MOONHACKER™ LUNAR DATA ANALYTICS: A CASE STUDY FOR EXPLORING AMUNDSEN CRATER.

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Introduction: MoonHacker™, the proprietary software of Lunar Station Corporation (LSC), is a geospatial analytics engine that ingests large, desperate lunar datasets and provides powerfully derived products to facilitate immersive and comprehensive understandings of the lunar domain. MoonHacker™'s analytics provide solutions for: lunar surface mobility; access to extreme environments; analysis of lunar surface lighting conditions; communication site lines; mineralogy; terrain characterization; space weather; thermal management; and many other analyses as well [Kornuta et al., 2019]. The impact of lunar data analytics will play an increasingly larger role in the lunar economy [Scatteia and Perrot, 2019]. MoonHacker™ is well-positioned to facilitate this economic and exploratory growth. Here, reveal a case study of an Artemis-inspired, crewed exploration campaign of the Moon's Amundsen Crater to demonstrate MoonHacker™'s analytical capabilities.

Amundsen Crater is a late-Nectarian aged complex crater centered near 84.5˚ S with a diameter of 100 km. A large permanently shadowed region (PSR) spans its northern floor and has been the subject of previous case studies [e.g., Lemelin et al., 2014]. NASA identified Amundsen's western rim as an Artemis III candidate landing region. Informed by this, we chose the varied geology of the central peak complex as an exploration region to illustrate MoonHacker™'s capabilities to enable Decadal Survey-level science (Fig. 1). Notably, our case study is more complex and less constrained than what is solicited by the Draft Artemis III Geology Team (A3GT) AO.

Science Goals in Amundsen: A mission to varied geologic terrains at Amundsen Crater (Fig. 1) could address Planetary Science Decadal questions related to Decadal Questions 3, 4, and 5. Specifically, Amundsen is well-suited to addressing questions related to the Moon's South Pole-Aitken basin; the mechanics of complex crater formation; lunar volatile inventory, distribution, transport, and evolution; and the structure and composition of the shallow lunar interior.

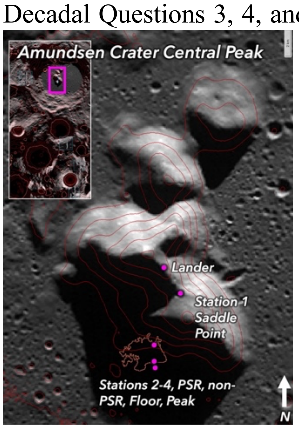

Figure 1: The central peak complex of Amundsen Crater reaches 1.4 km above the crater floor. Red curves are topographic contours and the orange enclosures are PSRs. The scale bar is 2 km and north is up (white arrow). Credit: NASA/ACT/ASU QuickMap.

MoonHacker™ Results: We selected five locations on or near the central peak complex: one landing/launching site (84.55127˚S,85.89116˚E), and four science stations. The exact science station locations are less important than the type of terrain represented by each—in or out of PSRs; and on or off the central peak versus the crater floor. We assume a pressurized Lunar Terrain Vehicle (LTV) will be limited to 25˚ slopes or less and that the crew will be limited to spending short periods (~minutes) in permanent shade.

Lunar Surface Mobility (Path and Slope): Given a maximum slope threshold, MoonHacker™ determined all viable paths below the slope threshold by way of a Monte Carlo simulation. In addition, the analysis can reveal the most probable "virtual highways" by identifying the most favorable routes that were traversed many times during the Monte Carlo simulations. In this case, 25˚ was the strict upper limit for slopes, 5˚ higher than allowed for in the A3GT. Favorable routes having an increased amount of illumination (power) elevates the probability of being selected. In addition, the algorithms determined whether a direct-ascent/descent was preferred versus a switchback traverse for specific areas and assumed a wheeled vehicle; a walking astronaut or vehicle would have fewer slope constraints.

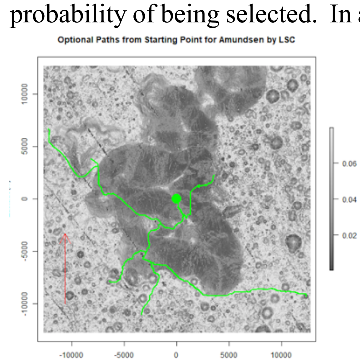

Figure 2. All possible paths unconstrained by science station destination originating at the landing site. The axes are meters, ticked at 5000 m increments.

Access to Extreme Environments (Lighting and Temperature): While the Moon's axial tilt is small (1.5˚), there are still lunar seasons which can affect the south polar lighting. MoonHacker™'s analysis of solar illumination and timing can determine, and optimize, the most viable paths to capture maximum sunlight and thermal efficiencies. This allows for better seeing and remote sensing by the astronauts as well as for solar power generation. Relatedly, maximizing the illumination also reduces the time spent at cryogenic temperatures below, e.g., -80˚C/193 K (dry ice at STP).

Line of Sight and Regional Remote Sensing: MoonHacker™ calculated time-integrated line-of-sight paths between the landing site, Earth, and L2 based on the regional topography (Fig. 3). This analysis could be repeated for any point along a traverse and at any height above the surface to enable planning for e.g., ground-based remote sensing or line-of-sight communications.

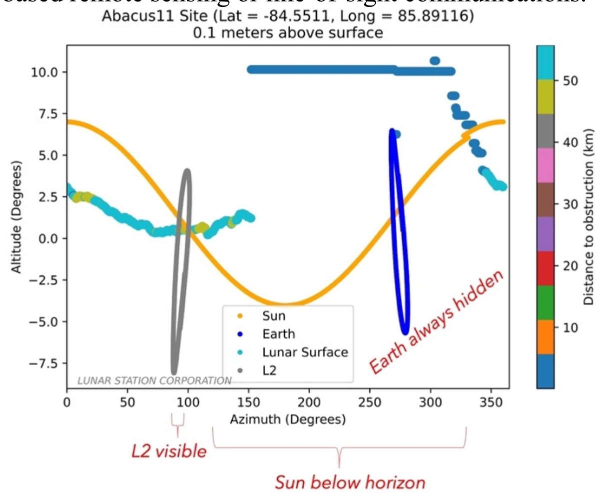

Figure 3. Astrometry plot showing a 360˚ view around the landing site indicating the position of the Sun, Earth, and L2 relative to the visible topography over the course of a lunar day. Any celestial feature, such as the Geo satellite belt, could be included.

Our case study's central peak slopes offer sweeping vistas of the interior of the crater and the far terraced crater walls, illustrating MoonHacker™'s ability for planning, e.g., multispectral remote sensing campaigns along the traverse and at science stations that could be a boon to geologic exploration. The views include the position of the Sun and Earth, and could be updated to include astronomical targets as guides, e.g., astronomical observation for science and navigation. In addition to the astrometry plots (Fig. 3), MoonHacker™ thus created simulated views of the interior of Amundsen crater with correct illumination for the time of the traverse at various points along the path, including the slopes (Fig. 4).

Compositional Spatial Gradients: Reflectance, neutron, and gamma ray spectroscopy reveal surface and near-subsurface rock and regolith compositions, currently from Clementine, Lunar Prospector, and Diviner datasets. MoonHacker™ can produce composition maps along the traverse path to inform sampling strategy, viewable as a color-coded guide.

Future Datasets: Lunar Station Corporation consistently updates MoonHacker™ for new use cases and when new data become available. For instance, ShadowCam [Robinson, 2022] will reveal surface features in PSRs with a pixel scale of 1.7 m/pixel and could also reveal the presence of icy frost; these data will be included once they are created and made public, expected in early 2024. Lyman-Alpha Mapping Project (LAMP) UV observations will soon be included in MoonHacker™ to enhance or enable nighttime surface operations and characterization of surface volatile abundance, distribution, and dynamics. MoonHacker™ will also be able to accommodate the proprietary or classified datasets of individual organizations.

Another example of updated data usage involves the threat from present-day meteoroid strikes and the associated ejecta spray. MoonHacker™ was the first solution to fuse the Apollo and MEO lunar impact data to predict the probability that a given site could experience impacts or ejecta spray in its vicinity. New meteor impact data will enhance the predictive capabilities [Cahill et al., 2020].

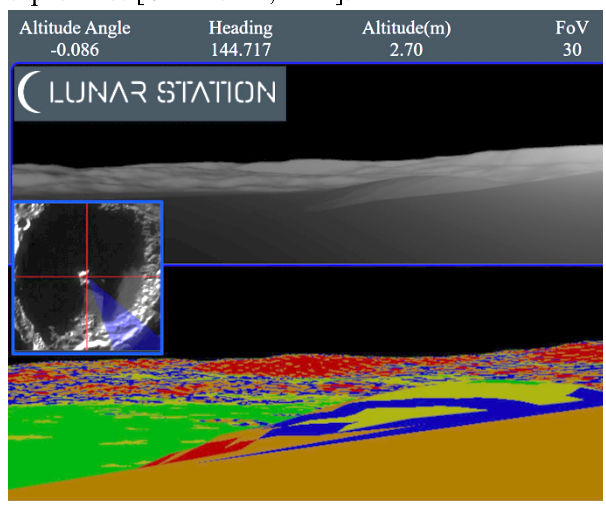

*Figure 4: **Top:** Simulated 180˚ panorama of the south-western wall of Amundsen Crater as seen from a point along the traverse. The positions of astronomical objects in the sky is accurate though they may not always be visible to crew. **Bottom:** Similar view showing variation in slope.*

Conclusion: MoonHacker™ can analyze and enable powerful interpretation of any location on the Moon for any use case ranging from exploration missions to economic development endeavors to scientific data analysis to national security applications. Contact Lunar Station Corporation (https://lunarstation.space/; info@lunarstation.net and dennis@lunarstation.net) to discuss your requirements and learn more about LSC's advantages for custom analysis of your specific slice of the Moon.

| **References: Cahill**, J.T.S., et al., (2020). Assessing the Present-Day Impact Flux to the Lunar Surface Via Impact Flash Monitoring and Its Implications for Sustained Lunar Exploration: A White Paper for the National Academies Planetary Science and Astrobiology Decadal Survey. | **Kornuta**, D., et al. (2019). Commercial lunar propellant architecture: A collaborative study of lunar propellant production. *Reach*, *13*, 100026. | **Lemelin**, M., et al. (2014). High-priority lunar landing sites for in situ and sample return studies of polar volatiles. *Planetary and Space Science*, *101*, 149-161. | **Robinson**, M. (2022). ShadowCam: Seeing in the Moon's Shadows. *44th COSPAR Scientific Assembly. Held 16-24 July*, *44*, 299. | **Scatteia,** L., and Perrot, Y. (2019). Lunar market assessment: market trends and challenges in the development of a lunar economy. Research paper prepared by PwC. https://www.pwc.com.au/industry/space-industry/lunar-market-assessment-2021.pdf