Engaging Students and the Public by Demonstrating Geologic and Scientific Concepts with DTM-Based Visualization in Blender. L. M. Davis, V. H. Silva, N. M. Estes, A. K. Boyd, K. S. Bowley, and the LROC Team School of Earth and Space Exploration, Arizona State University, Tempe, AZ (ldavis@ser.asu.edu)

Introduction: The Lunar Reconnaissance Orbiter Camera (LROC) Science Operations Center (SOC) team is creating a series of educational videos that explore geologic and exploration concepts. This video series can be used as a standalone educational tool or with the featured image articles available on the LROC webpage. The purpose of the videos is to make the discoveries highlighted in the articles accessible to those without a strong lunar geology background. The videos are intended to make the science come alive for students and the public.

The LROC SOC team produced the videos with a newly developed, simplified procedure to import both terrain and spacecraft position information into the open-source image visualization tool Blender [**1**], enabling the creation of accurate representations of lunar features and spacecraft movement from arbitrary viewpoints.

Procedure: Blender scenes can utilize either local (Figs. **1,2**) or global (Figs. **3,4**) digital terrain models (DTMs). In both instances, any DTM readable by GDAL can be used to render the terrain [**2**].

Local scenes are generated using LROC Narrow Angle Camera (NAC) DTMs [**3**]. In most cases, the orthophoto released with the DTM is used as the image overlay; however, in some mosaics seams are visible or the lighting may not be appropriate to highlight the surface features of interest. In those cases, Lunaserv, an open-source web map service (WMS) software package, can generate an image that matches the DTM's projection and bounding box from any available layer [**4**].

For broad area scenes, the LROC Wide Angle Camera (WAC) GLD100 DTM (100 m sampling) [**5**] is used with a WAC mosaic (providing the surface overlay, sometimes known as "texture"). Broad area views are best suited for integrating spacecraft motion using actual position and orientation data from spacecraft ephemeris files (SPICE) [**6**]. SPICE calculates real-world distances, and these values are scaled to fit the 3D model in Blender, allowing accurate cartographic positions in the video. The spacecraft orientation angles do not need to be scaled, but they do need to be mapped such that the axes of the spacecraft model in Blender match the spacecraft as represented by SPICE. The adjusted ephemeris data are linked to the Blender model for each output frame of the video.

Current Work: So far, the LROC team has released four videos created using this procedure. Two of the videos explain techniques used by the LROC science team in their research. The other two videos highlight a geographic feature and describe the feature and how it is formed in easily accessible terms.

"Irregular Mare Patches: Ina" (Fig. **1**) and "Lobate Scarps: D'Alembert," (Fig. **2**) are examples of videos describing geologic concepts. Instead of just a dictionary definition of the geologic features, these videos describe their formation and appearance with a virtual fly-over of the terrain. In the case of the irregular mare patch video, it also serves as a companion to the featured image article "New Evidence for Young Lunar Volcanism" [**7**]. The lobate scarp video illustrates the central geologic concepts discussed in featured image articles such as "Lunar Lobate Scarp" and "Taurus Littrow Valley, West-To-East" [**8,9**].

The process of generating a NAC DTM product is described in "How To: Digital Terrain Models" (Fig. **3**). The size of the spacecraft is exaggerated and the timeline is accelerated for optimum viewing, but the relative event timing and spacecraft motion, both orbit position and slew angles, are accurately represented using SPICE. The video transitions from a broad area

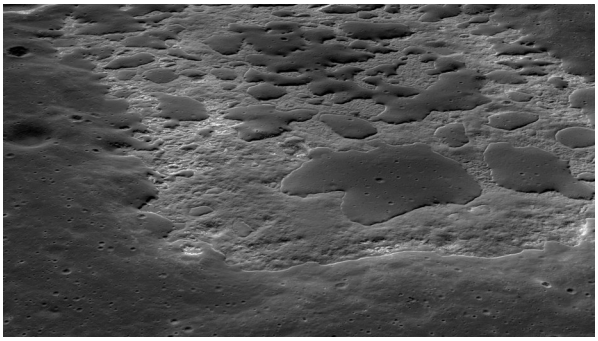

Figure 1.: Single frame from the video "Irregular Mare Patches: Ina" showing the important geologic features as the camera circles the area.

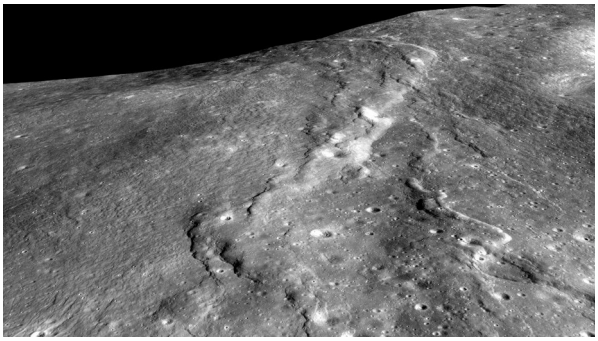

Figure 2: The video "Lobate Scarps: D'Alembert" highlights a lobate scarp and educates the viewer on how these features are formed.

view to the local area DTM to show how the images are aligned and elevation is extracted. While the algorithms and techniques are beyond the scope of a short educational video, this video outlines the steps involved in this process.

"Finding New Craters with Temporal Imaging" was created as a companion video for an LROC Featured Image highlighting a recent paper published in *Nature* and was also featured by *Wired* [**10,11,12**]. This video demonstrates the concept of temporal imaging using actual spacecraft position data from one such pair (Fig. **4**). The pair is then overlaid to reveal the newly discovered impact crater.

Future Work: The LROC SOC team plans to continue the series of videos covering both geologic and exploration concepts to include any feature type for which a DTM is available. The tool that calculates the spacecraft position and orientation and links it to a Blender object will be made more generic so that it can operate on any object with available SPICE data. This will make additional spacecraft maneuvers and concepts possible to demonstrate in video form.

Notes: The videos featured in this abstract can all be found at http://lroc.sese.asu.edu/images/videos. The LROC team plans to present a technical guide on how to produce 3D videos with DTMs and SPICE in Blender at the Planetary Data Workshop in Flagstaff, AZ, June 2017.

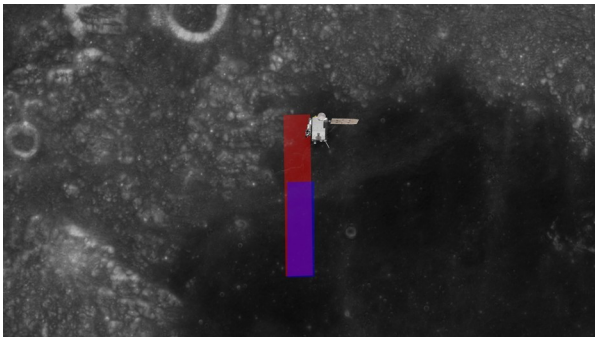

Figure 4: "Finding New Craters with Temporal Imaging" frame showing the second image in the temporal pair being captured by the spacecraft as it moves over the surface.

References: [1] http://www.blender.org [2] http://www.gdal.org [3] Henriksen, M.R,, et al.. (2017) *Icarus*, 283, 122-137. [4] Estes, N.M., et al. (2013) LPSC #2609 [5] Scholten, F., et al. (2012) *JGR*, . (2012) 117 E003926 [6] Acton, C.H. (1996) Plan. and Space Sci., 44, 65-70. [7] http://lroc.sese.asu.edu/posts/818 [8] http://lroc.sese.asu.edu/posts/374 [9] http://lroc.sese.asu.edu/posts/573 [10] Speyerer, E.J., et al. (2016) Nature 538, 215–218 [11] http://www.wired.co.uk/article/dating-moon-craters [12] http://lroc.sese.asu.edu/posts/943

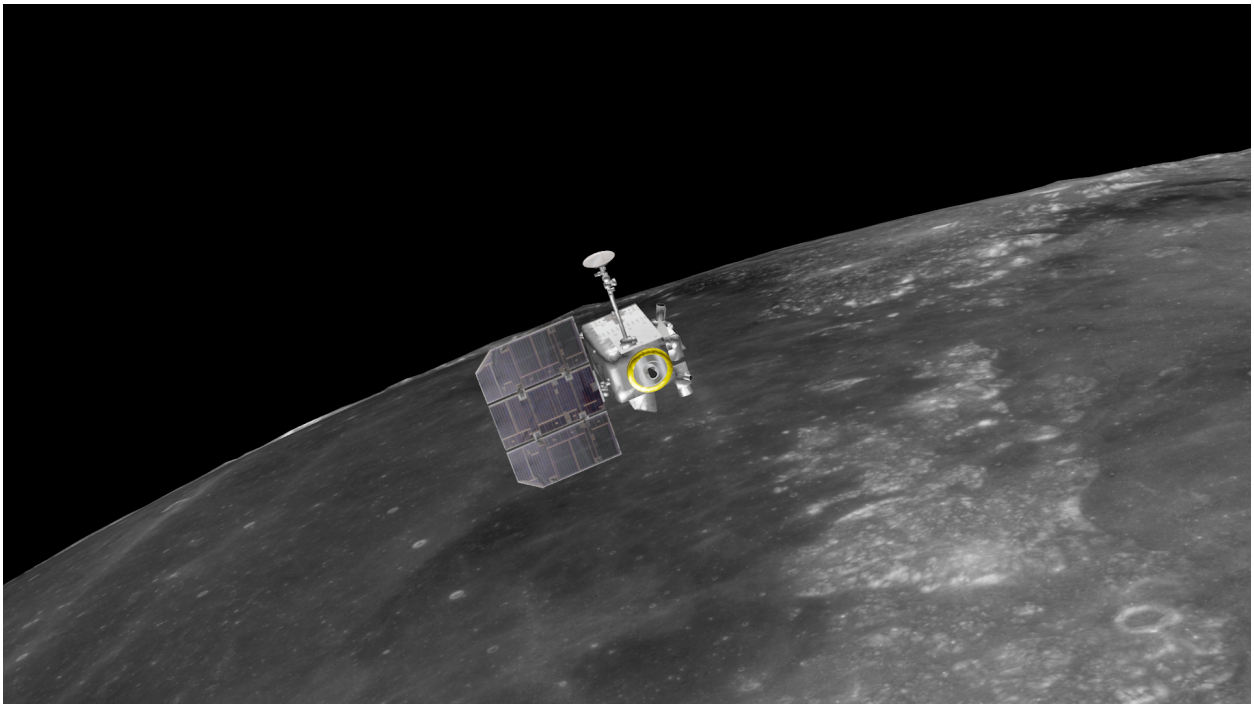

Figure 3: Example camera view from "How To: Digital Terrain Models" scene showing the spacecraft slewing before taking an image in the stereo pair. The unit sphere terrain displacement by the GLD100 can been seen on the horizon.