Artemis III landing sites identified using mapping and algorithm techniques

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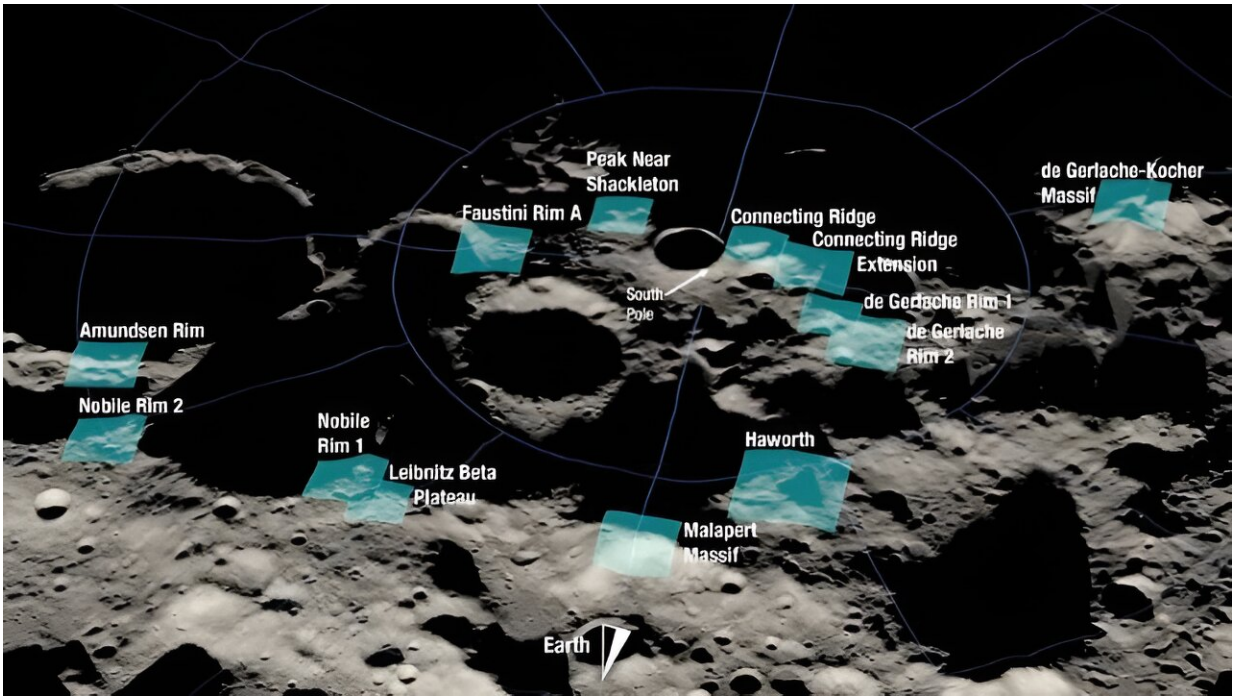

The 13 candidate landing site regions for NASA's Artemis III mission, with each region measuring approximately 15 by 15 kilometers (9.3 by 9.3 miles). Final landing sites within those regions measure approximately 200 meters (656 feet) across. Credit: NASA

Where would be the most ideal landing site for the Artemis III crew in SpaceX's Human Landing System (HLS)? This is what a recent study submitted to *Acta Astronautica*, and available on the *arXiv* preprint

server, hopes to address as an international team of scientists investigated plausible landing sites within the lunar south pole region, which comes after NASA selected 13 candidate landing regions in August 2022 and holds the potential to enable new methods in determining landing sites for future missions, as well.

Here, Universe Today discusses this research with Dr. Juan Miguel Sánchez-Lozano from the Technical University of Cartagena and Dr. Eloy Peña-Asensio from the Politecnico di Milano regarding the motivation behind the study, significant findings, the reasons for determining the final landing site, location to Shackleton Crater, and if a lander smaller than HLS would have changed the outcome?

Therefore, what was the motivation behind the study?

Dr. Sánchez-Lozano tells Universe Today, "Our motivation was to contribute to the selection process for the Artemis III landing site by introducing methods that are well-established in other fields of study to the context of space exploration for the first time.

"Specifically, we identified that Geographic Information Systems combined with Multi-Criteria Decision-Making (GIS-MCDM) methodologies could provide significant value in evaluating and prioritizing the candidate landing sites.

"Therefore, we aimed to demonstrate the utility of these methods to NASA and apply them in practice by identifying and recommending the most suitable landing locations."

For the study, the researchers used these methods to analyze 1,247 locations within the 13 candidate landing regions near the lunar south pole previously identified by NASA to ascertain the most precise landing sites for HLS.

They accomplished this by combining their GIS-MCDM methodologies with a Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) algorithm to analyze specific criteria: lunar surface visibility, line of sight for HLS astronauts, Permanently Shadows Regions (PSRs), sunlight exposure, direct communication with Earth, geological units, and abundance of mafic (volcanic rock high in iron or magnesium) materials.

Therefore, what were the most significant findings from this study?

Dr. Peña-Asensio tells Universe Today, "In addition to demonstrating the applicability of MCDM to these challenges, our analysis identified Site DM2 (Nobile Rim 2) as the optimal landing site based on criteria such as visibility, solar illumination, direct communication with Earth, geological diversity, and the presence of mafic materials.

"The best nine locations identified in our study are all situated within this region. Surprisingly, this site is not among the most favored regions within the scientific community."

Site DM2 is one of the furthest landing regions within the 13 candidate landing regions, located approximately 250 kilometers (150 miles) from Shackleton Crater, the latter of which has a portion located directly on the lunar south pole. The researchers identified the exact location of the optimal landing site being 84°12'5.61" S and 60°41'59.61" E, which is located near a PSR crater.

The reason PSR craters are of exploration importance is due to the craters being so deep that no sunlight has reached their depths in possibly billions of years, potentially resulting in their potential housing of water ice deposits.

Therefore, what were the specific reasons for selecting Site DM2 and

what are some potential backup landing sites?

Dr. Sánchez-Lozano tells Universe Today, "Site DM2 offers exceptional performance across several key criteria, including the highest percentage of solar illumination, optimal proportions of explorable ice-hosting areas, and extended communication windows with Earth. The strength of the decision-making methodology we employed, particularly the TOPSIS technique, lies in its compensatory nature.

"This approach allows criteria with merely acceptable values to be offset by others with excellent values, resulting in a comprehensive ranking of alternatives. Consequently, adjacent landing sites to the optimal location may also present highly viable options with a high degree of acceptability."

Regarding back sites, Dr. Peña-Asensio tells Universe Today, "As potential backup sites, we consider DM1 (Amundsen Rim) particularly compelling, as it offers locations with consistently high averages across all evaluated parameters. We also highlight Site 004, centered at the edge of the Shackleton Crater, which our analysis identifies as one of the best landing sites."

As noted, one of the primary criteria for determining the most optimal landing site is HLS, which will attempt to land the first humans on the lunar surface for the first time since Apollo 17 in 1972. However, the height of HLS is almost 10 times greater than the Apollo lander at 50 meters (160 feet) and 5.5 meters (17.9 feet), respectively, which means landing a larger spacecraft carries its own benefits and challenges.

For context, the original spacecraft design for Apollo called for landing a large spacecraft on the lunar surface known as direct ascent, which Wernher von Braun was initially in favor of using. However, the direct ascent technique was scrapped in favor of the Lunar Orbit Rendezvous

(LOR) technique, which is argued to be less risky due to a smaller spacecraft needing to land on the lunar surface.

Therefore, if a smaller lander than HLS (i.e., Apollo-sized) was being used, how would this influence the landing site selection?

Dr. Peña-Asensio tells Universe Today, "This would directly impact our results, as we considered criteria such as the lander's solar illumination received for energy recharging, visibility from the lander windows to help astronaut extravehicular activities and to allow intravehicular science, and direct communication with Earth.

"A lower lander could intensify the challenges posed by local topography, obstructing sight lines and the sunlight. However, it might also offer increased stability for the lander (by reducing its center of mass height), potentially decreasing the terrain slope safety restrictions and thereby opening up new landing site options for exploration."

As landing sites for the Artemis III mission continue to be debated, NASA is currently scheduled to launch Artemis II late next year with a four-person crew whose mission will be to orbit the moon and return to the Earth like Apollo 8 in December 1968.

Additionally, the commercial space industry is taking their own shots at landing near the lunar south pole with the upcoming IM-2 mission courtesy of Intuitive Machines, which earlier this year successfully landed the first American spacecraft on the moon for the first time since 1972.

This study demonstrates that a plethora of methods can be used to determine optimal landing sites for the Artemis missions and potentially other missions to other planetary bodies throughout the solar system, specifically the use of mapping and machine learning algorithms.

Therefore, as we approach the Artemis III mission and the first human landing since Apollo 17, these methods will continue to evolve and improve to develop enhanced landing methods as humanity continues its journey into the cosmos.

Dr. Sánchez-Lozano tells Universe Today, "This research demonstrates how methodologies from the field of engineering projects and the business world, such as multi-criteria decision-making techniques, can be applied to solve decision problems of interest to the international astronomical community, such as the proposed case study: the selection of the optimal landing site for the Artemis III mission."

More information: Eloy Peña-Asensio et al, Evaluating potential landing sites for the Artemis III mission using a multi-criteria decision making approach, *arXiv* (2024). DOI: 10.48550/arxiv.2406.19863

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