Lunar South Pole Development and Exploitation

Sun Burn

Where to land? This study examines the distribution of possible landing areas near the Lunar South Pole and their geospatial consequences for power development and mineral exploitation. It utilizes generalities provided for Lunar rover capabilities studied by NASA for the Apollo space program. A slope analysis is conducted based off the limitations of the Lunar rover to establish areas where it can or cannot travel. Aspect analysis is provided to establish locations in relation to the cardinal directions of the Moon. Hillshade reliefs are rendered to provide an idea of Solar illumination. Three landing sites are identified with four cardinal direction perspective views generated.

Introduction

Lunar exploitation and development requires knowledge and capital to assist Humankind in reaching for the stars. Water is second only to a breathable atmosphere in enabling us to achieve our destiny as settlers of space. The nearest location of water outside the Earth is on our own Moon and has been studied by the international community (NASA, 2007).

The study is organized as follows: the second section is background to why the Moon is our next destination and best choice. Section three sets the stage by introducing the unified geography of the Moon and Lunar South Pole illumination and its impact to successful preliminary exploitation and development. Section four breaks out the data being used and analyzes the lunar geography. Section five brings the geographical analysis together with the geospatial consequences of preliminary exploitation and development.

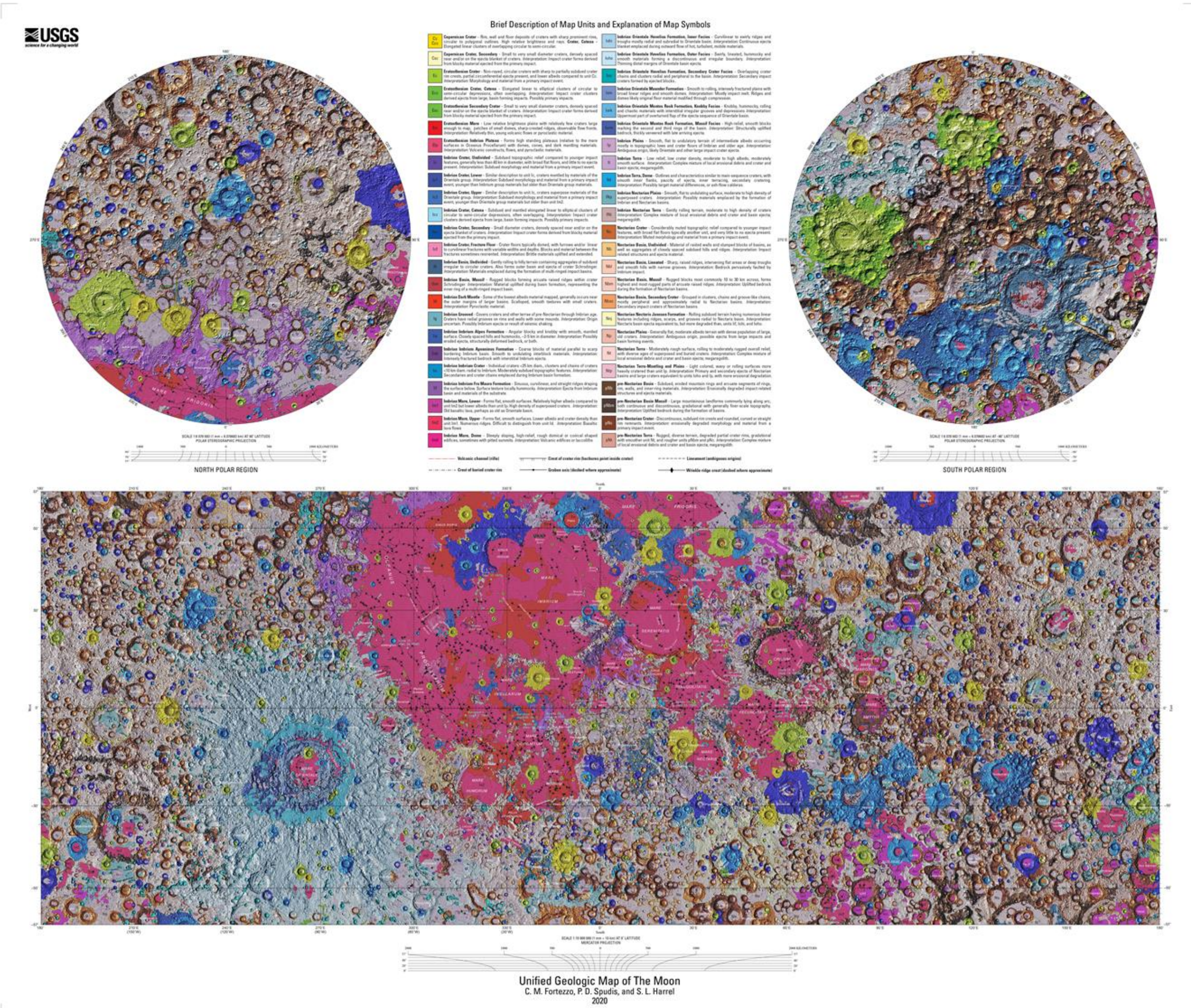
Background

The universe is vast. Like an expansive ocean Humankind resides on a lonely, isolated island of life. Our Solar System is several orders of magnitude smaller but offers us an exciting opportunity to expand and flourish. Our species, as well as much of life here on Earth, require certain atmospheric conditions containing just the right amount of oxygen and water. Both are very probably available within the craters of the moon which are in permanent shadow (Arizona State University, 2010). By harnessing these volatile elements for exploitation Humankind will take another step towards settling the star.

Lunar Geography

The surface of the moon is a barren wasteland filled with rocks and craters. The topography has been studied closely in Fig. 1 and a comprehensive analysis of its better known features has recently been created in May of 2020 (Fortezzo, Spudis, & Harrel, 2020).

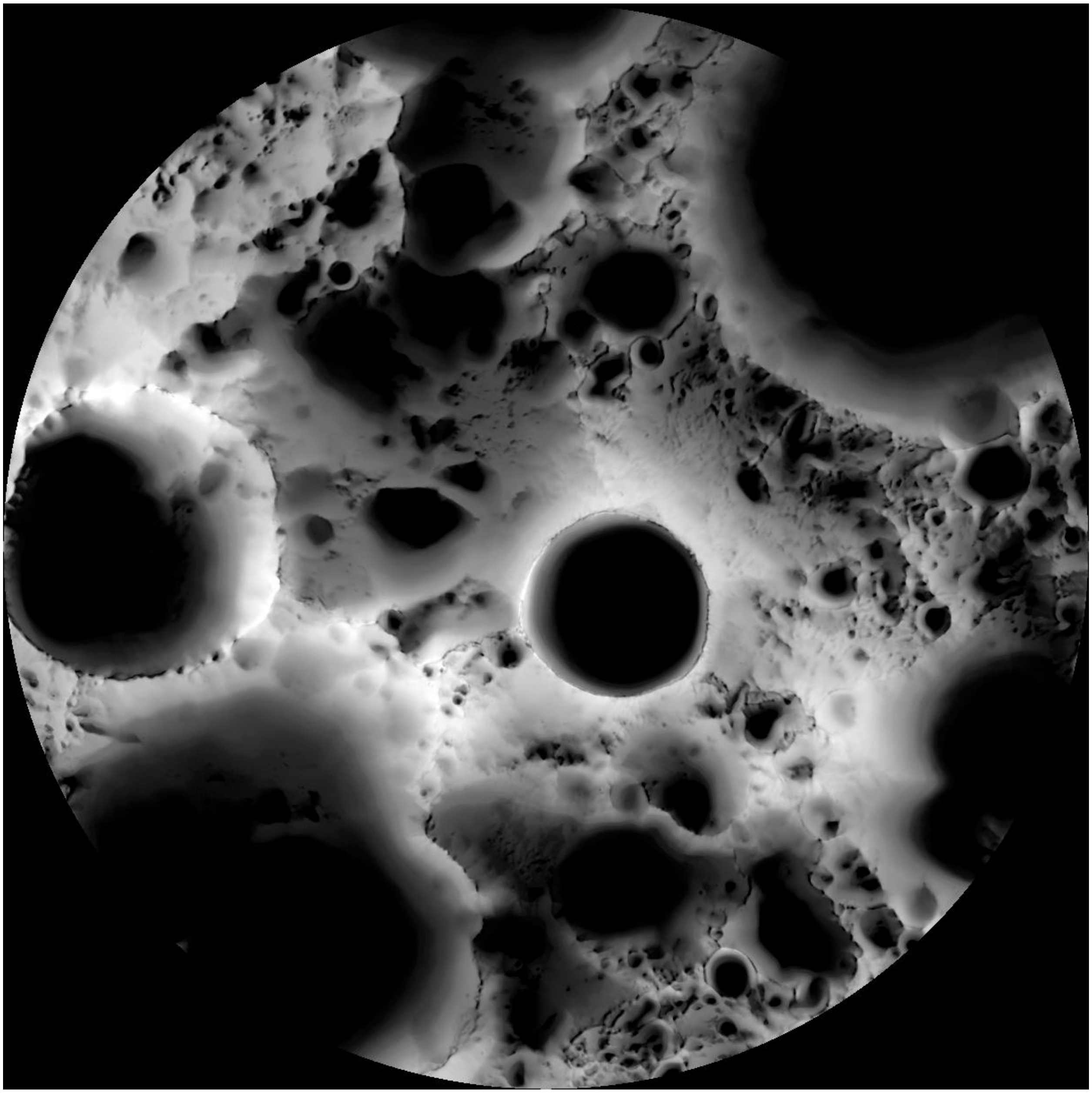
Figure 1. Unified Geological Map of the Moon



The Unified Geological Map of the Moon courtesy of the United States Geological Survey's Astropedia (Fortezzo, Spudis, & Harrel, 2020). Courtesy of the United States Geological Survey.

The locations on the moon with the best chances of finding ice are located at the Lunar South Pole where Solar illumination in Fig. 2 of the rims and ridges offer great changes in elevation causing deep shadows which prevent its evaporation (Arizona State University, 2010). They are also locations where near-continuous Solar energy may be captured for these initial industrial processes which lunar prospectors may require (Speyerer, et al., 2016).

Figure 2. Lunar South Pole Illumination Map

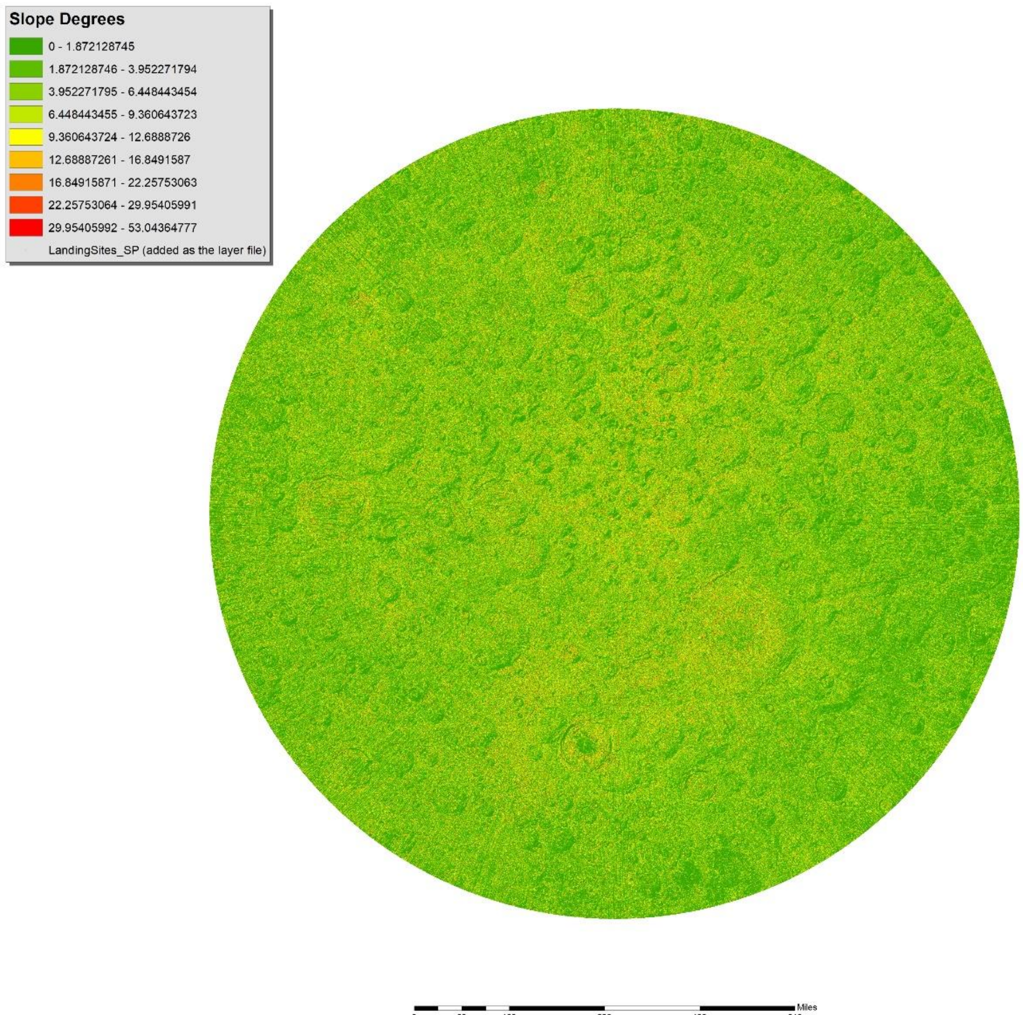


Multi-temporal illumination map of the Lunar South Pole, Shackleton crater (19km diameter) is in the center, the South Pole is located approximately at 9 o'clock on its rim (Arizona State University, 2010) (United States Geological Survey, 2020). Courtesy of Arizona State University and the United States Geological Survey.

Lunar South Pole

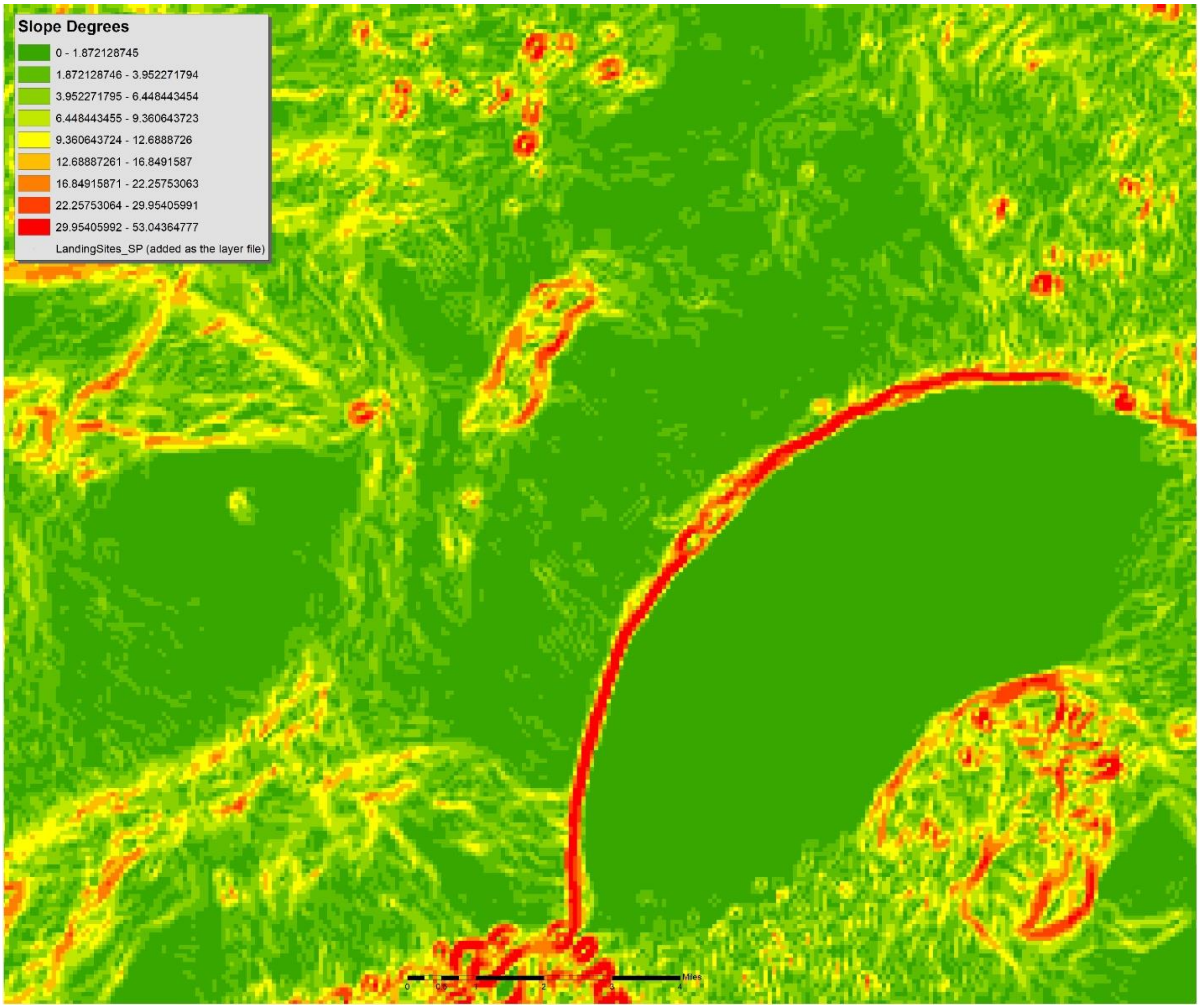
The Lunar South Pole lies at roughly the 9 o'clock position of the Shackleton crater (Arizona State University, 2010). The Shackleton crater is a prime candidate for preliminary Lunar exploitation (Speyerer, et al., 2016). Safe landing sites and room to for industrial expansion are key to finding these locations on the Moon. Understanding the slopes at the South Pole of the Moon in Figs. 3 and 4 assist us with that analysis. The large green areas are good slopes for landing and exploitation.

Figure 3. Lunar South Pole Overview Slope Map



An overview slope map of the Lunar South Pole and surrounding areas, Shackleton crater (19km diameter) is in the center (Arizona State University, 2010). *Slope derived from LRO_LOLA_Shade_SPole24_100m_v04 located in the United States Geological Survey's Astropedia.*

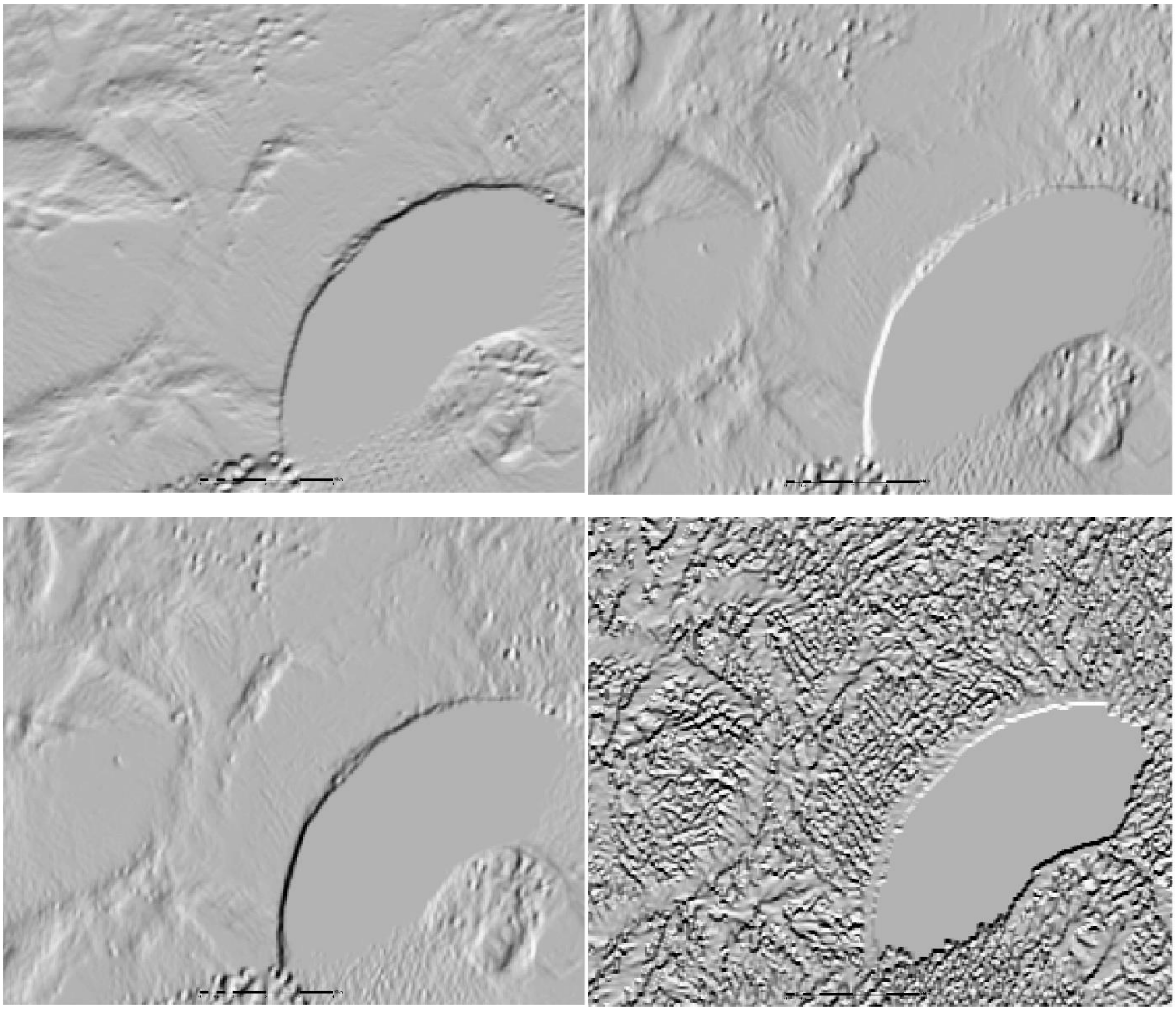
Figure 4. Lunar South Pole Close Up Slope Map



A close up slope map of the Lunar South Pole and surrounding areas, Shackleton crater (19km diameter) is in the center (Arizona State University, 2010). *Slope derived from LRO_LOLA_Shade_SPole24_100m_v04 located in the United States Geological Survey's Astropedia.*

Next, we look at the lay of the land in comparison to solar azimuth around the Lunar South Pole in all four directions in Fig 5.

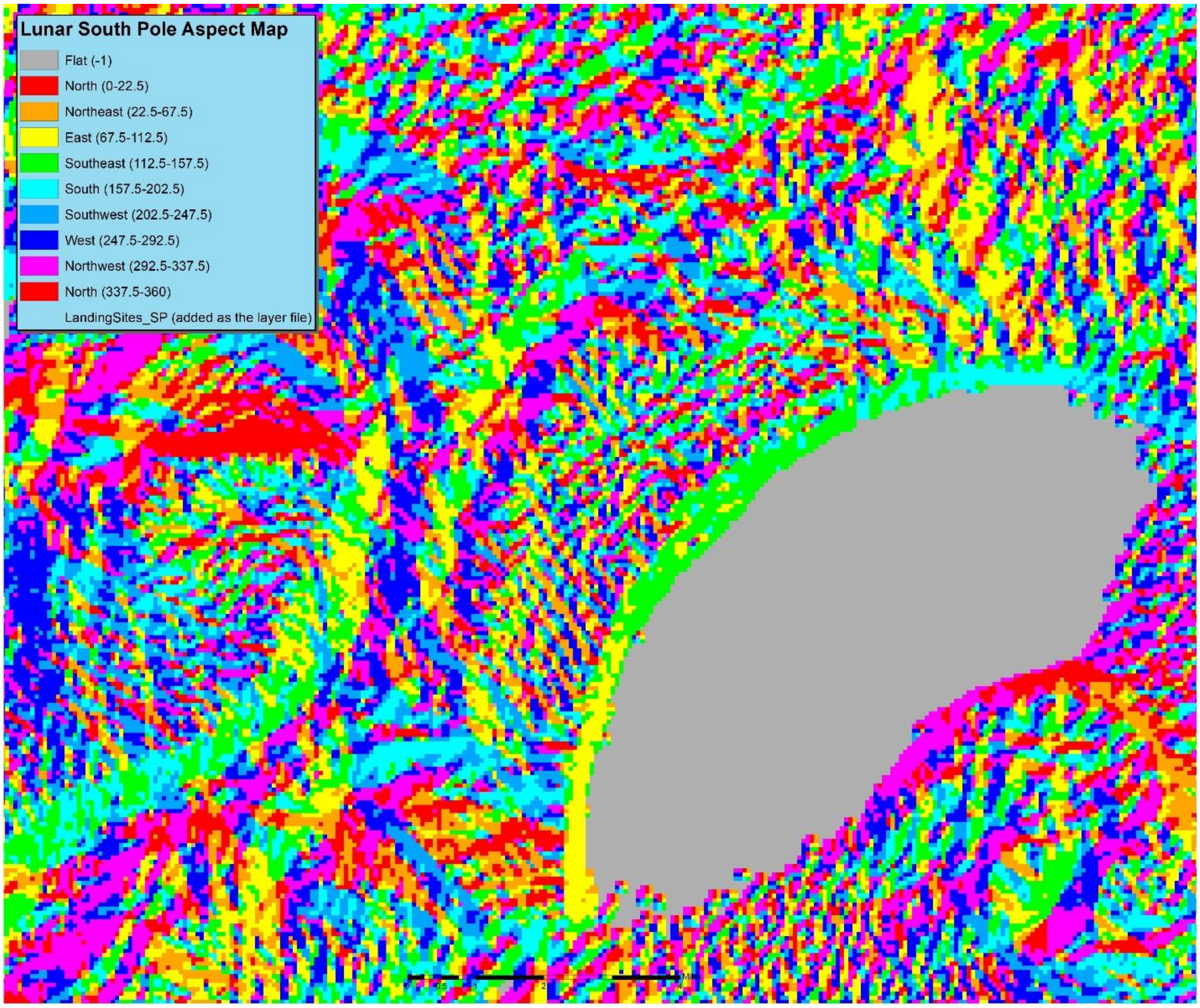
Figure 5. Lunar South Pole Hillshades 360/090/180/270



Clockwise from top left: Hillshades at 360, 090, 180, and 270 from the Lunar Reconnaissance Office (LRO) Lunar Observer Laser Altimeter (LOLA) LRO_LOLA_Shade_SPole24_100m_v04 courtesy of the United States Geological Survey's Astropedia.

In order to determine which sides of the area surrounding the Lunar South Pole, an aspect map is run in Fig. 6.

Figure 6. Lunar South Pole Aspect Map

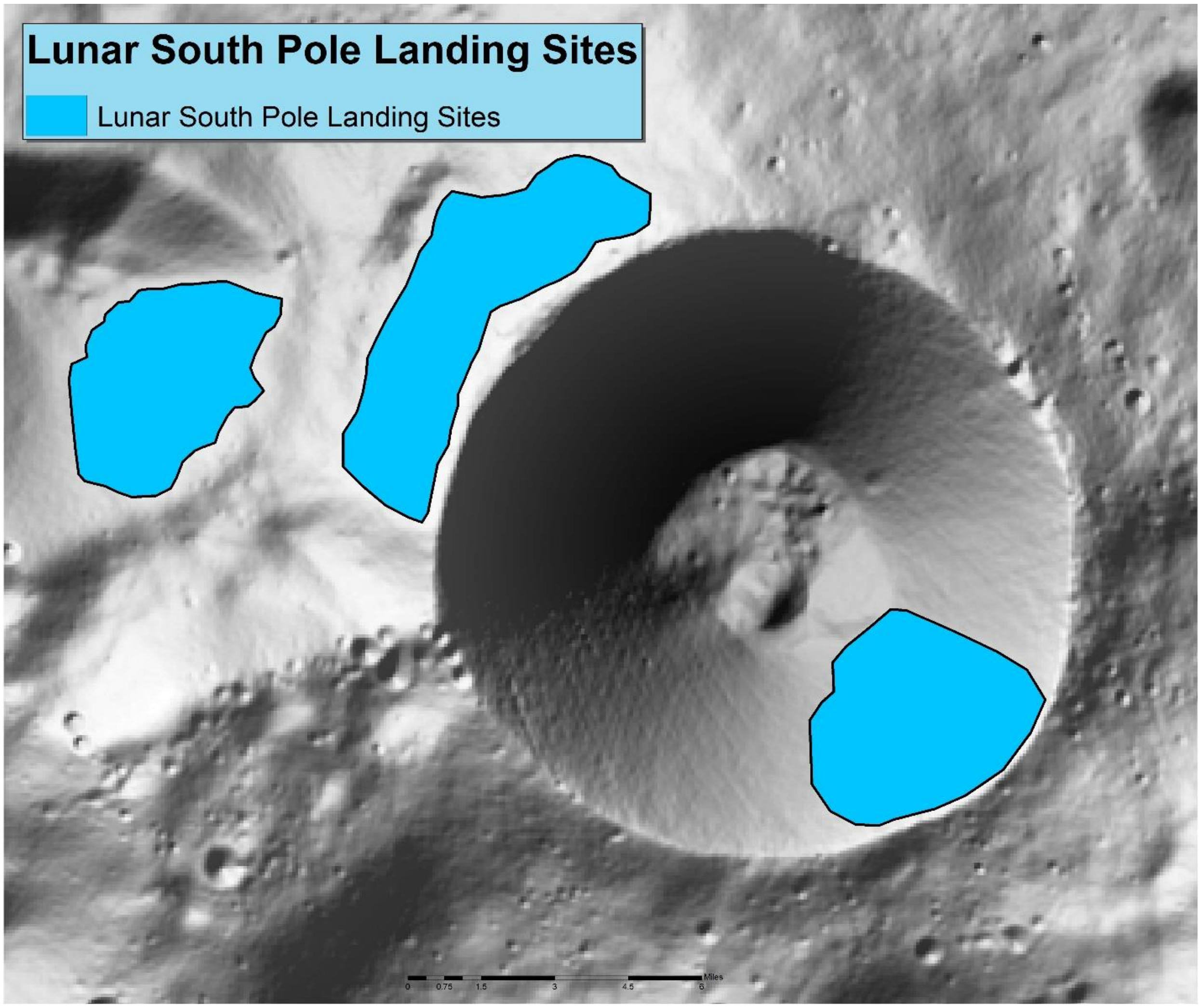


Courtesy of the Lunar Reconnaissance Office (LRO) Lunar Observer Laser Altimeter's (LOLA) data LRO_LOLA_Shade_SPole24_100m_v04.

After the slope map information has determined which sites we can land at, the hillshades have determined limited solar direction, and the aspect map has determined slope directions, an analysis of the area surrounding the Lunar South Pole reveals the landing sites in areas at least 30 square kilometers in Fig. 7. In Fig. 8 a composite of Lunar data is supplied for reference.

The Lunar South Pole reveals a fruitful selection of areas which landing engineers can choose from. Three ideal candidates lie outside the Shackleton Crater while the third lies within the crater. Each landing site is greater than 30 square kilometers which enable lunar prospectors room to expand.

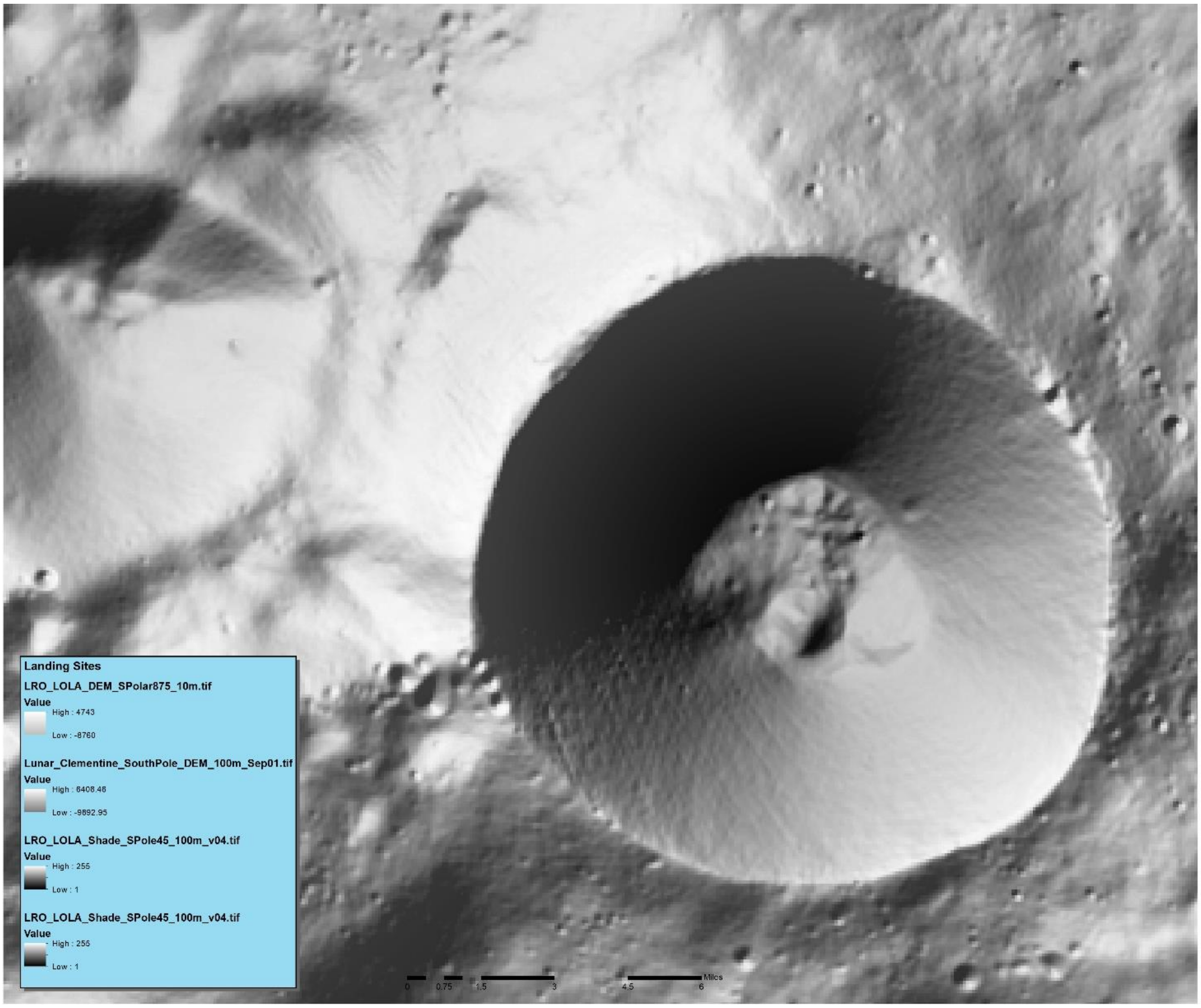
Figure 7. Lunar South Pole Landing Sites



From left to right, sites 1, 2, and 3 in and around Shackleton Crater at the Lunar South Pole.

Landing Site 1 measures approximately 33 square kilometers with a perimeter of approximately 23.5 kilometers. Landing Site 2 measures approximately 45 square kilometers with a perimeter of approximately 34.9 kilometers. Landing Site 3 measures approximately 37 square kilometers with a perimeter of approximately 22.9 kilometers. Landing Site three lies entirely within the Shackleton Crater which measures roughly 19 kilometers across, with an area of approximately 340.7 square kilometers, and a perimeter of approximately 66 kilometers. This represents about ten percent of the total area inside the crater.

Figure 8. Lunar Composite



Data acquired courtesy of the USGS Astropedia was utilized during this study and this composite was generated using four different data layers from the Lunar Reconnaissance Office. Note the shallow crater slope that has been ascertained within the lower right portion of Shackleton Crater. The upper left portion may appear smoothly sloping in the GIS but it is only due to a lack of data that this area appears so attractive. There is little known about this surface via the data sets provided due to a lack of light. The Digital Elevation Models created in this composite were taken by stereopairs and the Lunar Orbiter Laser Altimeter which rely on light to establish height (Arizona State University, 2010). *If no light shining into the dark region returns to the sensor, then no digital elevation model may be generated. By utilizing several layers of data, a composite image was created to remedy this short-coming and GIS best practices were utilized to determine areas which were not able to provide enough data to support the study.*

Geospatial Consequences to Lunar South Pole Exploitation and Development:

Initial exploitation of the Moon must secure water and electrical generation. Water is most likely present in the deep shadows of craters (Speyerer, et al., 2016). The Shackleton Crater is arguably the best candidate due to its deep shadows at the bottom and nearly perpetual light at its top (Speyerer, et al., 2016) (Arizona State University, 2010). Landing sites within the crater itself should be considered last as Solar power generation will be more degraded with shadows case by the crater rim. Although craters will provide the greatest chance of immediate recovery and cause the least amount of travel it would be prudent to land outside the crater and maneuver in.

This study contains an information gap between the prime landing sites outside Shackleton Crater and the dark, upper-left portion inside Shackleton Crater. This may be remedied with further LiDAR analysis from Clementine and other remote sensing missions to the Moon (Arizona State University, 2010).

Initial commercial exploitation of the Lunar surface should consider the geospatial accuracies in planning by initializing center to periphery expansion vice periphery to center. From a planning perspective it is far more accurate to begin planning from the middle of something with an established point of control and then moving to the periphery of, in this case, the Landing Sites. This is the same manner in which the Great Pyramids of Giza were thought to have been constructed and consistent with a Cartesian coordinate system (Bolstad, 2019). By securing the central portion of the Landing Sites, engineers can then set aside buffer zones for rocket launches, solar farms, and corresponding activities at each installation.

GIS can identify important geospatial opportunities as constraints. Both of which are uniquely represented by the Shackleton Crater. These synergies may be exploited and developed utilizing GIS&T.

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