WILL IT BLEND? GETTING SPICE-Y WITH DTMS AND PLANETARY VISUALIZATION L. M. Davis [1], V. H. Silva, N. M. Estes, A.K. Boyd and K. S. Bowley, and the LROC Team, School of Earth and Space Exploration, Arizona State University, Tempe, AZ [1](ldavis@ser.asu.edu)

Introduction: The Lunar Reconnaissance Orbiter Camera (LROC) Science Operations Center (SOC) team developed a tool to realistically animate terrain flyovers including spacecraft movement requiring a procedure to import regional and global digital terrain models (DTMs) into Blender, an open-source 3D modeling and animation program [1]. Realistic spacecraft movement is achieved with position information from Spacecraft and Planetary ephemerides, Instrument C-matrix and Event (SPICE) kernels [2] and is ingested using the Blender application programming interface (API). With the DTM import procedure, cartographically accurate, three-dimensional renderings and animations are possible. While DTMs have been imported into Blender before, the methods generally required the use of version-dependent plugins that were specific to a single dataset. Because the procedure outlined here does not require a plugin, it is more likely to continue functioning as Blender is updated. Additionally, our procedure is not specific to LROC data, and will work with any GDAL-readable DTM [3].

Importing SPICE: Spacecraft position and orientation is determined during Blender animation using SPICE. The Blender Python API provides scripting access to Blender. With the Blender API and the LROC Ruby SPICE wrapper [4], a suite of LROC scripts prepare Blender to receive SPICE data, including adjusting several Blender settings, such as orientation and scale of objects to match planetary bodies in view, and time per-frame allocation. These adjustments ensure compatibility with SPICE position and orientation functions. With the settings and scaling factors defined, standard SPICE calls generate position and orientation data for each frame in the animation sequence. For spacecraft animation, the relative spacecraft position is scaled to the lunar radius, and the orientation angles are given by SPICE quaternions in the Blender scene; these data are tied to the target Blender object as keyframes (Figure 1).

Importing DTMs: Blender does not support 32-bit TIFFs or Planetary Data System (PDS) IMG files, so we convert the DTMs to 16-bit unsigned integer PNGs as a compromise between supported formats and vertical resolution. The DTM height, width, pixel scale, and minimum and maximum elevations in meters are calculated with gdalinfo, and the DTM is converted by gdal_translate [3] into a 16-bit PNG using the minimum and maximum elevation values.

When a three-dimensional model is created, a raster matching the projection and extents of a DTM is imported into Blender with the "Import Image as Plane" menu option. The orthorectified image that accompanies each LROC DTM can be used; however, that image sometimes has visible seams or illumination that does

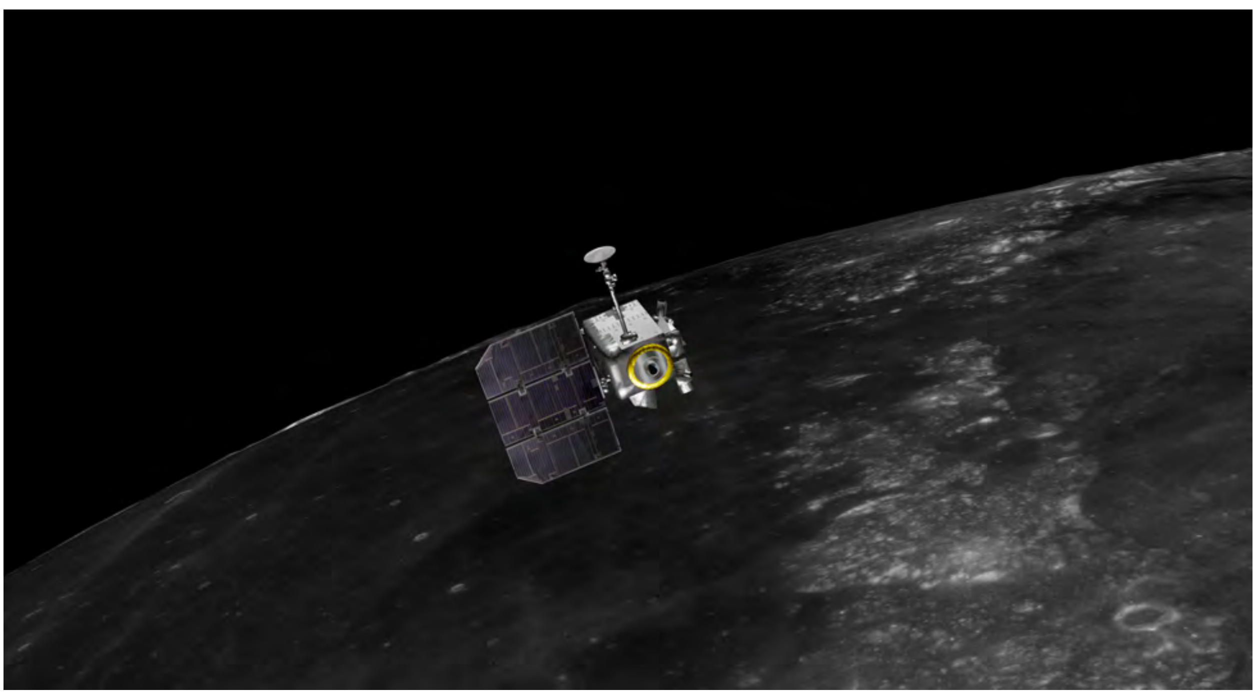

Figure 1: Sample frame showing the NASA LRO model position and orientation over the lunar surface at 2012-10-25 20:55:26 UTC as imported from SPICE into Blender.

not highlight the desired aspect of the scene. In this case, alternative textures include controlled mosaics or global products reprojected to match the projection and extents of the DTM by Lunaserv [6] or the ISIS program map2map. Blender crashes sometimes if a scene is too large in its virtual workspace (Blender units); to avoid this issue, the DTM length in kilometers is entered in the ”Plane Dimension” field. By doing so, one Blender unit is equal to one kilometer, setting the horizontal scale. Once the orthographic image is imported, the ”Subdivide Surface” modifier segments the fixed plane into a flexible mesh. Next, elevation is applied to the flexible mesh with the ”Displace” modifier utilizing the 16-bit PNG DTM as a heightmap. The strength of the displacement, or the amount of relief in the model, is determined by the difference between the maximum and minimum elevations calculated by gdalinfo in kilometers to match the horizontal scale (Figure 2). In the case of global scenes, the GLD 100 DTM [7], in simple cylindrical format, is reprojected to a sphere for displacement. To prevent too large of a scene for Blender to handle, global scenes are scaled such that the Moon’s radius is equal to one Blender unit, and the strength of the displace modifier is scaled to match. For global scenes, any mosaic with global coverage can be used (such as the LROC morphologic mosaic or the GLD 100 color shaded relief).

Rendering with LROC Processing Cluster: Rendering is conducted once a scene is animated with camera motions, SPICE-based movement, high-resolution imagery, and a DTM. Rendering the video on a single high-powered workstation can take over 1200 CPU hours (50 days). Because of the creative nature of the editing process, there will be revisions in camera movement and timing, so a lengthy turnaround time is impractical. Using Blender’s ability to render a single frame, the frames are dispatched to the job management software, Rector [8], enabling those individual frames to process in parallel on the LROC processing cluster.

Utilizing the processing cluster in this way can expedite rendering a video by a factor of 30-500, depending on the scene. The variability is due to memory usage: a highly complex scene with very large images takes more memory, thus fewer of those jobs can run in parallel on the cluster than a scene that takes less memory.

Results: The DTM import procedure, SPICE import tool, and rendering with the processing cluster enabled the LROC team to create a series of educational videos that explore geologic and exploration concepts intended to be accessible to those without a strong lunar geology background. The videos are effective as standalone educational tools or accompanying LROC featured image articles [9].

Future Work: The LROC team plans to produce 360° and virtual reality videos with DTMs and Blender. Additionally, updates to the SPICE import script suite to include other spacecraft and bodies will allow realistic animations using other SPICE objects.

References: [1] Blender Foundation, 2016. [2] Acton, C. H., (1996) *PSS*, 44(1):65. [3] Open Source Geospatial Foundation, (2017) GDAL Version 1.11.3. [4] Estes, N. M., et al., (2017) *Planetary Data Workshop*, Abstract #7022. [5] Robinson, M., et al., (2016) *Icarus*, 273. [6] Estes, N. M., et al., (2013) textitLPSC 44, Abstract #2609. [7] Scholten, F., et al., (2012) textitJGR: Planets, 117. [8] Henriksen, M. R., et al., (2013) *LPSC* 44, Abstract 1676. [9] Estes, N. M., et al., (2012) Planetary Data Workshop. [10] Davis, L. M., et al., (2017) *LPSC* 48, Abstract #2545.

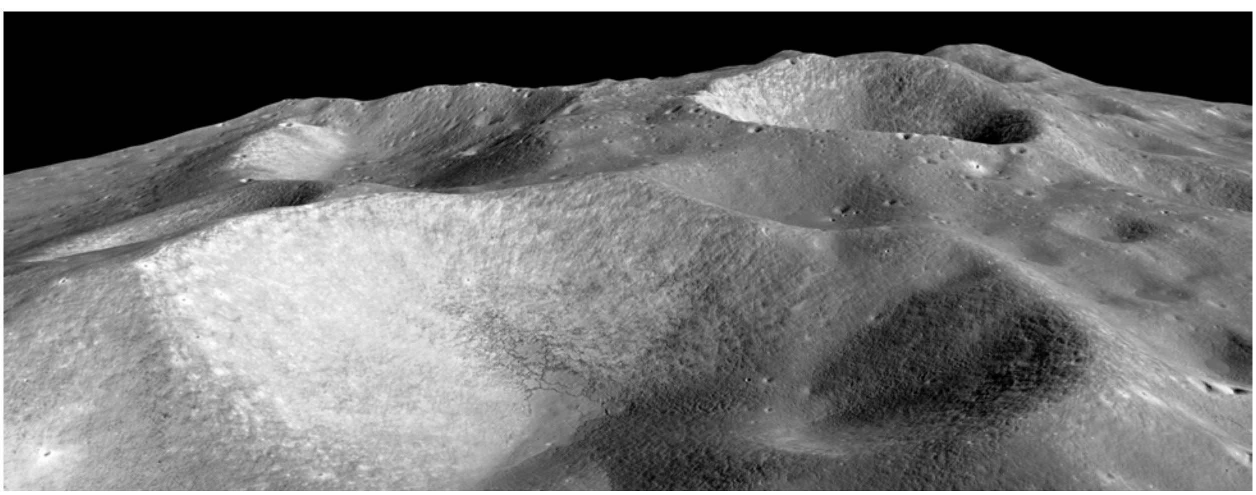

Figure 2: Sample frame showing a mosaic of the Highland Ponds (42.5° E, 167.7° N) [5] displaced by its DTM in Blender to create 3D terrain, image is approximately 15 km wide.