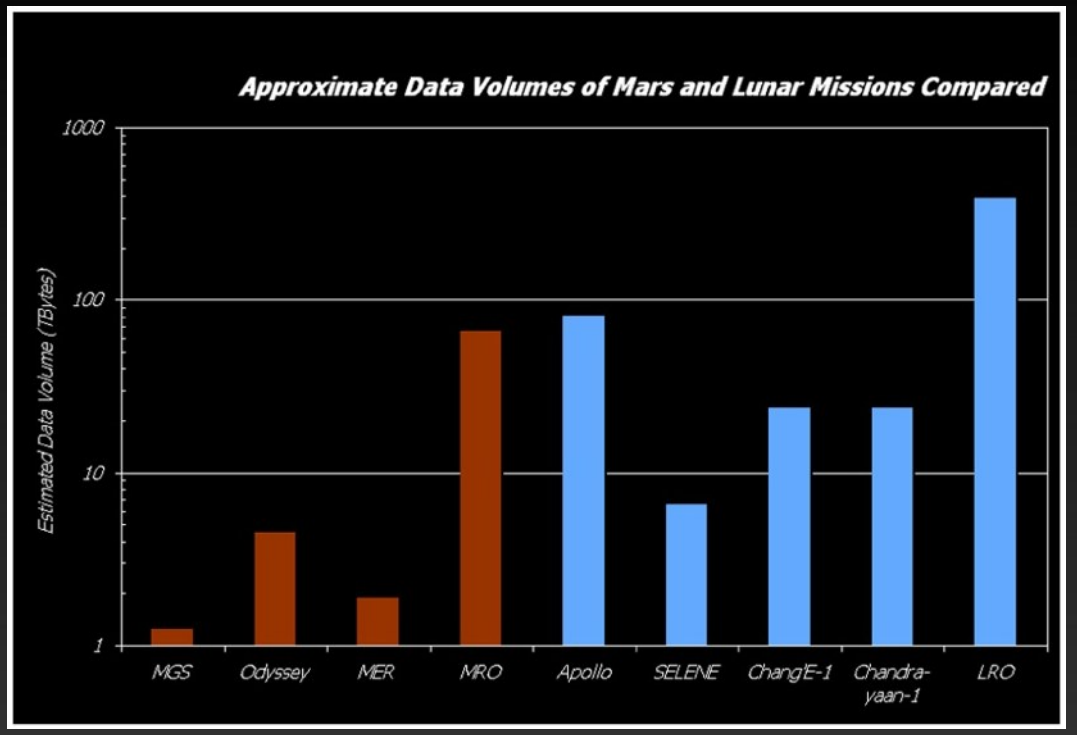
- Preparing for the Lunar data firehose. Are we ready?
- Super-scalable Data Processing
  - Automated tie-point generation
  - Large-scale mosaicking
  - Automated stereogrammetry
- Improved Data Access
  - Texture-based Image Search
  - Modern Geospatial Data Access
- Conclusions: Impacts to the Constellation planning process.



3D Surface Reconstruction from Apollo Metric Camera Frames AS15-M-0081 & AS15-M-0082

Preparing for the LRO Firehose

- Data volumes from LRO will be substantially larger than any previous mission. (note the *log scale* in the figure to the right...)
- Currently, critical efforts such as the Clementine or Lunar Orbiter mosaics or updates to the lunar control network take years to complete.
- Human intensive processes need to be automated so that data can be processed more efficiently.

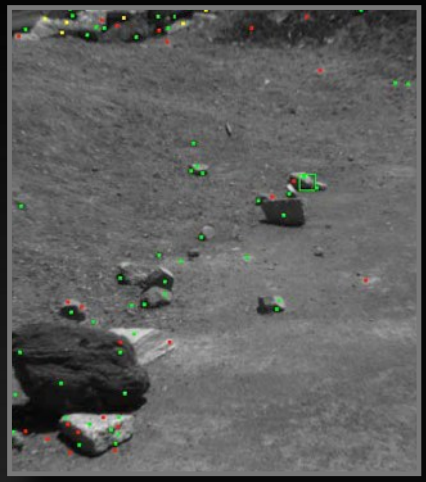


Source: B. A. Archinal, L. R. Gaddis, R. L. Kirk, T. M. Hare, and M. R. Rosiek. Urgent Processing and Geodetic Control of Lunar Data. Workshop on Science Associated with the Lunar Exploration Architecture, 2007.

With today's technology, we can process more data for less.

Automated Tie-Point Detection

- "Feature Based" image matching algorithms have been advancing in recent years to support image stitching and tracking applications in computer vision.
- These algorithms detect mathematically distinctive points
  - Repeatable & extremely robust

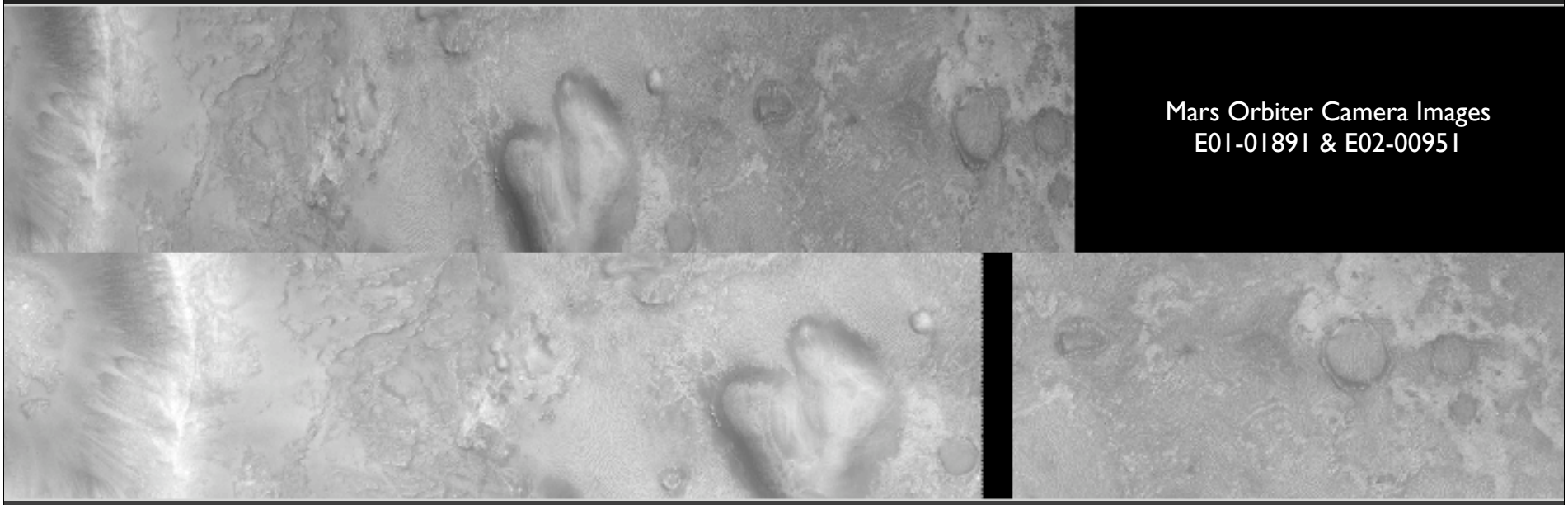


Current State of the Art

Human analyst, some automatic tie-point matching. (weeks to months)

Upcoming State of the Art

Fully automatic tie-point matching. (minutes to days)



Mars Orbiter Camera Images
E01-01891 & E02-00951

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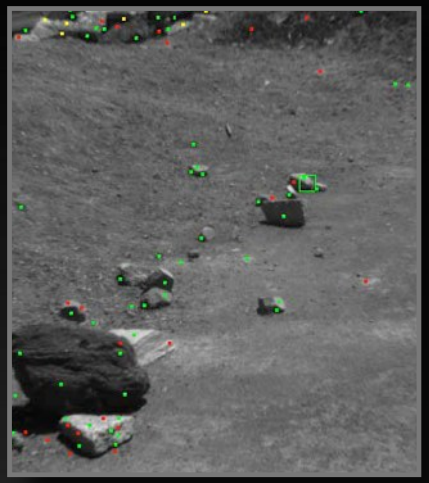

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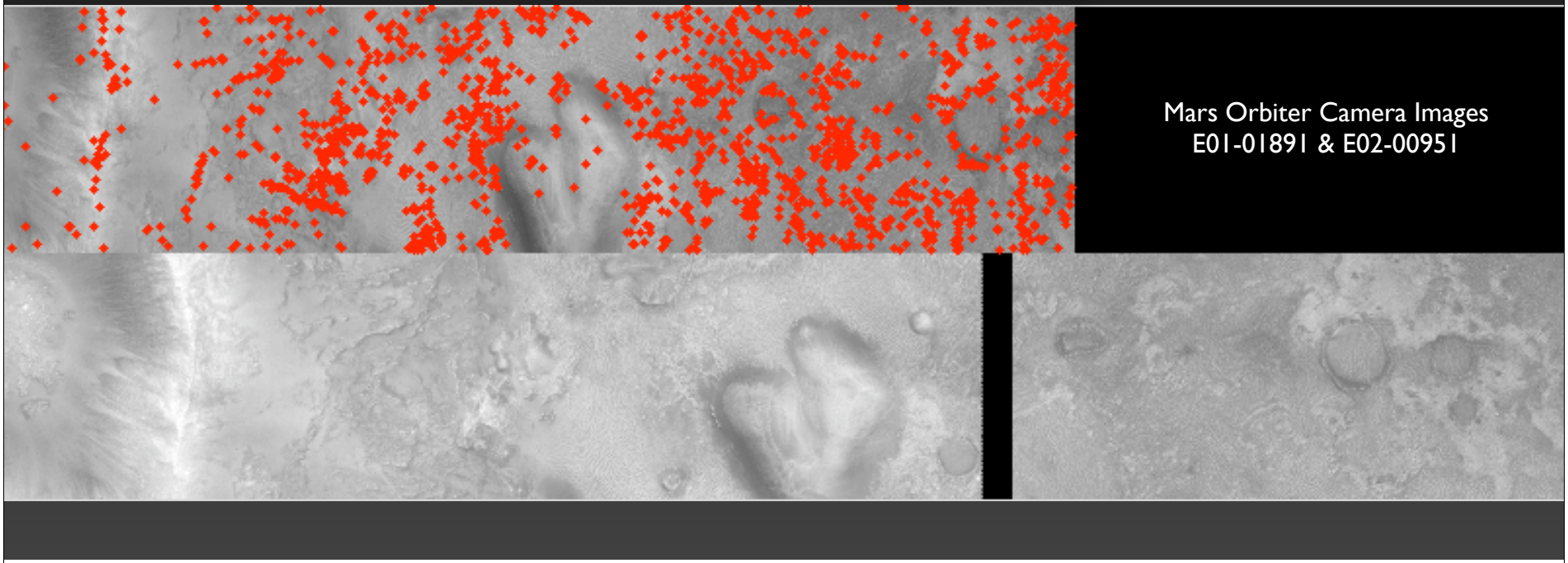

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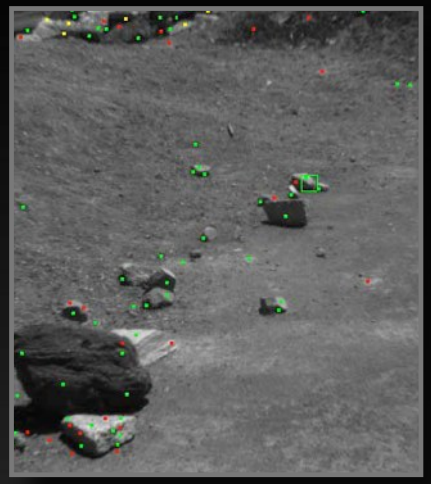

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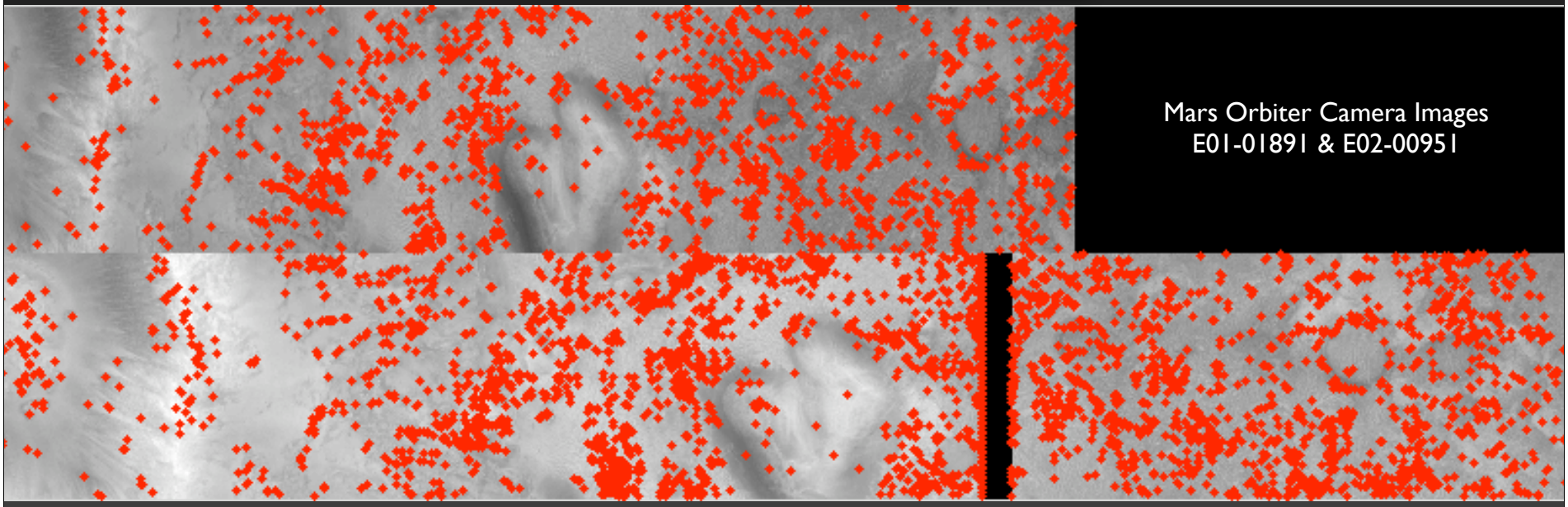

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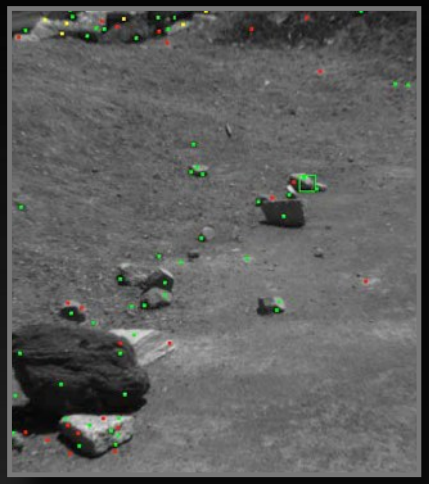

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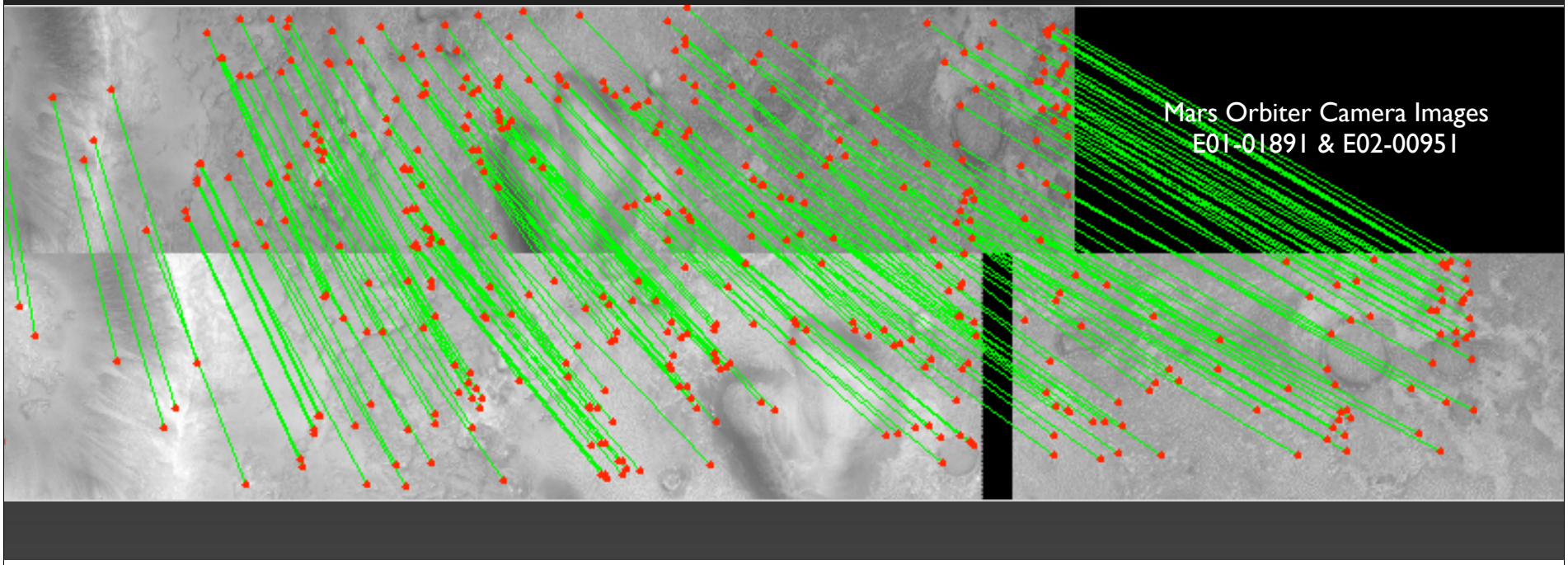
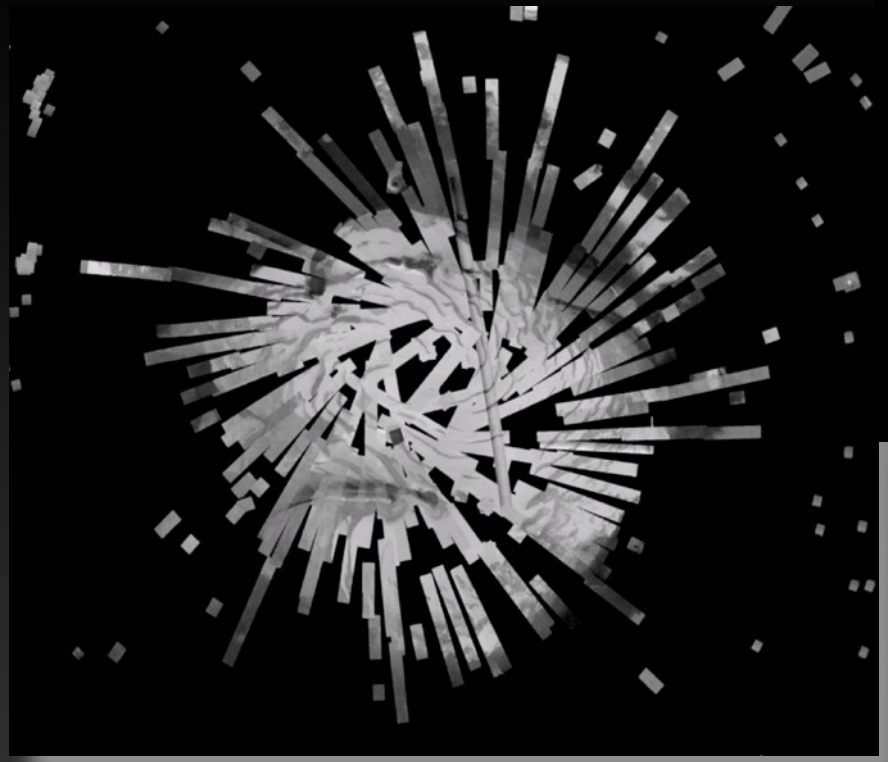


Large-Scale Mosaicking



CTX Polar Mosaic (Ames/MSSS)

- 1610 source images
- 305-GB of source imagery
- 40.3 Gigapixels
- 120 CPU-hours
- Two weeks of development time.

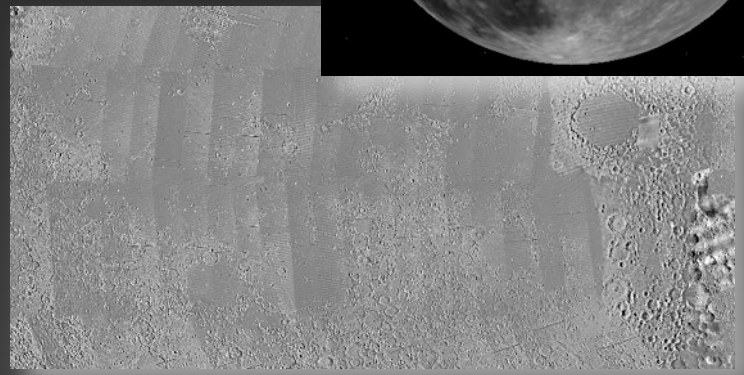
Current State of the Art

Clementine & LO-sized mosaics on powerful workstations (10-100's of GB)

Upcoming State of the Art

LROC & International mission composites on workstations and supercomputers (100's GB - 1's TB)

- Right: Clementine Mosaic (USGS)
- Below: Lunar Orbiter Mosaic (USGS)



Faster, more powerful Mosaicking capabilities for producing extremely large, global mosaics

- More imagery can be processed in a timely manner using NASA's supercomputers.
- Generate multiple level-of-detail imagery a la Google Earth.

Automated Stereo Image Processing

- Given multiple images, computes the 3D terrain using an area-based correlation technique or Stereo Photoclinometry (SPC).
- Very similar to the stereo processing pipelines that have been developed by our International partners (e.g. ESA and JAXA)
- Automation allows us to compute a VERY large number of stereo pairs of reasonable quality with no human intervention (but does not replace photogrammetric workstations for critical mapping applications).

Current State of the Art

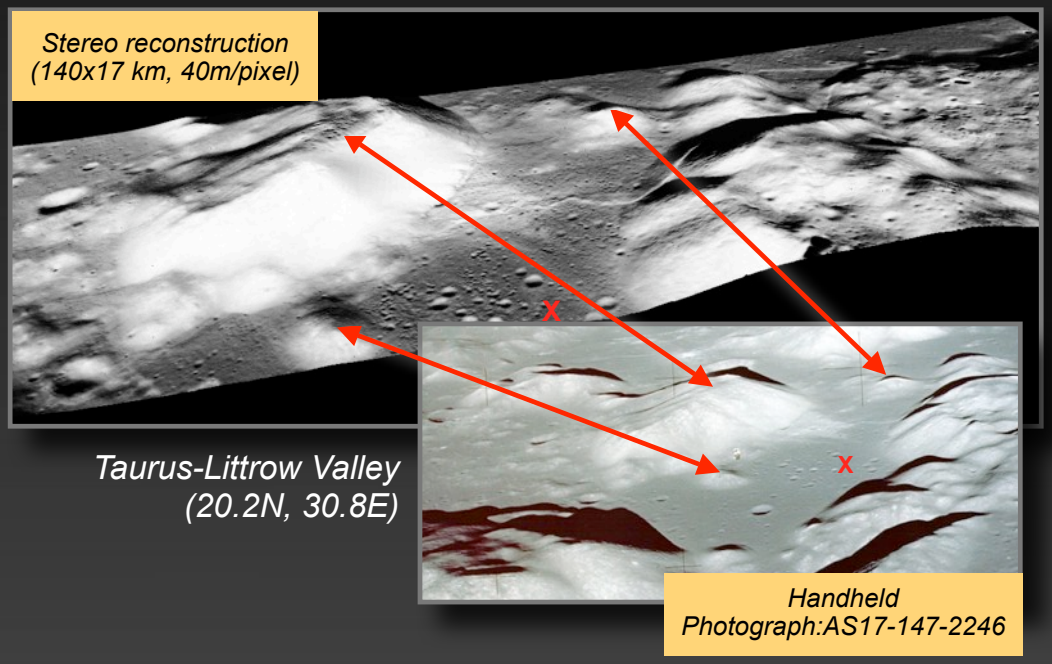
Photogrammetric Workstation w/ Human Operator (days to weeks)

Upcoming State of the Art

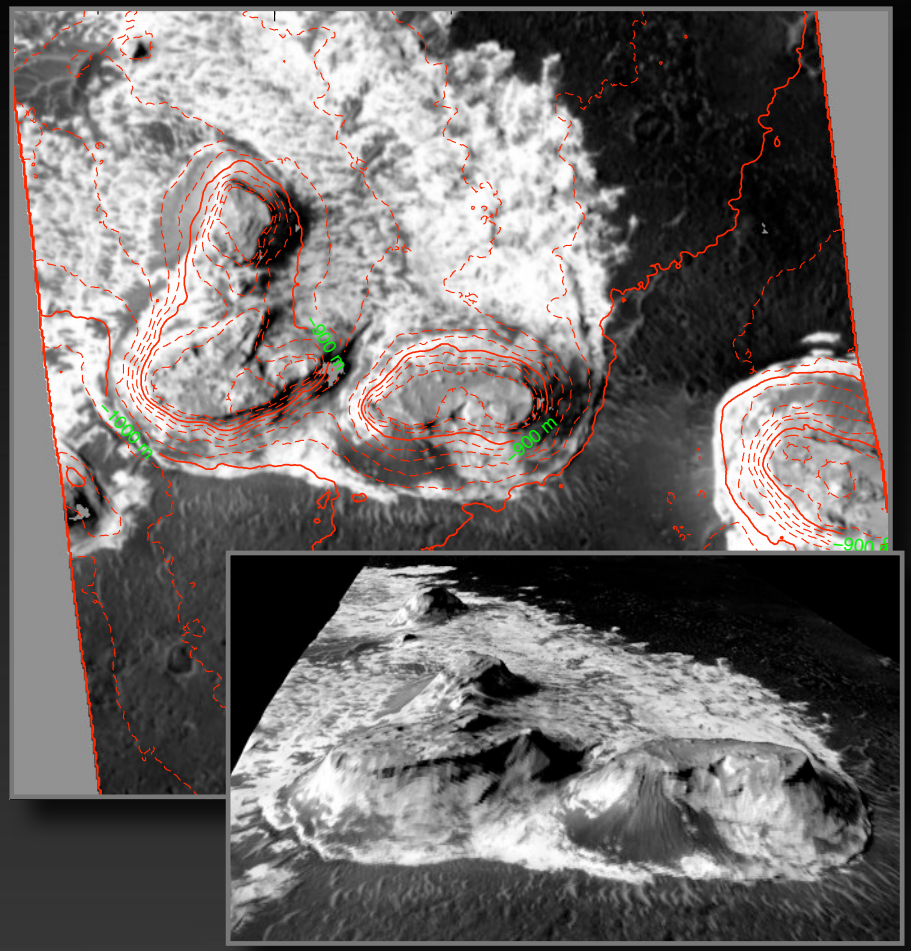
Automated stereo matching w/ human quality control. (minutes to days)

An increase DEM generation throughput will produce more, higher resolution DEMs!

- Landing Site Selection & Analysis: visible imagery and multi-spectral data is "draped" over DEMs prior to mosaicking. The better the DEM, the better the alignment.
- Terrain Relative Navigation: Regional, high resolution DEMs will serve ALHAT, the Lunar Surface Operations Simulator (LSOS), and other simulation and training programs.

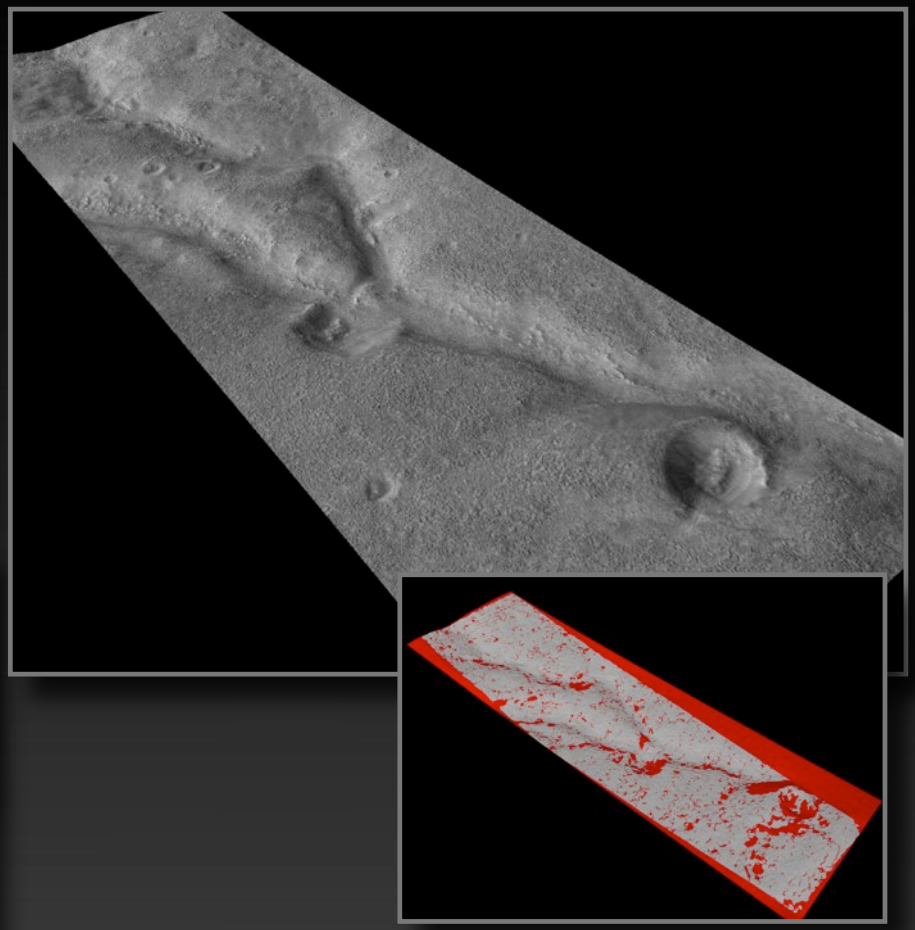


Automated Stereo Image Processing



Above Left: This DEM was generated from MOC images E04-01109 and M20-01357 (2.38°N, 6.40°E). The contour lines (20m spacing) overlay an ortho-image generated from the 3D terrain model.

Above Right: An oblique view of the corresponding VRML model.

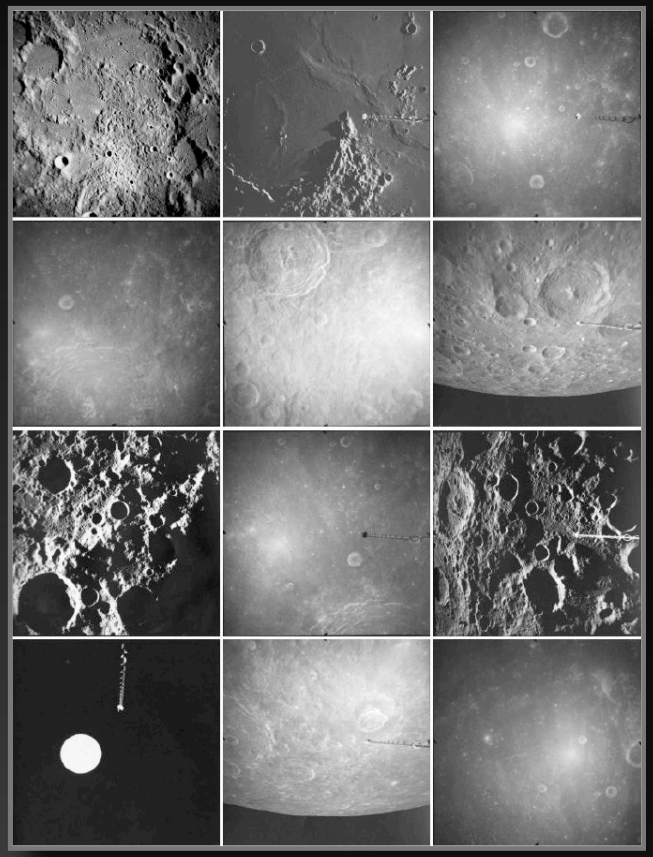


Above Left: This 3D model was generated from MOC-NA images E01-02032 and M07-02071 (42.66°S, 93.55°E).

Above Right: Areas of interpolated data are colored red. The complete stereo reconstruction process takes approximately five minutes on a 3.0GHz workstation (1024x8064 pixels)

Texture-based Image Search

Problem: Given an image, find others like it.



Example database: Apollo Metric Camera images

Image

512x512 Pixel Image

Current State of the Art
Search by target, spacecraft, location, lighting angle, etc.

Upcoming State of the Art
Search using example (query) image, geologic feature, scientific paper.

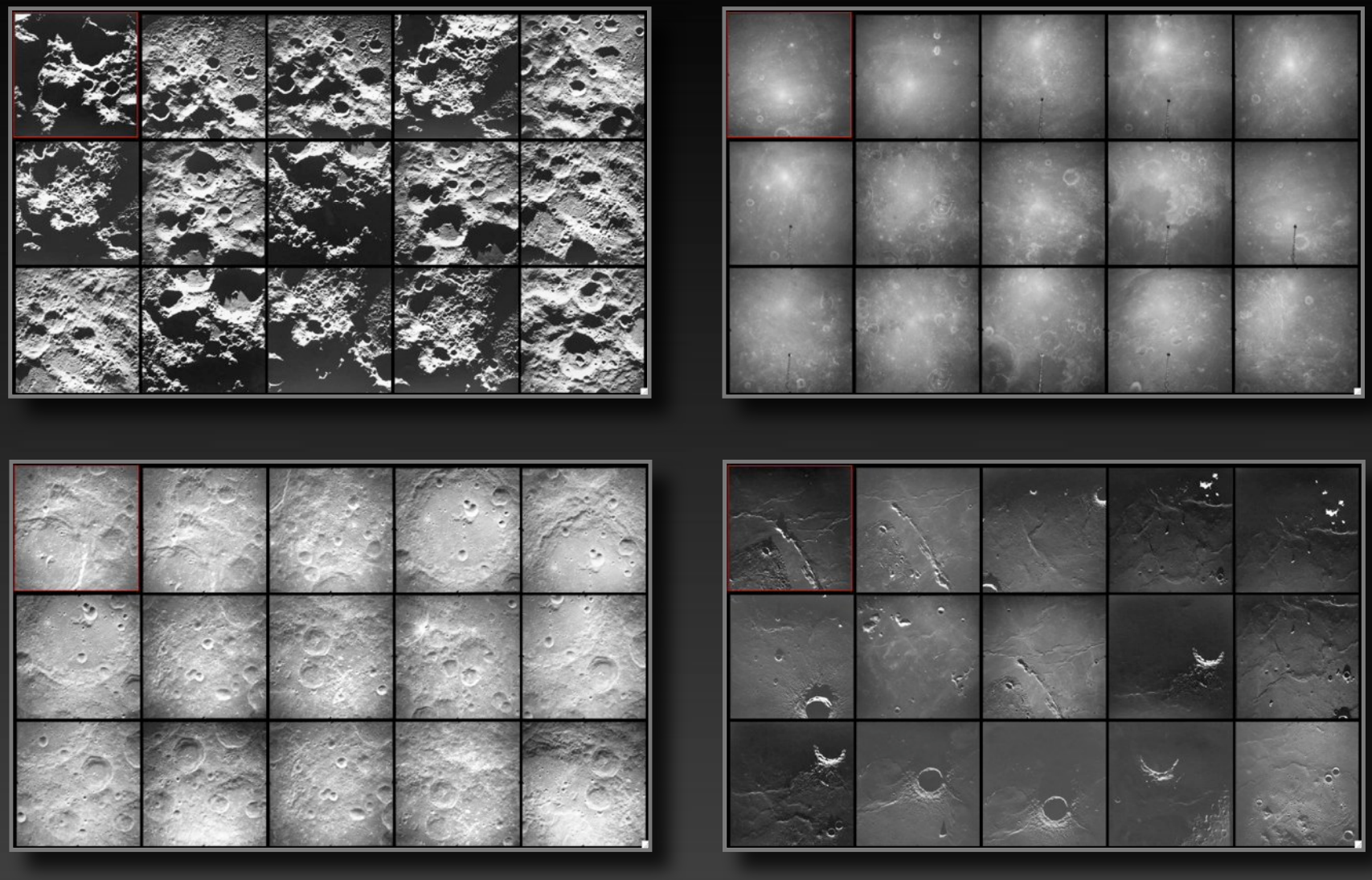
Filtering	Texture bank filtering (Gaussian 1st derivative and LOG)
Output Representation	Grouping to remove orientation Energy in a window
Segmentation	E-M Gaussian mixture model Iterative tryouts, MDL
Post-processing	Max vote
Summarization	Grouping Mean energy in segment

[0.2443, 3.234 , ...]

128-dimensional Vector

Texture Descriptor

Image Matching: Results



Modern Geospatial Data Access

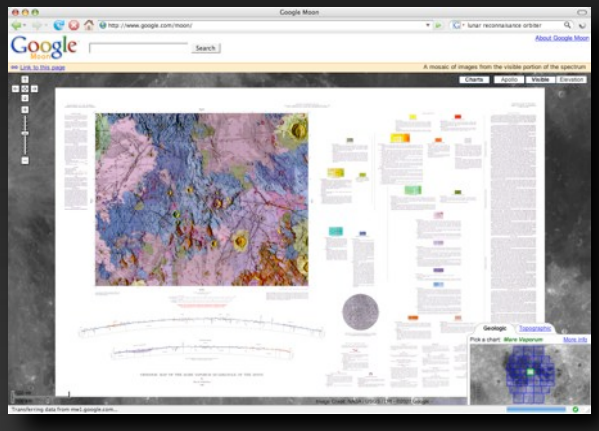
- Make NASA's Earth, Moon, & Mars imagery and geospatial information universally and easily accessible.
- Target both the general public and scientists as users.
- Leverage open standards and the Geobrowser platforms.

Current State of the Art

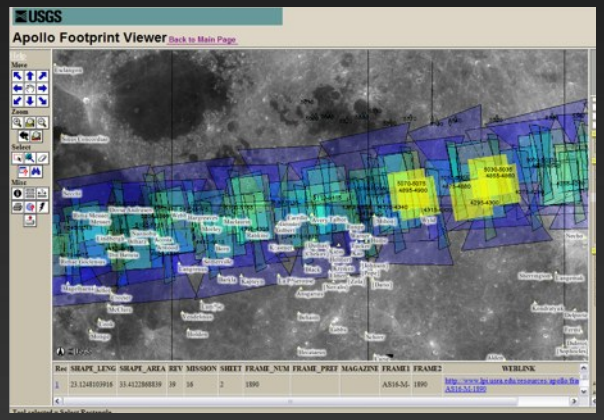
Access to data in archival form through GIS interfaces. (cumbersome, though powerful)

Upcoming State of the Art

Geobrowsers, web interfaces, and extensible API's. (efficient & intuitive, powerful in its own way)



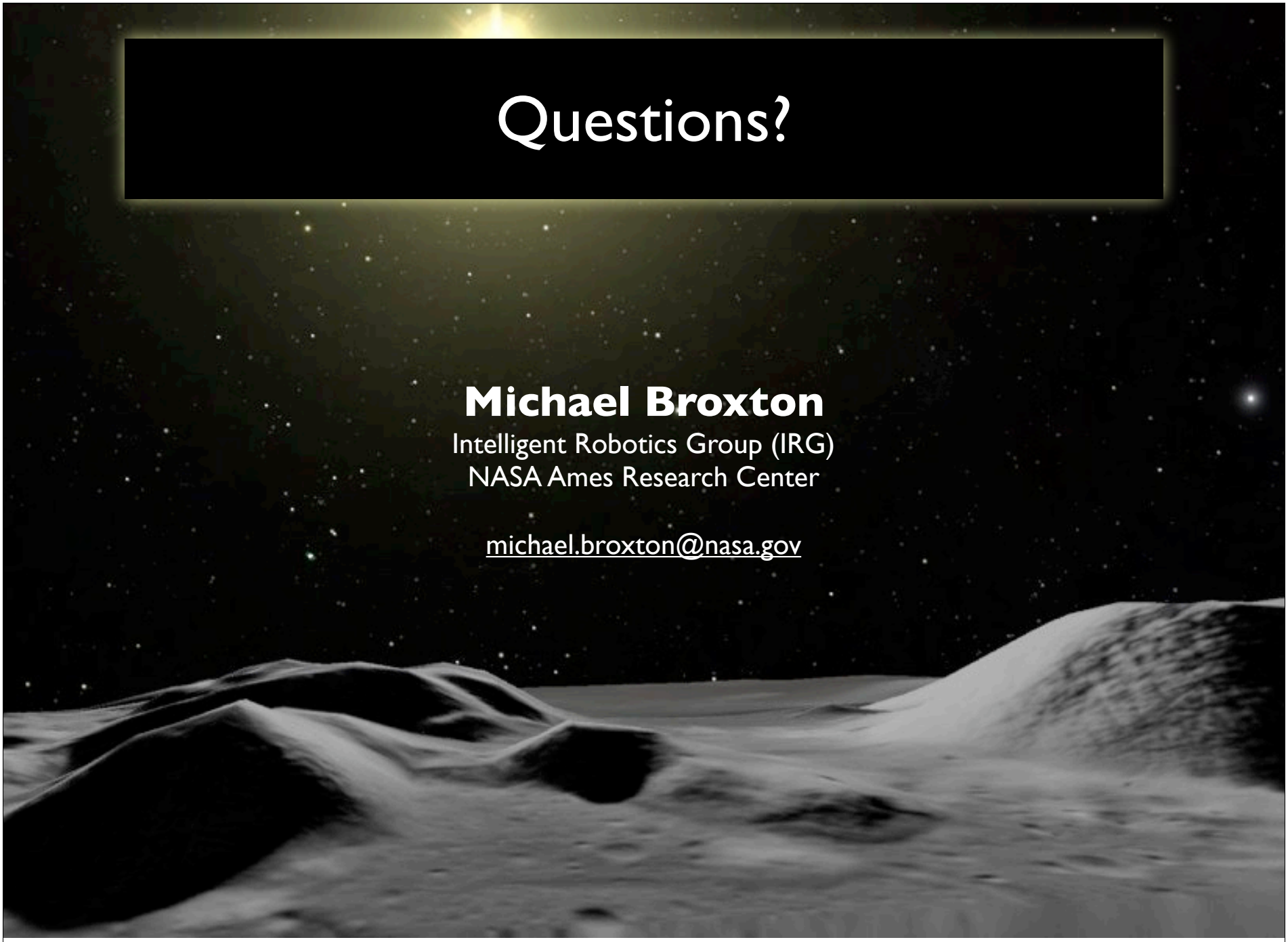
Unprecedented Data Availability & Fusion



Geospatial Image Browsing/Indexing

Open/Extensible APIs

http://moon.google.com



Questions?

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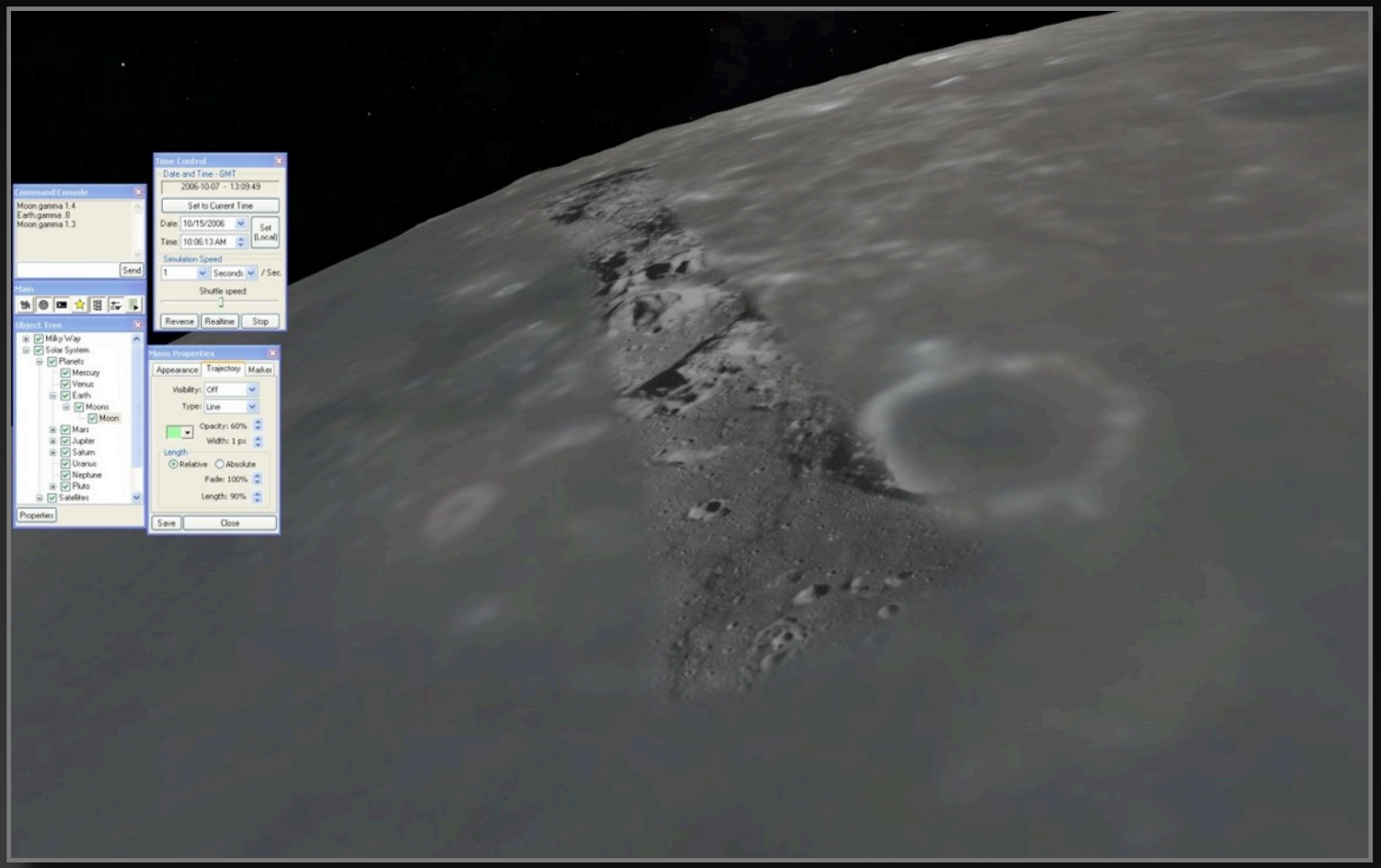
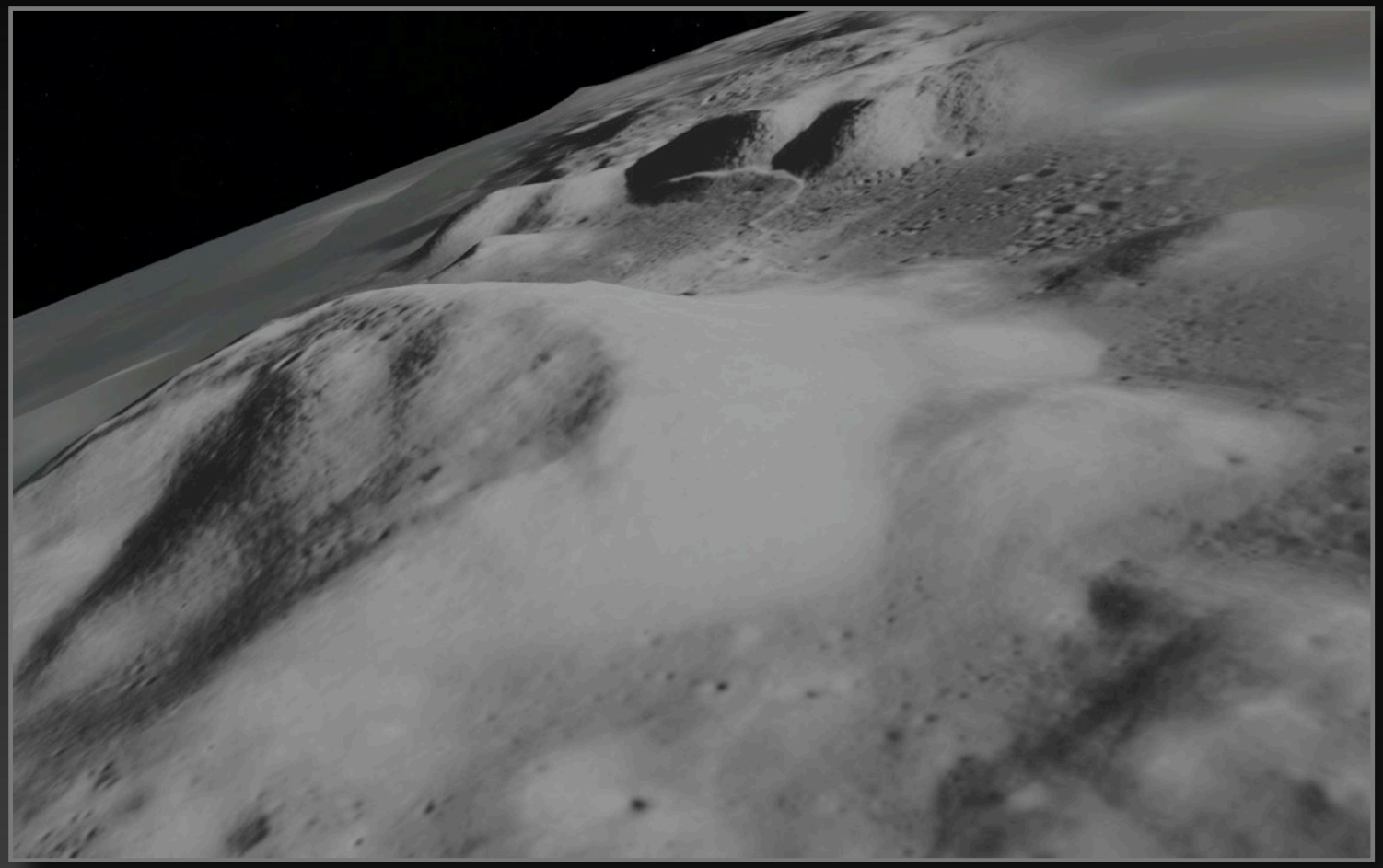
Extras: Landing "Simulation"



Example: Landing "Simulation"



Example: Landing "Simulation"