GLOBAL 3D DATA VISUALIZATION AND ANALYSIS PLATFORM WITH ADVANCED MACHINE LEARNING CAPABILITIES IN SUPPORT OF LUNAR EXPLORATION.

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Introduction: The science goals for NASA's Artemis program include: a) Understanding the character and origin of lunar polar volatiles, b) Conducting experimental science in the lunar environment and c) Investigating and mitigating exploration risks [1]. The permanently shadowed regions (PSRs) on the Lunar south pole are expected to host large quantities of water-ice and volatiles that are important for sustainable Lunar exploration [2]. There are several missions such as Korea Pathfinder Lunar Orbiter (KPLO: Korean name Danuri) with onboard ShadowCam camera [3], Astrobotic Peregrine Mission One [4], and other efforts underway to obtain high resolution topographic, minerals, volatiles, and other information on the Moon. We envision a need for software platforms to integrate these datasets, provide visualization and analytical functionalities in the context of a 3D Lunar globe for easier information access and analysis. NASA's Celestial Mapping System (CMS) [5] is being developed to address the need for planetary science investigations, mission planning, in-situ operations, in a 3D-first design constructed around a unified view of a planetary globe. At present CMS provides many critical functionalities that include: 1) equipment planning and optimized placement on the Lunar surface 2) line-of-sight (LOS) analysis 3) powerful measurement tools based on 3D terrain with realistic 3D models to represent rovers, astronauts and equipment 4) visualization of derived mapping products (e.g. resource maps), and 5) a data engine for hosting new observations that are not available in other contemporary lunar data tools [5, 7].

Planetary Data Ingestion: CMS can ingest and analyze data from locally hosted and external third party sources. It is compatible with Open Geospatial Consortium (OGC) data and file standards and currently integrates datasets from the Astrogeology Science Center of USGS. This includes global and local data acquired from NASA (LRO, Clementine, Lunar Orbiter) and JAXA (SELENE/Kaguya), with capability of integrating more datasets. In addition, users can specify other Web Map Service (WMS) -hosted data endpoints, which CMS can then query and stream data from automatically. As an example of ingestion, accurate rendering, visualization and analysis of external 3rd party planetary datasets within CMS, we present our process of ingesting unique dataset of super-enhanced images of the permanently shadowed regions (PSRs) at the lunar poles which were produced by the Hyper-effective nOise Removal U-net Software (HORUS) tool [8]. This tool was developed to enhance the extremely low-light images of the interior of PSRs and provide the ability to see within these regions and discern surface features (i.e. boulders and craters) down to 3 meters in size. We focused on the Nobile region on the Lunar south pole, selected site for the VIPER mission and stitched several images to create a high-resolution map within one of the PSR of Nobile crater. Figure 1 shows the dark PSR zone from the original NAC layer of LRO as the base layer (left image) and the illuminated areas within that crater (center) which was created by ingesting and merging several HORUS generated images. At present, we employ a semi-automated process to ensure spatial accuracy and merger of several overlapping zones. However, we are in the process of completely automating this process by employing Artificial Intelligence (AI) based techniques that would rank, sort, and stack the images based on their information density. The georectification of the images would employ selected features that are contained within the images.

Analysis on Ingested Planetary Datasets: Once an external planetary dataset is successfully ingested, georectified and merged seamlessly as a data-layer; CMS' numerous analysis tools can be used on this data. A Line of Sight (LOS) tool has been developed for CMS which analyzes terrain profiles and obstructions to determine visibility for remote observers [5,6]. Figure 1 (right image) shows the viewshed analysis on the same PSR in the Nobile region. The yellow pin shows the observer location outside the PSR. The yellow area shows the visible part of the PSR. The obstructed area with no visibility for the observer is shown in red.

The Measurements tool allows the user to take area and distance measurements of features on the terrain using various shapes. Measurement type can be specified in a number of ways: Line, Path, Polygon, Circle, Ellipse, Square, Rectangle or Freehand. Once the shape is specified, elevation information can then be extracted along each of these shapes. Figure 2 (left) shows the measurements performed on a crater on the HORUS illuminated PSR in Nobile region. These features will be vital for traverse path planning for rovers and humans. The next steps would be to create hazard maps.

The equipment placement tool allows the user to place a 3D equipment model at a desired location and analyze its coverage area. The equipment placement tool is coupled with LOS to determine the coverage area. Figure 2 (right) shows an equipment placed on the Lunar terrain and its coverage area. The red rays are blocked sight lines, the green rays are non-obstructed sight lines with the cyan lines showing the point of intersection with the terrain. More details are provided in the video demonstrations in Reference 5. This feature can be extremely useful for equipment placement planning for Artemis and other missions towards sustainable human presence on the Moon.

Overcoming Polar Distortions: 3D geospatial applications exhibit significant distortions in polar imagery due to several reasons: 1) distortions in the source imagery, 2) incompatible tessellation algorithms at the poles, and 3) map projections. Addressing these distortions are of paramount importance, on the Lunar poles as these distortions could lead to image placement inaccuracies ranging from few meters to 1000s of meters [7]. We are leveraging new tessellation algorithms and reprojecting data using projections that are better suited for Lunar poles. The goal is to seamlessly switch to polar projections while maintaining 3D view and navigation.

Acknowledgments: NASA interns G.K. Norman, K. J. Dickinson, T. A. Lucarz; HORUS team member V.T. Bickel; and M. Robinson, LRO MOON LROC 2 EDR V1.0, LRO-L-LROC-2-EDR-V1.0, NASA Planetary Data System (PDS), 2009. https://doi.org/10.17189/1520643 for enabling NAC base layers.

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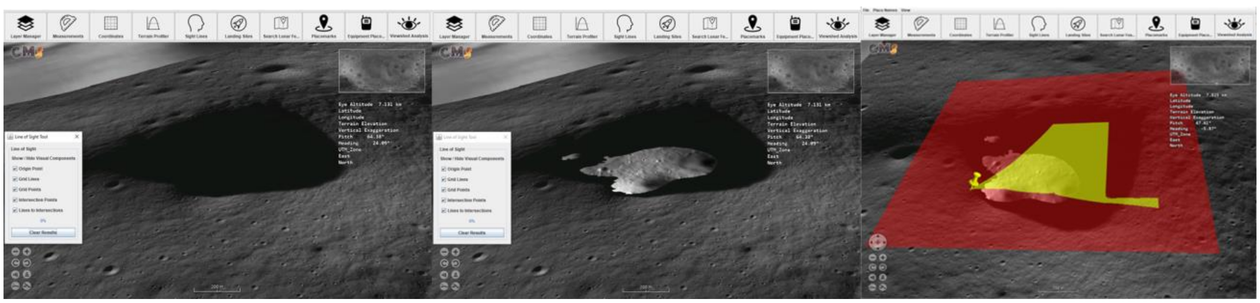

Figure 1: (left) PSR in the Nobili region, rendered in LROC NAC layer of CMS (center) HORUS ingested and merged images within the PSR shown with LROC NAC layer as baseline (right) Viewshed Analysis of the same PSR with observer location shown by yellow pin.

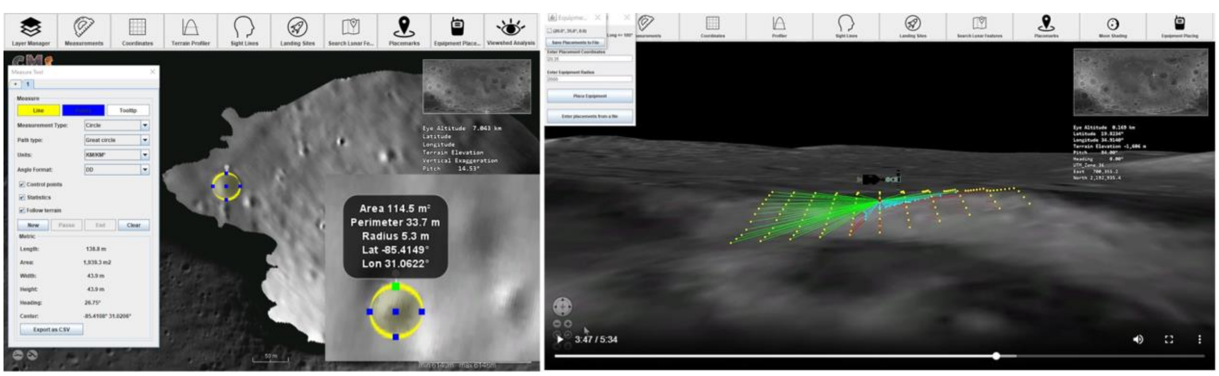

Figure 2: (left) Measurement of a crater inside the PSR by 3D measurement tool. (right) Equipment placement and coverage analysis