THE APOLLO DIGITAL IMAGE ARCHIVE. M. S. Robinson[1,2], S. J. Lawrence[1], W. Close[3], R. Bode[3], J. M. Grunsfeld[3], R. Ingram[3], L. Jefferson[3], S. Locke[3], R. Mitchell[3], T. Scarsella[3], M. White[3], M. A. Hager[4], S. Mackwell[4], T. R. Watters[5], E. Bowman-Cisneros[1], J. Danton[1], E. Speyerer[1], A. Dam[7], A. Calarco[7], and J. Garvin[8], [1]School of Earth and Space Exploration, Arizona State Univ., Tempe, AZ, [2]mrobinson@asu.edu [3]NASA Lyndon B. Johnson Space Center, Houston, TX [4]Lunar and Planetary Institute, Houston, TX, [5]National Air and Space Museum Regional Planetary Image Facility, Washington, D. C., [6]United States Geological Survey Branch of Astrogeology, Flagstaff, AZ, [7]Leica Geosystems Geospatial Imaging, Atlanta, GA, [8]NASA Goddard Space Flight Center, Greenbelt, MD.

Introduction: Thousands of photographs were acquired with handheld and automated camera systems during the Apollo missions. These photographs are of profound historical and scientific importance. The original flight films were processed, analyzed, and stored at the NASA Johnson Space Center (JSC). Because of their historical significance, typically only duplicate (2nd or 3rd generation) film products are currently available for study or reproduction. To allow full access to the original flight films, JSC and the Arizona State University (ASU) School of Earth and Space Exploration (SESE) are scanning all of the original Apollo flight films and creating an online digital archive [**Fig. 1;** http://apollo.sese.asu.edu].

Background: The Apollo Lunar Mapping Camera system, also referred to as the metric camera, was carried aboard the command service modules of the final three Apollo lunar missions [**1**]. The metric camera was designed to provide medium- to high-resolution photographs of the lunar surface under sunlit conditions and acquired photos from lunar orbit throughout the mission. 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. During the course of Apollos 15, 16, and 17, over 10,000 individual frames were produced by the metric cameras, resulting in photographic coverage of almost 20% of the lunar surface [**1**].

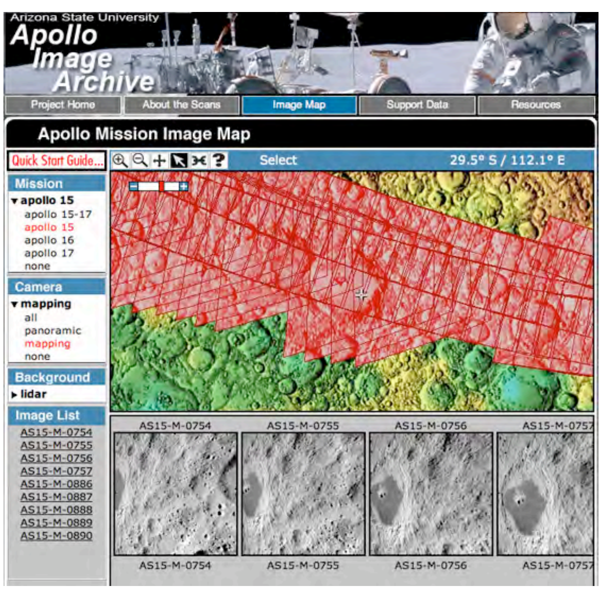

Fig. 1: *Web-based interactive interface for the Apollo Digital Image Archive. The red squares show the orbital track and image footprint of metric frames.*

Procedures: All of the original Apollo flight films are stored in the Film Archive (Building 8) at Johnson Space Center (JSC). The film is stored in a freezer (0° F), which is located in a large refrigerator that is maintained at 55° F. The staff at JSC follows rigorous procedures to remove film from the freezer for scanning. The sealed film canister is identified and transferred from the freezer to the refrigerator where it equilibrates for 24 hours. The sealed canister is then removed from the refrigerator and placed in an ambient temperature environment for an additional 24 hours. The film is then removed from the canister and hand-cleaned using exacting procedures set forth by the JSC curatorial staff. Absolutely no abrasive techniques are used in the cleaning process in order to preclude the possibility of damage to the film. As a consequence of this precaution, the cleaning process only removes debris that are loosely adhered to the film (i.e., dust and lint) but any strongly adhered debris are simply left on the film and noted during subsequent digital image processing.

Finally, the films are scanned. An important aspect of this project is the effort to record as much of the information content of the film very as possible. Each metric frame is scanned using a Leica Geosystems DSW 700 photogrammetric scanner, which obtains a 200 pix/mm (5 micron pixels) spatial resolution and 14-bit A/D (16,384 shades of grey). The DSW 700 was modified from the original 12-bit A/D to a 14-bit A/D because the Moon is a very high-contrast target and the original film is capable of capturing a very wide range of grey scale variation. The combination of small pixels (5 micron) and the 14-bit gray scale results in a very detailed scan and thus a very large file (~1.3 Gbytes). Following the scanning process, the film is placed back in the canister, sealed, and then returned to the cold vault.

The scans are further processed using a standard set of procedures. First, the unexposed portions of the film along the edges of a scanned frame are cropped, and the frame is straightened. Second, the background (film base plus fog) is estimated and subtracted: we assume that the average digital number (DN) values of the unexposed regions at the edge of each raw image represent the background. Third, a flatfield correction (derived from the actual image data) removes vignetting to the first order. Fourth, the individual reseaux are located and removed from the images.

Fifth, a logarithmic transformation is applied to the image. This correction is necessary because of the logarithmic response of film, which results in the high visual contrast of the raw scan products. Since photographic paper also has a logarithmic response and reverses the film response, conventional paper prints exhibit a natural contrast range. The logarithmic correction and reversal to a positive image produces a "virtual print" that simulates the natural contrast of a conventional paper print.

Sixth, since the uncompressed images produced by the initial scanning process result in large files, the scale is reduced by the square root of two, reducing file size by 50%. For distribution and browse products, 8-bit (255 gray levels) [**Fig. 2**], versions are produced to promote ease of distribution by providing maximal compatibility with common web browsers and image software. *The original 16-bit raw scans are also available through the webpage.* Two commonly used data file formats have been selected for the distribution: Portable Network Graphics (PNG) and Tagged Image File Format (TIFF). The original raw scans are stored as 16-bit TIFF files. The processed images can each be obtained as a large 16-bit TIFF file and as 8-bit low-, medium-, and high-resolution PNG files.

Finally, we are reducing Apollo Command Module state vectors to SPICE kernels from scans of microfilm produced by the National Space Science Data Center [**2**]. The SPICE kernels put the Apollo images in a cartographic framework for searching and mapping.

Future Work: The scanning process will take about three years to complete. First, all of the Apollo 35-mm photographs were scanned (about 620 frames). Currently, the 10,153 frames collected by the metric camera are being scanned. Next, the 4,612 frames from the Panoramic camera system will be scanned. Finally, the approximately 20,000 Hasselblad photographs will be scanned. All of these image products will be distributed through the ASU interactive web archive [**Fig. 1;** http://apollo.sese.asu.edu].

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References: [**1**] Masursky H., Colton G. W., El-Baz, F., *Apollo Over the Moon: A View From Orbit,* NASA SP-362. [**2**] Schultz A. *et al.* (2008) LPSC XXXIX.

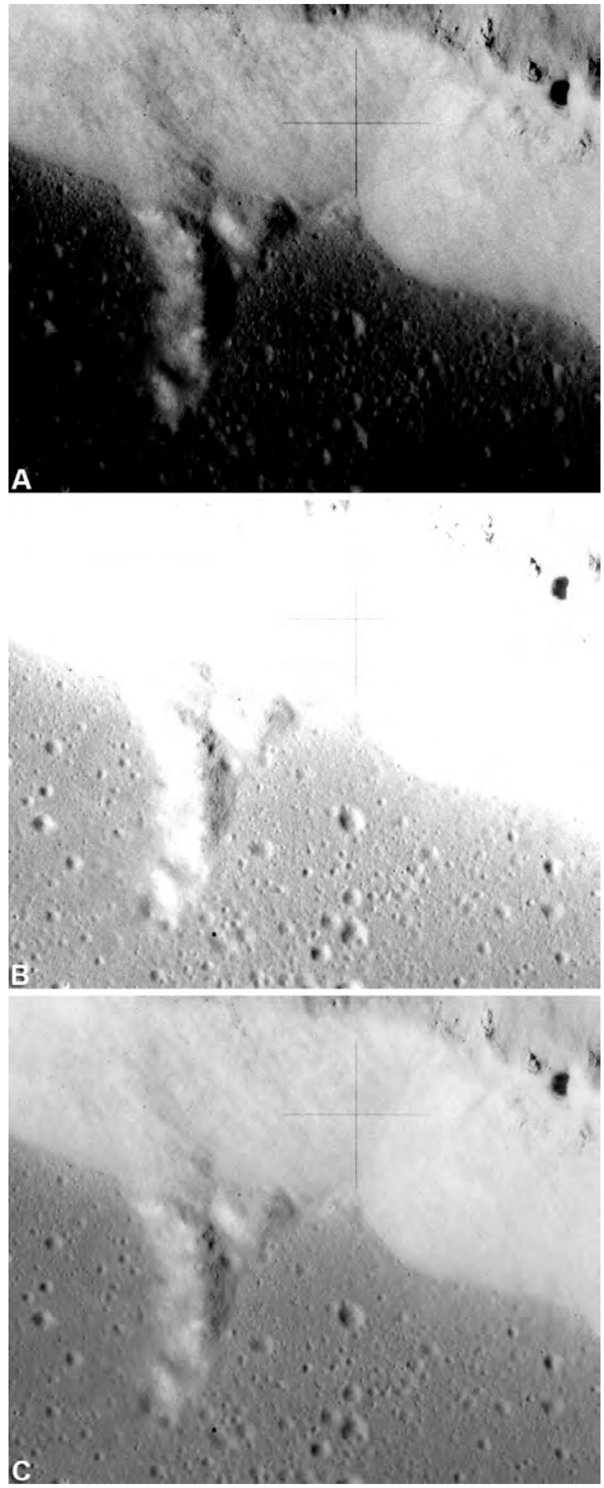

Fig. 2: Converting the original 14-bit scale scans (16,384 gray levels) to 8-bit scale (256 gray levels) results in a loss of shading information. An extreme case is shown above. **A**) Stretched to emphasize highlands (5250 original gray levels), **B**) mare specific stretch (5250 gray levels), and **C**) a compromise stretch for the whole area (8850 original gray levels).