FIRST AND HISTORIC LUNAR FARSIDE LANDING AND EXPLORATION OF CHINA'S CHANG'E-4 MISSION.

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Introduction: Numerous robotic landing, sample return, and manned lunar exploration missions have been successfully conducted since 1960. In which, the US accomplished 5 robotic soft landings (Surveyor) and 6 manned missions (Apollo). The former USSR completed 7 robotic soft landings including 3 sample return missions. Forty years later, China has become the third nation successfully landed on the Moon since the success of Chang'e-3 (CE-3) in 2013 [1]. However, all these landing sites were limited to the near side of the Moon (Fig.1a). Until today, there is no landing on the farside of the Moon and many fundamental scientific questions could not be answered without direct in-situ exploration data return from there. Thus, the China's Chang'e-4's (CE-4) successful landing on the farside of the Moon (Fig. 1b) on January 3 of 2019 has becomes a new historic milestone for human beings and opened a new window for studying the Moon.

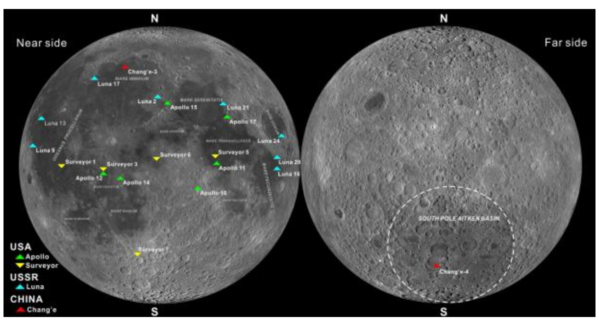

Figure 1. Landing sites of the Moon. Left, near side; right, far side.

Chang'e-4 Mission Briefing: CE-4 spacecraft was initially a back-up of CE-3. With the successful mission of CE-3 in 2013, CE-4 has an ambitions to explore somewhere never been touched. Finally, the Von Kármán Crater in the far side of the Moon was selected as the target landing site for CE-4.

However, as the Moon itself shields all direct radio signals from our Earth, it is impossible to establish any direct radio link from Earth to the far side of the Moon. Thus, the mission has to carry out two launches. Firstly, it needs a relay satellite to make communication between Earth and the far side of the Moon possible. On 20 May 2018 UTC (21 May BJT), the relay satellite, named Queqiao ("Magpie Bridge"), was launched toward the Earth-Moon Lagrange Point 2 (L2), located 65,000 km beyond the Moon. "Queqiao" was then positioned to the halo orbit of the L2 point on June 14, 2018, remaining all-time visible to both ground stations on the Earth and the lunar far side (Fig. 2).

Then the CE-4 spacecraft was launched on Dec. 8, 2018. After 26 days flight, it precisely landed at the planned site on Jan. 3, 2019 with the guidance of the relay satellite. Because the farside is generally featured with rugged terrain, safe landing and allowing the rover to drive is a big challenge. For avoiding impacting on the rough terrain, the CE-4 applied a vertical landing technology after careful and precise positioning. The final landing site is 177.6 °E, 45.5 °S (CNSA/CLEP).

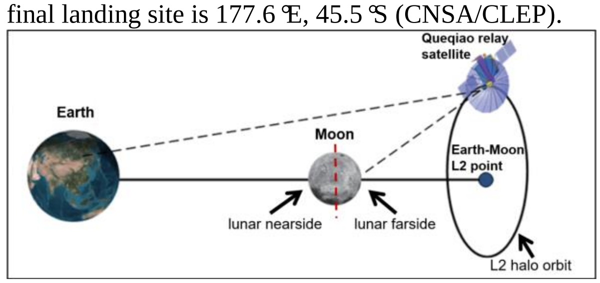

Figure 2. The engineering schematic of Chang'e-4 mission [2].

The Landing Site: The predesigned landing region is a rectangle area within the Von Kármán crater, which is a 180 km diameter impact crater in the northwest of the South Pole-Aitken (SPA) basin [2, 3](Fig. 1). The CE-4 spacecraft landed accurately in the center of the predesigned landing region at 177.6 °E, 45.5 °S (Fig. 3). The landing site is in a smooth crater floor plain, where has a slope smaller than 2°. The elevation around the CE-4 landing site is ca. -5920 to -5980 m.

The landform and surface regolith are different between the CE-4 and CE-3 landing site. As showing in Fig. 4, the CE-4 landing site is smoother and has less boulders/rock fragments than that of CE-3. The foot pad of CE-4 was buried deeper than that of CE-3, it might indicate the regolith of CE-4 is looser than CE-3 site. This is consist with the surface rock distribution phenomena showing in the pictures. The CE-3 landed on the ejecta blanket of a young impact crater [4], where there is plenty of visible large boulders (Fig. 4), while there is no visible boulders in the CE-4 landing site. It indicates the CE-4 landing site may have thicker fine regolith, or the nearby impact crater is too small to excavate underneath basement rocks.

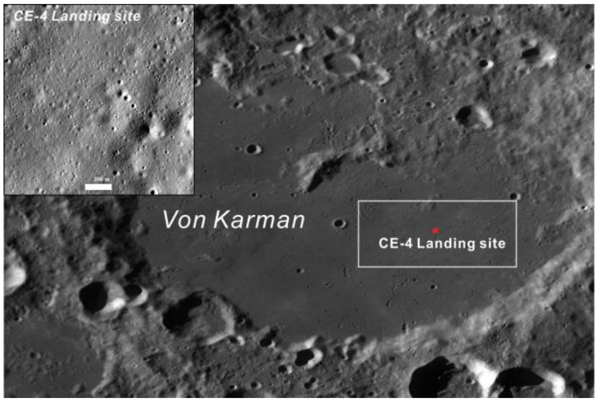

Figure 3. Hit the Bull's-eye, a pinpoint landing! Landing site of CE-4. The red point in the center of planned landing region Von Kármán crater [2] indicates the final landing site (177.6°E, 45.5°S)(CNSA/CLEP) .

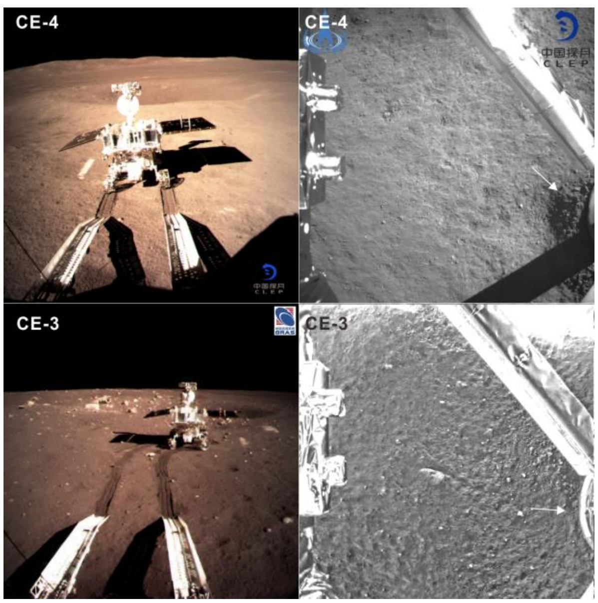

Figure 4. Upper left, the image captured by Panoramic Camera on the lander. Upper right, last-stage Landing Camera image of CE-4 landing site, just after landing; Lower left, Panoramic Camera image of CE-3; Lower right, last-stage Landing Camera image of CE-3 landing site. Obviously, there are more boulders on the surface of CE-3 landing site. Photos credit: CNSA/CLEP.

Scientific goals: The scientific goals of CE-4 include 1) determine the geomorphology, geology, and composition of the landing site, 2) explore the shallow subsurface structure along the patrol path of the rover, and 3) conduct low-frequency radio astronomy from lunar orbit and from the lander [5]. To fulfill these goals, CE-4 lander and rover brought with 8 scientific payloads: Landing Camera (LCAM), Panoramic Camera (PCAM), Terrain camera (TCAM), Lunar Lander Neutrons, and Dosimetry (LND, Germany) , Low Frequency Explorer (NCLE, Netherlands), Lunar Penetrating Radar (LPR), Visible and Near-infrared Imaging Spectrometer (VNIS), and Advanced Small Analyzer for Neutrals (ASAN, Sweden).

Scientific Potentials: The Von Kármán crater is an ancient, complex impact crater located within the SPA basin. SPA is the Moon's largest, deepest, and oldest impact basin. Its depth and gravity measurements suggest that the huge impact may have exposed the Moon's mantle or deep crustal materials. CE-4's exploration data will illuminate the history of the SPA basin and the evolution history of the Moon [3]. The unique space environment of the far side is extremely favorable for radio astronomy, and it is worth to wait for returned data.

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References: [1] Xiao L., (2014), *Nature Geosciences*; [2] Wu W. R., et al. (2017), *Journal of Deep Space Exploration*, *4*(2), 111-117; [3] Huang J. et al. (2018) *JGR-Planets*, 123, 1684-1700; [4] Long X. et al. (2015) *Science*, 6227, 1226-1229; [5] Jia Y. et al. (2018) *Planetary and Space Science*, 162, 207-215.