USGS ISIS TOOLS SUPPORTING LUNAR SELENE "KAGUYA" DATA FROM TERRAIN CAMERA, MULTIBAND IMAGER AND SPECTRAL PROFILER INSTRUMENTS.

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Introduction. The Japan Aerospace Exploration Agency (JAXA) Selenological and Engineering Explorer (SELENE) "Kaguya" mission mapped the Moon in 2007-2009 [1]. Onboard SELENE was the Lunar Imager/Spectrometer (LISM) instrument package that housed the Terrain Camera (TC, [2]), the Multiband Imager (MI, [3]) and the Spectral Profiler (SP, [4]). The USGS Integrated Software for Imagers and Spectrometers (ISIS) [5] now provides ingestion support for these LISM instruments so that users can take advantage of further planetary cartographic data processing and visualization enabled by ISIS. Here we describe the capabilities of the currently available tools and our plans for future development.

SELENE "Kaguya" LISM Instruments: Along with laser altimeter, gamma ray spectrometer, magnetometer and other SELENE datasets, the Kaguya LISM data are available from the SELENE Data Archive Web site ([6], see http://l2db.selene.darts.isas.jaxa.jp/). TC data are available as Level-2 map-projected, tiled mosaics (4096 pixels/degree, 3x3 degrees in size) that have ~7.4 m/pixel spatial resolution and both morning and evening illumination. There are two versions of these data products, and a merged product with simulated vertical illumination ("ortho" data), for a total of five TC products. These data have also been mosaicked into near-global versions and released through the PDS Imaging Node Annex ([7], see http://astrogeology.usgs.gov/search/details/Moon/Kaguya/TC/Morning/v04/tc_mor_v04_global_64ppd/cub) at USGS. A tutorial for downloading these data from the Kaguya archive site is available at the PDS Imaging Node site (see http://pds-imaging.jpl.nasa.gov/portal/kaguya_mission.html). MI data are 9-band multispectral frames, with ~17 m/pixel (visible or VIS, 415, 700, 900, 950, 1000 nm) and 62 m/pixel (near-infrared or NIR, 1000, 1050, 1250, 1550 nm). The MI data are available from the Kaguya archive site as radiometrically calibrated, Level-2 coregistered frames that require cartographic processing, and as mosaicked, map-projected (MAP) versions that require mosaicking only. Radiometrically calibrated (Level 2B) Spectral Profiler data (500 m footprint, 140 m on the lunar surface; ~512-1676 nm for VIS and NIR1, 702-2588 nm for NIR2) were collected along the center of each MI frame, and these provide hyperspectral data for extraction of compositional data from lunar soils. A Level 2C product that has been photometrically corrected is also available [8].

Like the Clementine UVVIS and NIR data [9], wavelengths of the MI-VIS and -NIR cameras and Spectral Profiler were selected to maximize information on the mineralogy of the lunar surface [1, 10, 11]. For example, the MI data have been used to determine the global distributions of olivine-rich sites [12], purest anorthosite (PAN) sites [13], and pyroxene-rich sites [14]. Cross-calibrations among the SP VIS and NIR1 data, including comparisons to the Multiband Imager, Moon Mineralogy Mapper (M^3), and the Robotic Lunar Observatory [15-17].

ISIS Software. The USGS ISIS planetary cartographic software [5] is free to users (see http://isis.astrogeology.usgs.gov/) and is used worldwide by planetary scientists performing rigorous scientific research on image and spectral data from space missions. Several ISIS programs are now available for users working with the Kaguya LISM data.

TC data processing in ISIS: The ISIS program ***kaguyatc2isis*** allows users to import Level-2 TC data from the native JAXA archive format to an ISIS single-band cube format. (Note that the TC data are downloaded as "file.sl2" files; one must rename that to "file.tar" and use the Unix command *tar* to uncompress the data before ingesting the file into ISIS.) A user can select desired DN values for stretching or masking the data, and the ISIS program ***automos*** can be used to create mosaics of TC images of the lunar surface. The program ***kaguyatc2isis*** works for all five of the tiled TC frame products from the Kaguya archive.

MI data processing in ISIS: The ISIS program ***kaguyami2isis*** must be used to import Kaguya Level 2 MI frames into ISIS cubes. The VIS and NIR data are ingested separately, and then the ISIS program ***cubeit*** will allow users to combine data from both instruments into a 9-band, spatially coregistered cube that is tied to the TC data. The program ***kaguyami2isis*** accesses the ISIS camera model for the MI data, ensuring that proper camera attributes are included in the image labels, tests that it is ascending or descending data and spatially orients the files, trims excess data from band overlaps, and creates the labeled ISIS 9-band, multispectral cube. A user can select desired DN values for stretching or masking the data, and the ISIS program ***automos*** can be used to create mosaics of MI images.

For the MI map-projected (MAP) data, no camera model is required. The ISIS program ***pds2isis*** can be used to ingest the frame data and the program ***automos*** can be used to create multispectral mosaics. These can be displayed as single-band "albedo" views, as "natural" color products (bands 3, 2 1 as R, G, B), color-ratio composites [18], or used to derive rock-type thematic maps [19] or iron and titanium (wt. %) maps of the lunar surface [20, 21].

SP data processing in ISIS: The ISIS program ***kaguyasp2isis*** ingests a SP binary data file ("file.spc") to a tab-delimited text file. The program imports all of the available columns in the binary file (wavelength, radiance, reflectance, etc.) and all wavelengths (296 channels) from the VIS, NIR1, and NIR2 sensors. The user can limit the number of observations in the output as desired, but the program does not eliminate overlapping channels between sensors. Also, there is a "quality assessment" (QA) parameter that can be used to eliminate redundant channels, noisy bands, etc. (see p. 82 of the LISM_SPICE document for more information on QA: http://l2db.selene.darts.isas.jaxa.jp/help/en/LISM_SPICE_Fromat_en_V01-03.pdf).

Next Steps: Future work will address an expansion of capabilities for the ISIS software, especially for the SP data. Improvements for the latter will include application of the QA parameter to the imported SP observations, removal of redundant bands between sensors, and continuum-removal at user-selected wavelengths. If feedback is received on these tools and more capability is desired, we will seek additional funding to support further expansion.

Acknowledgements: This work was funded by the NASA Planetary Geology and Geophysics program.

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Figure 1. *Kaguya SELENE views of the western floor of Alphonsus crater showing a small crater surrounded by dark, volcanic deposits (so called "Vent 8"). (Left) Terrain Camera (morning) mosaic; (Center) Multiband Imager "natural" color composite (bands 3, 2, 1 as R, G, B); (Right) Spectral Profiler (SP_2C_02_2693_S141_E3565) file showing 500-m observation footprints (yellow circles) superimposed on MI scene. The green outline shows the coverage of the TC and MI views.*