NEW PRODUCTS AND TOOLS FOR WORKING WITH KAGUYA TERRAIN CAMERA DATA. L. Gaddis[1], T.M. Hare[1], B. Archinal[1], S. Goossens[2,3], E. Mazarico[3], E. Speyerer[4], Junichi Haruyama[5], Takahiro Iwata[5], and Noriyuki Namiki[6]. [1]USGS Astrogeology Science Center, Flagstaff, AZ 86001, USA; [2]Univ. Maryland, Baltimore County, Baltimore, MD, USA; [3]NASA Goddard Space Flight Center, Greenbelt, MD, USA; [4]Arizona State University, Tempe, AZ, USA; [5]JAXA, Sagamihara, Japan; [6]National Astronomical Observatory of Japan, Tokyo, Japan (lgaddis@usgs.gov)

Introduction: The SELenological and ENgineering Explorer (SELENE) "Kaguya" spacecraft mission to the Moon from the Japanese Space Agency (JAXA) returned several types of data, including high-resolution monochrome and color images and laser altimeter data. Launched in September 2007, the Kaguya primary mission (PM) was completed at the end of October 2008 and the extended mission (XM) phase started at the beginning of November 2008. During XM Kaguya was in a lower orbit at 50 km average altitude compared to 100 km during PM, and until the end of the mission in June 2009 the Kaguya spacecraft was put into lower orbits. Although data collected during Kaguya XM have an increased spatial resolution, the orbit errors during this phase are much larger, up to several km [1] due to larger gravitational perturbations on the spacecraft, a reduction in the amount of tracking after the end of the nominal mission, and spacecraft attitude control problems associated with loss of the reaction wheels. The resulting degraded orbit quality during XM severely limits the usability and scientific value of these high-quality data (***Figure 1***).

Improved XM Orbits: Recent efforts by our team [e.g., 2] have resulted in significantly improved XM orbits (***Figure 2***). These orbits have been redetermined for the main satellite using 1) improved gravity field models of the Moon derived from Gravity Recovery and Interior Laboratory (GRAIL) mission data [3] and 2) improved knowledge of lunar topography from laser altimeter data of the Lunar Orbiter Laser Altimeter (LOLA) onboard the Lunar Reconnaissance Orbiter (LRO) [4]. Through the analysis of orbit overlaps, we estimate the precision of our new orbits to be at the level of several tens of meters or better during the times when altimetry data are available (almost continuously from Feb 13, 2009 until the end of the mission).

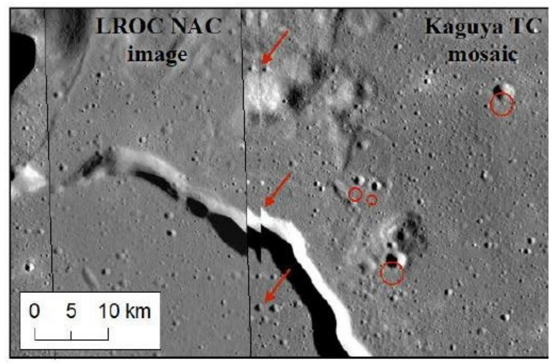

Figure 1. A LROC NAC image (M1127106676R, 1.3 m/pixel) of the Apollo 15 landing site area overlain on a Kaguya TC mosaic. Our work will significantly improve co-registration of TC images, and of such images to other lunar datasets such as LRO/LROC WAC and NAC.

ISIS3 Software for TC: To support the validation of these improved orbits, we will use the USGS/Astrogeology ISIS3 software (https://isis.astrogeology.usgs.gov/UserDocs/index.html) to develop a test mosaic from Kaguya Terrain Camera (TC) data of the Apollo 15 landing site area near Hadley Rille. Two ISIS3 programs are being developed for this effort: 1) an ingestion program that reads TC "PDS-like" file header information and ports them into a single-band ISIS3 cube file, and 2) a linescan camera model for the two TC instruments. Camera models describe the mathematical relationship between the coordinates of a 3D scene and its projection onto the image plane of a camera; for orbital imaging systems such models must also account for spacecraft coordinates and movements. The goal is to be able to treat data from the two TC cameras as ISIS3 cube files so that they can be geometrically rectified and map-projected accurately onto the lunar surface. The camera model includes appropriate camera parameters such as focal length, pixel pitch, boresight coordinate, affine coefficients for focal plane mapping, and optical distortion coefficients. These programs will be publicly released with regular ISIS3 releases on a monthly schedule.

Test Mosaic: We focus in this project on the Hadley Rille area for several reasons: 1) The region has been a "standard" test site for many lunar mapping products, with several other publicly available mosaics and digital terrain models (DTMs) for comparison of our products (see https://astrogeology.usgs.gov/maps/moon-lro-dtms-and-mosaics); 2) The availability of high-resolution mapping of the central portion of this area done under the Lunar Mapping and Modeling Project [e.g., 5], including a ~20 x 20 km, 0.50 m/pixel image mosaic, and a 1.5 m/pixel DTM [6]; 3) Most types of lunar terrain are covered in this area, including flat plains to high mountains; 4) Surface photographs from the Apollo 15 mission are available for comparison with any surface image or 3D products; and 5) This site contains the largest (105 x 65 cm) of the five Lunar Laser Ranging RetroReflector (LRRR) arrays. This array serves as the primary target for laser ranging to the Moon, with a 3D position measurable (relative to the Earth and the other arrays) at the cm level and known absolutely to the meter level so it can be used for absolute coordinate system comparisons.

Future Work: Following validation, the improved Kaguya trajectory data (SPICE SPK) will be delivered to PDS, NAIF and the NASA GSFC Planetary Geodesy Data Archive (https://pgda.gsfc.nasa.gov), along with adjusted LALT altimetric and LMAG magnetic data. A TC mosaic of the Hadley Rille area will be the last product of this project, to be delivered later in 2019 or early 2020.

References: [1] Goossens et al. (2009) Proceedings of the 19th Workshop on JAXA Astrodynamics and Flight Mechanics, pp. 247–256, Institute of Space and Astronautical Science, JAXA. [2] Goossens et al., this meeting. [3] Zuber et al. (2012) Science, doi:10.1126/science.1231507. [4] Smith et al. (2017) Icarus, doi:10.1016/j.icarus.2016.06.006 [5] Noble et al. (2009) Annual Meeting of Lunar Exploration Analysis Group, abs. #2014. [6] Archinal et al. (2011) LPS XLII, abs. #2316.

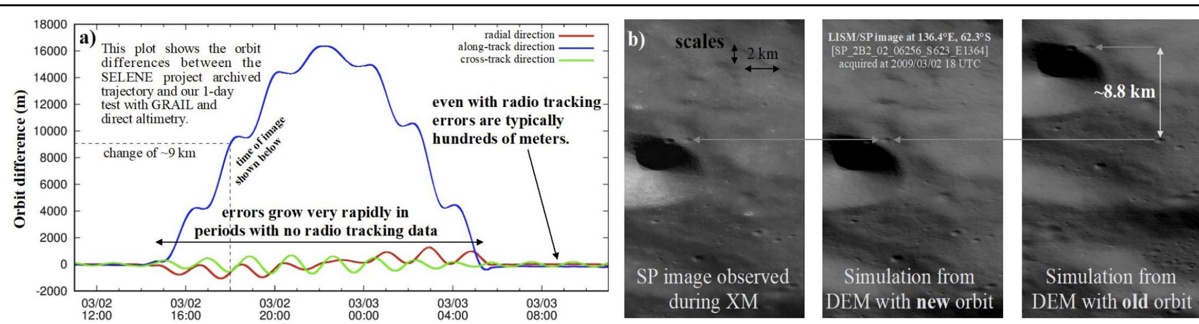

Figure 2. Orbit errors (left) are reduced from multi-km levels in a 1-day test period. At right is a 10 m/pixel Multiband Imager (MI) image from XM (R-left), which cannot be well reconstructed with currently archived Kaguya trajectory files (R-right). Our orbit reconstruction in XM removes geolocation errors (R-center).