#1376

Controlling Oblique Apollo 15 Metric Camera Images: Final Results

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INTRODUCTION

The USGS Astrogeology Science Center (ASC), the Intelligent Robotics Group of the NASA Ames Research Center (ARC), and the Arizona State University (ASU) are working together to develop mapping data from Apollo lunar missions AS15, AS16, and AS17 into versatile digital map products with a variety of scientific/engineering uses.

The NASA Johnson Space Center and ASU scanned the original image negatives at film-grain resolution and created a digital record of support data. With the Ames Stereo Pipeline and the USGS Integrated Software for Imagers and Spectrometers (ISIS), the ARC previously completed our joint project to produce a controlled, orthorectified digital image mosaic (DIM) and terrain model (DTM) from AS15-17 nadir Metric Camera (MC) images. Now the USGS has completed photogrammetric control of the oblique MC images from AS15.

Apollo lunar missions AS15-17 included a Metric (mapping) Camera (MC), a high-resolution Panoramic Camera (PC), and a star camera and laser altimeter to provide support data.

Apollo Command and Service Module (CSM) with Lunar Mapping Camera system and Panoramic Camera in the Scientific Instrumentation Module (From NASA image AS15-88-11972). Mapping Camera System detail (NASA/Fairchild).

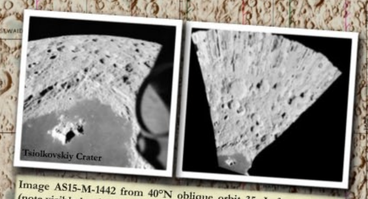
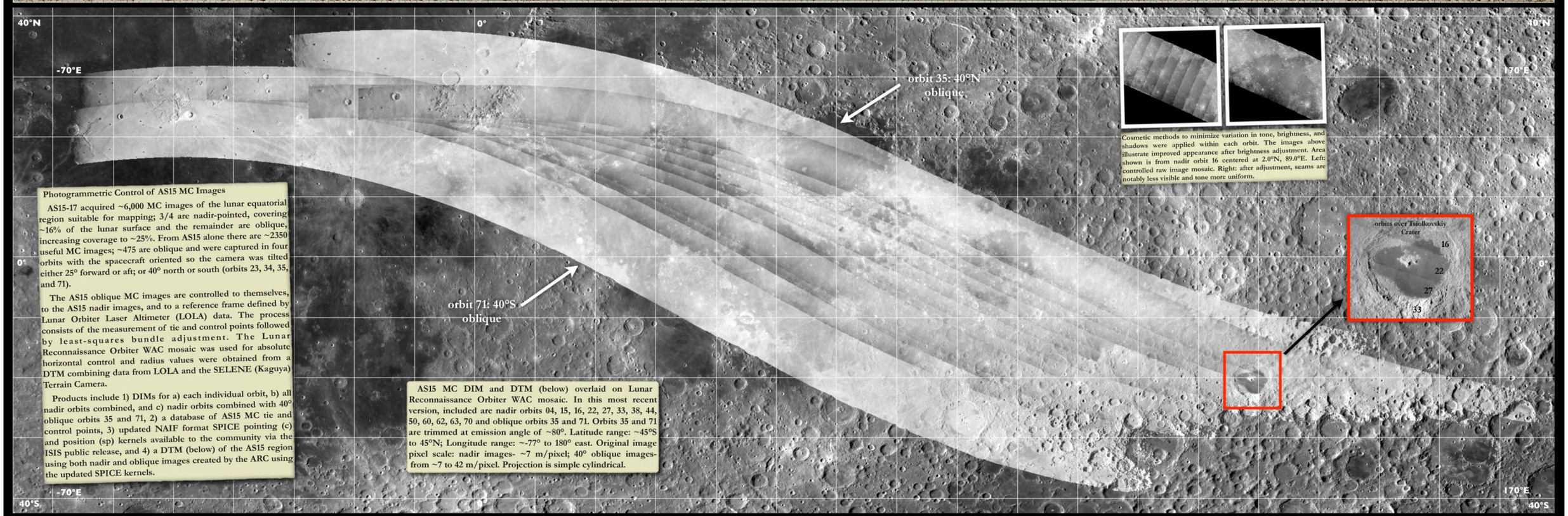


Image AS15-M-1442 from 40°N oblique orbit 35. Left: raw image (note visible hardware). Right: projected image shows artifacts that may occur when projecting oblique data toward the limb.



Cosmetic methods to minimize variation in tone, brightness, and shadows were applied within each orbit. The images above illustrate improved appearance after brightness adjustment. Area shown is from nadir orbit 16 centered at 2.0°N, 89.0°E. Left: controlled raw image mosaic. Right: after adjustment, seams are notably less visible and tone more uniform.

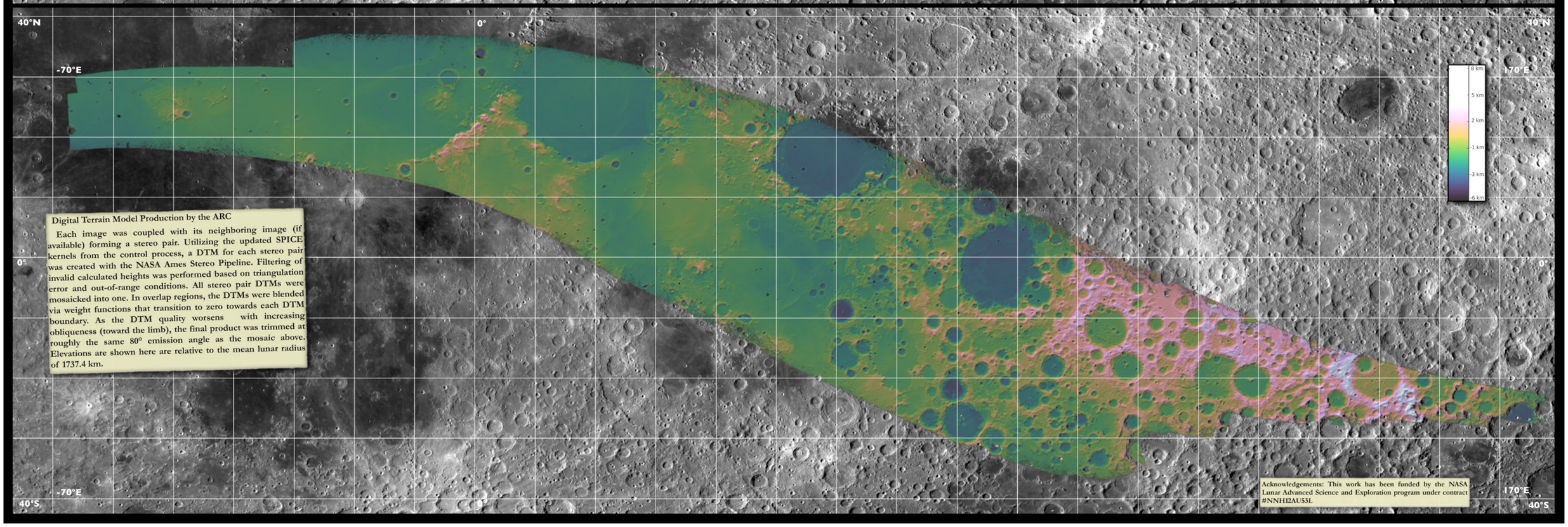
Photogrammetric Control of AS15 MC Images

AS15-17 acquired ~6,000 MC images of the lunar equatorial region suitable for mapping; 3/4 are nadir-pointed, covering ~16% of the lunar surface and the remainder are oblique, increasing coverage to ~25%. From AS15 alone there are ~2350 useful MC images; ~475 are oblique and were captured in four orbits with the spacecraft oriented so the camera was tilted either 25° forward or aft; or 40° north or south (orbits 23, 34, 35, and 71).

The AS15 oblique MC images are controlled to themselves, to the AS15 nadir images, and to a reference frame defined by Lunar Orbiter Laser Altimeter (LOLA) data. The process consists of the measurement of tie and control points followed by least-squares bundle adjustment. The Lunar Reconnaissance Orbiter WAC mosaic was used for absolute horizontal control and radius values were obtained from a DTM combining data from LOLA and the SELENE (Kaguya) Terrain Camera.

Products include 1) DIMs for a) each individual orbit, b) all nadir orbits combined, and c) nadir orbits combined with 40° oblique orbits 35 and 71, 2) a database of AS15 MC tie and control points, 3) updated NAIF format SPICE pointing (c) and position (sp) kernels available to the community via the ISIS public release, and 4) a DTM (below) of the AS15 region using both nadir and oblique images created by the ARC using the updated SPICE kernels.

AS15 MC DIM and DTM (below) overlaid on Lunar Reconnaissance Orbiter WAC mosaic. In this most recent version, included are nadir orbits 04, 15, 16, 22, 27, 33, 38, 44, 50, 60, 62, 63, 70 and oblique orbits 35 and 71. Orbits 35 and 71 are trimmed at emission angle of ~80°. Latitude range: ~45°S to 45°N; Longitude range: ~-77° to 180° east. Original image pixel scale: nadir images- ~7 m/pixel; 40° oblique images- from ~7 to 42 m/pixel. Projection is simple cylindrical.



Digital Terrain Model Production by the ARC

Each image was coupled with its neighboring image (if available) forming a stereo pair. Utilizing the updated SPICE kernels from the control process, a DTM for each stereo pair was created with the NASA Ames Stereo Pipeline. Filtering of invalid calculated heights was performed based on triangulation error and out-of-range conditions. All stereo pair DTMs were mosaicked into one. In overlap regions, the DTMs were blended via weight functions that transition to zero towards each DTM boundary. As the DTM quality worsens with increasing obliqueness (toward the limb), the final product was trimmed at roughly the same 80° emission angle as the mosaic above. Elevations are shown here are relative to the mean lunar radius of 1737.4 km.

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Scanned map courtesy Lunar and Planetary Institute
http://www.lpi.usra.edu/resources/mapcatalog/apolloindex/apollo15/