APOLLO 17 LANDING SITE TOPOGRAPHY FROM LROC NAC STEREO DATA – FIRST ANALYSIS AND RESULTS. J. Oberst[1,2], F. Scholten[1], K.-D. Matz[1], T. Roatsch[1], M. Wählisch[1], I. Haase[2], P. Gläser[2], K. Gwinner[1], M.S. Robinson[3], and the LROC Team. [1]German Aerospace Center (DLR), Institute of Planetary Research, Rutherfordstr. 2, D-12489 Berlin, Germany, (juergen.oberst@dlr.de), [2] Technical University Berlin, Institute for Geodesy and Geoinformation Sciences, Berlin, [3]School of Earth and Space Exploration, Arizona State University, Tempe AZ, USA.

Introduction: The Lunar Reconnaissance Orbiter Camera (LROC) [1,2] provides image data with across-track stereo coverage from which digital terrain models (DTM) of the lunar surface can be derived. The commissioning phase (until September 15, 2009), was characterized by an elliptical orbit (45-190 km). LRO is now in the primary mission phase circular orbit, with its altitude varying about a mean of 50 km. We adapted the DLR photogrammetric processing system, which has been used operationally for 5 years for DEM generation from Mars Express HRSC [3,4] and other stereo imagery. While LROC WAC images (~100 m/pxl) are used for the derivation of global topography [5], we concentrate on LROC NAC data (~0.5-1.5 m/pxl) for local topographic mapping. We focus on the Apollo 17 landing site, which allows us to verify the model against the Lunar-fixed coordinate system and which is also of considerable interest to geologists. This work is part of a joint investigation on NAC stereo data within the LROC team [6,7,8,9].

NAC data: LROC NAC consists of 2 pushbroom scanners, NAC-L and NAC-R, both with an IFOV of 2 arcsec, 5,000 pxl/line. Camera distortion and alignment parameters have been calibrated prior to launch. SPICE kernels provide information about spacecraft clock, nominal orbit position, and pointing data. We used NAC data with 1.4 m/pxl from 2 subsequent orbits of the commissioning phase (orbit #533/534, Δt ~2 h, flight directions: N->S) with both L-images overlapping almost completely, both R-images respectively. Observation conditions are characterized by ~57° incidence and ~60° phase angle. The stereo angle is ~15°. The stereo models cover approx. 1000 km^2 (18.77°-21.15° N and 30.44°-30.91° E). The R-images include the Apollo 17 landing site at 20.19080 North, 30.77168 East, 1734814 m radius (Mean-Earth/Polar-Axis coordinates of the lunar module, LM, from [10]).

Analysis of camera alignment: While NAC prelaunch distortion parameters were used (without showing evidence of significant additional distortion parameters), relative alignment (NAC-L to NAC-R) and alignment of NAC to spacecraft was checked and corrected by comparison of the apparent position of the visible Apollo 17 LM with its position given by [10]. Within the NAC-R data the LM appeared 193 m north and 48 m east of the reference point. Within a first step, these metric deviations were transformed to two angular corrections of the NAC-R/spacecraft alignment, so that NAC-R data fit to the reference within the pixel scale. NAC-L alignment corrections were then derived by tying NAC-L to the alignment corrected NAC-R within the R/L overlap (NAC-L features appeared 99 m south and 35 m west of NAC-R, resp. 94 m north and 13 m east of the reference coordinates). Within a second step, corrections for the third alignment angle (vertical z-axis rotation) were found by minimizing stereo ray intersection variations across the swath of another stereo model, where a NAC-L and a NAC-R dataset from adjacent orbits overlap almost entirely (orbit #218/219, west of Apollo 16 landing site). Steps 1 and 2 were finally iterated until no further improvements could be achieved. With the retrieved alignment NAC-L and NAC-R images fit to each other at the pixel scale. The relative accuracy of nominal position and pointing for adjacent orbits is indicated by the remaining offset of 17 m resp. 6 m for the orbits of the Apollo 16 and 17 landing sites. The absolute accuracy for orbit/position data of single orbits is reflected by the deviation to reference coordinates of about 160 m at the Apollo 16 site (Apollo 17 has been perfectly tied to the reference).

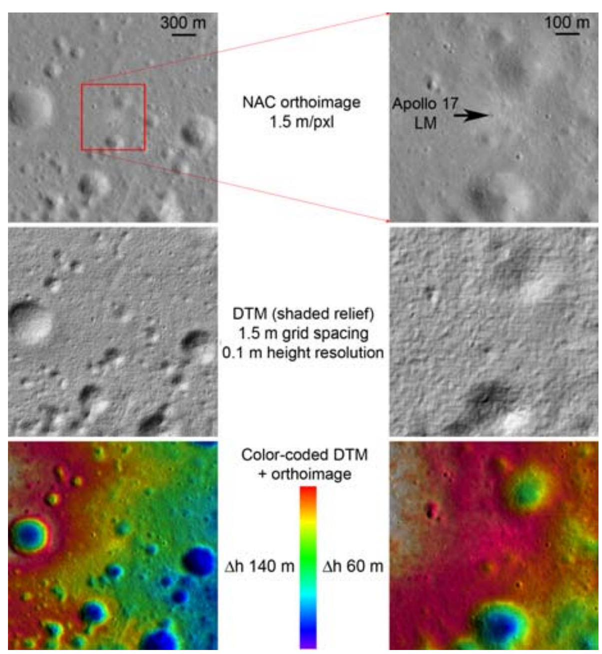

Fig. 1: Orthoimage and NAC DTM subsets @ Apollo 17 site

DTM and orthoimage generation: With the alignment corrections we calculated a DTM of the entire NAC strip by forward ray intersection using image coordinates from area-based image matching [11]. For analysis we used a grid spacing of the DTM of 1.5 m (close to the ground scale of the image data) and ortho-rectified the image data with this DTM to the same scale. We also corrected for a vertical 67 m offset (NAC DTM lower than reference), which was measured at the LM position.

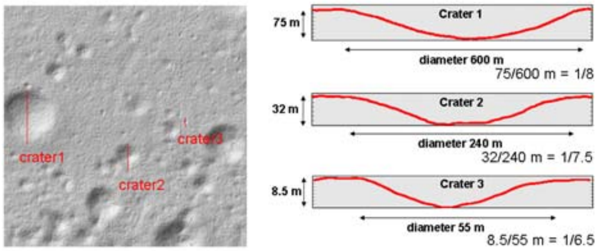

Fig.2: Exemplary crater profiles from NAC DTM

First results: Subsets of the Apollo 17 landing site DTM are shown in Fig. 1. The left side covers an area of 2.8 x 2.8 km, the right side 0.9 x 0.9 km. Fig. 2 illustrates, that craters of sizes down to at least 50 m are clearly represented, for statistics of depth/diameter ratios and detailed studies of crater morphologies. The profiles show low noise, i.e. few decimeters, fairly below the image ground scale (only barely visible within Fig. 2). With Fig. 3 we provide a perspective view from South-East to the Apollo 17 landing site in the Taurus-Littrow Valley the South Massif at the lower left side, and the North Massif in the upper central part. The entire NAC-R/R DTM is shown in Fig.4.

Summary and outlook: We could demonstrate the huge potential of LROC NAC stereo data for DTM generation at the meter scale. With improved alignment parameters a NAC stereo model of the Apollo 17 landing site could be precisely tied to LM reference coordinates. These preliminary alignment values are affected by orbit/pointing errors of the particular commissioning phase datasets that were involved. We will use other landing site datasets of the nominal mission to obtain better statistics and to further improve the alignment. Finally, LROC NAC DTM data are currently used for detailed comparisons with LRO LOLA altimeter data [12].

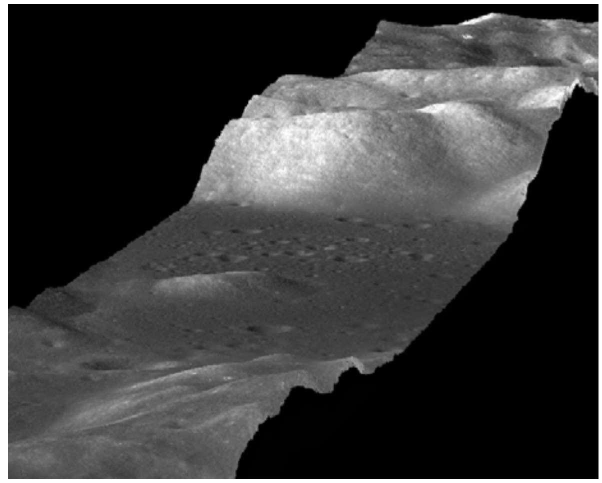

Fig 3: Perspective view of NAC-R orthoimage and DTM

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References: [1] M.S. Robinson et al. (2005) *LPSC XXXVI, Abstract #1576*. [2] G. Chin et al (2007) *Space Sci. Rev., 129:391–419, doi 10.1007/s11214-007-9153-y*. [3] K. Gwinner et al. (2009) *PE&RS, 75(9), 1127-1142*. [4] K. Gwinner et al. (2009) *Earth Planet. Sci. Lett., doi:10.1016/j.epsl.2009.11.007 (in press)*. [5] F. Scholten et al. (2010) *LPSC XLI, this conf*. [6] R.A. Beyer et al. (2010) *LPSC XLI, this conf*. [7] B.A. Archinal et al. (2010) *LPSC XLI, this conf*. [8] J. Danton et al. (2010) *LPSC XLI, this conf*. [9] S.S. Mattson et al. (2010) *LPSC XLI, this conf*. [10] M.E. Davies and T.R. Colvin (2000) *JGR 105(E8)*. [11] F. Scholten et al. (2005) *PE&RS, 71(10), 1143-1152*. [12] D.E. Smith et al. (2009) *Space Sci. Rev., 100, doi 10.1007/s11214-009-9512-y*.

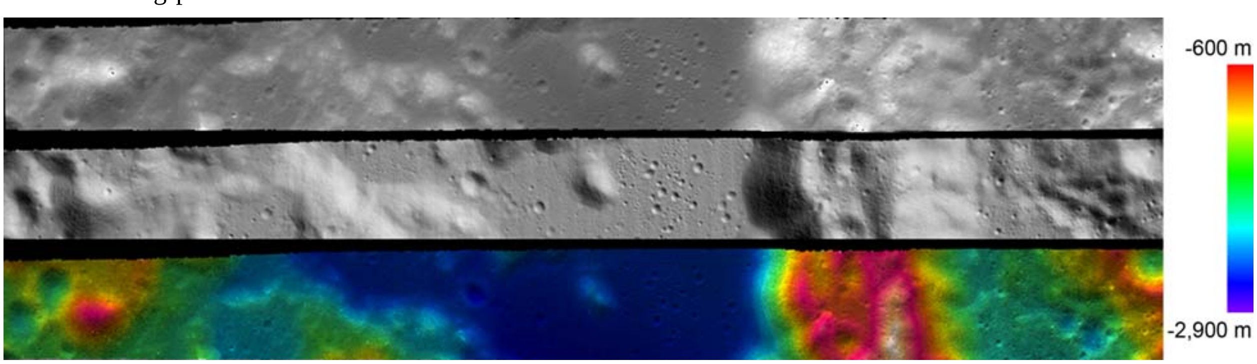

Fig.4: Orthoimage,DTM shaded relief, and color-coded DTM with orthoimage of entire NAC model (North to the right)