

THE APOLLO DIGITAL IMAGE ARCHIVE: NEW RESEARCH AND DATA PRODUCTS

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Introduction: Tens of thousands of images were acquired with handheld and automated camera systems during the Apollo missions. These scientifically and historically profound films were processed, analyzed, and are now stored at the NASA Johnson Space Center (JSC). Because of their historical significance, typically only 2nd or 3rd generation film products have been available for study or reproduction. To allow researchers and the general public access to the original flight films for the first time, JSC and the Arizona State University (ASU) School of Earth and Space Exploration (SESE) are scanning all of the Apollo flight films and creating an online digital archive [Figure 1; <http://apollo.sese.asu.edu>]. A description of the Archive is provided in [1]. Here, we provide information on the current status of the Archive and discuss examples of the exciting new data products enabled by this project.

Background: The Apollo missions carried a variety of photographic equipment, from handheld 35mm and 70mm Hasselblad cameras to sophisticated photogrammetric cameras mounted on the Apollo Command Module (CM).

Metric Frames: The Apollo Lunar Mapping Camera, also known as the metric camera, was carried aboard the final three Apollo missions [2]. The metric camera was designed to provide medium- to high-resolution photographs of the lunar surface from orbit under sunlit conditions. The metric images were acquired as a series of overlapping frames to enable the creation of detailed topographic and geologic maps of the lunar surface. More than 10,000 individual metric photographs covering nearly 20% of the lunar surface were acquired [2].

Procedures: A complete description of the scanning and archival procedures is provided in [1]. Briefly, the original Apollo flight films are stored in sealed canisters within the Film Archive (a freezer vault within a refrigerator) at JSC. These original films are removed from the Archive's freezer and allowed to slowly equilibrate with the ambient refrigerator temperature over a period of several days. The film is removed from the canister, non-abrasively hand-cleaned by the JSC curatorial staff, and scanned.

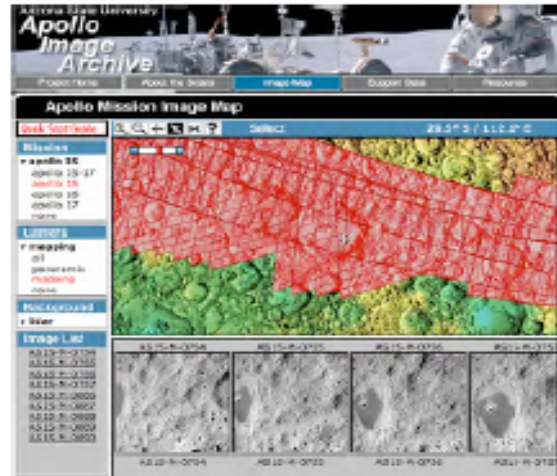


Figure 1: Web-based interactive interface for the Apollo Digital Image Archive. The red squares show the orbital track and image footprint of each frame.

This project strives to capture as much of the information content of the film as practical. Each metric frame is scanned using a Leica Geosystems DSW 700 photogrammetric scanner, which obtains 200 pix/mm (5 $\mu\text{m}/\text{pixel}$) spatial resolution and 14-bit A/D ($\sim 16,000$ gray levels). The small pixel size and 14-bit grayscale result in very detailed scans and very large files (~ 1.3 Gbytes). After scanning, the film is returned to the freezer vault for archiving.

The raw scans, which are stored as 16-bit Tagged Image File Format (TIFF) files, are processed to create virtual prints. As described in [1], the end product is a straightened, flatfield-corrected, reseau-removed "virtual print" that simulates the natural contrast of a conventional paper print. These virtual prints are provided as scaled large 16-bit TIFF files and 8-bit low-, medium-, and high-resolution Portable Network Graphics (PNG) files. The original 16-bit raw scans are also archived and available from the webpage.

Utilization: The digital availability of ultra-high resolution images from the Apollo missions enables many new research and educational outreach activities. Examples include:

Mosaics: We are reducing the original Apollo CM state vectors to SPICE kernels from scans of micro-film produced by the National Space Science Data

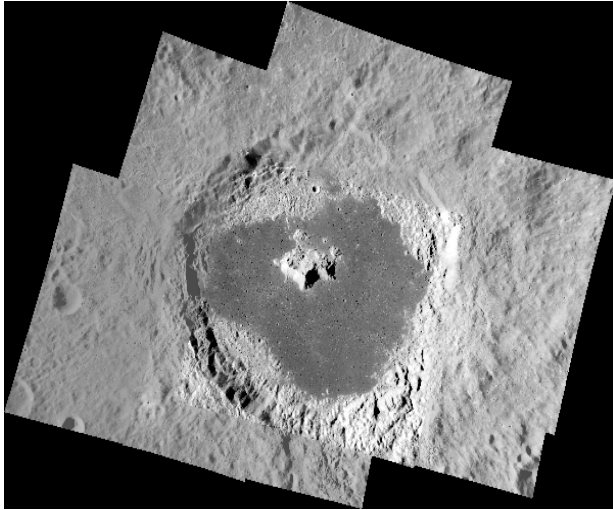


Figure 2: Preliminary mosaic of Apollo Metric Mapping Camera frames showing Tsiolkovsky crater.

Center (NSSDC) [3]. The SPICE kernels allow the metric frames to be put into a cartographic framework for searching, reprojecting, and mapping. To facilitate the creation of large mosaics, we will eventually provide ISIS3 headers for all of the metric frames available from the online Archive. **Figure 2** shows an example of a mosaic of Tsiolkovsky crater created using the Apollo image SPICE kernels and the USGS ISIS3 software package.

Stereo: The complete set of Apollo Metric Camera scans represent tens of terabytes of stereo image data that could be processed *in bulk* to produce a high resolution digital elevation model (DEM) covering significant portions of the equatorial region of the Moon. A pilot project is underway at Ames Research Center to assess the feasibility of an efficient approach to this large data processing effort using automated stereo reconstruction tools that run on NASA's Columbia Supercomputer. This software, the Ames Stereo Pipeline [4], has been integrated with the USGS ISIS software package [5]; thereby allowing efficient access to the Apollo Metric Camera model (and Panoramic Camera model, when it becomes available) implemented in ISIS3 by ASU. **Figure 3** illustrates digital elevation model results from an early run of the Ames Stereo Pipeline.

Outreach: To help increase public interest in lunar exploration, ASU SESE is providing a "Lunar Image of the Week" that features a metric frame showing a significant feature of the lunar surface accompanied by commentary from lunar scientists. The Lunar Image of the Week is accessible online at <http://apollo.sese.asu.edu/LIW>.

Exploration Preparation: The digital scans of the Apollo metric frames are of comparable size to the

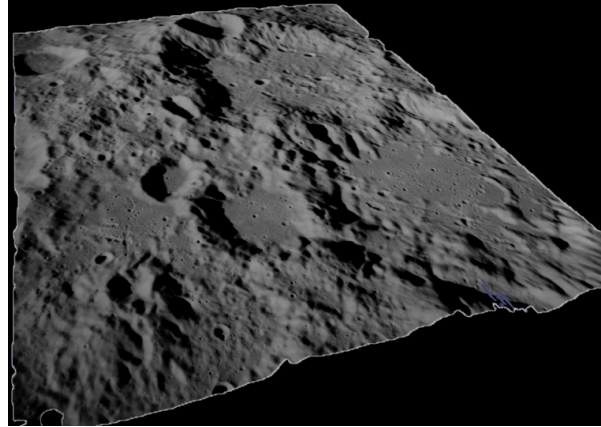


Figure 3: Three-dimensional surface reconstruction from Apollo Metric Camera Frames AS15-M-0081 and AS15-M-0082. Smooth areas represent interpolated data.

data products that will be produced by ASU's Lunar Reconnaissance Orbiter Camera (LROC) when it reaches the Moon in late 2008. Apollo image processing is therefore being used to perform invaluable testing and development for the software and processing pipelines that will manage the forthcoming LROC data stream.

Current Status: As of April 2008, all of the metric frames have been scanned, and over 1000 Apollo 15 metric frames have been processed for distribution and are available for public download from the web Archive. Newly processed metric frames are being added on a bi-weekly schedule as the image processing continues.

Future work: We continue to make improvements to our web interface on the basis of user comments and our experience base. A special public web interface for the 620 Apollo 35mm photographs is under construction. Processing of the 10,153 metric frames should be completed by the end of 2008. Scanning of the 4612 images from the Apollo Panoramic camera system and the 20,000 handheld Hasselblad photographs has just begun. All of these image products will be distributed through the same ASU interactive web archive [<http://apollo.sese.asu.edu>].

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References: [1] Robinson M. S. et al. (2008) LPSC XXXIX Abstract 1391. [2] Masursky H., Colton G. W., El-Baz F., *Apollo Over the Moon: A View From Orbit*, NASA SP-362. [3] Schultz A. et al. (2008) LPSC XXXIX Abstract 2085. [4] Broxton, M.B., et al. (2008) LPSC XXXIX. [5] Gaddis, L.R., et al., (1997) LPSC XXVIII, 387-388.