NASA MOON TREK APPLICATIONS IN LUNAR SCIENCE AND EXPLORATION. E. S. Law[1], B. H. Day[2], and the NASA Solar System Treks Team[1], [1]Jet Propulsion Laboratory, California Institute of Technology. M/S 168-200. 4800 Oak Grove Dr. Pasadena, CA, USA 91109. (Emily.S.Law@jpl.nasa.gov, +01-818-354-6208), [2]NASA Solar System Exploration Research Virtual Institute. NASA Ames Research Center. M/S 17-1. Moffett Field, CA, USA. 94035. (Brian.H.Day@nasa.gov, +01-650-604-2605).

Introduction: NASA's Moon Trek (https://trek.nasa.gov/moon/) is one of a growing number of interactive, browser-based, online portals for planetary data visualization and analysis produced by NASA's Solar System Treks Project (SSTP). Moon Trek continues to be enhanced with new data and new capabilities enabling it to facilitate lunar scientific research, and the planning and conducting of upcoming lunar missions by NASA, its commercial partners, and its international partners.

A Comprehensive Online Web Portal: Developed at NASA's Jet Propulsion Laboratory (JPL) and managed as a project of NASA's Solar System Exploration Research Virtual Institute (SSERVI) at NASA Ames Research Center, Moon Trek is a browser-based web portal. There is nothing additional to buy or install. Moon Trek provides a suite of interactive tools that incorporate observations from past and current lunar missions, creating a comprehensive lunar research Web portal. The online Web portal allows anyone with access to a computer to search through and view a vast number of lunar images and other digital products. The portal provides easy-to-use tools for browsing, data layering, data product blending, and feature search, including detailed information on the source of each assembled data product and links to NASA's Planetary Data System. Interactive maps, include the ability to overlay a growing range of data sets including topography, mineralogy, abundance of elements and geology. In 2020, SSTP introduced a new and improved release of Moon Trek featuring capabilities such as spatial search, tools and layers that are now consistent across polar and global projections, and a more intuitive layout for interfacing with Trek data.

A Diverse Lunar Analysis Toolkit: Moon Trek features a generalized suite of tools facilitating a wide range of activities including lunar surface scientific research, analysis of large amount of data returned from past and current lunar missions, the planning, design, development, test and operations associated with lunar sortie missions; robotic (and potentially crewed) operations on the surface; planning tasks in the areas of landing site evaluation and selection; design and placement of landers and other stationary assets; design of rovers and other mobile assets; developing terrain-relative navigation (TRN) capabilities; deorbit/impact site visualization; and assessment and planning of science traverses.

Its baseline visualization and analysis tools, available to all users, allow users to measure the diameters, heights and depths of surface features. Users can plot Sun angles (altitude and azimuth for user-specified points over user-specified time/date ranges and time intervals). Custom 2D visualizations can be easily rendered based on polar and equatorial projections. Visualizations in 3D are equally easily rendered and provide the capability for interactive flyovers of lunar terrain. A virtual reality component allows the user to draw a path using the web client, and then fly along that path in virtual reality using VR goggles. User-specified bounding boxes can be used to generate STL and/or OBJ files to create physical models of surface features with 3D printers. In addition to visualizing a vast range of data products in multiple ways, users can access the metadata for the individual data products and can download any of our served data products for use in other applications.

More advanced account-level tools allow users to perform more computationally-intensive analyses. These include ray-traced lighting analysis for user-specified areas over user-specified time/date ranges and time intervals. Lighting analyses also produce maps of watts per square meter for the area specified. Electric surface potential analyses can also be generated for user-specified areas and intervals. Machine learning-based hazard analyses include boulder detection and distribution, crater detection and distribution, and slope analysis. Large data products can be subsetted, allowing users to download regions of specific interest. The LRR/LLR Geometry Calculator will allow researchers to find, visualize, and analyze images taken by the Lunar Reconnaissance Orbiter (LRO) that are applicable to Lunar Laser Retro-Reflector (LRR) and Lunar Laser Ranging (LLR) studies and planning [1].

Important new tools are currently being integrated into Moon Trek. A Convolutional Neural Network (CNN) is being implemented, trained to automatically detect rockfalls in LRO NAC imagery, and integrated into Moon Trek. Such rockfalls are interesting because they enable remote analysis of tectonic activity, surface evolution, and mechanical surface properties [2]. A new line-of-sight tool will support detailed

studies of solar illumination, line-of-sight communications with the Earth, and communications with assets in lunar orbit.

Significant advantages are afforded by Moon Trek's features facilitating collaboration among members of distributed science and engineering teams. Team members can share visualizations and add new data to be shared either with the entire Moon Trek community or only with members of their own team. Sharing of multi-layered visualizations is made easy with the ability to create and send URL-encoded visualization links.

Moon Trek continues to be enhanced with the addition of additional data products and new tools. Enhanced integration with the growing number of other portals of SSTP has been provided by its incorporation into the new SSTP home site (https://trek.nasa.gov). This site provides a common entry point into the various Trek portals as well as a number of additional supporting features.

Diverse Applications for Lunar Exploration: Moon Trek is being used for growing number of mission planning, mission support, technology development, and lunar science applications. Using an in-house stereo workflow, SSTP is able to produce new NAC-based high-resolution mosaics (Fig 1) and DEMs. These are particularly useful in our work with Commercial Lunar Payload Services (CLPS) providers using Moon Trek in site characterization for landing and surface operations. Moon Trek is able to significantly enhance the value and utility of mission data by putting it in the context of a vast collection of other data products gathered from many instruments on many missions. We are taking advantage of this as we plan specific enhancements optimizing Moon Trek for use as a support tool for the science backroom of NASA's upcoming VIPER mission. SSTP continues to work with the Italian National Institute of Nuclear Physics in enhancing Moon Trek's capabilities for LRR/LLR studies. The South Korean Space Agency is planning the use of Moon Trek as a mission planning tool for their Korean Pathfinder Lunar Orbiter, and as a testbed for development of terrain relative navigation systems. SSTP is working with NASA's Astromaterials Acquisition and Curation Office to integrate their database of Apollo lunar samples into Moon Trek. This will allow researchers to enter a catalogue number for a specimen into Moon Trek, and have the portal take them to the collection site where they can study the sample's setting and geological context. We are currently extending the capabilities of the Solar System Treks to facilitate terrestrial analog studies that support human lunar exploration missions. Moon Trek is the direct successor to the Lunar Mapping and Modeling Portal (LMMP). While LMMP was built to support landing site characterization for the Constellation Program, Moon Trek greatly enhances those capabilities and extends that heritage into the age of Artemis.

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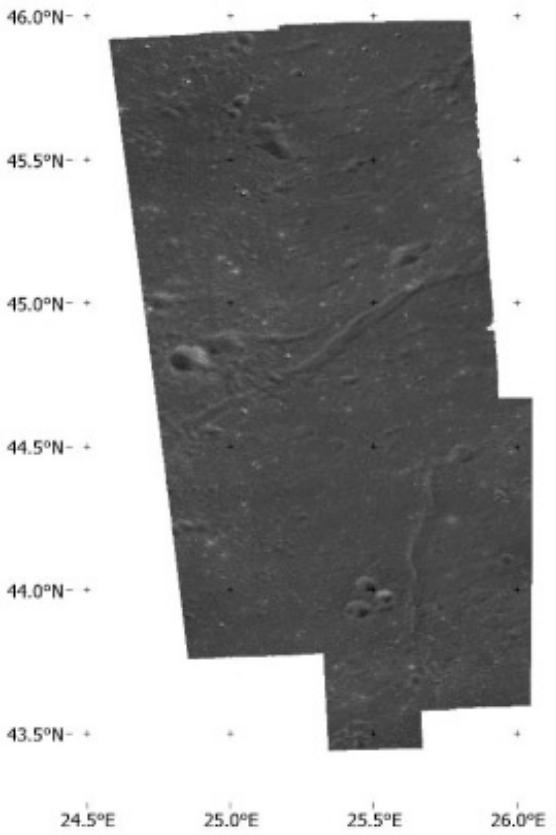

Fig. 1. Moon Trek Orthophoto mosaic of the Lacus Mortis CLPS target site

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