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Candidate Landing Sites for Artemis 3 in Two NASA Candidate Landing Regions Nearest The Lunar South Pole

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CANDIDATE LANDING SITES FOR ARTEMIS 3 IN TWO NASA CANDIDATE LANDING REGIONS NEAREST THE LUNAR SOUTH POLE.

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Summary: Candidate landing sites are proposed for Artemis 3 within two NASA-selected candidate landing regions nearest the lunar south pole.

Introduction: NASA announced in August 2022 its selection in the lunar south polar region of 13 candidate landing regions for the Artemis 3 mission [1]. Artemis 3 will be the first mission to return American astronauts to the lunar surface since Apollo 17. The mission is scoped to entail two astronauts exploring the lunar sur- face on foot only, within a range of 2 km from the landed Human Landing System (HLS), over a surface mission duration of 6 Earth days. "Accessible" terrain has been defined by NASA as restricted to slopes < 5°, and areas illuminated by the sun and allowing direct-to- Earth (DTE) visibility (at least via the HLS) at the time of the surface mission.

The selection of a specific landing site for Artemis 3 must meet a wide range of requirements for crew safety, mission robustness, operational flexibility, but also optimize science promise and exploration productivity. Given the specific operational constraints of Artemis 3 - short stay, short-range, on-foot only exploration -, a landing site that would be highly desirable for a mission equipped, like Artemis 5 and missions beyond, with a Lunar Terrain Vehicle (LTV) or a pressurized rover, might be suboptimal or even unproductive for Artemis 3. Conversely, Artemis 3'slimitations might be ideal for a one-time exploration of a site or region of lesser ap-peal for long-term exploration.

We conducted a survey of NASA's 13 candidate landing regions for Artemis 3 to search for an optimal candidate landing site within each. We report here on two candidate sites identified within "Connecting Ridge" and "Peak Near Shackleton", two candidate landing regions closest to the Lunar South Pole.

Approach:

Tools. We used Arizona State Univer-sity's (ASU) Lunar Reconnaissance Orbiter Camera(LROC) Quickmap lunar data browsing, display, map-ping, visualization and analysis tool to investigate each candidate landing region and search for landing sites.

Safety and Operational Prioritization. Three key safety and operations criteria were applied to identify a suitable landing site, defined as a 2 km-radius circular exploration zone (EZ) (12.57 km2) centered on an HLS landing spot 100 m x 100 m: a) Slope ≤ 5° over at least 25% of the EZ, including the landing spot and contiguous terrain allowing for on-foot traverses to local targets of interest; b) Solar illumination ≥ 33% of the time; c) direct-to-earth (DTE) visibility ≥ 50% of the time. Solar illumination and DTE visibility are in reality dynamic, and our preliminary study took into account that these factors vary with location, but not how they do so through time. The high thresholds chosen, however, allow frequent 6 to 10 day surface missions with continuous insolation and DTE visibility.

Scientific Prioritization. NASA's Artemis Plan, the Artemis 3 Science Definition Team Report, the National Academies' Decadal Survey, and references therein, identify priorities in lunar science for Artemis 3 and missions beyond [2-4]. Among many lunar sciencegoals and objectives, two are consistently considered of topmost priority: 1) to understand the origin, formation,and evolution of the Moon, by acquiring and investigating materials excavated from depth from the South Pole-Aitken Basin (SPAB); 2) to understand the origin, evolution, and present distribution of volatiles on the Moon, especially H2O and its relation to Permanently Shadowed Regions (PSRs).

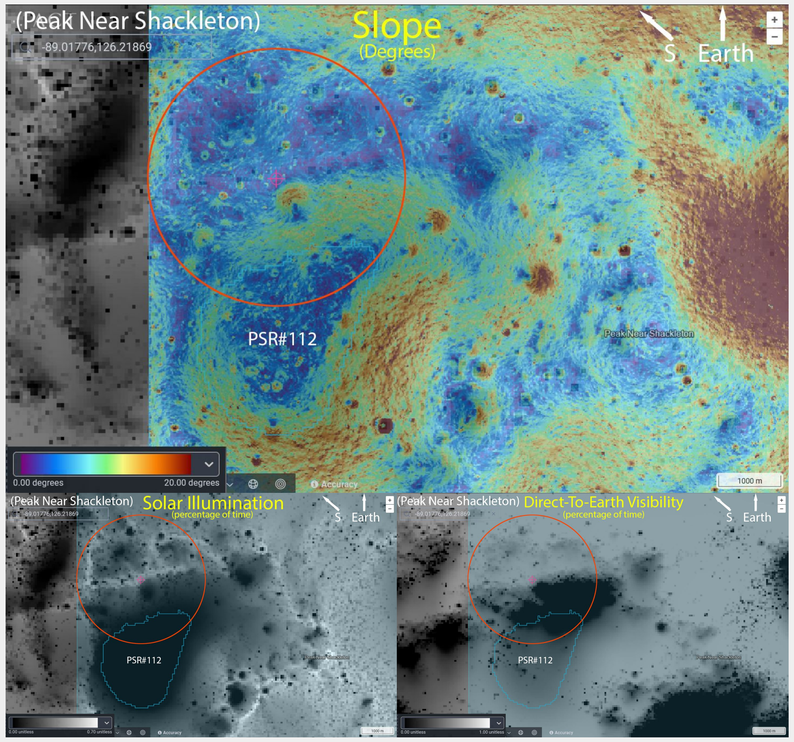

Figure 3: *Candidate landing site in "Peak Near Shackleton" candidate landing region. Top: Slope; Bottom Left: Solar illumination; Bottom Right: Direct-To-Earth visibility.*

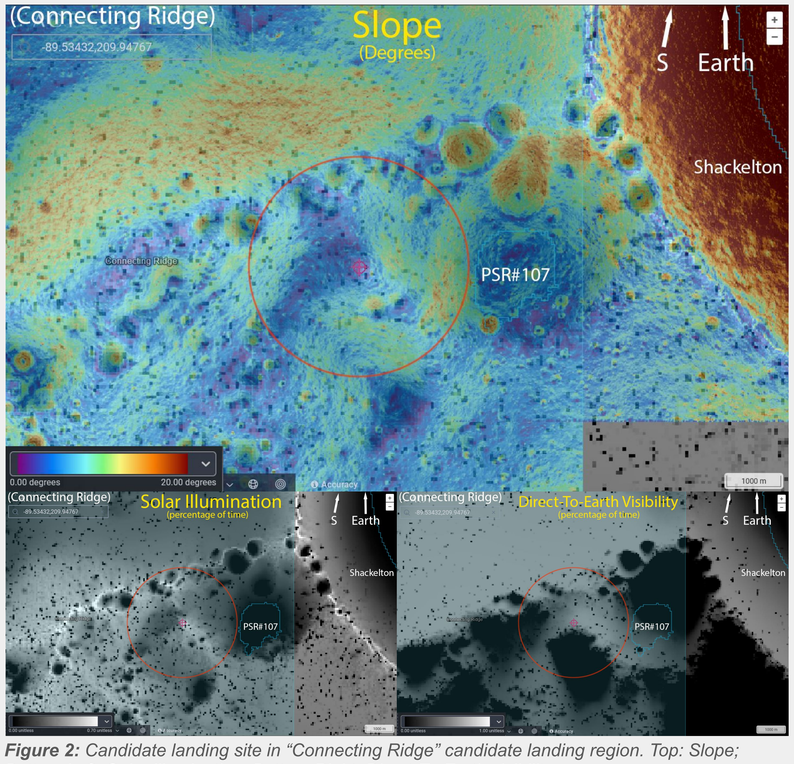

Figure 2: *Candidate landing site in "Connecting Ridge" candidate landing region. Top: Slope; Bottom Left: Solar illumination; Bottom Right: Direct-To-Earth visibility.*

Butler and Lee [5] conducted a comparison of thenscience opportunities presented by NASA's 13 Artemis 3 candidate landing regions, ranking them based of twocriteria: i) opportunity to sample SPAB materials; ii) opportunity to investigate H2O-ice bearing PSRs.

Regarding the sampling of SPAB material, the opportunity presented will vary by candidate landing region, but much less so within each region [5,6]. "Connecting Ridge" and "Peak Near Shackleton" rank #3 and #2 among the 13 NASA-selected candidate landing regions for the SPAB fraction presented by their terrain: 46% and 47%, respectively [5,6]. But no specific SPAB criterion was applied to selecting the optimal landing site within each region, beyond the requirement that each landing site must present slopes ≤ 5° over least 25% of its EZ area to enable good SPAB sampling opportunities

H2O-ice bearing PSRs are a subset of lunar south polar PSRs, identified by Lemelin et al. [7] as presenting surface exposures of H2O ice. While Moye & Lee's [8] H2O-based terrain classification shows that H2O maybe present on the Moon even outside PSRs (in the shallow subsurface), and all six of their "real-world" terrain classes should be investigated in order to fully understand the origin, evolution, and present distribution of H2O on the Moon, targeting the immediate vicinity of an H2O-ice bearing PSR would ensure that Artemis 3 examines early, one of the most significant features of the lunar polar regions for science and potential lunar resource access: exposed H2O ice. Our candidate landing site selection within each candidate landing region thus targeted locations allowing direct "line-of-sight" examination (via ground-based remote observations) of an H2O-ice bearing PSR, including in cases where the H2O-ice bearing PSR itself is located outside the limits of the landing region, so long as the Artemis 3 crew could examine it from within the region.

Results:

On the basis of Artemis 3's general operating constraints and the Artemis Program's top science priorities, one optimal candidate landing site is proposed in each of two NASA candidate landing regions nearest the lunar South Pole.

"Connecting Ridge" Landing Site. A candidate landing site is identified within the Artemis 3 "Connecting Ridge" candidate landing region at coordinates **- 89.53432°S, 209.94767°E** (**Fig. 2**, Center of 2 km radius red circle). The site is located near the rim of the crater containing H2O-ice bearing PSR #107 [7].

"Peak Near Shackleton". A candidate landing site is identified within the Artemis 3 "Peak Near Shackleton" candidate landing region at coordinates **-89.01701°S, 126.27302°E** (Fig.3, Center of 2 km radius red circle). The site is located near the rim of the crater containing H2O-ice bearing PSR #112 [7].

Conclusion and Next Steps:

Two candidate Artemis 3 landing sites are identified within the "Connecting Ridge" and "Peak Near Shackleton" NASA candidate landing regions near the lunar South Pole. Each site would allow direct line-of-sight examination of an H2O-ice bearing PSR, as well as several square kilometers of sunlit, DTE-visible, foot-trafficable terrain to access small craters, boulder fields and other SPAB sampling sites, as well as other small PSRs. More detailed work is needed to validate the potential value of these sites, especially taking into account their insolation dynamics.

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