THE TOPOGRAPHIC DATA RECOVERING FOR CHANG'E-4 LANDING SITE AND ROVING SITE. X. Ren[1], J. J. Liu[1], C. L. Li[1], W. Yan[1], W. L. Chen[1], X. X. Zhang[1], W. Zuo[1], X. Y. Gao[1], X. G. Zeng[1], and Z. B. Zhang[1], [1]National Astronomical Observatories, CAS (renx@nao.cas.cn).

Abstract: Chang'e-4 (CE-4) successfully landed in the Von Kármán crater3 on the floor of the South Pole-Aitken basin on 3 January 2019. The CE-4 lander and rover carry three cameras, LCAM , NCAM and PCAM. In these study, their images were used to generated the accurately topographic data with an accuracy of cm level around the CE-4 landing and roving site using the method of photogrammetry.

Introduction: The South Pole-Aitken basin, approximately 2,500 km in diameter and 13 km deep, is thought to be the largest impact crater in the solar system. The basin may form from an impact that penetrated through the Moon's distinctive plagioclase-rich crust and may expose fragments of the lunar mantle [1],[2],[3],[4]. Therefore, exploration of this region may inform our understanding of the early impact flux on the Moon.

Chang'e-4 (CE-4) successfully landed in the Von Kármán crater on the floor of the South Pole-Aitken basin on 3 January 2019 (Fig. 1). CE-4 lander and its rover, Yutu-2, carry a landing camera (LCAM), a terrain camera (TCAM), a panoramic camera (PCAM) and a navigation camera (NCAM). These instruments will enable analysis of the topography, regolith and geological structure of the landing and roving sites. Until this writing, CE-4 has been carried out three lunar days of the lunar surface exploration. We have generated the topographic data near the landing and roving sites using the LCAM, NCAM and PCAM image data.

Data: LCAM is one of the scientific payloads installed on the bottom of Chang'E-4（CE-4）lander. CE-4 Lander gradually approached the landing area using a vertical descending mode during the approaching stage. The overlap of LCAM sequence images are greater than 94%. Over 40% of images cover the landing site. NCAM and PCAM are an engineering payload and a scientific payload onboard CE-4 rover respectively. They were both installed on the top of rover mast. NCAM or PCAM was a binocular stereo camera system, which included two cameras. NCAM obtained images surrounding the landing site at the top of the lander before the rover was separated from the lander. During the first three lunar days, PCAM has obtained images surrounding the 10 roving site. Based on these images, topographic data of the landing site and roving site with an accuracy of cm level can be reconstructed by the method of photogrammetry.

Method and Results: According to the photogrammetric bundle adjustment theory [5], the relationship between the lunar surface points, the corresponding image points and the camera projection center can be expressed by the classical collinear equation. Using Taylor's formula, the linearized error equations of each pixel can be derived. The Exterior Orientation (EO) parameters (position and attitude of the camera at imaging time) of each image and the lunar coordinates of each tie point can be solved by the least squares method.

During LCAM processing, the 13 evenly distributed ground control points (GCPs) close to the landing site were extracted from the CE2TMap2015 map. The root mean square (rms) error of the reprojection error for all tie points is 0.5 pixels. The horizontal and vertical rms error of GCPs are 0.715m (1δ), and 1.040m (1δ), respectively. Then, a DEM and a DOM of LCAM with 5cm spatial resolution within 80m around the landing site was generated.

During PCAM or NCAM processing, about 15 GCPs were selected from LCAM DOM for each roving site. The rms error of the reprojection error for all tie points is better than 0.2 pixels after the adjustment. The GCPs horizontal rms error is 0.017m (1δ), and the Vertical rms error is 0.031m (1δ). A total of 11 DOMs and DEMs with 2cm spatial resolution within 20m around the roving site was generated (Fig. 2, Fig.3). These data accurately describe the terrain variation on the Yutu-2 roving path.

Summary: The LCAM , NCAM and PCAM images were used to generated the accurately topographic data with an accuracy of cm level around the CE-4 landing and roving site. These data accurately describe the terrain variation on the CE-4 landing site and Yutu-2 roving path. These will provide a geodetic datum for the study on topography, geological structure, regolith, and subsequent exploration plan of Yutu-2 rover.

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References: [1] Garrick-Bethell, I. & Zuber, M. T. (2009) Icarus, 204, 399-408. [2] Moriarty, D. P. & Pieters, C. M. (2018) JGR, 123,729-747. [3] Melosh,

H. J. et al. (2017) Geology, 45, 1063-1066. [4] Wu, W. R., Li, C.L., et al. (2019) Nature Geosciencevolume, 12, 222-223. [5] Wang, Z.Z. (1990) Principles of Photogrammetry [with Remote Sensing], page 17.

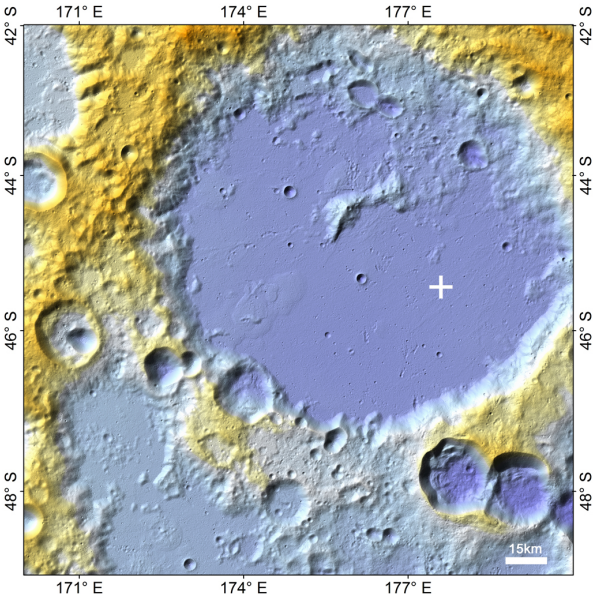


Fig.1 Location of the CE-4 landing site. The white cross marks the location of the landing site.

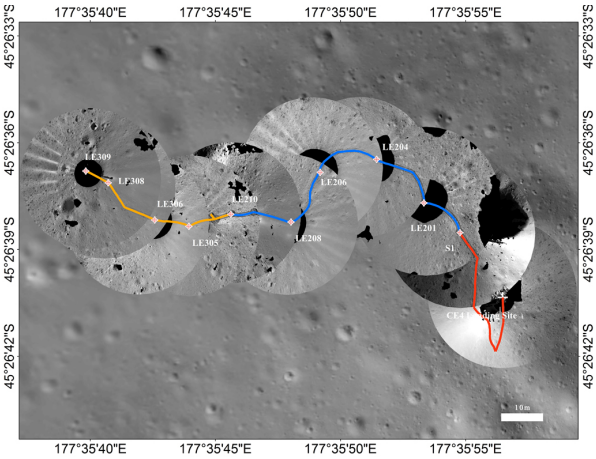
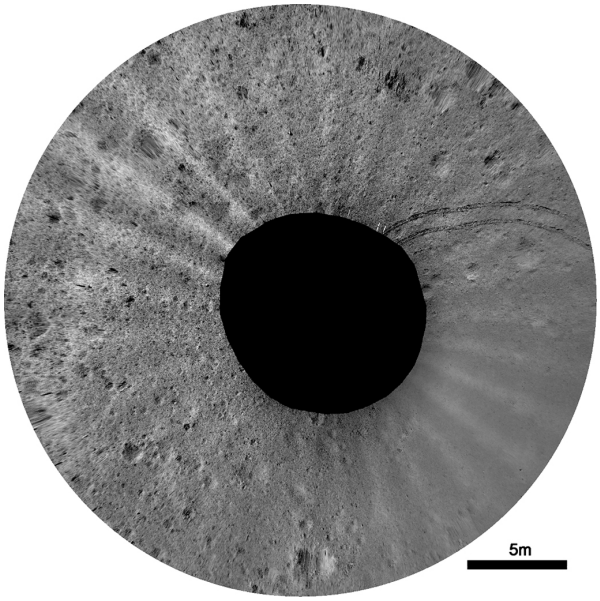
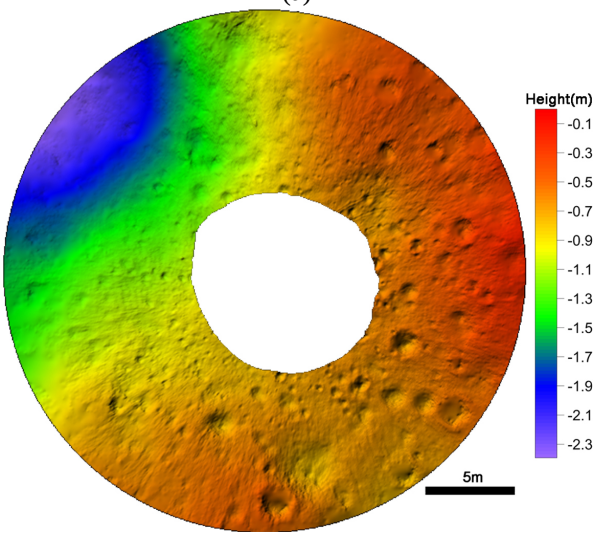


Fig.2 DOM From LCAM, NCAM and PCAM. The background image is LCAM DOM with a resolution of 5cm. The eleven "Circle" image is the PCAM and NCAM DOM. One of them (near landing site) is from NCAM. And The other ten (near roving site) are from PCAM. The red line is the Yutu-2 roving path of the first lunar day. The blue line is for the second lunar day. And the yellow line is for the third lunar day.



(a)



(b)

Fig.3 DOM and DEM of PCAM at the roving site LE206. (a) is DOM. (b) is DEM, colors represent elevation values (colorbar on the (b) right side).