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PHOTOGRAMMETRIC CONTROL OF OBLIQUE APOLLO 15 METRIC CAMERA IMAGES

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1. INTRODUCTION

In the early 1970s, an integrated photogrammetric mapping system was flown on the last three Apollo lunar missions (15, 16, and 17). The system included a Metric (mapping) Camera (MC), a high-resolution Panoramic Camera (PC), and a star camera and laser altimeter to provide support data [1]. Of the ~6,000 MC images suitable for mapping, ~3/4 are nadir-pointed, covering ~16% of the lunar surface. The remaining ~1,500 images are oblique, increasing useful coverage to ~25%. In the following, we address photogrammetric control of the MC images, in particular those with oblique geometry acquired on Apollo 15.

The NASA Johnson Space Center and Arizona State University (ASU) recently produced digital scans of the original MC negatives at film-grain resolution and created a digital record of support data (available via the ASU Apollo Digital Image Archive; http://apollo.sese.asu.edu) [2,3]. This work enables an ongoing collaboration between USGS Astrogeology, the Intelligent Robotics Group of the NASA Ames Research Center (ARC), and ASU to achieve the most complete cartographic development of Apollo mapping system data into versatile digital map products. In contrast to hardcopy image mosaics and topographic contour maps produced in the years immediately following the Apollo flights, digital Apollo images can be integrated easily with other digital lunar data and can be updated geodetically and cartographically as needed. This enables a variety of scientific/engineering uses of the data including mission planning, geologic mapping, geophysical process modeling, slope dependent correction of spectral data, and change detection.

2. CONTROLLING APOLLO 15, 16, AND 18 NADIR IMAGES

The ARC has completed our joint project to process the nadir images by making a photogrammetrically and geodetically controlled, orthorectified digital image mosaic (DIM) and digital terrain model (DTM) sampled at ~30 m/pixel and tied to a reference frame based on Lunar Orbiter Laser Altimeter (LOLA) data [4]. This work was achieved with the Ames Stereo Pipeline (ASP) software developed by the ARC [5] and the Integrated Software for Imagers and Spectrometers (ISIS) planetary cartography package developed by the USGS [6].

3. CONTROLLING APOLLO 15 OBLIQUE IMAGES

While oblique geometry complicates feature recognition and orthorectification, the USGS has previously shown such images can be rectified and provide valuable topographic information [7,8]. Though we will eventually control oblique images from all three missions, work is currently focused on Apollo 15. The ~450 Apollo 15 oblique images were acquired in four orbits with the spacecraft oriented so the camera was tilted either 40° south or north; or 25° aft or forward (orbits 71, 35, 34, and 23 respectively). At the time of writing, the four oblique orbits have been controlled separately in ISIS with the bundle adjustment module *jigsaw* [9] (**Table 1**). The Lunar Reconnaissance Orbiter Camera Wide Angle Camera mosaic [10] and LOLA DTM served as ground control.

Table 1: Apollo 15 oblique bundle adjustment statistics.

Orbit	# Images	Points			Rms residuals (pixels)
		# tie	# control	# measures	
23	115	907	12	3902	1.54
34	105	982	33	3350	1.51
35	116	727	6	2964	1.14
71	127	293	12	1428	1.12

3.1 Ongoing Work

We are working to control the oblique MC images to the ~1,500 Apollo 15 nadir images and to the LOLA reference frame. Tie-point extraction and matching of oblique to nadir images are nearly finished. After a complete control solution we will generate improved image position/pointing data facilitating the creation of an updated DTM for the region. A new control solution will be performed with this DTM as ground control and improved position/pointing data will be regenerated. The process of performing control solutions and regenerating topography will be iterated as needed.

3.2 Final Products

Results of this work will include an expanded database of Apollo 15 MC tie-points (consistent with the LOLA reference frame); improved image position/pointing data in the form of NAIF SPICE kernels [11]; and a DIM and DTM of the region.

4. FUTURE WORK

Our ultimate goal is to control all MC images from Apollo 15, 16, and 17. This is an important step in preparation to geodetically control the much larger Apollo PC image dataset which we intend to accomplish under a future proposal.

5. REFERENCES

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